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ORIGINAL SCIENTIFIC PAPER

Validity of Wearable Monitors and Smartphone Applications to Measure Steps and Distance in Adolescents

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Abstract

The growing popularity of wearable physical activity (PA) monitors and fitness applications (apps) in recent years and the vast amounts of data that they generate present attractive possibilities for surveillance. However, measurement accuracy is indispensable when tracking PA variables to provide meaningful measures of PA. The purpose of this study was to examine the criterion validity of wearable PA monitors and a combination of GPS and accelerometer free of charge smartphone apps, during self-paced outdoor walking and running. Thirty-eight healthy adolescents (15.3±2.0 years) participated in this cross-sectional study. They were fitted with Garmin Forerunner 310XT, Garmin Vivofit, Medisana Vifit, and smartphones running the Runkeeper, Runtastic, Sports Tracker (GPS), Pedometer, Accupedo, Pedometer and Pedometer 2.0 (accelerometer) apps. They were asked to walk and run 1.22 km for each trial and two researchers counted every step taken during trials with a digital tally counter. Validity was evaluated by comparing each device with the criterion measure using Repeated measures analysis of variance (ANOVA), Mean Absolute Percentage Errors (MAPE) and Bland-Altman plots. MAPE were low for Forerunner and GPS apps for distance in both conditions (2.27%-9.73%), and significantly higher for the accelerometer monitors and apps (6.92%-39.02%). Vivofit (MAPE=6.51%) and Vifit (MAPE=6.66%) accurately estimated the number of steps during walking, however only Vivofit (MAPE=3.95%) was accurate during running. All accelerometer-based apps had high MAPE for step counting (9.87%-40.26%). The findings suggested that GPS monitors and apps were accurate tools for counting distance during walking and running, while accelerometer-based monitors and apps had higher errors. Vivofit provided accurate estimates of step count in both conditions, and Medisana Vifit was valid during walking. Accupedo was the only app with an acceptable step count error.

Keywords: *wearable activity tracker, GPS, accelerometer, fitness tracker, step count*

Introduction

The World Health Organization's (WHO) guidelines on physical activity (PA) and sedentary behavior were recently updated (WHO, 2020). Children and adolescents should complete at least an "average of 60 minutes/day" of moderate-to-vigorous physical activity (MVPA), rather than the previously stated "60 minutes/day of PA" as indicated in 2010 WHO recommendations (Bull et al., 2020). Updated PA guidelines pose challenges to PA surveillance; however, device-based measurements may facilitate surveillance (Troiano, Stamatakis, & Bull, 2020).

Wearable PA monitors and fitness applications (apps) have grown in popularity in recent years, and the vast volumes of data they create present appealing surveillance opportunities (Omura, Carlson, Paul, Watson, & Fulton, 2017). Unfortunately, these consumer-targeted wearable technologies designed for general wellness purposes are not required to go through a standardized evaluation process to ensure their accuracy, validity and reliability, and most product manufacturers only provide the minimum requirements when releasing information (Bent & Dunn, 2020). Nevertheless, for any research project where PA

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is either an end measure or an intervention, accurate and reliable measurements are crucial for tracking PA variables in order to produce relevant PA estimates (Nelson, Kaminsky, Dickin, & Montoye, 2016).

Most previous studies on the validity of PA monitors and smartphone apps were conducted on adults. According to a recent review of step counting wearable technologies' validation on a treadmill, Mean Absolute Percentage Error (MAPE) values were 7% to 11% for wrist-worn, 1% to 4% for waist-worn, and ≤1% for thigh-worn monitors (Moore, McCullough, Aguiar, Ducharme, & Tudor-Locke, 2020). Two other systematic reviews examined the validity of Fitbit and Garmin monitors. Fitbit devices were likely to meet acceptable accuracy for step count approximately half the time, with a tendency to underestimate steps in controlled testing and overestimate steps in free-living settings (Feehan et al., 2018). Step counting accuracy was likewise high on Garmin activity monitors, however distance validity was low, with MAPE surpassing the acceptable limits (Evenson & Spade, 2020). Further review of the literature suggests that all Global Positioning System (GPS) units, regardless of sampling rate, are valid for tracking distance in team sports, with adequate intra-unit reliability to allow multiple comparisons of a single device (Scott, Scott, & Kelly, 2016).

Regarding the validity of smartphone apps, a recent review concluded that there is conflicting and insufficient evidence on the validity and reliability of apps for measuring PA. Nevertheless, velocity and the place where the smartphone is carried seem to have an impact on validity, as absolute errors decreased with higher velocities (Silva, Simões, Queirós, Rodrigues, & Rocha, 2020). In this review, only two studies tested the apps for distance validity in outdoor settings. The first study tested the app during walking and running in a circuit with a known distance and with the app attached to the arm (Adamakis, 2017) and the second study during a marathon/half-marathon with no indication where the app was carried (Pobiruchin, Suleder, Zowalla, & Wiesner, 2017). Apps' MAPE in both studies were less than 4.5% (Adamakis, 2017; Pobiruchin, Suleder, Zowalla, & Wiesner, 2017).

Due to the fact that there is an apparent potential of PA monitors and apps to measure and promote PA, there is a need to carry out more studies of high methodological quality in various populations. Thus, the purpose of the present study was to validate step count and distance travelled of one GPS and two consumer-based monitors, as well as six Android apps (three pedometer- and three GPS-based apps) in a sample of healthy adolescents. Based on the evaluation framework proposed by Keadle, Lyden, Strath, Staudenmayer and Freedson (2019), a naturalistic validation study design in real-world conditions was used, which included self-paced outdoor walking and running. The submaximal outdoor walking and running tests were performed in regular outdoor conditions with the aim of providing data from uncontrolled and sometimes challenging conditions, where participants would train and perform their regular fitness activities.

Methods

Study design

This was a cross-sectional study investigating the accuracy in recorded distance and step count values for nine wearable technology monitors and apps. The research design was similar to a previously published validation study (Adamakis, 2020). Thirty-eight healthy adolescents, with no contraindications for exercise and no known orthopaedic limitations that would prevent them from completing the assessments, participated. All adolescents, as well as their parents, read and signed an informed consent form approved by the School of Sport Science and Physical Education of Athens Research Ethics Committee, informing them of the risks and benefits of the study.

Participants reported to the researchers twice. During the first visit, anthropometric measures were obtained in controlled laboratory settings. The second visit (2 - 3 days after the first visit) took place in a track and field elliptical stadium. Field tests were performed outdoors between November and January, during days when it was not raining, and the temperature was above 10°C. These conditions are typical outdoor training conditions and, hence, provide a good benchmark for challenging real outdoor training conditions that are faced by adolescents while exercising. All participants were instructed to wear their own outdoor sports clothing as appropriate for the current weather during the test.

The participants were fitted with three different activity trackers and three smartphones, each one running simultaneously two different apps (one GPS and one pedometer-based app). Garmin Vivofit (Vivofit) and Garmin Forerunner 310XT (Forerunner) were both worn on the left wrist. Medisana Vifit (Vifit), as well as the three smartphones, were strapped close to the body on a waist-worn elastic belt over the left hip, near the anterior axillary line, and were counterbalanced for anterior and posterior placement on the hip among participants. All devices were updated with the participants' age, sex, height, dominant hand, weight, and step length. All monitors' firmware and apps' software were updated to the latest available version. In addition to the devices, a heart rate monitor (Garmin HRM-Dual™) was placed around participants' chest to capture exercise heart rate.

Participants had to perform a total of two field tests in regular outdoor conditions: overground walking and submaximal running, at a self-selected pace. The only limitation that existed was that walking speed should be between 3 and 6 km/h and running speed should be above 8 km/h, following the American College of Sports Medicine (2006) recommendations (speed between 6 and 8 km/h is considered a transitional speed between walking and running and should be avoided in experimental procedures). The actual average walking speed, estimated by Forerunnner, was 5.27±0.62 km/h (1.47±0.17 m/s) for walking and 11.05±1.47 km/h (3.07±0.41 m/s) for running, respectively. Between the two trials, participants could rest for 5 minutes and all devices were paused simultaneously. During pause, all apps' specific settings were changed from walking to running option.

Distance was objectively recorded with a manual distance measuring wheel [Roadrunner RR182 (Keson)], by measuring the walking route two times and then taking the mean distance for an ending point. The total distance that all participants had to walk, and run was 1.22 km for each trial (2.44 km in total). In addition, two manual counters objectively measured steps. For all self-paced walks and runs they were instructed to follow the participants and were separated so they could not view each other's thumb motion nor hear the "clicking" from the tally counter. This prevented any synchronized counting between the two. The reliability of this method was tested by comparing a video recording for two walking and running video sequences of one of the subjects. An intra-class correlation coefficient value of 0.99 was obtained through the analyses of the video sequences and the steps recorded by the researchers. Smartphones were set to airplane mode to avoid interactions with the mobile phone providers (i.e., no data connection), and all devices were activated simultaneously. In the end of each trial, data initially were stored manually and at a later time were uploaded to the relating devices' software.

Participants

A power calculation with findings of observed step counts (correlation of 0.50), alpha two-tailed value of 0.05, and a power of 0.80 indicated a sample size of 29 participants. In total, 38 healthy adolescents (n=16 boys, n=22 girls) with an age range of 12-18 years (15.7±1.8 years), body mass index range of 15.1 - 28.6 kg/m2 (21.1±2.3 kg/m^2) were screened and participated in the study (with no dropouts).

Anthropometric assessment

Standing height was measured to the nearest 0.1 cm using a wall mounted Harpenden stadiometer (Harpenden, London, UK) using standard procedures. Body mass was measured with participants in light clothes and bare feet on an electronic scale (Omron BF-511) to the nearest 0.1 kg. Body mass index was calculated as weight (kg) / height squared (m^2). The average walking step length was calculated by performing 20 normal steps and measuring the distance between the start and end line, then dividing the total distance by 20 steps. The same procedure was followed to calculate running step length. All anthropometric measurement results are presented in Table 1.

Table 1. Participants' characteristics (Mean±SD)

	Boys	Girls	Total
	M±SD	M±SD	M±SD
Age (years)	15.3±2.0	16.0±1.7	15.7±1.8
Weight (kg)	70.1±11.4	55.4±6.5	61.6±8.2
Height (m)	1.76±0.09	1.66±0.05	1.70±0.09
Body Mass Index (kg/m^2)	22.4±3.6	20.1±1.8	21.1±2.3
Resting heart rate (bpm)	71.4±9.3	67.4±7.4	69.1±8.4
Walking step length (cm)	79.6±5.8	77.7±7.1	78.5±6.6
Running step length (cm)	124.6±20.8	120.2±16.7	122.1±18.4

Wearable monitors

Garmin Forerunner 310XT (Forerunner): Forerunner (Garmin International Inc., Olathe, KS, U.S.A.) is a mid-cost GPS-enabled training and heart rate wrist-worn monitor for multisport athletes. It tracks time, distance, average and lap speed and pace, heart rate with a premium heart rate monitor, on land and estimated calorie burn.

Garmin Vivofit (Vivofit): Vivofit (Garmin International Inc., Olathe, KS, U.S.A.) is a mid-cost wrist-based, triaxial accelerometer-based monitor that measures steps taken, distance travelled, calories expended and sleep quality. The Garmin Connect software was used to upload data for both Forerunner and Vivofit.

Medisana Vifit (Vifit): Vifit (Medisana AG, Neuss, Germany) is a low-cost waist-worn accelerometer that counts and keeps track of steps taken and calories burned. By means of a triaxial accelerometer and altimeter technology Vifit records PA. In comparison to more sophisticated PA monitors, it only has the option to insert walking step length (instead of both walking and running). Vifit also measures the duration and quality of sleep. The VitaDock Online software was used to assess step and distance data.

Android apps

This study used three Samsung smartphones S8 based on the Android operating system. Inclusion criteria for all apps were retrieved from previous protocols (Adamakis, 2020, 2021): (1) Free of charge indefinitely after download. Applications with a free trial period of finite length were excluded; (2) Full and efficient functionality after downloading, without additional software download being necessary; (3) Functionality only through the built-in accelerometer for the pedometers and GPS for the GPS apps (no 4G/5G signal); (4) Ability to record the number of steps taken, average speed, total distance and energy expenditure; (5) Adjustable sensitivity settings for the pedometers; (6) Manual input of demographic and somatometric data (sex, age, weight, height and step length for walking and running) for accurate EE estimation; (7) Manual choice of activity type (i.e. walking or running); (8) Among the most popular and downloadable applications, according to users' ratings and number of downloads from the Google Play Store. Specifically, for the pedometer apps, they should include an option to capture step count during walking and running separately, by inputting different step lengths for the two conditions.

Based on the previously described criteria, three GPS- and three accelerometer-based apps were selected: (1. GPS) Runkeeper (ASICS Digital, Inc.), Runtastic (Runtastic GmbH), Sports Tracker (Sports Tracking Technologies); (2. Accelerometer) Pedometer (ITO Technologies, Inc.), Accupedo (Corusen LLC), Pedometer 2.0 (DSD). Pedometer 2.0 was the only application with a self-calibration capability, which was used to determine the appropriate sensitivity settings for every participant separately. All wearable monitors and apps were included in the validation of distance travelled, however only pedometer monitors (i.e., Vivofit and Vifit) and apps (i.e., Pedometer, Accupedo, and Pedometer 2.0) were tested for step count validity.

Statistical analysis

Descriptive analyses were conducted to examine associations with the criterion measure. Repeated measures analysis of variance (ANOVA) statistical tests were performed to assess differences from all monitors and apps, and criterion measures for distance and step count. When the test statistic was significant, post-hoc pairwise comparisons with Bonferroni correction were performed. The significance level was set at $p<0.05$ and the partial η^2 was presented as a measure of effect size for F-tests. A partial η^2 value between 0.01 and 0.06 was associated with a small effect, between 0.06 and 0.14 with a medium effect, and 0.14 or greater with a large effect (Warner, 2012).

MAPE were also calculated to provide an indicator of overall measurement error {MAPE = [(monitor measurement-criterion measure) / criterion measure] x 100} and was used as an outcome measure. A smaller MAPE represents better accuracy. Johnston et al. (2020) recommend MAPE ≤5%, if the PA monitor is to be used as an outcome measure within a clinical trial or as an alternative gold-standard measurement tool for step counting, and MAPE ≤10%-15% if the device is being validated for use by the general population.

To further evaluate individual variations, Bland-Altman plots with corresponding 95% limits of agreement and fitted lines (from regression analyses between mean and difference) with their corresponding parameters (i.e., intercept and slope) were presented (Bland & Altman, 1986; Ludbrook, 2002). A fitted line that provides a slope of 0 and an intercept of 0 exemplifies perfect agreement. The statistical analyses were performed with SPSS version 27.0 for Windows (IBM SPSS Corp., Armonk, NY, USA) and MedCalc 12.7 (MedCalc Software bvba).

Results

Step count

Participants averaged 1450±119 steps during walking and 1070±134 steps during running trials, respectively. The repeated measures ANOVA for both walking [$F(2,74)=29.30$, $p<0.001$, $\eta^2=0.44$] and running [$F(2,74)=7.25$, $p=0.001$, $\eta^2=0.16$] were statistically significant, with large effect sizes. The post-hoc pairwise comparisons with Bonferroni corrections showed that only Vivofit [$F(1,37)=1.95$, $p=0.170$] did not differ significantly from the criterion during walking, while Vivofit [$F(1,37)=0.46$, $p=0.500$] and Accupedo [$F(1,37)=0.79$, $p=0.380$] did not differ significantly from the criterion during running. All remaining comparisons with the criterion resulted in statistically significant differences ($p<0.05$) (Table 2).

Table 2. Results of repeated measures ANOVA for step count and comparison with criterion measure

	Walking					Running				
	M	SD	Pairwise F	Pairwise p	95% CI	M	SD	Pairwise F	Pairwise p	95% CI
Criterion	1450	119	-	-	-	1070	134	-	-	-
Vivofit	1417	193	1.95	0.17	(-42) - 109	1078	120	0.46	0.50	(-49) - 31
Vifit	1532	110	31.89	<0.001	(-127) - (-36)	942	190	31.84	<0.001	57 - 199
Pedometer	1958	495	39.13	<0.001	(-762) - (-253)	1233	344	5.68	0.02	(-378) - 52
Accupedo	1537	146	11.17	0.002	(-168) - (-5)	1104	245	0.79	0.38	(-157) - 88
Pedometer 2.0	1973	493	41.74	<0.001	(-777) - (-269)	1217	375	4.40	0.04	(-367) - 73

Note. CI: confidence interval

During walking MAPE was least for monitors, Vivofit (6.51%) and Vifit (6.66%), while error rates for apps were higher (Accupedo: 9.87%; Pedometer: 39.43%; Pedometer 2.0: 40.26%). During running the magnitude of errors was least for Vivofit (3.95%). Error rates for the remaining monitors and apps ranged from 11.69% to 34.02% (Figure 1).

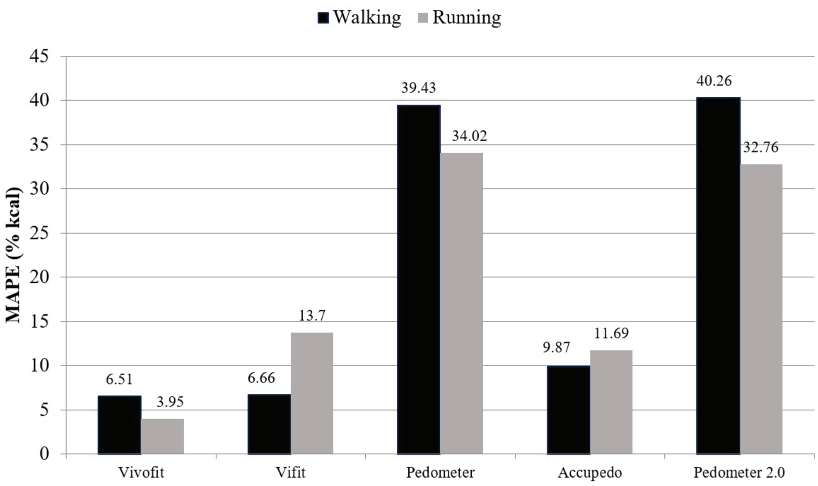

FIGURE 1. MAPE (% steps) of PA monitors and apps compared with criterion measure

The Bland-Altman results for step count for walking and running trials are presented in Table 3. For walking, the plots revealed the narrowest 95% limits of agreement for Vivofit (difference=33 steps), while values were the highest for Pedometer (difference=-507 steps) and Pedometer 2.0 (difference=-523 steps). During running, the narrowest 95% limits of agreement were observed for Vivofit (difference=-9 steps), followed by Accupedo (difference=-35 steps). The highest values were observed for Pedometer 2.0 (difference=-147 steps) and Pedometer (difference=-163 steps).

Distance

Participants averaged 1.22±0.01 km for both walking and running trials, respectively. The repeated measures ANOVA for both walking [$F(3, 104)=15.79$, $p<0.001$, $\eta^2=0.30$] and running [$F(3,104)=32.80$, $p<0.001$, $\eta^2=0.47$] were statistically significant, with large effect sizes. The post-hoc pairwise comparisons with Bonferroni corrections showed that only

Table 3. Step count Bland-Altman results during walking and running

	Walking					Running				
	M diff	95% CI	Slope	p	95% CI	M diff	95% CI	Slope	p	95% CI
Vivofit	33.45	(-15.07) - 81.96	-0.57	<0.001	(-0.86) - (-0.28)	-8.68	(-34.61) - 17.24	0.14	0.19	(-0.07) - 0.35
Vifit	-81.47	(-110.71) - (-52.24)	0.09	0.52	(-0.19) - 0.37	127.76	81.89 - 173.64	-0.39	0.008	(-0.68) - (-0.11)
Pedometer	-507.34	(-671.67) - (-343.01)	-1.72	<0.001	(-2.02) - (-1.43)	-163.00	(-301.58) - (-24.42)	-2.08	<0.001	(-2.67) - (-1.49)
Accupedo	-86.45	(-138.86) - (-34.03)	-0.32	0.20	(-0.81) - 0.18	-34.66	(-113.92) - 44.60	-0.84	<0.001	(-1.28) - (-0.41)
Pedometer 2.0	-522.84	(-686.82) - (-358.86)	-1.73	<0.001	(-2.03) - (-1.43)	-147.16	(-289.25) - (-5.06)	-1.86	<0.001	(-2.37) - (-1.36)

Note. CI: confidence interval; diff: difference

Sports Tracker [F(1,37)=0.48, p=0.500], Vifit [F(1,37)=3.37, p=0.070], and Accupedo [F(1,37)=0.40, p=0.530] did not differ significantly from the criterion during walking, while Sports Tracker [F(1,37)=2.27, p=0.140] and Accupedo [F(1,37)=2.63, p=0.110] did not differ significantly from the criterion during running. All remaining comparisons with the criterion resulted in statistically significant differences (p<0.05) (Table 4).

Figure 2 reports MAPE for all monitors and apps. During walking the magnitude of errors was least for Forerunner (2.27%) and Sports Tracker (3.92%), while error rates for all other were above 6.00% (6.82% - 35.94%). During running the magnitude of errors was least for Sports Tracker (3.07%), followed by Forerunner (3.40%) and Runkeeper (4.27%). Error rates for the remaining monitors and apps ranged from 8.83% to 39.02%.

Table 4. Results of repeated measures ANOVA for distance (km) and comparison with criterion measure

	Walking					Running				
	M	SD	Pairwise F	Pairwise p	95% CI	M	SD	Pairwise F	Pairwise p	95% CI
Criterion	1.22	0.01	-	-	-	1.22	0.01	-	-	-
Forerunner	1.24	0.04	4.48	0.04	(-0.03) - 0.01	1.26	0.03	58.66	<0.001	(-0.06) - 0.02
Runkeeper	1.30	0.14	10.83	0.002	(-0.15) - 0.05	1.25	0.07	4.27	0.04	(-0.06) - 0.02
Runtastic	1.15	0.15	8.31	0.007	(-0.02) - 0.16	1.13	0.07	78.47	<0.001	0.06 - 0.15
Sports Tracker	1.24	0.10	0.48	0.50	(-0.07) - 0.05	1.24	0.07	2.27	0.14	(-0.06) - 0.02
Vivofit	1.09	0.18	21.80	<0.001	0.03 - 0.24	1.14	0.20	7.33	0.01	(-0.03) - 0.20
Vifit	1.20	0.10	3.37	0.07	(-0.03) - 0.08	0.75	0.17	314.27	<0.001	0.38 - 0.57
Pedometer	1.54	0.56	11.48	0.002	(-0.63) - 0.01	0.99	0.30	23.75	<0.001	0.07 - 0.41
Accupedo	1.25	0.21	0.40	0.53	(-0.14) - 0.10	1.31	0.32	2.63	0.11	(-0.27) - 0.10
Pedometer 2.0	1.62	0.49	25.42	<0.001	(-0.67) - (-0.12)	1.46	0.42	11.73	0.002	(-0.48) - 0.01

Note. CI: confidence interval

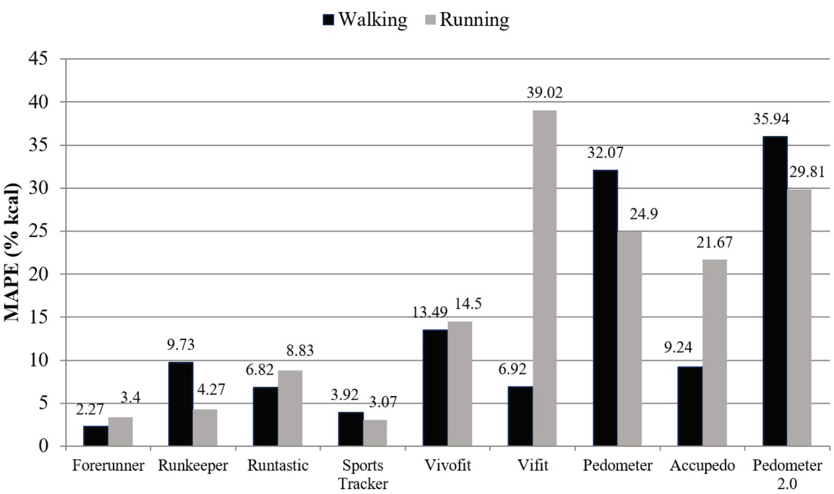

FIGURE 2. MAPE (% km) of PA monitors and apps compared with criterion measure

The Bland-Altman results for distance for both walking and running trials are presented in Table 5. For walking, the plots revealed the narrowest 95% limits of agreement for Forerunner (difference=-0.01 km) and Sports Tracker (difference=-0.01 km), and slightly higher values for Accupedo (difference=-0.02 km) and Vifit (difference=0.03 km), while values were the highest for Pedometer (difference=-0.31 km) and Pedometer 2.0 (difference=-0.40 km). During running, the narrowest 95% limits of agreement were observed for Sports Tracker (difference=-0.02 km), followed by Forerunner (difference=-0.04 km) and Runkeeper (difference=-0.05 km). The highest values were observed for Pedometer (difference=0.24 km) and Vifit (difference=0.48 km).

Table 5. Distance Bland-Altman results during walking and running

	Walking					Running				
	M diff	95% CI	Slope	p	95% CI	M diff	95% CI	Slope	p	95% CI
Forerunner	-0.01	(-0.02) - 0.00	-1.43	<0.001	(-1.72) - (-1.14)	-0.04	(-0.05) - (-0.03)	-1.35	<.001	(-1.66) - (-1.04)
Runkeeper	-0.07	(-0.12) - (-0.03)	-1.94	<0.001	(-2.05) - (-1.84)	-0.05	(-0.05 - 0.00	-2.03	<.001	(-2.25) - (-1.80)
Runtastic	0.07	0.02 - 0.12	-2.01	<0.001	(-2.11) - (-1.92)	0.11	0.08 - 0.13	-2.17	<.001	(-2.39) - (-1.95)
Sports Tracker	-0.01	(-0.04) - 0.02	-1.93	<0.001	(-2.08) - (-1.79)	-0.02	(-0.04) - 0.01	-1.83	<.001	(-2.02) - (-1.63)
Vivofit	0.14	0.08 - 0.18	-1.93	<0.001	(-2.00) - (-1.85)	0.09	0.02 - 0.15	-1.92	<.001	(-1.99) - (-1.86)
Vifit	0.03	0.00 - 0.06	-1.75	<0.001	(-1.86) - (-1.64)	0.48	0.42 - 0.53	-1.85	<.001	(-1.92) - (-1.79)
Pedometer	-0.31	(-0.49) - (-0.12)	-1.98	<0.001	(-2.01) - (-1.96)	0.24	0.14 - 0.34	-1.98	<.001	(-2.04) - (-1.95)
Accupedo	-0.02	(-0.09) - 0.05	-1.93	<0.001	(-1.99) - (-1.87)	-0.08	(-0.19) - 0.02	-1.98	<.001	(-2.02) - (-1.93)
Pedometer 2.0	-0.40	(-0.56) - (-0.24)	-1.99	<0.001	(-2.02) - (-1.96)	-0.23	(-0.37) - (-0.10)	-2.01	<.001	(-2.04) - (-1.97)

Note. CI: confidence interval; diff: difference

Discussion

The aim of the present study was to examine the accuracy of a variety of PA monitors and smartphone apps in measuring steps and distance during self-paced outdoor walking and running in a sample of healthy adolescents. To our knowledge, this is the first study to examine these estimates from competing technologies, including both GPS-accelerometer monitors and smartphone apps, in youth. The primary finding regarding step count was that accelerometer-based monitors (Vivofit and Vifit) were more accurate than smartphone apps in both walking and running conditions, and only the Accupedo app had an acceptable MAPE (≈10%) to be considered valid for use by the general population. Regarding distance validation, in which GPS and accelerometer-based monitors and apps were tested, it was found that only the GPS monitor and apps were valid in both conditions, with low individual errors (<10%). Accelerometer-based monitors and apps had high MAPE, except for Vifit and Accupedo during walking. An important finding was that all GPS freeware apps had comparable accuracy levels with the PA monitor in distance travelled, however only one app (i.e., Accupedo) had comparable accuracy to monitors for step count.

Due to a lack of studies in adolescents, comparisons for the PA monitors and apps from the current study were limited to studies in adult populations. Most previous reviews of validation studies for step count concluded that PA monitors were likely to meet acceptable accuracy levels (Dowd et al., 2018; Feehan et al., 2018; Evenson & Spade, 2020; Moore et al., 2020). Also, hip-worn PA monitors had greater accuracy in measuring steps than wrist-worn activity trackers (Gaz et al., 2018; Moore et al., 2020), and accuracy increased with increasing walking speed (Huang, Xu, Yu, & Shull, 2016; Höchsmann et al., 2018).

The results of the current study partially supported previous findings. Vivofit, which is a wrist-worn PA monitor, was more accurate in both conditions than Vifit (hip-based tracker), and Vivofit had increased validity during running, compared to walking. On the other hand, Vifit performed accurately during walking, with minimum group- and individual-level errors, however validity decreased when speed increased. A possible explanation for these inconsistent findings with previous studies, as mentioned by Adamakis (2020), is that Vifit uses one step-detection algorithm and this algorithm does not differentiate between various activities (i.e., walking vs running), failing to take into account the increased step length during running. Vifit can be considered suitable only for light activities in adolescents, such as brisk walking, while Vivofit is more accurate. Considering previous studies regarding Vivofit's step count validity (e.g., Huang et al., 2016; Höchsmann et al., 2018), this monitor can be used as an outcome measure within a clinical trial, while Vifit is valid for use by the general population.

A unique aspect of this validation study was the inclusion of both monitors and freeware GPS- and accelerometer-based apps. In general, GPS monitor and apps outperformed accelerometer-based monitors and apps for distance validity. Previous studies have shown that GPS devices provide accurate estimates of distance travelled during PA (Scott, Scott, & Kelly, 2016;

Adamakis, 2017; Tierney & Clarke, 2019), and Gray, Jenkins, Andrews, Taaffe, & Glover (2010) noted that GPS were more accurate in tracking distances during linear activities compared to nonlinear activities. This was supported by current results, as all GPS devices had low group- and individual-level errors. More specifically, Forerunner and Sports Tracker had comparable MAPE <5%, while Runkeeper and Runtastic had MAPE ≤10%, for both walking and running conditions.

On the contrary, accelerometer-based monitors and apps had higher distance errors, and only Vivofit had MAPE <15% in both conditions. Vifit and Accupedo had low MAPE during walking (≤10%), however their distance validity decreased significantly during running. The two remaining apps (Pedometer and Pedometer 2.0) had large individual and group errors for both walking and running conditions (>20%). This finding is consistent with previous studies, as most activity trackers and apps have been found accurate with step count but lacked accuracy in reporting distance (Evenson, Goto, & Furberg, 2015; Evenson & Spade, 2020; Gaz et al., 2018; Silva et al., 2020). This error in distance estimation might be a result of inaccurate initial step detection, inappropriate transformation algorithm(s) from step count into distance, and/or step length variability during PA. For example, Vivofit, which was the most accurate PA monitor for step count, was also the most accurate monitor for distance travelled, even though the error for distance estimation was significantly increased.

Regarding step count from accelerometer-based apps, it was previously concluded that there is conflicting and insufficient evidence on the validity and reliability of various apps for measuring PA, and speed and the place where the smartphone was carried had an impact on validity (Funk et al., 2019; Silva et al., 2020). Some studies showed that accelerometer apps slightly differed in their accuracy of step detection and generally demonstrated good validity (Case, Burwick, Volpp, & Patel, 2015; Höchsmann et al., 2018), while in other studies the apps showed moderate validity and did not meet the recognized standards (Orr et al., 2015). In the present study, Accupedo was the most accurate app for step count with acceptable errors (≈10%), while Pedometer and Pedometer 2.0 apps had high errors (>30%) in both conditions. Accupedo was also the only app with comparable validity to the monitors' validity, suitable for use by the general population. These differences are mainly because monitors and apps use proprietary methods to detect steps and hence, differences may exist in the types of movements that are captured as steps, and variability in step output is caused (John, Morton, Arguello, Lyden, & Bassett, 2018). The smartphones' position did not impact step detection accuracy, as all smartphones were placed close to the body, around the waist. We are uncertain whether the accuracy would improve if smartphones were placed in a different position, i.e., around the arm.

The main strengths of this study included the selection of monitors using various technologies (i.e., accelerometry and GPS), and the comparison to a criterion measure. Other strengths included a sample consisting of adolescents, even distribution of boys and girls, submaximal outdoor walking and running tests in a realistic setting and randomization of the two activities to prevent systematic bias in the measurement. Also, the running activity was performed at a high speed. Limitations to this study included the sample size consisting of healthy participants, while future studies should include more semi- or un-structured activities in free-living environment. In addition, future studies should examine the validity of apps during activities of daily living, preferably over a time frame of 2-4 days to assess the suitability of these devices to be used for long-term accelerometry. Finally, the role of smartphone's optimal position on the human body during exercise should be further investigated.

Conclusion

PA tracking devices have been shown to increase daily PA, but the reliability and validity of numerous commercially available monitors and apps remain unclear. In this validation study, each device returned some level of consistency and accuracy during outdoor walking and running in adolescents, GPS monitor and apps were deemed to be valid for distance during for both conditions tested. Forerunner and Sports Tracker showed comparable accuracy levels, suitable for use as an outcome measure within a clinical trial, while the two remaining GPS apps can be used by the general population. Accelerometer-based monitors and apps were not suitable for measuring distance; however, these monitors were valid for step count and only Accupedo app provided similar estimates. Similar studies should be continuously conducted as new fitness trackers, smartwatches and apps are released to the consumer market every year.

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Conflict of Interest
The author declares that there is no conflict of interest.

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ORIGINAL SCIENTIFIC PAPER

Motoric Abilities of Basketball Players According to Different Ranks of Competition and Playing Positions

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Abstract

Basketball is a complex sports game, interrupted by the constant change of defense and offense, and it is a combination of cyclic and most often acyclic movements. Since basketball involves sudden and intense changes in the movement direction, high frequencies of initiating dribbling and movement in posture, stoppings, and physical contact allowed by game rules, there is a link between the abilities needed for successful basketball playing and playing positions. This research aimed to determine the differences in motoric abilities, i.e. the change of direction speed, explosive strength, and running speed of basketball players who compete in different ranks of the competition in relation to the playing positions. The sample of 25 basketball players was divided into two subsamples in relation to the rank of the competition (elite and sub-elite). Eleven motoric ability tests were used in the study (change of direction speed – four tests, explosive strength – four tests, and running speed – three tests). Applying the analysis of variance (ANOVA and MANOVA), differences in motoric abilities were determined between basketball players of different ranks of a competition in relation to the playing positions in the team. Based on the results, a conclusion was reached that the players differ in favor of a higher rank of a competition in the tested abilities, namely those ones who play in the forward position. It can be inferred that a higher rank of a competition requires better quality preparation and players who differ in tactical thinking and better performance of measured abilities.

Keywords: *basketball, change of direction speed, explosive strength, running speed, playing positions, level of competition*

Introduction

Basketball is a complex sports game, interrupted by the constant change of defense and offense, and it is a combination of cyclic and most often acyclic movements (Erčulj, Blas & Bračič, 2010). Basketball is also characterized by frequent periods of high-intensity play which require frequent changes of direction, as well as specific technical skills and well-developed speed of movement (Stojanović et al., 2018). Since basketball involves sudden and intense changes in the course and direction of movement, high frequencies of initiating dribbling and movement in posture, stoppings, and physical contact allowed by the game rules, there is a link between abilities needed to successfully playing basketball and playing positions (Hobbs, 2008). Playing positions, as well as the specificities they bring with them in terms of preparation and tasks in the game, have been the subject of many studies (Apostolidis, Nassis, Bolatoglou & Geladas, 2004; Sallet et al., 2005; Cormery, Marcil & Bouvard, 2008; Mitić et al., 2018; Kocić, Mitić, Berić, Bojić & Milenković, 2019).

Playing positions can be mainly divided into three groups - guards (point and shooting), forwards (small and power), and centers. Besides, with the change of rules and the development of basketball tactics, playing positions are classified according to the specific role of the individual (Harris,

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Stone, O'Bryant, Proulx & Johnson, 2000). Guards play a more important role in organizing the basketball match-play. Forwards should help the guards in the organization of the offense when they are in offensive activities, while during defense they help to enclose their own basket in order to win the ball. Centers should use their superior characteristics and abilities compared to other players, to take the best possible position with their specific movement during the offensive and defensive jump and setting blocks (Sallet, Perrier, Ferret, Vitelli & Baverel, 2005). Each position in the team should necessarily have particular requirements and characteristics of motoric and specific motoric abilities, as well as technical and tactical mastery, in order to meet the goals of the basketball game and to implement planned realization during the match (Kryeziu & Asllani, 2016). Skillfulness, explosive strength, and sprint performance should be a prerequisite for successful basketball playing at the elite level, in all positions (Abdelkrim, Chaouachi, Chamari, Chtara & Castagna, 2010). Researches show that there are significant differences in physical abilities between basketball players of different levels of competition (in favor of higher-ranking players), especially in explosive and repetitive strength (Vukašević, Bubanja, Žarković, Jabučanin & Mašanović, 2021). Differences can also be seen in the maximum speed and isoinertial power (Marković, Ćuk, Radonjić & Momčilović, 2021). In terms of playing position, the biggest differences in physical abilities (agility and explosive strength) are recorded between guards and centers (Mitić et al., 2018).

One of the main problems in the game is selecting the best set of players who will be sent to the court to achieve the best result at any time during the game. This choice is a complex and delicate task because it can be influenced by many factors (Bianchi, Facchinetti & Zuccolotto, 2017). The change of direction speed, explosive strength, and running speed, in combination with other characteristics and abilities from the equation of specification of success in basketball, give an opportunity to create top basketball players. High-intensity basketball activities consist of a large number of jumps and explosive accelerations, often followed by quick stops, which lead the players to achieve maximum speed. Since it should be pointed out that considering the size of the basketball court (28x15m), there is not enough space to achieve the maximum running speed, then in the training process, it should be insisted on the development of starting speed and ability to accelerate. The activities of rapid change of direction and jumps are vastly applied in the game in terms of basketball structure, regardless of the playing position, so the training and the development of these abilities are of great importance in basketball. (Asadi & Arazi, 2012; Lehnert, Hůlka, Malý, Fohler & Zahálka, 2013; Nikolić, 2016; Nikolić, Kocić & Veličković, 2017; Mitić et al., 2018; Kocić et al., 2019). The change of direction speed depends on the number of factors, which include coordination, mobility of articular systems, reaction speed, stability of the locomotor system, and biomechanical structure of the movement. Therefore, during the game, it is necessary to make an adequate and correct decision depending on the situation, in order to achieve the expected results. A properly made decision depends primarily on the perception and analysis of the situation based on an assessment of available options.

This research was conducted out of the need to obtain additional information and suggestions for easier creation of training programs in specific playing positions in order to develop as many skills specific to basketball players as possible. So, this research aimed to determine the differences in motoric abilities, i.e. the change of direction speed, explosive strength, and running speed of basketball players who compete in different ranks of the competition in relation to the playing positions.

Methods

Participants

The sample consisted of 25 male basketball players between 19 and 30 years old, divided into two subsamples: a group of 12 elite basketball players (First Basketball League of Serbia team – Napredak Aleksinac) and a group of 13 subelite basketball players (Second Basketball League of Serbia team – Konstantin Niš), each of them divided into three groups (guards, forwards and centers). All of the players were in good health and had at least five years of basketball practice experience. This study was approved in advance by the Ethics Committee of the Faculty of Sport and Physical Education, University of Niš (approval number 04-2170/2). Having been informed about the details of the testing each participant voluntarily provided written consent for taking part in it. Participants, sports experts, and club management were acquainted with the manner and rules of testing. The consent of the club's management that the data obtained through testing could be used for scientific purposes was also acquired.

Measuring instruments

Four tests were used to estimate the change of direction speed: Agility T-Test, Hexagon Agility Test, Illinois Agility Test, and Lane Agility Drill (Pauole, Madole, Garhammer, Lacourse & Rozenek, 2000; Sigmon, 2005; Beekhuizen, Davis, Kolber & Cheng, 2009). The following tests were used to assess the explosive strength of the lower extremities: Squat jump, Countermovement Jump, Drop Jump and One-legged Countermovement Jump (Bosco, Luhtanen, & Komi, 1983). "Optojump" was used for measuring the explosive strength of vertical jumping performance (Microgate, Italy). Three tests were used to estimate running speed: 10x5m Shuttle Test (Boone & Bourgois, 2013; Kucsa & Mačura, 2015; Nikolić, Berić, Kocić & Daskalovski, 2017), Sprint fatigue test, and 15m running speed (Ademović, 2016; Nikolić et al., 2017).

Statistical processing of data

Data processing was performed by the statistics program SPSS (IBM Corp. Released 2011. IBM SPSS Statistics for Windows, Version 20.0). From the descriptive statistics, the basic central and dispersion parameters were used (Mean and St.Dev). To determine changes in the change of direction speed, explosive strength and running speed between basketball players of different ranks of competition about the playing positions, analysis of variance was used (ANOVA and MANOVA). The level of statistical significance is $p<0.05$.

Results

The following chapter presents the obtained research results in change of direction speed, explosive strength and running speed (Tables 1, 2 and 3), as well as their interpretation.

Using univariate analysis of variance of change of direction speed according to the playing positions between elite and

Table 1. Differences in Change of Direction Speed Between Elite and Sub-elite Basketball Players According to Playing Positions

Change of direction speed - Guards	Sub-elite basketball players	Elite basketball players	ANOVA	
			F	p
Agility T Test	9.35 (±0.30)	9.55 (±0.41)	0.64	.454
Hexagon Agility Test	13.00 (±1.34)	12.83 (±1.90)	0.02	.890
Illinois Agility Test	15.95 (±0.87)	16.33 (±1.06)	0.31	.597
Lane Agility Drill	12.85 (±0.84)	12.78 (±1.09)	0.01	.917
			MANOVA F= 2.13; p= .280	
Change of direction speed - Forwards	**Sub-elite basketball players**	**Elite basketball players**	**ANOVA**	
			F	**p**
Agility T Test	10.00 (±0.67)	9.32 (±0.33)	3.31	.119
Hexagon Agility Test	11.75 (±0.84)	10.79 (±0.41)	4.27	.084
Illinois Agility Test	17.40 (±1.07)	16.22 (±0.45)	4.15	.088
Lane Agility Drill	13.95 (±0.93)	12.76 (±0.30)	5.96	.050*
			MANOVA F= 15.10; p= .025*	
Change of direction speed - Centers	**Sub-elite basketball players**	**Elite basketball players**	**ANOVA**	
			F	**p**
Agility T Test	10.00 (±0.14)	10.00 (±0.50)	0.00	.992
Hexagon Agility Test	13.44 (±1.03)	14.79 (±1.39)	2.79	.139
Illinois Agility Test	17.00 (±0.80)	16.97 (±0.41)	0.00	.948
Lane Agility Drill	14.24 (±0.71)	13.46 (±0.40)	3.74	.094
The data represent Mean (±St.Dev) *Differences between groups are presented at the level of p<0.05			MANOVA F= 4.10; p= .100	

sub-elite basketball players (Table 1), it was found that there was no statistically significant difference in any test at guards. At forwards, there was a significant difference only in the LA Drill test (.050), while at centers there was also no statistically significant difference. At the multivariate level, there was no statistically significant difference betweenthe two teams for the guards and centers, while for forwards there was a statistically significant difference (.025).

Table 2. Differences in Explosive Strength Between Elite and Sub-elite Basketball Players According to Playing Positions

Explosive strength - Guards	Sub-elite basketball players	Elite basketball players	ANOVA	
			F	p
SJ	35.23 (±5.53)	38.30 (±3.39)	0.90	.380
CMJ	38.13 (±4.19)	36.77 (±4.21)	0.21	.665
DJ	46.90 (±7.24)	48.28 (±5.99)	0.09	.780
O-L CMJ	18.05 (±3.23)	23.15 (±2.47)	6.28	.046*
			MANOVA F= 6.38; p= .080	
Explosive strength - Forwards	**Sub-elite basketball players**	**Elite basketball players**	**ANOVA**	
			F	**p**
SJ	34.85 (±5.01)	51.35 (±2.54)	34.48	.001*
CMJ	37.45 (±5.07)	43.95 (±2.92)	4.93	.068
DJ	44.63 (±5.79)	58.48 (±6.31)	10.47	.018*
O-L CMJ	16.07 (±2.88)	26.60 (±0.49)	52.07	.000*
			MANOVA F= 16.14; p= .023*	
Explosive strength - Centers	**Sub-elite basketball players**	**Elite basketball players**	**ANOVA**	
			F	**p**
SJ	34.74 (±2.23)	37.10 (±6.08)	0.66	.442
CMJ	38.54 (±4.27)	35.63 (±6.01)	0.73	.421
DJ	47.88 (±7.01)	45.40 (±5.88)	0.32	.590
O-L CMJ	20.76 (±3.07)	18.98 (±4.24)	0.54	.486
The data represent Mean (±St.Dev) *Differences between groups are presented at the level of p<0.05			MANOVA F= 4.49; p= .079	

Note. SJ: squat jump; SMJ: counter movement jump; DJ: drop jump; O-L CMJ: one-legged counter movement jump

Using univariate analysis of variance of explosive strength according to the playing positions between elite and sub-elite basketball players (Table 2), it was found that at guards a statistically significant difference exists only in One-legged Countermovement Jump (O-L CMJ .046). At forwards, a significant difference was shown in Squat jump (SJ .001), Drop jump (DJ .018) and One-legged Countermovement Jump (O-L CMJ .000), while at centers there was no statistically significant difference in any test. At the multivariate level, no statistically significant difference was shown between guards and centers of the two teams, while at forwards, a statistically significant difference was shown (.023).

Table 3. Differences in Speed BetweenElite and Sub-elite Basketball Players According to Playing Positions

Speed - Guards	Sub-elite basketball players	Elite basketball players	ANOVA	
			F	p
15m running speed	2.59±0.07	2.51±0.13	1.15	.324
10x5m Shuttle Test	15.19±0.62	14.42±0.63	3.01	.133
Sprint fatigue test	0.98± 0.02	0.99±0.02	1.17	.320
			MANOVA F= 1.20;p= .417	
Speed - Forwards	**Sub-elite basketball players**	**Elite basketball players**	**ANOVA**	
			F	**p**
15m running speed	2.53±0.16	2.32±0.08	5.96	.050*
10x5m Shuttle Test	14.18±1.51	13.79±0.21	0.26	.625
Sprint fatigue test	1.00±0.02	0.97±0.02	6.00	.050*
			MANOVA F= 2.42; p= .206	
Speed - Centers	**Sub-elite basketball players**	**Elite basketball players**	**ANOVA**	
			F	**p**
15m running speed	2.58±0.16	2.52±0.10	0.48	.512
10x5m Shuttle Test	13.70±0.33	14.53±0.65	6.24	.041*
Sprint fatigue test	1.00±0.03	0.98±0.03	1.25	.300
The data represent Mean (±St.Dev) *Differences between groups are presented at the level of p<0.05			MANOVA F= 2.59;p= .166	

Using univariate analysis of the variance of speed according to the playing positions between elite and sub-elite basketball players (Table 3), it was determined that there was no statistically significant difference among guards in any speed test. In the case of forwards, there are significant differences in 15m running speed (.050) and Sprint fatigue test (.050), while at centers there was a statistically significant difference in only one test, 10x5m Shuttle Test (.041). At the multivariate level, no statistically significant difference was found in the playing positions of the two teams.

Discussion

The results of this research showed that there are differences in basketball players who compete in a higher rank of a competition and that the level of preparation and quality of players determines the playing position. These results are also confirmed by other researches (Köklü, Alemdaroğlu, Koçak, Erol & Fındıkoğlu, 2011; Korkmaz & Karahan, 2012). Basketball is a sports game in which height is a crucial factor. When eliminating the factors of body height and weight, it was found that the differences between the individual positions of the players are reduced, but not completely eliminated (Erčulj, Bračič & Jakovljević, 2011). Training of change of direction speed should be individualized depending on the playing position in the team (Delextrat & Cohen, 2009; Abdelkrim et al., 2010; Ademović, 2016). Today's approach to change of direction speed training differs from the one that used to be applied in the past and involves a combination of different training systems. Directed training of change of direction speed is the basis for training technical and tactical tasks of players in all playing positions (Trunić & Mladenović, 2015). The results obtained this way were expected, considering the fact that the tasks of change of direction speed type are the most pronounced with players in external positions and they confirm former results that, players in external positions achieve better results than players in internal positions, especially those who play in the higher ranks of competition (Scanlan, Tucker & Dalbo, 2014; Sekulić et al., 2017; Garcia-Gil et al., 2018; Ferioli et al., 2018; Trapero et al., 2019). The results of this study also confirm that players who play in the position of centers achieve the weakest results in the conducted testing (Abdelkrim et al., 2010; Erčulj et al., 2011), and that basketball technical and tactical skills (specific basketball motorics and tactical thinking) are the factors that make the difference between these two groups of basketball players (Ilić, 2013). That is why it can be concluded that activities such as change of direction speed are highly correlated with competitive success. The fact that the forwards from a higher rank achieved better results than the ones in a lower rank is probably a consequence of the specificities of movement which characterize that very position, as well as of a better subjective feeling of focus on the game, which is reflected primarily in the quality of the players themselves because they play in a higher rank of the competition (Gonzalez, Hoffman, Scallin-Perez & Fragala, 2012). The research also confirms that the level of physical qualities and performance of explosive strength is significantly related to the quality of the players themselves in relation to the rank of the competition. The results also showed that in the vertical jump tests, centers achieved significantly lower results than players in other positions, while forwards have more muscular strength than players in other positions (Boone & Bourgois, 2013; Kostopoulos, 2015; Pehar et al., 2017). Unlike researches (Mitić et al., 2018; Stamenković, 2018) in which the obtained results show that the greatest difference between guards and centers is in favor of the guards and that the differences are the greatest between guards and forwards and guards and centers, and that they also exist between forwards and centers only in some of the variables of explosive strength, this research found that only forwards differ for the benefit of those who compete in a higher rank of the competition. It is important to note that during the game, the maximum speed of movement is almost never developed because the ability to perform repeated runs of high, submaximal intensity is still a more dominant form (Alp, 2020). When the basketball game is decomposed, it can be seen that sprints usually last from two to six seconds (McInnes, Carlson, Jonnes & McKenna, 1995), at distances of 10–20m (Drinkwater, Pyne & McKenna, 2008), which is insufficient to develop maximum speed. However, it should be emphasized that all aspects of this motoric ability are present and necessary during the game where there are constant and fast shifts of defense and offense, a large number of sprints over short distances, as well as requirements for efficient and fast placement (reaction speed) in the best possible position for receiving the ball and successful realization. Also, the speed of movement with the ball during dribbling is very important, which is reflected in the reaction speed of the lower and upper extremities in relation to the direction of movement of the opponent and the ball (Zwierko & Lesiakowski, 2007). In the not-so-distant past, players were classified into positions in relation to morphological characteristics and based on technical-tactical tasks (Bianchi et al., 2017), while in recent years the situation is slightly different in the sense that playing positions (especially "low positions" of guards and forwards) are classified exclusively according to physical abilities, among which speed occupies a significant place. Hoare (2000) found in his study that running speed and playing position are related and that guards are significantly faster and more successful in running speed and change of direction in relation to forwards and centers, which was not confirmed in this study.

Conclusion

A conclusion was reached that the players differ in tested abilities in favor of a higher rank of the competition, especially those ones who play in the forward position. It was found that a higher rank of the competition requires better quality preparation and players who differ in tactical thinking and better performance of measured abilities. Previous studies had mainly dealt with playing positions according to pre-determined tasks and activities in the team. However, today's basketball especially stands out and appreciates the so-called polyvalent players who could play in all positions. There are a significant number of such players who play in the highest quality leagues. Monitoring the state of the change of direction speed, explosive strength, and running speed of basketball players and comparison with the corresponding sample can affect more correct planning and programming of the training process. The results obtained in this way provide information and suggestions for experts in the field of sports and coaches who should create a training program in specific positions, to develop as many skills specific to basketball players as possible. In addition, team leaders from lower levels of competition are encouraged to refine talent identification based on key fitness determinants in playing positions highlighted in current findings. Fitness trainers could develop training programs based on the weaknesses of the players shown during the testing, taking into account the specificity of the situation during the game in each position. In particular, it is proposed to focus more attention on training of change of direction speed and the explosive strength of players in the position of center. This can be integrated into tactical offensive and defensive training, to improve their efficiency and response to situational impulses.

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ORIGINAL SCIENTIFIC PAPER

Physical Performance and Psychological Status of Professional Football Players with Recurrent Ankle Sprains

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Abstract

This study aims to compare physical performance and psychological status between professional football players with no history of ankle sprain and those with recurrent ankle sprains. The participants in this study included 40 male professional football players from 6 football clubs in Thailand. Participants were classified into two groups, those with no history of ankle sprain (control) and those with recurrent ankle sprains, with 20 participants in each group. All participants were asked to perform four physical performance tests, namely, the weight bearing lunge test, star excursion balance test, vertical jump test, and Illinois agility test; and to complete two psychological questionnaires, assessing anxiety and burnout. The physical test results showed that the posteromedial direction in the star excursion balance test was significantly lower in the recurrent ankle sprain group compared to the control ($p<0.05$). There were no differences in anterior and posterolateral directions. In addition, there were no significant differences in weight bearing lunge, vertical jump, and Illinois agility between the groups. The results of the psychological questionnaires showed a significant difference in terms of the achievement dimension of burnout between the groups ($p<0.05$), while in other psychological parameters there was no difference. The difference was partially achieved, only in two tests, while in others there was no difference at all. Therefore, in accordance with the achieved results, the coach and rehabilitation team should raise awareness and include treatment programs to help athletes avoid physical and mental problems associated with recurring ankle injuries.

Keywords: *recurrent ankle sprain, professional football players, anxiety, burnout, physical performance*

Introduction

An ankle sprain is a common lower extremity injury that occurs 50% of the time during sports activity in healthy people and athletes (Miklovic, Donovan, Protzuk, Kang, & Feger, 2018). In amateur and professional athletes, an ankle sprain mostly occurs in contact and rotational movements such as jumping, landing, and cutting movements (McKay, Goldie, & Payne, 2002). An ankle sprain is defined as an injury of the ligament of the ankle joint, and medial and lateral ligament injuries are caused by excessive force applied to the medial and lateral sides of the ankle, leading to over eversion and inversion movements, respectively. Lateral ankle sprains occur at a higher incidence than medial ankle sprains (Delahunt & Remus, 2019). Previous studies have shown that an acute ankle sprain does not only damage the structure around the ankle joint but also leads to defects in mechanoreceptors, joint tension, joint pressure, and proprioceptive joint sense; and to movement disability in daily life (Michelson & Hutchins, 1995).

A study about the incidence of ankle sprains in the

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Netherlands discovered that only a small number of injured athletes received medical treatment and rehabilitation to improve ankle joint functions, where the structural and functional features after an acute ankle sprain were not fully recovered. For example, more than 70% of people affected by their first ankle sprain still displayed signs and symptoms such as weakness of the calf and intrinsic foot muscle, post-traumatic osteoarthritis, pain, and high risk of recurrent ankle sprains which might develop into chronic ankle instability (CAI) (Stubbe et al., 2015). A previous study has found that recurrent ankle sprains can occur among volleyball, American football, basketball, and football players with an incidence of 46, 43, 28, and 19%, respectively (Herzog, Kerr, Marshall, & Wilktrom, 2019). An acute ankle sprain causes weakness of the dorsiflexion, plantarflexion, inversion, and eversion of the foot. In addition, it results in tightness of the ankle plantar flexor muscle, tightness of the gastrocnemius and soleus muscles, increased tension of the capsular joint, and limited movement of the talus bone in the posterior direction of the ankle joint (Hubbard, Hertel & Sherbondy, 2006; Frigg, Magerkurth, Valderrabano, Ledermann, & Hintermann, 2007). However, only limited research has examined the effects of recurrent ankle sprains on the functional movement of the ankle joint, such as its range of motion, strength, balance, and agility upon activity. Alghadir, Iqbal, Iqbal, Ahmed, and Ramteke (2020) found the impairment of foot proprioception, static and dynamic balance that tested by degree of foot position sense, single-leg stance time and Y-balance test respectively, in athletes who have grade 1 or 2 ankle sprain within one year compared with the control group. Mitchell, Dyson, Hale, and Abraham (2008) investigate the postural sway in a person with an ankle sprain and functional instability and found that the medial and lateral sway of the functional ankle instability was significantly greater than the control groups. However, these studies were done in the amateur athletes and healthy persons, no study involved the professional player who has a high degree of training.

A physical injury does not only affect physical function and performance but also causes mental impairment in healthy individuals and athletes (Clanton, Matheny, Jarvis, & Jeronimus, 2012). Shadloo and colleagues (2016) found that the probability of recurrent injuries was associated with psychological problems. Among athletes who have had an injury, 19% suffered psychological problems (Gould, Bridges, Udry, & Beck, 1997). Most of the psychological impairment of athletes was related to their physical performance and included anxiety, depression, disappointment, stress, and fear related to the recurrent injury (Podlog & Eklund, 2010). First-time ankle sprain athletes displayed lower self-esteem, fear, and anxiety (Nippert & Smith, 2008). Athletes suffering fear and anxiety have a high risk of getting recurrent injuries or injuries in other areas (Podlog & Eklund, 2010). In addition, a study has found that prolonged anxiety or stress is correlated with burnout and reduced readiness for athletic competitions, eventually leading to a behavioral change and a decline in sports performances among athletes (Nippert & Smith, 2008; van Wilgen, Kaptein, & Brink, 2010). From the literature review, there is still a lack of knowledge about the effects of a recurrent ankle sprain on the psychological profiles, especially the anxiety and burnout in professional athletes. Several studies focused on the fear of reinjury in ankle sprain athletes (Fukano, Mineta, & Hirose, 2020). Kosik et al. (2020) investigated health-related quality of life between adults with CAI, coper and uninjured controls. Results showed that participants with CAI report a higher score of depression and a lower score of ability to participate in social roles and activities than uninjured control.

Currently, only a limited number of studies have focused on physical performance and psychological status related to recurrent injuries, especially among professional football players with recurrent ankle injuries who continue to be exposed to intense physical training and stress conditions. Therefore, the aim of this study was to assess the physical performance and psychological status related to ankle joint injury among professional football players with recurrent ankle sprains.

Methods

Participants

This study employed a descriptive design. Ankle sprain injury data related to physical performance and psychological status were collected from male professional football players within Thai League 3. Forty male professional football players participated in the study. The sample size was calculated with G*Power Version 3.1 using the mean and standard deviation of the posterolateral direction of the star excursion balance test from the study of Doherty et al. (2016) (alpha: 0.05, power: 0.80). Participants (n = 40) were classified into two groups: athletes who have never had an ankle sprain (control group; n = 20) and those who have had a history of ankle sprains in only one leg more than one time (recurrent ankle sprain group; n = 20). Participants who had experienced ankle sprains in both legs; knee injury involving the ligament, bone, or meniscus; back and lower limb pain within seven days; fractures; or post-operative lower limb surgery were excluded from the study. The inclusion criteria for participant recruitment included: 1) age between 18-35 years, 2) playing in a professional football club for more than one year, 3) regular training with a team more than five days per week for at least two hours per day, and 4) Cumberland Ankle Instability score of less than 27 for the recurrent ankle sprains group. A recurrent ankle sprain was defined as an ankle sprain occurring for an athlete more than one time within three years before the study. An ankle sprain was identified as an injury to the ankle ligament that causes pain, swelling, redness, warmness, and limited function of the foot and ankle; and that prevents that participant from training with their team for at least three days. All participants signed an informed consent form before participating in the performance tests. Ethical approval was obtained from the Human Research Ethics Committee of Walailak University, Thailand (WUEC-20-306-01).

Procedure

All participants were asked to complete a questionnaire about their general information (age, weight, height, and body mass index), health status, training details and history of ankle sprains, as well as the type and number of injuries that they had sustained in the previous three years. To assess ankle instability, the Cumberland Ankle Instability questionnaire was provided for the participants to complete. All participants were asked to complete two additional questionnaires for psychological assessment, including a revised version of the Competitive State Anxiety Inventory-2 and the Athlete Burnout Questionnaire. Afterward, all participants performed four functional performance tests related to the ankle joint in the following order: weight bearing lunge test, star excursion balance test, vertical jump test, and Illinois agility test. These tests assisted in examining the dorsiflexion range of motion during weight bearing, dynamic balance, power, and agility performances, respectively. Before the test, resting heart rate, blood pressure, oxygen saturation, and rate of perceived exertion were measured. Participants were allowed to rest between each test until their vital signs returned to resting conditions.

Physical performance tests

Weight bearing lunge test

The weight bearing lunge test (WBLT) was performed to measure the dorsiflexion range of motion of the ankle joint during weight bearing. The participants performed the WBLT on their injured limb for the recurrent ankle sprain group or on a randomized limb for the control group. The participants were instructed to stand in a tandem stance with the test limb in the front, to bend their knee and touch the wall, and to maintain heel contact with the ground. The participants placed their untested limb behind the tested limb in a comfortable position, placed their hands on the wall to maintain stability, and moved their test foot away from the wall. The maximum horizontal distance from the toe to the wall was measured using a tape when participants performed maximum ankle dorsiflexion with heel contact with the ground (Hall & Docherty, 2017). The participants performed three practice trials followed by three test trials.

Star excursion balance test

The star excursion balance test is a clinical test aimed to detect functional performance deficits associated with lower extremity pathology and reflects ankle strategy for balance control during weight bearing (Hertel, Braham, Hale, & Olmsted-Kramer, 2006). The participants were instructed to stand on the ankle sprain side for the recurrent ankle sprain group or on a randomized side for the control group. While standing on a single limb, the participants stretched out their reaching limb along each reaching line as far as possible, lightly touched the line with the most distant part of the reaching foot without shifting weight to the reaching limb, and then returned the reaching limb back to the center. If the participants touched heavily on the reaching point, touched the ground with the reaching foot for stabilization, or lifted or shifted any part of the stance foot during the trial, the trial was considered incomplete. The distance reached by the reaching foot on the line was measured (Gribble, Hertel, & Plisky, 2012). The test was repeated three times each for the anterior, posterolateral, and posteromedial directions.

Vertical jump test

The vertical jump height was measured through the Vertec Vertical Jump® apparatus (USA) with longitudinal cells of 1.5 cm. The participants were instructed to stand with legs shoulder-width apart and with one hand extended over the head to touch the Vertec slate, and the number was recorded. Then, the participants were asked to perform a maximum jump with as much hip and knee flexion as possible. The test was repeated three times with a 2-minute rest between each repetition, and the maximum value was recorded.

Illinois agility test

For the Illinois agility test, the participants were instructed to run through a field, 10 meters in length and 5 meters in width, with four cones placed at the corners of the field and four cones down the center length of the field. The participants started at one corner of the field and had to run after cones placed in eight positions. The participants had to swerve between cones while running through the four cones placed down the center length of the field. The test started on the "go" command, and the participants had to run as fast as possible. Performances were recorded in seconds using a timer. The test was repeated three times, and the best score was used for analysis.

Psychological assessment

The Competitive State Anxiety Inventory-2 (CSAI-2R) questionnaire in a Thai version that based on the original version of Martens and colleagues was used to assess competitive state anxiety in athletes, consisting of three subscales: cognitive anxiety, somatic anxiety, and self-confidence (Choosuwan, Ratrujithong, & Tungthongchai, 2019). The severity of anxiety was classified into low, moderate, and high levels. The Athlete Burnout Questionnaire (ABQ) in a Thai version was used for assessing athlete burnout symptoms (Polyotha et al., 2014). It consisted of three dimensions including emotional/physical exhaustion, sport devaluation, and a reduced sense of accomplishment. This questionnaire was composed of 15 items, with 5 items for each dimension. All items were semantically anchored on a 5-point Likert-type scale ranging from 1 (almost never) to 5 (almost always), and means were computed to obtain subscale scores.

Statistical analysis

Statistical Package for Social Sciences (SPSS) for Windows was used for statistical analysis. The characteristics of the participants (age, weight, height, BMI, and Cumberland Ankle Instability score), burnout score, and physical performance parameters (weight bearing lunge, star excursion balance, vertical jump, and Illinois agility) were examined with an independent t-test to determine differences among the two groups. The difference relative to the Revised Competitive State Anxiety Inventory score between the groups was tested by Mann-Whitney U tests since the distribution of data was not normal. The significance level was set to $p<0.05$ for data analysis.

Results

Participants in the recurrent ankle sprain group have the experience of ankle sprains more than one time (average 3±1.25 times) for only one leg, whereas those in the control group have had no experience of an ankle sprain. The Cumberland Ankle Instability score for the recurrent ankle sprain group was significantly lower compared with the control group (23.50±2.46 and 29.52±0.24 for the recurrent ankle sprain group and the control group, respectively). There was no difference in age, weight, height, and body mass index (BMI) between groups as shown in Table 1.

Table 1. Characteristics of the participants including age, weight, height, body mass index, and Cumberland Ankle Instability score in the control and recurrent ankle sprain group

Characteristics	Mean±SD		p-value
	Control group (n=20)	RAS group (n=20)	
Age (year)	24±4.88	24±3.30	.309
Weight (kg)	67.05±8.46	66.96±5.34	.967
Height (cm)	174.70±8.20	174.38±4.11	.873
BMI (kg/m^2)	21.99±2.58	22.00±1.16	.993
CAI score	29.52±0.24	23.50±2.46	.000*

Legend: RAS group - Recurrent ankle sprain group; BMI = Body Mass Index; CAI score - Cumberland Ankle Instability score; * significantly different compared between groups (p<0.05)

Physical performance

The weight bearing lunge test, star excursion balance test in three directions (anterior, posteromedial, and posterolateral), vertical jump test, and Illinois agility test were performed by all participants. The results showed that only the posteromedial direction of the star excursion balance test was significantly lower in the recurrent ankle sprain group compared to the control group (p<0.05). However, the anterior and posterolateral directions did not show a significant difference. In addition, there was no significant difference between the groups in weight bearing lunge, vertical jump, or Illinois agility as shown in Table 2.

Table 2. Physical performance of the participants in the control and recurrent ankle sprain groups

Parameters	Control group (n=20)	RAS group (n=20)	p-value
Weight bearing lunge test (cm)	9.68±3.62	9.25±4.13	.608
Star excursion balance test (cm)			
- Anterior	84.22±12.42	83.38±8.52	.108
- Posteromedial	101.69±11.57	94.18±6.10	.044*
- Posterolateral	95.37±13.74	92.29±10.30	.666
Vertical jump test (inch)	22.03±3.92	22.96±2.48	.119
Illinois agility test (sec)	15.85±0.52	13.04±0.76	.052

Legend: RAS group - Recurrent ankle sprain group; * significantly different compared between groups (p<0.05)

Psychological status

The psychological status including athlete anxiety and burnout were evaluated using questionnaires. The results showed a significantly greater reduced sense of achievement dimension of athlete burnout in the recurrent ankle sprain group compared with the control group (p<0.05) without a significant difference in the other dimensions. However, no significant difference was found for anxiety between the control and recurrent ankle sprain groups as shown in Table 3. The percentages of the control participants in the low, moderate, and high levels of anxiety were 40.00, 60.00, and 0.00%, respectively. In contrast, the recurrent ankle sprain group displayed 20.84, 79.16, and 0.00%, respectively, for the same levels of anxiety.

Table 3. Psychological status including athlete anxiety and burnout of the participants in the control and recurrent ankle sprain groups

Parameters	Control group (n = 20)	RAS group (n = 20)	p-value
RCS Anxiety Inventory	35.50 (23-42)	37.00 (23-44)	.162
Classification of anxiety level			
Low (%)	40	20.84	
Moderate (%)	60	79.16	
High (%)	0	0	
Athlete Burnout Questionnaire			
Emotional and physical exhaustion	2.22±0.45	2.38±0.64	.136
Sports devaluation	1.88±0.75	1.50±0.64	.519
Reduced sense of achievement	2.23±0.39	2.36±0.45	.043*
Total score	6.30±0.94	6.28±0.94	.961

Legend: RAS group - Recurrent ankle sprain group; RCS Anxiety Inventory - Revised Competitive State Anxiety Inventory; * significantly different compared between groups (p<0.05)

Discussion

The purpose of this study was to determine the physical performance and psychological status of professional football players who sustained recurrent ankle sprains. Only a limited number of studies have focused on these parameters among professional athletes. The main finding of the present study was the reduced distance of the star excursion balance test only in the posteromedial direction among athletes with recurrent ankle sprains. In addition, the reduced sense of achievement assessed through the Athlete Burnout Questionnaire was significantly higher among the recurrent ankle sprain group compared to the control group.

The present study found that balance control in the posteromedial direction of athletes with recurrent ankle sprains was significantly reduced compared to the control group. This finding is similar to the study of Hertel et al. (2006), which determined that the posteromedial direction of the star excursion balance test is most affected by chronic ankle instability in young adults. Whereas Khuman, Devi, and Kamlesh (2014) demonstrated that people with CAI showed a shorter star excursion balance test reaching distance in all directions compared to healthy asymptomatic participants, with a number of ankle sprains occurring on the same side at 1.43±0.62 times. Dynamic postural control during the star excursion balance test requires the ability to maintain the center of gravity over the base of support without compromising balance. A small reaching distance indicates the reduction ability of dynamic postural control. This might be influenced by impaired neuromuscular control and proprioception. Ankle sprain not only damages the structural integrity of ligaments but also affects mechanoreceptors, joint capsules, and tendons around the ankle complex. Mechanoreceptors provide feedback on joint pressure, tension, movement, and proprioception; and affect postural control upon ankle sprain (Michelson, & Hutchins, 1995; Hertel, 2008).

This study found no significant difference in weight bearing lunge, vertical jump, and Illinois agility performance between the recurrent ankle sprain and control group. This result was in contrast with the findings by Hoch and colleagues that weight bearing lunge was significantly lower in healthy subjects who have CAI (Hoch, Staton, McKeon, Mattacola, & McKeon, 2012). The differences might be due to a different study population; in this study, participants were professional athletes, physically active, and regularly trained at high volume. Almost training for professional football players involves movement and function of the ankle and lower limb muscle; therefore, regular training might promote ankle biomechanics. In addition, the participants of this study could return to training and competition, and the results showed that strength training such as resistance exercise and plyometric training was added into the training program of all teams. Plyometric training, related to the improvement of muscle power, might result in preserved vertical jump performance in athletes with recurrent ankle sprains (Kubo et al., 2007).

In this study, the reduced sense of achievement dimension of athlete burnout was found to be greater among the recurrent ankle sprain group compared to the control group. A sense of achievement is defined as the self-evaluation of sports abilities and achievements (Raedeke & Smith, 2001). Several factors contributing to athlete burnout include extremely high training volume, demanding performance expectations, frequent and intense competitions, inconsistent coaching practices, and negative performance evaluations. Personal characteristics also contribute to burnout such as negative perfectionism, a need to please others, obsessive passion, low self-esteem, and unidimensional self-conceptualization (Malina, 2010; Matos, Winsley, & Williams, 2011). In addition, some overuse injuries may result in long-term health consequences, including burnout and previous illnesses related to burnout in young athletes (DiFiori et al., 2014). A previous study stated that the fear of selection is one stressor for athletes, especially in a professional context, as athletes might lose their income if they do not perform at a high standard. In addition, a football career is considerably shorter than other occupations, and so injury and worry about the risk of injury are unique aspects of elite sports (Stambulova, 2006). However, the overall burnout score in the recurrent ankle sprain group was not different from that of the control group. Moreover, this study found that the competitive state anxiety in athletes was not significantly different between the two groups. This might be caused by three reasons. Firstly, 54.17% of athletes with recurrent ankle sprains in the present study reported their last ankle sprain more than one year before the study. Turner and colleagues reported that a high level of anxiety was found in the acute phase of injury, independent of the area and types of injury; later, the level of anxiety gradually declined when athletes returned to training (Turner et al., 2017). Secondly, a recent study found that the physical performance of athletes with recurrent ankle sprains was not different from the control group except for the posteromedial direction of the star excursion balance test. This suggests that the physical performance of this group of subjects had nearly recovered, and this could be related to a reduction in anxiety. It has been reported that anxiety has a statistically and significantly inverse correlation with an athlete's physical performance, where high performance reduces anxiety (Parnabas, 2015). Finally, rehabilitation programs and social support from friends, family, and coaches might help reduce anxiety (Covassin et al., 2014). However, the researchers did not record data on the treatment and rehabilitation programs that the participants received after an ankle sprain, which is a limitation of this study. Early and appropriate rehabilitation by medical teams might result in rapid recovery and reduced psychological issues.

This study showed a significant difference in the posteromedial direction of the star excursion balance test and in the sense of achievement dimension of athlete burnout in professional football players with recurrent ankle sprains compared to the control. Therefore, it is necessary to be aware that rehabilitation or training programs could improve balance and prevent its further decline, and that mental support could prevent the reduction of the sense of achievement of professional athletes.

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Conflict of interest
The authors have no conflict of interest relevant to this article.

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ORIGINAL SCIENTIFIC PAPER

Comparative Efficacy of Isometric versus Dynamic Exercises on Cervical Spondylosis

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Abstract

Cervical spondylosis is a degenerative disorder in the neck that is very common and worsens with age: it can limit the ability to participate in normal activities and is also costly to treat. The purpose of this study was to observe the effect of isometric and dynamic exercises on cervical spondylosis. This study was conducted at the center for physical therapy and rehabilitation in "Banja e Kllokotit", Kllokot, Kosovo. The total number of patients included in the study was 60 people of both sexes, who were randomly divided into two groups (group A, n=30; group B, n=30) and received ten sessions of physical therapy. Group A was treated with thermotherapy, electrotherapy, dynamic exercises for the muscles of the cervical region, stretching and deep transverse massage; while group B was treated with thermotherapy, electrotherapy, isometric exercises, and stretching. Range of motion was measured with a standard goniometer, while the level of pain was estimated by the numerical rating scale of pain (NRS). Evaluation of patients was done before and after ten sessions of treatment. The results showed significant difference between groups related to mobility in flexion (P=0.052), extension (P =0.743) side bending (P<0.000) and pain parameters (P<0.000); the group of patients treated with dynamic exercise showed better results and performance after 10 sessions of physical therapy. It can be concluded that dynamic exercise produces better results compared to isometric exercises.

Keywords: *cervical spondylosis, neck pain, isometric exercise, dynamic exercise*

Introduction

Neck is one of the most complex parts of the human body. This complexity is attributed to its anatomic and physiologic construction. Neck pain is a common medical condition that can limit the ability to participate in normal activities and is also costly to treat (Kay et al., 2012). Neck pain can be caused by several disorders and diseases; it may involve any of the tissues in the neck and the most common cause of neck pain is a degenerative disorder (Hirpara, Butller, Dolan, O'Byrne, & Poynton, 2012). Neck pain is also referred to as cervical pain, which is commonly associated with dull aching: sometimes, neck pain may become worse with movement of the neck or turning of the head.

There are many treatments available for neck pain, but not all of them have the same effects on the neck, which is the reason for many scientific contradictions regarding treatment techniques. The most frequent techniques used are the McKenzie method, manual mobilization, gliding techniques and exercise (Falla et al., 2007; Salt, Kelly, & Soundy, 2016). In a previous study (Kendall et al., 2018), it has been stated that dizziness may be dangerous for older people because dizziness, which is a symptom of neck pain, may cause them to fall. 'Spinal manipulative therapy (SMT)' is another method that is widely used to treat neck pain: this method is beneficial because it has been shown to lower neck pain especially in older people, without causing any side effects. It is well known that people have different pain perception threshold. Because cervical pain is almost always chronic and continuous, we should consider the influence of exercise on stress hormones. A recent study has shown that regular aerobic physical activity has a positive effect on stress hormones, thus decreasing the chronic pain threshold (Gashi et al., 2020; Gashi et al., 2021).

Based on the literature, there is a lack of studies applying standard treatment approaches for patients with neck pain; ma-

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ny conservative treatments are prescribed by combining different treatment techniques and modalities; most of the studies describe the advantages of strengthening exercises (Khan, Soomro, & Ali, 2014; Sowmya, 2014; Abelkader, 2021). However, there is not enough evidence for the effectiveness of dynamic exercises, and the need to have more evidence for dynamic exercise effectiveness is the reason and the aim of this study. The purpose of this study is to compare the efficacy of two main types of exercises (i.e., isometric and dynamic strengthening exercise) and to determine whether dynamic exercise is more effective at reducing pain and improving mobility in patients with cervical spondylosis.

Materials and methods

Participants

This is a prospective short term study which was conducted at the center for physical therapy and rehabilitation "Banja e Kllokotit", Kllokot, Kosovo. The total number of patients included in the study was 60 people of both sexes, and they received ten sessions of physical therapy. The patients were randomly divided into two groups (group A, n=30, and group B, n=30). To perform the study according to the ethical medical standards, the permission from the ethical committee of the rehabilitation center was received (nr. 01/13).

Experimental treatment

Group A was treated with thermotherapy for 15-20 min in the cervical region, electrotherapy transcutaneous electrical nerve stimulation (TENS) for 20 min, dynamic strengthening exercise against gravity for the muscles of the cervical region, stretching, and deep transverse massage. Dynamic strengthening exercise involves movement that produces changes in muscle length. These types of exercises involve two types of contractions (i.e., concentric and eccentric contractions), which produce changes in muscle length and joint angles. During concentric contractions, the muscles contract as they shorten; while during eccentric contractions, the muscles lengthen; during both forms of exercise, the muscles produce force and strengthen; in addition, the movement of the joint increases, other surrounding structures (e.g., ligaments, capsule, and muscles) will gain more flexibility, which means that dynamic strengthening will occur in all ranges of movement in the joint (Sowmya, 2014).

Group B was treated with thermotherapy (15-20 min), electrotherapy (TENS for 2 min), isometric strengthening exercisewhich is a static form of contraction of the muscles; the contraction must be held against resistance for a minimum 6 s to increase the tension in the muscle and to allow metabolic changes to occur (Sowmya, 2014), and passive stretching of the cervical muscles, which was applied to each muscle group for 10-15 s.

Measurements

The range of motion for flexion, extension and side bending of the neck was measured with a standard goniometer (6" Baseline 360 Degree Goniometer, 12-1002HR, Fabrication Enterprises, QM338800), (Whitcroft et al. 2010; Farooq et al. 2016), while pain was estimated by the numerical rating scale of pain (Hjermstad et al. 2011; Ferreira-Valente, Pais-Ribeiro, & Jensen, 2011; Alghadir et al 2018). The evaluation of patients was done before and after ten treatment sessions. The inclusion criteria were patients with sub-acute and chronic cervical spondylosis. While the exclusion criteria were acute stage of disease, and patients with other cervical spine problems (e.g., intervertebral disk hernia on the cervical spine and, spinal stenosis).

Statistical analysis

Presentation of data was done through tables and graphs. Data processing was done with the InStat statistical package (Beath & Davies, 1994). From the statistical parameters, the arithmetic averages, standard deviation, as well as minimum and maximum value were calculated. For non-parametric data testing, the Mann-Whitney test was used. Verification of the tests for the degree of reliability was P>0.05.

Results

A total of 60 participants were recruited into this study from the center for physical therapy and rehabilitation. The two groups were compared regarding mobility in flexion after ten sessions of physical therapy. Using the Mann - Whitney test, we did not obtain a statistically significant difference between groups in flexion (U'=581, P=0.052, P>0.05), (Table 1) and in extension (U'=472.5, P=0.743, P>0.05), (Table 2).

Table 1. Flexion difference parameters by groups

Flexion	**Group A**	**Group B**
N	30	30
Mean	2.5	1.1
DS	2.0	0.9
Min	0	0
Max	7	3
Mann-Whitney test	U'=581, P=0.052	

Table 2. Extension difference parameters by groups

Extension	**Group A**	**Group B**
N	30	30
Mean	4.0	2.1
DS	1.2	0.8
Min	2	0
Max	6	4
Mann-Whitney test	U'=472.5, P=0.743	

The mean difference in the left lateral neck flexion after ten sessions in both groups was 3.70 (DS±2.10), range 0-100. Using the Mann-Whitney test we obtained a statistically significant difference between groups (U'=842.5, P <0.000), (Table 3). In the right neck side bending the mean difference after ten sessions in both groups was 3.70 (DS±2.70), range 0-100. Using the Mann-Whitney test, we obtained a statistically significant difference (U'=845.5, P<0.000), (Table 4).

Table 3. Difference parameters in lateral neck flexion on the left side

lateral neck flexion on the left side	Group A	Group B
N	30	30
Mean	5.1	2.3
DS	2.0	0.8
Min	0	0
Max	10	4
Mann-Whitney test	U'=842.5, P<0.000	

Table 4. Difference parameters in lateral neck flexion on the right side

lateral neck flexion on the right side	Group A	Group B
N	30	30
Mean	5.6	1.8
DS	2.4	1.2
Min	0	0
Max	10	4
Mann-Whitney test	U'=845.5, P<0.000	

Comparing the values of pain in both groups, the obtained results showed that the mean difference in pain after ten sessions in both groups was 4.00 (DS±1.00), the mean difference in pain after ten sessions in group A was 4.80 (DS±0.60) while in group it was 3.20 (DS±0.40) although the mean difference in pain after ten sessions in both groups was 4.00 (DS±1.00). Using the Mann-Whitney test, we obtained statistically significant difference between groups (U'=877.5, P<0.000), (Table 5).

Table 5. Parameters of difference in pain by groups

Pain	Group A	Group B
N	30	30
Mean	4.8	3.2
DS	0.6	0.4
Min	4	3
Max	6	4
Mann-Whitney test	U'=877.5, P<0.000	

Discussion

Physiotherapy has been shown to be very effective in the treatment of cervical spondylosis (Laucheet al., 2016; Azemi et al., 2018); based on the evidence, different treatment methods have shown high effect on pain and mobility in cervical spine (Leaver, Refshauge, Maher, & McAuley, 2010; Hirpara, Butller, Dolan, O'Byrne, & Poynton, 2012). In this study we compared the effect of isometric and dynamic exercises in patients with spondylosis. The obtained results showed that the level of pain was significantly decreased in both groups, and cervical mobility was improved.

Both exercise protocols (i.e., dynamic and isometric exercise) were very effective. Dynamic exercises and deep transverse massages were more effective in treating cervical spondylosis, Similar results have been reported by other authors who concluded that dynamic exercises were more effective in treating cervical spondylosis (Cramer et al., 2012; Lauche et al., 2016; Wong, Shearer, Mior, Jacobs, & Cote, 2016; Gashi et al., 2019). Of note, the combination of both techniques may be more effective in treating cervical spondylosis. However, in our study, mobility during flexion and extension was not significantly increased, and there was no significant difference between groups. One factor that may have influenced these results is the combination of treatment techniques which may have approximately the same effect on flexion and extension mobility: another factor might be the short duration of treatment. While lateral flexion in both sides was significantly increased, these data are comparable to those of other authors (Boyles, Toy, Mellon, Hayes, & Hammer, 2011; Gemma V., & Antonia, 2014).

Based on the evidence, different forms of manual treatment have shown to be very effective treating cervical spondylosis. In this study, the use of deep transverse massage in combination with dynamic exercise may have had higher effect on reducing neck pain: this technique has been shown to be very effective: the same data have been also reported by authors (Bernal-Utrera et al., 2020).

However, other authors have reported that supervised exercises are more effective than unsupervised neck exercises in the treatment of patients with cervical spondylosis: in addition other authors have reported that supervised, controlled home exercise have a positive effect on reducing pain (Kuukkanen, Tiina, et al., 2007; Ibrahim et al., 2018). A recent study has reported that after an 8-week intensive home-exercise therapy program, there is a significant increase in cervical range of motion in flexion, extension, lateral flexion and rotation (Freimann, Merisalu, & Pääsuke, 2015).

Another recent study has shown that motor control with segmental exercises is effective at reducing short-term pain and disability, but long-term outcomes have not been investigated (Gashi & Azemi, 2019; Price, Rushton, Tyros, Tyros, Heneghan, 2020). These data are in line with our results: however, our study did not evaluate long-term treatment. Therefore, the main limitation of this study is that it does not have a large sample size: thus a larger sample size may refute our findings.

Conclusion

The results suggest that the use of both dynamic and isometric exercise treatment may improve cervical range of motion among patients with cervical spondylosis. Regarding statistical significance, it can be concluded that dynamic exercises produce slightly better results compared to isometric exercises. Further studies are needed to develop this simple but effective home-exercise therapy protocol to help motivate patients with cervical spondylosis to perform such exercises regularly.

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Conflict of Interest
The authors declare that there are no conflicts of interest.

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ORIGINAL SCIENTIFIC PAPER

The FIFA 11+ Kids Injury Prevention Program: Awareness, Implementation, and Opinion of Children's Football (Soccer) Coaches

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Abstract

The Fédération Internationale de Football Association (FIFA) 11+ Kids Injury Prevention Program was developed and shown to effectively reduce football-related injuries in numerous studies. The aim of this study was to assess the awareness, implementation, and opinion of children's football coaches worldwide regarding the FIFA 11+ Kids Injury Prevention Program efficacy using a self-administered questionnaire. Six hundred children's football coaches were invited through their local Football Federations to complete the online survey consisted of questions relating to awareness, implementation, and coaches' opinions of the FIFA 11+ Kids Injury Prevention Program. A total of 486 children's soccer coaches completed the survey. The survey was available in different languages. A total of 202 (41.6%) of the children's football coaches reported awareness of the FIFA 11+ Kids Injury Prevention Program and 155 (31.9%) reported implementing the FIFA 11+ Kids Injury Prevention Program in their current practice. Participants who reported implementation of the FIFA 11+ Kids Injury Prevention Program also reported a positive attitude towards program efficacy, with a score of 8.19±0.88 out of 10. To conclude, there is a need for further efforts and research to increase international awareness and implementation of the FIFA 11+ Kids Injury Prevention Program.

Keywords: *kids injury prevention programs, perception, application, worldwide, children's football coaches, soccer*

Introduction

Soccer (football) is one of the most popular sports in the world particularly among kids and adolescents (Dvorak et al., 2004). According to the Fédération Internationale de Football Association (FIFA, 2019) about 265 million players are playing football around the world. A majority of them (57%) are under the age of 18 years and nearly three-quarters of these young footballers are aged less than 14 years (Yalfani et al., 2020). In football, injuries are prevalent regardless of age, sex, and competition level (Peterson et al., 2000). It has been shown that high incidence of football injuries amongst young and adult players, the type and characteristics of these football-related injuries in kids between 7-12 years old differ than their adult counterparts (Yalfani et al., 2020). For example, upper body and bones injuries in kids 7-12 years old are relatively more common than adults (Rössler et al., 2018). Sport-related injuries have been associated with an increase in the rate of children drop-

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ping out of their sports during competition (Maffulli et al., 2010; Bangsbo et al., 2014) and, as a result of these injuries they become less physically active (Rössler et al., 2016). Therefore, injury prevention is a very important aspect to consider when training a young athlete given the negative consequences affecting their performance (Ekstrand, 2013), as well as their short and long-term health.

Another aspect of sports-related injuries to consider is the monetary cost of performance decline and rehabilitation. Therefore, applying injury prevention strategies at this young age group is not only valuable to reduce risk of injuries and disabilities as well as avoid various other negative effects on players' health (Rössler et al., 2014).

The FIFA 11+ Kids Injury Prevention Program, which was developed by various international experts for children between the age of 7 and 13 year is warm-up program that aims to minimize risk factors that may lead to injury (Rössler et al., 2018). The FIFA 11+ kids injury prevention program was previously investigated and was found to efficiently reduce football-related injury occurrences in numerous studies (Peterson et al., 2000; Maffulli et al., 2010; Bangsbo et al., 2014; Rössler et al., 2014, 2016, 2018; Gatterer et al., 2018; Zarei et al., 2020). A study by Rössler et al. (2018) examined the effect of the FIFA 11+ injury prevention program for kids and on injury rate and found a 48% reduction in overall injury rate. Furthermore, Zarei et al. (2020) assessed the efficacy of the FIFA 11+ Kids Injury Prevention Program in high-level young male football players between the ages of 7 and 14 years and found an overall reduction in injury rate by 50%. In the same study, overall injury was reduced by 58%, and lower limb and knee injuries were reduced by 55% and 66%, respectively. More specifically, the program was found to enhance physical fitness components like balance which has been shown by many studies to be associated with sports injuries and may be helpful in the prevention of injuries when improved (Zarei et al., 2018). The FIFA 11+ Kids injury prevention program was also shown to significantly reduce healthcare costs by more than 50% over the course of 1000 hours per football exposure (Rössler et al., 2019). Moreover, a cluster randomized controlled trial conducted by Al Attar et al. (2021b) to investigate the effect of the FIFA 11+ Kids injury prevention program on reducing the incidence of injuries among children soccer players aged 7-13 years. In their study, ninety-four boys' soccer teams (780) players (under 8 years, under 9 years, under 11 years, and under 13 years age groups) were randomly allocated into the experimental or a control group. The experimental group performed the FIFA 11+ Kids injury prevention program as warm-up during training sessions for at least twice a week, and the control group performed their usual warm-ups. They found that implementation of the FIFA 11+ Kids injury prevention program reduced overall injury rates in boys' soccer players more than the usual warm-up by 57% over 1000 hours per football exposure.

The FIFA 11+ Kids injury prevention program is primarily focused on improving coordination, balance, strengthening of the leg and core muscles, and recovery from perturbation (Rössler et al., 2016). As described in the FIFA 11+ Kids Injury Prevention Program's manual (Rössler et al., 2016), the program includes seven exercises and is suggested to be performed as a warm-up before the athletes' training session. Each exercise has five levels of difficulty ranging from level one to five. Youth coaches are advised to be cognizant of the young athlete's posture and motor control and correct them as needed. The program was reported to take approximately 15 to 20 minutes to complete and was advised to be performed twice a week for at least 12 weeks (Rössler et al., 2016). The program is advised to be performed under the supervision of the coach (Steffen et al., 2013) as their knowledge, awareness, and positive outlook is essential to take advantage of the program and help the athletes' reach their athletic potential. Therefore, the primary aim of this study was to investigate the level of awareness and perceptions of worldwide football coaches towards the FIFA 11+ Kids Injury Prevention Program. The outcomes of this study may be a guide to discovering reasons behind youth coaches' apprehension towards utilizing the FIFA 11+ Kids Injury Prevention Program.

Materials and methods

Survey development

A survey was developed specifically for the current study according to previous validated questionnaires Al Attar, et al. (2021a), and Al Attar et al. (2022). The self-administered questionnaire consisted of socio-demographic questions and questions regarding their awareness of the FIFA 11+ Kids Injury Prevention Program. Children's football coaches who reported to be aware of the FIFA 11+ Kids Injury Prevention Program were then asked if they were implementing it. The participants who responded affirmatively were then asked of their opinion of the program's efficacy on a linear scale of 0-10 (ineffective-very effective). The survey was developed in English and translated to 10 languages (Arabic, Chinese, French, German, Italian, Japanese, Portuguese, Russian, Spanish and Turkish). The Biomedical Ethics Committee at Umm Al Qura University reviewed and approved the study. Approval No. (HAPO02K012202010459).

Survey dissemination

Six hundred children's football coaches were invited through their local Football Federations to complete the online survey Google Forms (Alphabet Inc., Mountain View, California, United States). A total of 486 children's soccer coaches completed the survey (response rate of 81%). The invitation provided a brief background of the survey and encouraged coaches to participate. Participants clicked on an electronic link that led them to the survey description. Once the participants read the scope and aim of the survey, they were asked to provide informed consent and access the survey. The survey was filled anonymously and electronically via an online survey software. Responses were collected from June 2019 to June 2020.

Sample Size and Statistical analysis

Considering a 4% margin of error at 95% confidence level, the target number of participants was 597. Frequencies and percentages of all nominal variables, mean, standard deviation (SD) for score of opinion were calculated using Microsoft Excel 2010 (Microsoft Corporation, Redmond, WA, USA). A Chi-square test was used to compare different geographical locations with respect to awareness, implementation. A one-way analysis of variance (ANOVA) was used to compare different geographical locations with respect to opinion. Results were considered significant for P-values below 0.05 (P<0.05). Statistical analysis was performed using Statistical Package for the Social Sciences (SPSS) version 24.0 (SPSS Inc, Chicago, IL, USA).

Results

The total number of respondents was 486 children's soccer coaches; most of them were males (96.3%). The highest participation rate was reported from the Union of European Football Associations (UEFA) (38.9%) and the lowest was reported from the Oceania Football Confederation (OFC) (2.9%). The participant characteristics are shown in Table 1.

Level of awareness

When participants were asked if they were aware of the FIFA 11+ Kids Injury Prevention Program, less than half (41.6%) answered with "yes" while a greater percentage at 58.4% answered "no". Statistically significant differences (P<0.001) were found in the awareness levels between the different continental football federations (CFFs). The OFC reported the greatest percentage at 57.1%, followed by the UEFA at 51.9%, the Asian Football Confederation (AFC) at 41.6%, the South American Football Confederation (CONMEBOL) at 39.4%, the Confederation of North, Central American and Caribbean Association Football (CONCACAF) at 33.3%, and the Confederation of African Football (CAF) at 17.6%. The awareness levels are shown in Table 2.

Level of implementation

The implementation level among participants who reported awareness of the program (41.6%) was calculated to be 31.9% with 9.7% of those who reported awareness

Table 1. Participants Demographics

Variable	n (%)
CFFs	
UEFA	189 (38.9)
CONMEBOL	33 (6.8)
AFC	137 (28.2)
CAF	74 (15.2)
CONCACAF	39 (8.0)
OFC	14 (2.9)
Gender	
Male	468 (96.3)
Female	18 (3.7)
Aware	
Yes	202 (41.6)
No	284 (58.4)
Implement	
Yes	155 (31.9)
No	47 (9.7)
Opinion	
0	0 (0)
1	0 (0)
2	0 (0)
3	0 (0)
4	0 (0)
5	1 (0.2)
6	2 (0.4)
7	32 (6.6)
8	55 (11.3)
9	61 (12.6)
10	4 (0.8)
Mean ± SD	8.194 ± 0.883

Note AFC, Asian Football Confederation; CAF, Confederation of African Football; CFFs, Continental Football Federations; CONCACAF, Confederation of North, Central American and Caribbean Association Football; CONMEBOL, The South American Football Confederation; OFC, Oceania Football Confederation; UEFA, Union of European Football Associations.

Table 2. Awareness level of FIFA 11+ kids injury prevention program

Variable	Aware of the 11+ Kids program n (%)	No aware of the 11+ Kids program n (%)
Gender		
Male	189 (40.4)	279 (59.6)
Female	13 (72.2)	5 (27.8)
CFFs		
UEFA	98 (51.9)	91 (48.1)
CONMEBOL	13 (39.4)	20 (60.6)
AFC	57 (41.6)	80 (58.4)
CAF	13 (17.6)	61 (82.4)
CONCACAF	13 (33.3)	26 (66.7)
OFC	8 (57.1)	6 (42.9)

Note AFC, Asian Football Confederation; CAF, Confederation of African Football; CFFs, Continental Football Federations; CONCACAF, Confederation of North, Central American and Caribbean Association Football; CONMEBOL, The South American Football Confederation; OFC, Oceania Football Confederation; UEFA, Union of European Football Associations.

reported no implementing the injury prevention program. The football coaches who reported implementing the current the FIFA 11+ Kids Injury Prevention Program were asked of their perception of the program's efficacy, and the results demonstrated a relatively positive perception, with a mean (±SD) score of 8.19 (±0.88) out of 10, and a median of 8 out of 10. A statistically significant difference (P>0.05) was also found in the level of implementation between the different CFFs. Furthermore, the current study results showed a significant association between the awareness and the implementation level, as a significant greater percentage of aware participants reported implementation at 76.7%, and a P<0.001. The implementation levels are shown in Table 3.

Table 3: Implementation level of FIFA 11+ kids injury prevention program

Variable	Implement the 11+ Kids program n (%)	Not implement the 11+ Kids program n (%)
Gender		
Male	147 (77.8)	42 (22.2)
Female	8 (61.5)	5 (38.5)
CFFs		
UEFA	78 (79.6)	20 (20.4)
CONMEBOL	11 (84.6)	2 (15.4)
AFC	44 (77.2)	13 (22.8)
CAF	9 (69.2)	4 (30.8)
CONCACAF	9 (69.2)	4 (30.8)
OFC	4 (50.0)	4 (50.0)

Note. AFC, Asian Football Confederation; CAF, Confederation of African Football; CFFs, Continental football federations; CONCACAF, Confederation of North, Central American and Caribbean Association Football; CONMEBOL, The South American Football Confederation; OFC, Oceania Football Confederation; UEFA, Union of European Football Associations.

Sex differences

As shown in Table 1, a total of 486 worldwide football coaches participated in the current study; 96.3% were male and 3.7% were female. There was a significant difference P=0.003 in participation by gender between the different CFFs, where the greatest male participation was from CONMEBOL at 100%, and the greatest female participation from CONCACAF at 5.4%.

The results showed female football coaches having a significantly greater awareness level of the FIFA 11+ kids' injury prevention program when compared to their male counterparts at 72.2% versus. 40.4%, respectively, with P=0.007. On the other hand, the level of implementation was not significantly different by gender; it was lower among female coaches at 61.5% compared to 77.8% among their male counterparts, with P=0.157.

Geographical location

The largest proportion of the participants was from the UEFA at 38.9% followed by 28.2% from the AFC. The statistical analysis showed OFC to have the lowest participation level at 2.9% followed by CONMEBOL 6.8%. When investigating perception and opinion scores, all federations reported a relatively positive perception. Since the vast majority scored it as either "8"at 35.5% or "9" at 39.4%. Although not statistically significant P=0.904, CONCACAF demonstrated the greatest perception score at 8.44 (±0.88) out of 10. Comparison between the CFFs is shown in Table 4.

Table 4. Comparison between the continental football federations

Variable	UEFA n (%)	CONMEBOL n (%)	AFC n (%)	CAF n (%)	CONCACAF n (%)	OFC n (%)
Gender						
Male	183 (96.8)	33 (100)	134 (97.8)	72 (97.3)	33 (84.6)	13 (92.9)
Female	6 (3.2)	0 (0.0)	3 (2.2)	2 (2.7)	6 (15.4)	1 (7.1)
Aware						
Yes	98 (51.9)	13 (39.4)	57 (41.6)	13 (17.6)	13 (33.3)	8 (57.1)
No	91 (48.1)	20 (60.6)	80 (58.4)	61 (82.4)	26 (66.7)	6 (42.9)
Implement						
Yes	78 (79.6)	11 (84.6)	44 (77.2)	9 (69.2)	9 (69.2)	4 (50)
No	20 (20.4)	2 (15.4)	13 (22.8)	4 (30.8)	4 (30.8)	4 (50)
Opinion						
0	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
1	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
2	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
3	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
4	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
5	1 (1.3)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
6	1 (1.3)	0 (0.0)	1 (2.3)	0 (0.0)	0 (0.0)	0 (0.0)
7	17 (21.8)	1 (9.1)	9 (20.5)	3 (33.3)	1 (11.1)	1 (25.0)
8	28 (35.9)	7 (63.6)	13 (29.5)	2 (22.2)	4 (44.4)	1 (25.0)
9	30 (38.5)	3 (27.3)	19 (43.2)	4 (44.4)	3 (33.3)	2 (50.0)
10	1 (1.3)	0 (0.0)	2 (4.5)	0 (0.0)	1 (11.1)	0 (0.0)

Note AFC, Asian Football Confederation; CAF, Confederation of African Football; CFFs, Continental Football Federations; CONCACAF, Confederation of North, Central American and Caribbean Association Football; CONMEBOL, The South American Football Confederation; OFC, Oceania Football Confederation; UEFA, Union of European Football Associations.

Discussion

This is the first published study to assess the awareness and implementation levels of the FIFA 11+ Kids Injury Prevention Program among football coaches globally. Although coaches represent the program deliverers and are essential to participant safety, our results showed that most of the worldwide children football coaches are relatively unaware of the FIFA 11+ Kids Injury Prevention Program. The results revealed low levels of awareness but high levels of implementation among the participants who have reported awareness of the FIFA 11+ Kids Injury Prevention Program, which is in line with that have been observed in a similar study by Al Attar et al. (2018) and Zarei et al. (2018). The awareness levels of the FIFA 11+ Kids Injury Prevention Program was 41.6% among children's football coaches in the current study which is lower than the reported level of awareness of the FIFA11+ Injury Prevention Program among coaches of adolescent female football teams, which was at 58% (Donaldson et al., 2018), and also lower than the level of awareness of lower limb injury prevention programs among coaches of young football players in other international studies (Norcross et al., 2016; Morgan et al., 2018). This might be attributed to the lack of educational programs and instructions about the FIFA11+ Kids Injury Prevention Program from the specialized authorities or might be due to the lack of facilities that might support implementing this program (Maffulli et al., 2010; Bangsbo et al., 2014; Rössler et al., 2014, 2016; Gatterer et al., 2018;).

Although these results revealed some awareness of the FIFA 11+ Kids Injury Prevention Program, approximately one-quarter of the kids' football coaches did not utilize this intervention. Incomplete implementation or no implementation was reported in studies investigating other injury prevention programs (McKay et al., 2014; Wilke et al., 2018). This could be due to the lack of knowledge or maybe something psychological that may be causing this apprehension. So, emphasizing an in-depth understanding and knowledge of injury prevention and thus, understanding the FIFA 11+ Injury Prevention Program may encourage utilizing the program by more adult and youth coaches around the world. Coaches may find going beyond simply being provided the program instructions to be more beneficial (O'Brien & Finch, 2016).

A great awareness level of 80% of participants was reported from coaches of Swedish amateur players using the FIFA 11 (a precursor to the FIFA 11+) (Junge et al., 2011). Ninety-one percent of coaches in eight Swedish district football associations were aware of similar neuromuscular training programs (Lindblom et al., 2014). The main resource for information regarding injury prevention and injury prevention programs is the governing body of football whether it be state, national, or international governing football associations (Herman et al., 2012; Donaldson et al., 2018). Therefore, increasing awareness levels of the FIFA11+ Kids Injury Prevention Program can be done utilizing these governing associations reach by spreading educational material via communication channels like websites, e-newsletters, and social media platforms, as well as the influence of informal learning networks (Poulos &

Donaldson, 2012).

Reasons for lack of implementation of the FIFA11+ Kids Injury Prevention Program were not investigated in this study. However, Donaldson et al. (2018) investigated the knowledge and perception of female football coaches about the FIFA 11+ Injury Prevention Program in Australia. They found that 27 participants from a total of 64 respondents were not aware of the FIFA 11+ Injury Prevention Program. Nineteen of the 64 participants did not use program in its entirety, and 18 participants used the program did not use it in its recommended frequency. Therefore, it can be gleaned that barriers to implementing the FIFA 11+ Injury Prevention Program indeed includes lack of knowledge and limited awareness of the program as also seen in this current study. Another study conducted by O'Brien and Finch (2016) aimed to study the perception of football coaches, fitness coaches, and physiotherapists working with four male elite junior football teams towards injury prevention and level of implementation of the FIFA 11+ Injury Prevention Program during the season (2014/2015) in Australia. They found that 61% of respondents have some knowledge of the FIFA 11+ Injury Prevention Program with some suggesting certain modifications in order to integrate the program as part of the athlete's training regimen, which may explain some of the apprehension to implanting the program as a permanent solution to reducing the rate of various sports-related injuries.

Based on the current study findings, program implementation is highly dependent on levels of awareness. However, there is a need to further examine and address the possible causes of low levels of awareness and inconsistent implementation of the FIFA 11+ Kids Injury Prevention Program among football coaches around the world.

Conclusion

Globally, kids football coaches demonstrated a relatively poor level of awareness of the FIFA 11+ Kids Injury Prevention Program. However, implementation levels among those who have reported awareness was adequate. Kids football coaches reported an overall positive perception regarding the efficacy of the FIFA 11+ Kids Injury Prevention Program in reducing and preventing injuries. Future research can aim to specifically define and address the different factors contributing to these variables such as program utilization, feasibility, and suitability. Addressing specific reasons for lack of implementation may be of use for developing a more accessible injury prevention, thus reducing negative consequences of sports-related injuries.

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ORIGINAL SCIENTIFIC PAPER

Analysis of Association of the Anthropometric, Motor and Functional Parameters on Competitive Efficiency in Youth Football Players

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Abstract

In a complex team sport setting, such as during a football game, the match's outcome is determined by numerous factors, such as the technical, tactical, physical and psychological preparedness of all the players, who have to act like a unit. This study aimed to identify anthropometric characteristics and motor and functional abilities that affect the competitive efficiency of U-15 football players. A total of 20 football players, classified either as starters (N=10) or non-starters (N=10), underwent morphologic measurements comprising body height and body weight and motoric assessments and testing of functional capacity: 5-meter sprint, 10-meter sprint, 20-meter sprint, broad jump, medicine ball throw, and triple jump on the left and right legs. Additionally, the age of peak height velocity (APHV) was calculated for each participant. The results showed that the body weight (OR:0.86; 95%CI:0.75-0.99) and medicine ball throw (t=2.24; p=0.02) were significant predictors of one's competitive efficiency in the observed sample of young football players. Since upper body power is highly influenced by anthropometric characteristics at this age, starters will most likely receive more playing time and have superiority over their peers due to morphologic advantages. This study once again confirmed that early maturing players have an advantage over others because of their body size, which seems to be a significant determinant of success at that age.

Keywords: *puberty age, competitive efficiency, motor abilities, morphology, maturation*

Introduction

In a complex team sport setting, such as during a football game, the match's outcome is determined by numerous factors, such as the technical, tactical, physical, and psychological preparedness of all the players in a team, who have to act like a unit (Rowat, Fenner, & Unnithan, 2016). The game of football is physically highly demanding and is characterized by a combination of sprint bouts, high-intensity running, tackles, jumps, and turns that can be performed in any direction or plane of motion (Mohr, Krustrup, Nybo, Nielsen, & Bangsbo, 2004; Alexandre et al., 2012). The physiological stress of the match play, which usually lasts around 90 minutes, can be observed through an increase in cardiovascular and metabolic output, rise in core temperature, glycogen depletion, and high energy expenditure (Reilly & Gilbourne, 2003). It is well known that elite-level football players can cover up to 12 km per match and that high-speed running accounts for 1.5-3.3 km of the total distance (Rebelo, Brito, Seabra, Oliveira, & Krustrup, 2014). During the match, average and peak heart rate values are around 85% and 98% of maximal values, respectively, corresponding to an average oxygen uptake of approximately 70% of VO2max (Bangsbo, 2014). Additionally, on average, every 2 to 4 seconds during the match, footballers perform changes of direction, jumps, accelerations, and decelerations, for a total of 1200-1400 of these intensive actions (Sporis, Jukic, Ostojic, & Milanovic, 2009). In recent years, the technical and tactical demands of the game have also increased substantially, likely due to tactical modifications, and as a result, there has been a

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significant increase in the sprint distance and distance covered in high-speed running (Collins et al., 2021). Due to the outlined specificities of the sport, it is of utmost importance to train and develop players' abilities accordingly so that they can perform these intense actions and recover quickly from these periods of high-intensity exercise (Bangsbo, Mohr, & Krustrup, 2006).

Young football players usually cover 5-7 km during the match, with approximately 15% of the total distance (0.4-1.5 km) including high-intensity activities (Di Giminiani & Visca, 2017). The average heart rate frequency varies between 165 and 171 heartbeats per minute, which corresponds to 85% of maximal heart rate value (Rebelo et al., 2014; Di Giminiani & Visca, 2017). Studies have shown that U-15 players have a similar relative VO2max but poorer running mechanics compared to senior players and that a higher aerobic capacity results in an increase in the total distance covered and high-speed running (HSR) (Stølen, Chamari, Castagna, & Wisløff, 2005; Lovell, Bocking, Fransen, Kempton, & Coutts, 2018). The activity pattern of elite youth and senior football players does not differ much, suggesting that the aerobic capacity and game load of the aforementioned categories are comparable (Strøyer, Hansen, & Klausen, 2004). The anaerobic energy system is crucial when performing explosive activities such as sprinting, jumping, or changing direction, i.e., actions that define key moments of the match (Stølen et al., 2005). An exponential increase in muscle size and power occurs during the pubertal phase, which, combined with carefully planned strength and power training, results in enhanced power-speed abilities manifested in sprints and jumps (Di Giminiani & Visca, 2017). Paul, Gabbett, and Nassis (2016) stated that power, speed, and agility training are necessary for the comprehensive/complete growth and development of young football players. A player's conditional characteristics, such as endurance, strength, and agility, as well as technical and tactical aspects, should be developed for a team's prosperity (Mouloud, 2019).

Previous studies investigating predictors of situational efficiency in youth football showed that young elite players are taller, heavier, more mature, and achieve better results in power, flexibility, and specific football skill parameters (Williams & Reilly, 2000; Malina et al., 2005; Figueiredo, Gonçalves, Coelho E Silva, & Malina, 2009). Ré, Cattuzzo, Santos, and Monteiro (2014) highlight that anthropometric indices, such as body height and body mass - as they have a large influence on the selection of adolescent players - favor biologically advanced individuals. Rowat et al. (2016) indicated that functional capacities and specific football skills are also influenced by maturity status and morphologic components.

Elite players usually perform better in tests of sprints, vertical jumps, and endurance shuttle runs in contrast to average and below-average players (Malina, Ribeiro, Aroso, & Cumming, 2007). This leads to the phenomenon where more mature players, characterized as elite, receive higher-quality coaching and are exposed to increased football-specific loads. The disproportion of these physical and technical loads eventually aggravates or even ceases the developmental path of late-maturing players (Lovell et al., 2018). However, the problem with a sport-selection system that is oriented to physical characteristics emerges at the senior level when these biological distinctions gradually disappear and players are differentiated via specific technical and tactical competencies (Ré et al., 2014).

Given the fact that this phenomenon is still evident in the world of sports in general, particularly in football, the main aim of this study was to identify which anthropometric characteristics and motor and functional abilities affect the situational and competitive efficiency of elite U-15 football players. Rationale of the study was to examine potential distinctions within the morphologic dimensions, and motor and functional abilities of the observed groups. Obtained results could provide us with better understanding of the complex and the multifactorial approach to the squad selection process.

Methods

Participants

The sample included 20 young male football players. Participants were members of a team that competed in the first division of the Croatian national championship and were categorized by the coaching staff either as starters (N=10, on average 14.12 years old), or non-starters (N=10, on average 14.0 years old). The study was conducted at the beginning of the summer preparation period for the 2021/2022. season. All the players were healthy at the time of testing, without evident injury or illness. This study was approved by the Ethics Committee of the Faculty of Kinesiology, University of Split, with approval number 2181-205-02-05-22-004.

Measurements

Variables in this study included anthropometric indices, indirect estimation of the biological age (peak height velocity), and a set of motor and functional variables (sprinting 5, 10, and 20 meters, broad jump, medicine ball throw, unilateral triple jump on both legs, and 30-15 intermittent fitness test).

Anthropometric measurements

Anthropometric measures consisting of body height (BH) and body mass (BM) were recorded. Body mass was measured at 0.1 kg, and body height in cm (encompassing nearest 0.5 cm).

Motor measurements

Acceleration and sprinting abilities were evaluated with the sprint test of 5 meters (5 m), 10 meters (10 m), and 20 meters (20 m) using photoelectric timing gates (Powertimer, New test, Finland). Placed 1 meter behind the starting line, the participant assumed the flying start position and was instructed to start when feeling ready, run as fast as possible, and decelerate after passing the gates. One pair of gates was installed on the starting line, and the second pair was placed 5, 10, and 20 meters away from the starting line, respectively. Lower body power was assessed with the broad jump (BJ), triple jump on the left leg (TJL), and the triple jump on the right leg (TJR). The broad jump test was used to assess the coordination and (horizontal) explosive power of the lower extremities. The participant performed two-legged broad jump without falling forward or moving their feet during landing, and the distance between the starting line and the heel of the back foot was measured. In the triple jump on the left (TJL) and the right leg (TJR), the participant executed 3 maximal consecutive (unilateral) jumps, without pushing off the floor with the other leg, and the distance between the rear heel and the marked line was recorded. The medicine ball throw was used as an indicator of the trunk and upper body power. Holding the 2 kg medicine ball in hands and with feet positioned in parallel stance, athletes performed maximal extension of the body followed by powerful ejection of the medicine ball.

Functional measurements

The 30-15 Intermittent Fitness Test was carried out to estimate aerobic fitness of the players (Buchheit, 2008). The test is performed on a 40-meter-long turf, comprising two alternating periods – 30-second shuttle run and 15-second passive rest. The 30-15 IFT starts at 10 km/h, and the speed gradually increases by 0.5 km/h per level. All tests, excluding 30-15 IFT, were performed twice, with the best result being taken into statistical analysis.

Mirwald, Baxter-Jones, Bailey, and Beunen (2002) algorithm, which calculates age of the peak height velocity (APHV) and maturity offset (DIFF), was used for assessment of biological age.

Statistical analysis

After assessing normality of the distributions using Kolmogorov-Smirnov test, descriptive statistic parameters (arithmetic means and standard deviations) were calculated for all variables. To compare the groups (starter vs. non-starters), Student t-test was used. The differences between starters and non-starters were evaluated by magnitude-based Cohen's effect size (ES) statistics with the following criteria: <0.2 = small magnitude of difference; <0.5 = medium magnitude of difference, and >0.8 = large magnitude of difference. Additionally, to establish associations between predictors (anthropometrics, biological age, motor-functional status) and players' abilities (starters vs. non-starters), binary logistic regression was used. Statistica 13.0 (TIBCO Software Inc, USA) was used for all calculations with a p-level of 95%.

Results

Results of the descriptive statistics (arithmetic means and standard deviations) and Student's T-test (t and p values) are presented in Table 1. Significant differences between starters and non-starters were found in the BM and MT variables. Although the difference is not significant, it can be seen in Table 1 that starters are biologically more mature, entered the APHV period earlier, and have a larger difference between the actual chronological age of APHV.

Table 1. Descriptive statistics and Student t-test

	Group 1		Group 2			
Variable	AM	SD	AM	SD	t-value	p
AGE (years)	14.12	0.33	14.00	0.46	0.67	0.51
APHV (years)	13.30	0.49	13.66	0.56	-1.53	0.14
DIFF (years)	0.82	0.63	0.34	0.72	1.59	0.13
BM (kg)	61.62	7.99	53.67	6.30	2.47	0.02*
BH (cm)	176.25	9.35	170.40	8.28	1.48	0.16
5 m (sec)	1.09	0.06	1.08	0.05	0.19	0.85
10 m (sec)	1.85	0.07	1.82	0.07	1.01	0.33
20 m (sec)	3.21	0.09	3.19	0.09	0.51	0.62
BJ (cm)	2.09	0.11	2.02	0.13	1.26	0.22
MT (cm)	8.91	1.53	7.59	1.06	2.24	0.04*
TJR (m)	6.01	0.38	5.87	0.60	0.65	0.52
TJL (m)	6.03	0.31	5.80	0.55	1.14	0.27
IFT (level)	19.22	1.09	18.88	0.92	0.70	0.49

Legend: AGE – chronological age, APHV – age at peak height velocity, DIFF – difference between AGE and APHV, BM – body mass, BH – body height, 5 m – 5 meters sprint, 10 m – 10 meters sprint, 20 m – 20 meters sprint, BJ – broad jump, MT – medicine ball throw, TJR – triple jump on right leg, TJL – triple jump on left lef, IFT – 30-15 intermittent fitness test

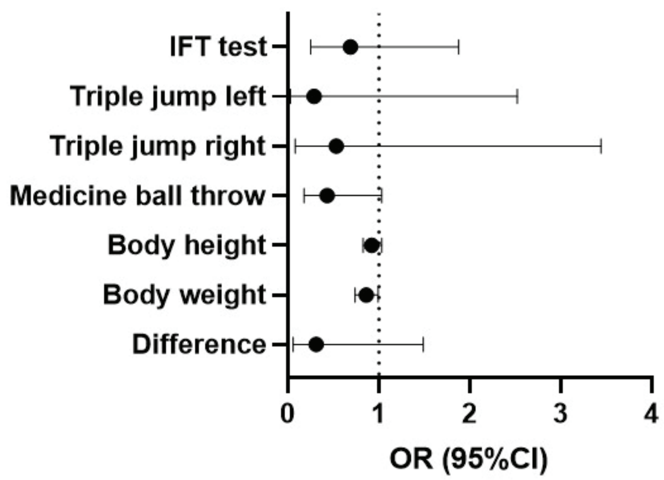

FIGURE 1. Logistic regression results (OR – Odds Ratio, CI – Confidence Interval)

The results of binary logistic regression are graphically presented in Figure 1. It can be seen that the only significant predictor of competitive efficiency was the BM variable.

ES values indicated large magnitude of difference between starters and non-starters in the BM (Cohen's d=1.105) and MT (Cohen's d=1.003) variables.

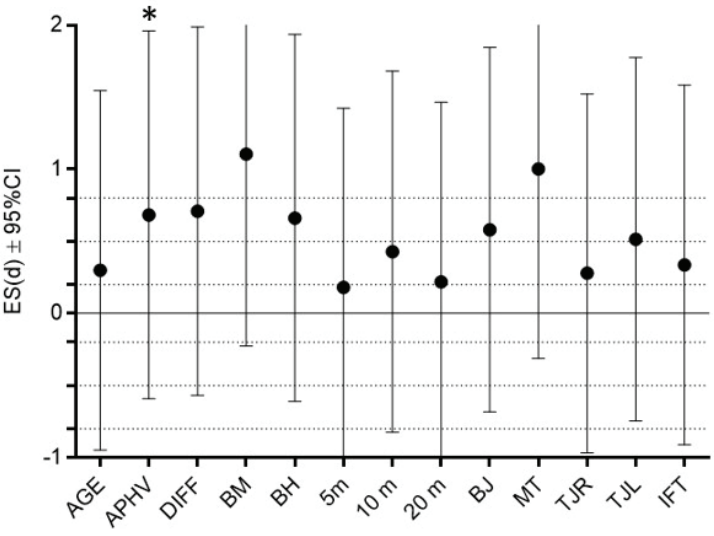

FIGURE 2. Effect Size (ES) differences between observed groups
*APHV variable shows higher values for group 2

Discussion

The results of this study suggest several important findings. First, anthropometric indices (primary body mass) are the factor that differentiates starters and non-starters. Second, there are significant differences in the power of the upper body between the groups.

The results of our analyses suggest that body mass is the most significant factor that contributes to the quality of the players, with starters being heavier than non-starters. To explain such findings, it is important to note that due to higher concentrations of testosterone and growth hormone, boys aged 13-18 experience major weight and height gain, thus enlarging their stature and physical size (Pearson, Naughton, & Torode, 2006). Previous investigations dealing with the body dimensions of youth football players showed that players of higher performance levels are usually biologically more advanced, i.e., they are taller and have a greater body mass in contrast to players of lower performance levels (Rosch et al., 2000; Malina et al., 2005; Malina et al., 2007). These findings are not specific to football only. For example, Gabbett, Kelly, Ralph, and Driscoll (2009) observed an elite junior rugby sample and concluded that starters were heavier and taller than non-starters. Given the fact that our sample is composed of elite young football players, it can be expected that heavier players most likely possess a greater amount of lean body mass (muscle mass). It is well documented that muscle volume directly affects one's ability to produce force, so it seems that players with greater muscle mass are capable of higher force/power production (Sekulic & Metikos, 2007). Although no significant differences in motor variables were observed (except in MT), we can assume that players will exploit this produced force in football-specific activities, such as aerial or ground duels. Therefore, it is reasonable to speculate that coaches will perceive these players as more efficient or successful and give them more playing time.

Furthermore, our results suggest that upper body power (MT) is a significant predictor of the performance level of youth football players. Although intuitively, upper body power does not seem to be a significant factor in football efficiency, this finding can be linked with the already explained difference in body mass. Studies have confirmed that body size and maturity significantly influence the performance of strength and power tests (Malina et al., 2005; Mala, Maly, Zahalka, & Hrasky, 2015). Force production has a regional character and depends on the neuromuscular control, length, and arrangement of the fibers and the muscle cross-section area (Pearson et al., 2006). In a study carried out on an elite sample of Australian football players, Bilsborough et al. (2015) also indicated a high correlation between lean body mass and the manifestation of upper body power. Additionally, for our study, it is important to note that the most significant strength increment in males happens in the adolescent period, between the age of 14 and 16, when gains in muscle size occur due to a higher concentration of androgens (Pearson et al., 2006). The simultaneous development of the nervous system, biochemical properties, and (theoretical) fiber type differentiation happens during the pubertal stage, highlighting the need to improve ballistic movements, such as that evidenced through MT in our study (Kraemer, Fry, Frykman, Conroy, & Hoffman, 1989; Newton, Kraemer, Häkkinen, Humphries, & Murphy, 1996).

Results of the study, conducted on Croatian young footballers from three different age groups (U-15, U-17 and U-19, respectively), indicated significant increase of both absolute and relative VO2 max, reduced heart rate frequencies during submaximal loads, upgraded maximal minute ventilation and advanced breathing economics throughout the older age (Erceg, Rađa, Sporiš & Antonić, 2018). It had been shown that pubescent male football players have 50% less anaerobic capacity compared to their adult counterparts, which could result in a reduced number of sprints and high-intensity running sequences (Nikolaïdis, 2011; Atan, Foskett & Ali, 2016). Herdy et al. (2018) reported lower levels of knee flexion and extension isokinetic strength in U-15 category in contrast to U-17 and U-20 football players (Herdy et al., 2018). Another study revealed that U-15 players performed poorer in SJ and CMJ tests, tests in which lower limb explosive power is estimated, in contrast to U-17 and U-19 category (Sukreški, Krakan & Tomić, 2011).

It is anecdotally known that coaches and scouts often select the players according to their anthropometric-morphological attributes while neglecting smaller players with the same abilities. This approach to talent identification can lead to a premature drop-out of the late-maturing boys who are not included in the training process because of their (relatively) weak stature and (consequently) less-developed motor abilities (Malina et al., 2007; Figueiredo, Coelho e Silva, & Malina, 2011; Ré et al., 2014). Likewise, players labeled as those most talented in puberty usually do not live up to expectations at the senior level, when persistent late-maturing individuals catch up with their body size and strength and power levels (Malina et al., 2007). Some authors propose the idea that the physical inferiority of late-maturing boys can be compensated by improvements in technical and tactical skills that will eventually enhance their perseverance and competitiveness in the game (Vandendriessche et al., 2012). When assembling a team for an important match, most football coaches will most certainly choose the best individuals at that particular moment because of their desire to win. However, such an approach ignores and even obstructs the developmental path of talented, but physically unmatured individuals (Strøyer et al., 2004). Therefore, although players should be selected based on their skills and abilities rather than physical size, in a team that is composed of players of similar football skills, it can be expected that physically larger players will ultimately be chosen to participate more (Williams & Reilly, 2000).

Conclusion

The present study revealed the differences in some anthropometric/morphologic attributes and motor abilities in performance levels among U-15 football players. Namely, starters are heavier and superior in upper body power than non-starters. One of the major strengths of this study was the sample of elite youth football players, as HNK Hajduk is ranked in the top 20 football academies in Europe (CIES, 2021).

Although the sample was relatively homogenous, i.e., composed of equally skilled players, the results indicate that physically advanced players will most likely be selected for the starting squad more frequently, hence receiving more playing time.

In the process of selection, football scouts and coaches usually favor larger players over their weaker teammates because of their perceived robustness, but this is the paradigm that has to be shifted in the future to enable the most talented players to express their football potential, regardless of their stature. Football coaches, especially those working in high-level academies, are constantly pressured to achieve competitive success, which is why they rely more on the larger, physically more dominant players. This is in disagreement with the main goal of the football academy – the production and development of high-quality players.

Conclusions from this study should be interpreted carefully, given the small sample size (N=20). Also, results of this cross-sectional study could be somewhat biased and consequently cannot determine causality link between predictor variables and quality rang.

Future studies should include more objective measures of players' competitive efficiency, such as technical and tactical components of the match that will precisely distinguish between performance levels in high-level football.

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Conflict of Interest
The author declares that there is no conflict of interest.

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ORIGINAL SCIENTIFIC PAPER

The Relationship between Respiratory Muscle Strength and Physical Performance in College Volleyball Players

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Abstract

Physical performance and respiratory muscle strength are the effective factors that influence sport competence. This study aimed to determine the relationship between respiratory muscle strength and leg strength, power, speed, and agility in college volleyball players. Twenty-eight college volleyball players (age: 20.79±1.71 years; body mass index: 23.22±3.48 kg/m2; sport experience: 4.68±2.21 years; training frequency: 4.43±1.26 days/week) were included into the study. Maximal inspiratory and expiratory pressure (MIP and MEP) tests were performed using a mouth pressure meter for respiratory muscle strength assessment. Leg muscle strength and power were measured using a back and leg dynamometer and a Yardstick device, respectively. The 10-meter sprint test was performed to assess speed performance. Agility was measured by the agility T-test. MIP was positively correlated with leg strength (r=0.406; p=0.032), while it was negatively correlated with speed, and agility (r=-0.416; p=0.028, r=-0.469; p=0.012, respectively). There was no relationship between MIP and power (p=0.197). For MEP, it was negatively correlated with speed (r=-0.392; p=0.039). Other parameters of physical performance were not significantly correlated with MEP (p>0.05). In the light of the results, muscle strength, speed, and agility of college volleyball players develop parallel to respiratory muscle strength, particularly inspiratory muscle. Thus, it is believed that inspiratory muscle training should be added to exercise training programs for enhancing players' physical performance.

Keywords: *MIP, MEP, strength, speed, agility, volleyball*

Introduction

Volleyball is an intermittent sport in which players engage in short bouts of high-intensity action, followed by periods of low-intensity activity (Künstlinger, Ludwig, & Stegemann, 1987). During the competition, change of direction and jumping activities such as spike, block, topspin, and floating serves are required players' strength, power, speed, and agility, which are essential components of sports performance (Häkkinen, 1993).

Besides the considerable role of the neuromuscular system, respiratory function is also a crucial factor that affects the players' ability. Due to high-intensity activities with long duration of the volleyball match (around 90 minutes), work of respiratory system is increased to provide sufficient oxygen for energy reproduction (Baker, McCormick, & Robergs, 2010). Furthermore, it works to drive alveolar ventilation in proportion to metabolic requirements for maintaining acid-base homeostasis and preventing arterial hypoxemia (Romer & Polkey, 2008). The upper extremity (UE) movement also increases the respiratory work that can be explained by the connection between muscles of UE and core (Han & Kim, 2018). During arm movement, the upper limb muscles contract and pull on the origin of the diaphragm, which acts as a roof over the core. As a result, respiratory muscle works increasingly for controlling postural stability during movement (Hodges & Richardson, 1999).

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In some cases, the increased effort of breathing during sustained exercise causes respiratory muscle fatigue (Johnson, Babcock, Suman, & Dempsey, 1993) and could limit exercise performance (Aaron, Seow, Johnson, & Dempsey, 1992; Dempsey, Mckenzie, Haverkamp, & Eldridge, 2008). Because of higher metabolic demand on the inspiratory muscles, the activation of the respiratory metaboreflex is stimulated to contribute to the redirection of blood flow circulation from peripheral muscles to respiratory muscles (St Croix, Morgan, Wetter, & Dempsey, 2000). Previous studies demonstrated the relationship between respiratory muscle strength and strength of upper and lower extremities among athletes (Kocahan, Akınoğlu, Mete, & Hasanoğlu, 2017; Akınoğlu, Kocahan, & Özkan, 2019). However, there is a lack of studies that determine the relationship of respiratory muscle strength with other physical skills such as muscle power, speed, and agility which are important factors for sport performance among volleyball players. Thus, this study aimed to correlate respiratory muscle strength with leg muscle strength, power, speed, and agility in college volleyball players.

Methods

Participants

This cross-sectional study was approved in advance by the ethical committee of Walailak University (WUEC-20-038-01). All participants signed informed consent before enrollment for the study. The sample size was calculated by the G*Power (version 3.1.9.4) from the relevant study (Kocahan, Akınoğlu, Mete, & Hasanoğlu, 2017), the correlation was equal to 0.475, $Z\propto$ was set to 0.05, and $Z\beta$ was set to 0.8. Twenty-eight collegiate volleyball players who had volleyball practice at least three days a week, and had volleyball competition experience for at least two consecutive years were enrolled in this study: 19 males (67.86%) and 9 females (32.14%), with a mean age of 20.79±1.71 years. The average body mass index (BMI) of the participants was 23.22±3.48 kg/m2. The average volleyball competition experience and frequency of practice were 4.68±2.21 years and 4.43±1.26 days/week, respectively. All participants did not have a history of smoking and a chronic respiratory disease such as asthma. Moreover, they were free from moderate pain (pain scale ≥4/10) from upper limbs, lower limbs, or back injury during three months before participating in the study.

Procedures

Before testing, participants were asked to sleep at least 7 hours during the night; refrain from eating for at least 2 hours; avoid alcohol or caffeine consumption, and engaging in strenuous activity for at least 24 hours. Assessment of respiratory muscle strength was performed firstly. The participants were then instructed to warm up by jogging and dynamic stretching for 10 minutes. After that, leg muscle strength, power, speed, and agility of all participants were measured.

Measurement

Respiratory Muscle Strength

The respiratory muscle strength values were obtained from maximal inspiratory and expiratory pressure (MIP and MEP) tests using a mouth pressure meter (MicroRPM®, England). The protocol was performed in a sitting position. For the MIP test, each participant was asked to exhale entirely at the residual volume (RV) and then take a quick and deep breath. For the MEP test, participants were asked to inhale the air fully at the total lung capacity (TLC) and then exhale fast and strongly. The inspiratory and expiratory efforts had to be maintained for at least 1 second. Three maximum maneuvers, which difference of less than 20%, were recorded. The highest values of MIP and MEP were used for analysis (Laveneziana et al., 2019).

Physical Performance

Leg strength

The leg muscle strength was measured by the back and leg dynamometer (T.K.K.5402, Japan). Participants were instructed to stand on the platform of the equipment. They then flexed their knees to about 110 degrees and held the center of the bar with both hands. The chain length was adjusted appropriately. Then, participants extended the legs with maximal effort and pulled the hand bar simultaneously. This test was performed three times with 1 minute of rest between trials, and the best value was used for analysis (Sonchan, Moungmee, & Sootmongkol, 2017).

Leg power

The leg power was measured by the Swift Yardstick vertical jump device. Participants were instructed to reach their dominant hand to the Yardstick for assessing baseline value, while the non-dominant hand was placed on the waist. They then flexed their knees to about 90 degrees and jumped to reach their hand as far as they can to the Yardstick for maximum jump height. Participants were not allowed to swing their arms or take any preparatory step before jumping. This test was measured three times with 1 minute of rest between trials. Leg muscle power was calculated from the difference between baseline value and maximum jump height. The best value was used for statistical analysis (Young, MacDonald, Heggen, & Fitzpatrick, 1997).

Speed performance

Speed performance was measured by a 10-meter sprint test. The length of the trial was 10 meters in a straight line. Participants were instructed to run as fast as possible from the starting to the finishing point. The time was started when participants passed the starting point, and the time was stopped when they passed the finishing point. Each participant completed the test three times with two minutes rest between trials. The fastest value was used for analysis (Duthie, Pyne, Ross, Livingstone, & Hooper, 2006).

Agility

The agility of participants was assessed by the agility T-test which includes forward, lateral, and backwards running. Four cones were placed at the starting/finishing and three turning points. Participants were instructed to run as fast as possible from the starting to the finishing point. Firstly, they sprinted forward 10 meters and touched the cone with their right hand. They then shuffled to the left 5 meters and touched the cone with their left hand. After that, they shuffled to the right 10 meters and touched the cone with their right hand. They then shuffled to the left 5 meters and touched the cone with their left hand again. Lastly, participants sprinted backward to pass through the finishing point, which was the same point as starting. The time was started when participants passed the starting point, and the time was stopped when they passed the finishing point. This test was measured three times with 3 minutes of rest between trials, and the fastest value was used for statistical analysis (Sonchan, Moungmee, & Sootmongkol, 2017).

Statistical analysis

Baseline characteristics were summarized as mean and standard deviation (SD). The Shapiro-Wilk test was used to verify the normality of the data. All of the data used to evaluate MIP, MEP, leg strength, power, speed, and agility had a normal distribution. As a result, the Pearson correlation coefficient was used to examine the relationship between these parameters. All data were analyzed using the SPSS (version 24). The statistical level was set as $p<0.05$.

Results

Table 1 showed baseline characteristics data of all participants. The average maximal inspiratory and expiratory pressure were 106.96±26.76 and 91.00±20.46 cmH2O, respectively. The average leg strength and power were 126.30±27.36 kilogram and 47.54±10.22 centimeter. The mean speed of the participants was 2.41±0.27 seconds and the mean agility was 12.52±1.17 seconds.

Table 1. Baseline characteristics data of participants (n = 28)

Variable	Mean ± standard deviation
Maximal inspiratory pressure (cmH_2O)	106.96 ± 26.76
Maximal expiratory pressure (cmH_2O)	91.00 ± 20.46
Leg strength (kg)	126.30 ± 27.36
Leg power (cm)	47.54 ± 10.22
Speed (s)	2.41 ± 0.27
Agility (s)	12.52 ± 1.17

There were the moderate relationships between MIP and several physical performance parameters ($p<0.05$). MIP was positively correlated with leg muscle strength ($r=0.406$; $p=0.032$) (Figure 1a), whereas it was negatively correlated with speed, and agility ($r=-0.416$; $p=0.028$, $r=-0.469$; $p=0.012$, respectively) (Figure 1b and c). In the other hand, there was no significant correlation between MIP and leg power ($p=0.197$). For MEP, it was negatively correlated with speed in moderate level ($r=-0.392$; $p=0.039$) (Figure 2). The relationship between this parameter with leg muscle strength and power, and agility were not found ($p>0.05$).

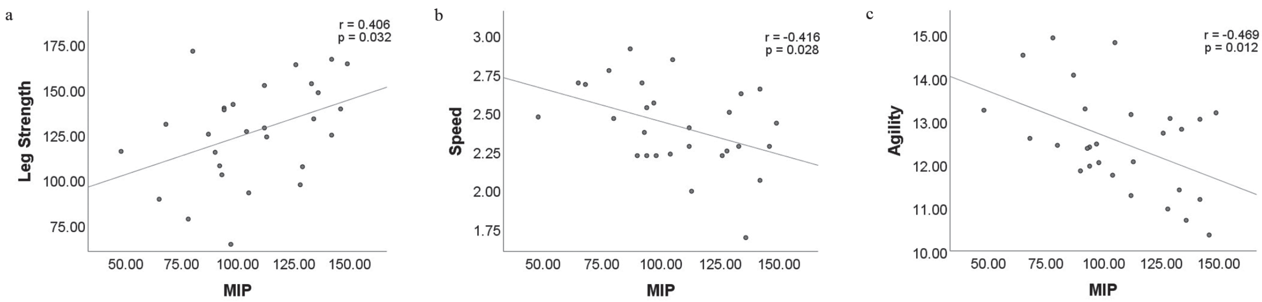

FIGURE 1. Correlation between MIP and a: Leg strength; b: Speed; c: Agility

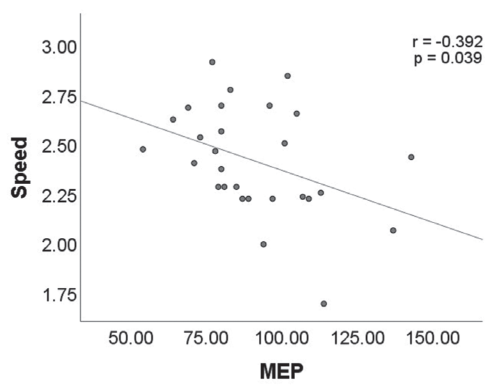

FIGURE 2. Correlation between MEP and Speed

Discussion

This is the first study to provide data regarding the relationship between respiratory muscle strength and leg muscle strength, power, speed, and agility in college volleyball players. The results of the present study demonstrated the significant moderate relationship between MIP and leg muscle strength, speed, and agility, while MEP has a significant moderate relationship with speed.

Muscle contraction requires energy from the breakdown of adenosine triphosphate (ATP). The efficiency of musculature performance for prolonged periods depended on the ability to constantly reproduce ATP (Baker, McCormick, & Robergs, 2010). During continuous activity, the skeletal muscle needs a great deal of oxygen to replenish the hydrolyzed ATP. Consequently, the respiratory system works increasingly to provide sufficient oxygen to contracted muscles. Furthermore, UE movement during playing volleyball is closely related to inspiratory muscle due to the connection between upper limb muscles and diaphragm. For this reason, it can be explained a significant positive relationship between MIP and leg muscle strength in our result, which is consistent with previous studies (Kocahan, Akınoğlu, Mete, & Hasanoğlu, 2017; Akınoğlu, Kocahan, & Özkan, 2019). However, there was no significant correlation between MEP and leg muscle strength. This result was not consistent with previous studies (Kocahan, Akınoğlu, Mete, & Hasanoğlu, 2017; Akınoğlu, Kocahan, & Özkan, 2019). It was possible that the work of expiratory muscles occurred during forced exhalation. Thus, these muscles were involved indirectly to produce energy for muscle contraction. Agility has been defined as the ability of the body to change direction quickly (Šimonek, Horička, & Hianik, 2017). We found a negative correlation between MIP and agility. Although there is a lack of data to discuss the correlation between this performance and respiratory muscle strength, the probable explanation for this relationship might be described by the relation of agility to muscular strength (Paul, Gabbett, & Nassis, 2016). During the change of direction movements, muscle strength, especially eccentric contraction, is required to decelerate the player's velocity and prepare for acceleration of new directional changes (Spiteri, Wilkie, Hart, Haff, & Nimphius, 2013).

In our result, the leg muscle power measured by the vertical jump height was not significantly correlated with respiratory muscle strength. The possible reason might be that because the vertical jump is an essential part of the spike, block, topspin, set, and floating serves in volleyball, all positions of volleyball players had to mainly practice this skill (Borràs, Balius, Drobnic, & Galilea, 2011). Thus, similar training programs may lead to analogous vertical jump performance among volleyball players. The result of a previous study seems to support this explanation that there was no significant difference in vertical jump performance between Thai national and Youth national volleyball players (Limroongreungrat & Kamutsri, 2014).

Regarding speed, the result of the present study showed a significant negative correlation between respiratory muscle strength and this performance. Previous studies that demonstrated the effect of inspiratory muscle training (IMT) on speed in athletes were used for discussing this relationship (Archiza et al., 2018; Sunthonghao & Tongtako, 2019). After 6-week of IMT, the lactic acid removal and sprint performance in Futsal players were improved (Sunthonghao & Tongtako, 2019). Lactic acid is a chemical response from anaerobic glycolysis. When the body has insufficient oxygen during intense activity, anaerobic glycolysis transformed glucose into lactic acid, resulting in muscle fatigue and limiting physical performance (Sahlin, 1986). Thus, the increased lactic acid removal may improve the ability to sprint. In addition, Archiza et al. (2018) reported that IMT reduced deoxyhemoglobin and total hemoglobin blood concentration in the respiratory muscle, while oxyhemoglobin and total hemoglobin blood concentration in the peripheral muscle were increased. This finding suggested that IMT may attenuate the inspiratory muscles metaboreflex and improve oxygen and blood supply to limb muscles during high-intensity exercise (Callegaro, Ribeiro, Tan, & Taylor, 2011). Moreover, the chest and ribcage expanded as a result of deep inspiration. This positioned the thoracic spine to be able to rotate freely from side to side during sprint, and allowed the runner to efficiently transfer energy from the arm strides, through the chest, and into the legs, resulting in increased power output.

One limitation in this study should be acknowledged. We enrolled the participants unequally between male and female. Thus, it may affect the physical performance parameter, and might impact the relationship between respiratory muscle strength and physical performance. We suggested controlling the gender of participants equally or choose only male or female. Additionally, these correlations are needed to be considered among the athletes who have higher performance in further study.

In conclusion, physical performance such as muscle strength, speed, and agility were moderately correlated with inspiratory muscle strength, while expiratory muscle strength was moderately correlated with speed among college volleyball players. These findings suggested respiratory muscle strength and physical performance should be developed parallelly.

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Conflict of interest
The authors declare that there are no conflicts of interest

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ORIGINAL SCIENTIFIC PAPER

The Effect of Chicken Formulations on Muscle Mass and Strength in Thai Healthy Male Volunteers

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Abstract

This study aimed to examine the effect of high protein from chicken breast products during resistance exercise training on muscle mass and strength in healthy Thai male volunteers. In this study was double-blind randomized placebo-controlled study. This study assessed changes in muscle mass and strength of 60 healthy men aged 20-35 years with normal BMI (23.04±2.52 kg/m2). Participants were randomly divided into three groups receiving controlled placebo tablet (CG, n=18, lactose-based containing 12.0 g lactose/day), chicken tablet (CT27, n=18, 27.0 g protein/day), and chicken chip (CC36, n=19, 36.8 g protein/day) during 69-day period. In addition, all groups were instructed to perform the same resistance training program (4 times per week). Body composition (BIA), anthropometry (AMC, CMC), and muscle strength were measured. After 9 weeks of the study, CC36 group had a statistically significant increase ($p<0.05$) in the percentage of skeletal muscle from baseline when compared other two groups. Additionally, a significant increase ($p<0.01$) in arm muscle circumference, back-leg extension, and hand grip strength were observed in both groups receiving chicken protein products. The same result was also detected in the placebo group but at a much slower rate. Resistance training exercise along with intake of the chicken protein products could increase muscle mass and strength.

Keywords: *Chicken breast protein, Body composition, Anthropometry, Muscle strength, Double-blind study*

Introduction

Protein is an essential nutrient that plays a primary role in body metabolism as an essential component of tissues, hormones, and enzymes (Hoffman et al., 2004). Daily protein consumption can be taken from various sources, such as animals, plants, and milk (Hartman et al., 2007; Hoffman et al., 2004). Protein is the most needed nutrient for people who exercise regularly or athletes (Kårlund et al., 2019; Pasiakos et al., 2015). Beyond normal dietary protein intake, the benefits of additional protein consumption for people of all ages participating in resistance training are to help the body be repaired after exercise, maintain muscle mass, and increase power and strength (Helms et al., 2014; Pasiakos et al., 2015). Because of the high demands for protein in athletes, assorted supplements such as snacks, drinks, powder, and tablets are valuable useful alternatives for those who cannot obtain adequate protein from daily diet (Kårlund et al., 2019).

Animal meat is a significant source of protein supplement ingredient due to the rich in essential amino acids, which helps synthesize muscle and is essential to the net processes within the body more than other sources (Berrazaga et al., 2019; Hoffman et al., 2004). Diets consisting of meat result in greater

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gains in lean body mass than subjects on a lactoovovegetarian diet (Campbell et al., 1999). High protein diets from the animal sources have also been shown to cause a significantly greater net protein synthesis than a high vegetable protein diet (Berrazaga et al., 2019). Currently, protein supplements in various forms such as powder, tablets, snack bars, and chips are prevalent because they can be consumed easily. Several effects of protein supplements on human body have been reported (Cintineo et al., 2018; Mertz et al., 2021). For example, 46 grams of beef, chicken, and whey protein compared to a maltodextrin control on lean mass and strength during 8 weeks of resistance training were reported to enhance lean body mass and reduce fat mass in young males and females (Sharp et al., 2018). High-protein snacks from dried egg white efficiently increase the mass and strength in human muscle (Kato et al., 2011).

Chicken products, including fresh meat, are famous worldwide since it is convenient, cheaper than others due to the cost of production, and quick to prepare (Erian et al., 2017). In addition, chicken meat contains various nutritional benefits such as being low in fat and saturated fat (Kralik et al., 2018). Chicken breast meat is a complete protein source that contains all twenty-two amino acids required to build protein-based structures such as muscle, hair, skin, and other connective tissues (Hoffman et al., 2004; Marangoni et al., 2015). Additionally, it contains creatine, a non-essential amino acid used to produce energy for stronger contractions in muscles, increasing lean muscle mass, and improving performance in bodybuilders and athletes, in the same amount as beef and lamb meat (0.4 grams of creatine/100 g of cooked chicken breast) (Kaviani et al., 2020). Leucine, isoleucine, and valine, a group of three branched-chain amino acids (BCAAs) involved in stimulating muscle growth, are also abundantly found in chicken breast (Zhang et al., 2017).

Several studies have examined the influence of protein supplementations, mostly in the form of whey protein or planted-based protein snacks, on muscle mass and strength, but not for meat-based protein (Brown et al., 2004; Grubic et al., 2019). Furthermore, protein snacks are usually high in salt and fat, which adversely affect the body and are expensive. Therefore, in this work, the effects of two snack formulations of chicken breast meat (CT27, Chicken Tablet containing 27.0 g of chicken protein/serving/day VS CC36, Chicken Chip containing 36.8 of chicken protein/serving/day) with low salt (not exceeding to 180.7 mg/serving) on body composition, anthropometry, and muscle strength of people involved in a resistance-training program were studied in people involved in a resistance-training program of 69 days.

Methods

Participants

Sixty Thai male subjects aged 20-40 years were recruited for this double-blind, randomized, clinical trial. Participant should be physical activity 3–4 days a week for at least two months before the study, have Weight stable (±2 kg) for at least two months before the study and Body mass index (BMI) between 18.5 to 29 kg/m^2. Prior to the commencement of the study, a complete explanation of the purpose and procedures of the investigation was given to the participants who were requested to sign a written informed consent document. This followed the protocol approved by the Institutional Review Board of Naresuan University (NUIRB) (COA No.061/2019; Approval Date: January 21, 2019), which complies with the Declaration of Helsinki revised in 1983.

The participants were required to maintain a food diary for the three days immediately prior to the start of the experiment. On the first day of the experiment, the 3-day food diary was analyzed, a clinical history was elicited from each participant, and all participants underwent a physical examination. Volunteers with metabolic or cardiovascular abnormalities, musculoskeletal injuries, who were current tobacco users or were currently using protein supplements or taking medication that would affect protein metabolism, or had food allergies, were excluded.

Experimental protocol

This study was designed to assess the effects of protein from chicken breast products intake on muscle mass and strength. Using a randomized design, the participant received either chicken tablet product, chicken chip product, and placebo by random allocation using a 'block of four' prior to the 3-day food diary was analyzed. Participant, investigator, laboratory staff and data extraction staff were blinded to allocation until all data was analyzed. The participants were assigned to a group that received placebo tablets as the control group (CG, n=18, lactose-based formulation containing 12 grams lactose/serving/day), a second group received Chicken Tablet (CT27, n=18, 27.0 grams of protein/serving/day), and the third group received Chicken Chips (CC36 n=19, 36.8 grams of protein/serving/day). Each serving of supplements was to be taken on every day of the 69-day period of the study. Also prior to commencement, daily practice manuals regarding diet and strength training exercises, including daily eating records and exercise records, were provided.

Participants were required to perform resistance-type exercise on each of the four workout days/week to maintain muscular levels. On each workout day, participants were instructed to consume half of their serving of supplements 30 minutes before their workout and the other half immediately following their workout. On each resting day (no workout on these days), the participants were instructed to consume the placebo and supplement twice, once at about 10 am. and then again at about 3 pm. Three ordinary meals per day were assumed. On the first day of the study, baseline measurements of vital signs, body composition, anthropometry (mid-arm and calf circumferences), muscle strength testing, and nutritional consultation were taken. On days 23 and 46, and on the final day of the study, day 69, participants were again assessed to check vital signs, body composition analysis (weight, body mass index, total body fat percentage, and the percentage of skeleton muscle mass), with anthropometry, muscle strength, and nutrition assessment. The trial was conducted at the Exercise and Rehabilitation Sciences Research Unit, Faculty of Allied Health Sciences, Naresuan University, Phitsanulok, Thailand. The complete food and exercise records were recalled from the participants on the final day, and any adverse reactions or adverse effects experienced by the participants were identified and discussed.

Dietary analysis and supplementation protocol

Participants were instructed to maintain their habitual diet and complete a 3-day food diary on five occasions: first, immediately prior to the initial baseline testing day, and subsequently immediately prior to days 23, 46 and 69 (which was the last day of the testing period). The participants had been given detailed instructions recording their normal diet which was to encompass 3 consecutive days each time, including 2 weekdays and 1

Table 1. Demographic and baseline muscle characteristics of subjects (N = 55).

Characteristic	Placebo	Chicken tablet	Chicken chip
n	19	18	18
Age	23.05±3.50	22.76±3.87	22.75±3.57
BMI	24.21±2.81	23.59±3.10	21.31±1.66
Vital sign			
Blood pressure (mm/HG)			
Systolic	129.8±12.5	128.2±8.0	122.7±10.9
Diastolic	74.6±7.0	73.3±6.8	72.2±8.3
Heart rate (beats/min)	69.6±7.9	70.1±6.4	78.7±12.2
Body temperature (°C)	36.77±0.24	36.75±0.25	37.15±0.25
Body composition			
Total fat (%)	18.69±1.11	19.83±1.36	16.38±0.71
Skeletal muscle (%)	35.47±0.47	35.09±0.61	36.01±0.34
Anthropometry			
Arm muscle circumference	28.99±0.86	29.80±0.67	27.69±0.86
Calf muscle circumference	35.15±0.72	34.90±0.56	33.98±0.48
Muscle strength			
Back extension (kg)	106.86±6.83	104.25±7.61	95.71±5.49
Leg extension (kg)	112.08±8.68	98.17±7.89	93.18±6.18
Hand grip (kg)	40.29±1.45	39.34±1.83	37.02±1.27

Note Values are means±SEM, Homogeneity was determined using analysis of variance

weekend day (on the assumption that their weekend diet may vary from their weekday diet). These records were used to estimate total daily energy expenditure (TEE) to compare against nominally required kilocalories, using the Harris-Benedict equation for persons with a physical activity level of 1.5.

BEE (for men) = 66.47 + (13.75×Weight(kg)) + (5.00×Hight(cm)) - (6.75×Age(years))

TEE = BEE×Activity factor×Stress factor

The dietary intake data was collected and estimated using the INMUCAL-Nutrients software, version 4 (Kittisakmontri et al., 2021), developed by the Institute of Nutrition, Mahidol University, Thailand.

Training program

The training program was resistance-type exercises for 1 hour on 4 days per week for each of the 9 weeks (69 days) of the study period. Each day's session began with about five minutes of warm-up on a cycle ergometer or treadmill, followed by five to ten minutes of flexibility training and then a sixty-minute resistance training period. Each of the four sets of resistance exercises was undertaken with twelve repetitions at 80% of 1RM (repetition maximum) (Krzysztofik et al., 2019). The resistance training protocol included pectoralis and triceps exercises on the first day, back and biceps exercises on the second day, deltoids on the third day, and quadriceps, hamstrings, and calves on the fourth day (Thomas et al., 2016). Training logs were maintained that recorded each participant's completion of the number of repetitions, sets, and loads for the workout session. These logs were then reviewed at the end of each day by the training staff.

Measurements

Body composition

An Omron Body Composition Monitor (HBF-375, Omron Cooperation, Tokyo, Japan) was used to assess bioelectrical impedance. Measurements were collected at 50 Hz using the standard settings based on the height, gender, and age of the participants. The participants were barefoot and were posed with outstretched arms and feet touching all four metal plates of the monitor.

Anthropometry

Calf circumference is commonly measured with a tape at the point of the greatest circumference of the calf. The left leg is measured for naturally right-handed persons with the person in a sitting position with both feet flat on the floor and knees bent at a right angle. Calf circumference was taken to the nearest 0.1 cm. Caution was taken to avoid compressing the subcutaneous tissue.

The mid-arm circumference was measured with a measuring tape on the upper arm, at the mid-point between the olecranon process of the shoulder and the acromion, with the participants in a seated position. The measure was accurate to the nearest 0.1 cm. The triceps skinfold thickness was measured using a calibrated skinfold caliper (range 0.00–50.00 mm; minimum graduation 0.2 mm). Skinfold thickness was recorded to the nearest 0.2 mm. For both these parameters, an average of three measurements was calculated.

Muscle strength measurement

Assessment of leg strength

Participants, wearing training shorts, stood on the footplate of the Takei dynamometer (Takei Scientific Instruments Co., Ltd, Tokyo, Japan) with their scapulae and buttocks positioned flat against a wall. The back of the footplate was approximately 15 cm from the wall. Participants flexed their legs, sliding down the wall until the leg extension angle equaled 135' (2.36 rad). Participants then reached down with the elbows fully extended. The pull-bar of the dynamometer was placed in the hands and the chain length was adjusted appropriately. Participants were instructed to extend the legs with maximal effort, pulling the bar smoothly without 'jerking'. The highest of three scores was recorded.

Table 2. Dietary intake in healthy male participants.

Variable	Time period		Chicken protein products 2 times/day
	Baseline	At day 69	
Total energy, kcal/d			
CG	1453.8±183.3	1523.9±170.7	115.6
CT27	1426.1±163.4	1416.9±52.9	121.8
CC36	1567.1±85.9	1482.6±79.9	251.6
Protein intake			
Absolute, g/d			
CG	82.9±10.3	81.4±6.9	0.0
CT27	79.2±13.0	76.8±8.3	27.0
CC36	79.7±5.1	100.3±15.7	36.8
Relative, g/kg/d			
CG	1.11±0.14	0.96±0.08	0.00
CT27	1.18±0.23	1.23±0.12	0.43
CC36	1.20±0.05	1.37±0.17	0.50
Carbohydrate intake			
Absolute, g/d			
CG	158.7±21.9	149.5±25.8	27.8
CT27	164.8±23.1	151.5±7.0	13.6
CC36	145.4±16.6	135.2±18.1	11.4
Relative, g/kg/d			
CG	2.07±0.30	1.76±0.31	0.32
CT27	2.45±0.43	2.42±0.11	0.21
CC36	2.20±0.22	1.85±0.22	0.15
Fat intake			
Absolute, g/d			
CG	54.2±8.1	66.7±12.7	0.0
CT27	50.0±4.0	55.9 ± 5.0	4.4
CC36	74.1±8.1	60.1±11.6	6.6
Relative, g/kg/d			
CG	0.76±0.11a	0.79±0.16	0.00
CT27	0.77±0.08a	0.70±0.10	0.07
CC36	1.13±0.15b*	0.82±0.16*	0.10

Note Values are mean±SEM, a different from b, 1-way ANOVA, *p<0.05.

Assessment of back strength

Participants stood on the footplate of the Takei dynamometer, initially in the same manner as for the measurement of leg strength. The legs were kept straight and the back was flexed at the hip. Flexion continued until, with fully extended elbows, the tips of the index fingers reached the patellae. The pull-bar of the dynamometer was then placed in the hands and the chain length was adjusted. A reverse grip was adopted for the measurement of back strength to deter the use of shoulder muscles during the 'pull'. The highest score from three pulls was recorded.

Assessment of handgrip strength

The Takei T.K.K.5401 GRIP-D handgrip dynamometer (Takei Scientific Instruments Co., Ltd, Tokyo, Japan) was used to measure the handgrip strength, which is a simple and popular test for general strength levels. Each participant squeezed the dynamometer handgrip for 3 s, twice in succession without rest. The highest 'squeeze strength' value was recorded. There for, quantitative variables were measured.

Statistical analysis

All data were expressed as the mean±standard deviation. Baseline participant characteristics are described using common descriptive statistics, and a 1-way ANOVA was used to confirm homogeneity between groups. Changes in body composition and muscle strength as a response to consuming the dietary supplement were calculated to determine differences over time between diet groups. All outcome variables were analyzed using a mixed-model repeated-measures ANOVA including within-subjects factors for time (study days) and with a between-subjects factor of diet group (placebo, chicken tablet, and chicken chip). Where a significant interaction between these variables was observed, post hoc pairwise analyses were conducted using Bonferroni adjustments for multiple comparisons. The level for significance was set at p<0.05. Data were analyzed using SPSS 25 for Windows (Chicago, IL).

Results

Flow of subjects through the study

Three subjects did not meet the criteria. As a result, fifty-seven subjects were enrolled. During the study for 9 weeks, two subjects were lost to follow up with their own personal reason that not involved with this study. Finally, fifty-five subjects completed the study. Flow of subjects through the study is shown in Figure 1.

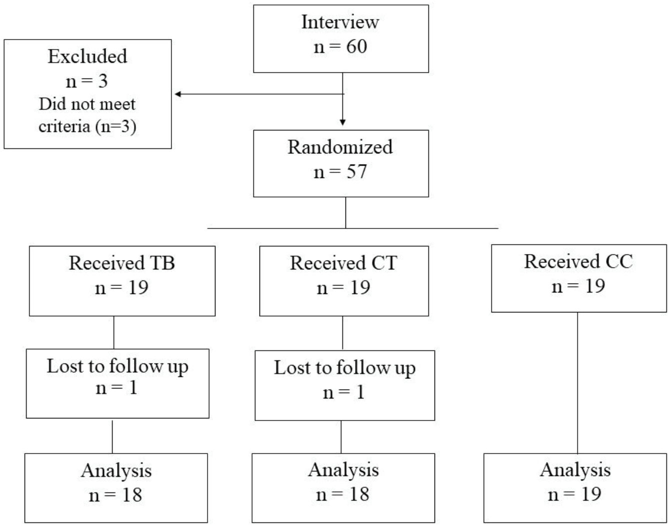

FIGURE 1. CONSORT (Consolidated Standards of Reporting Trials) diagram of study recruitment, enrollment, randomization follow-up, and analysis.

Demographic data

Table 1 shows the demographic of fifty-five subjects completed the study. The age range of subjects was 20 to 35 years (23 years in average). Almost of them are working as the university employees 32.7% and studying at the university 67.3%.

Assessment of body composition

In the following sections, reference to 'the four time points' refers to Day 0, Day 23, Day 46 and Day 69 of the study period. Day 0 is also referred to as the baseline day.

There was similarity across the four-time points (p>0.05) but significant differences between groups (p<0.05) in skeletal muscle percentage (Figure 2a). There was also a significant between time x group interaction (p<0.05). By following up this interaction, there was no significant difference between groups at baseline. However, the mean scores of the CC36 group showed a significant increase between day 69 compared with the baseline, day 23, and day 46 time periods (p<0.05, time x diet group interaction). For total fat percentage, there was a non-significant difference between the two dietary protein groups over time (p<0.05), nor was the CG group (p>0.05) (Figure 2b).

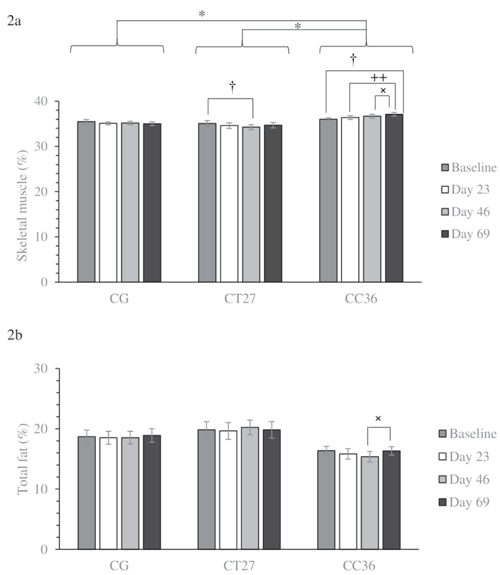

FIGURE 2. Effects of high protein from chicken breast products on percentage of skeletal muscle (2a) and total fat (2b) values. They were collected on baseline (dark gray bar), day 23 (white bar), day 46 (light gray bar), and day 69 (black bar) after the application of the tests.

Assessment of anthropometry

At commencement, there was no significant difference between groups (p>0.05), regarding arm muscle circumference. There were significant differences across the four time points (p<0.01) between all groups (Figure 3a). There was also a significant between time x group interaction (p<0.05), indicating that consumption of the two protein supplements had a significant effect with the mean scores of the CT27 and CC36 groups showing a significant and constant increase over baseline at day 23, day 46, and day 69 (p<0.01). For the within-group results for the CC36 group, there was a statistically significant increase in the arm muscle circumference value from day 23, which was observed at day 69 (p<0.05).

For calf muscle circumference, there was similarity across the four-time points (p>0.05) and significant differences between all groups (p<0.05) (Figure 3b). The mean scores of the placebo group significantly decreased after day 23.

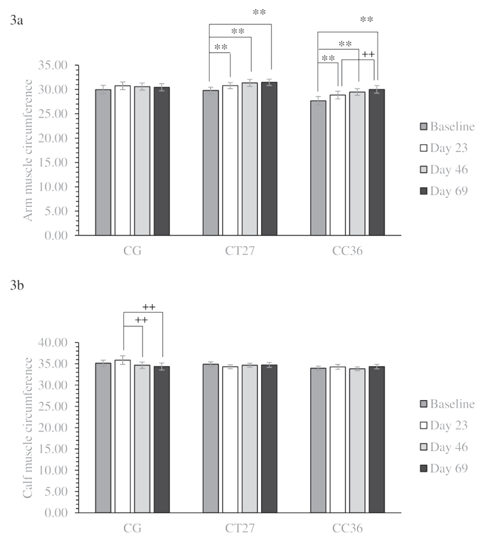

FIGURE 3. Effects of high protein from chicken breast products on arm (3a) and calf muscle circumference (3b) values. They were collected on day 0 (baseline) (dark gray bar), 23 (white bar), 46 (light gray bar), and 69 (black bar) after the application of the tests.

Assessment of muscle strength

The three aspects of muscle strength tested were back extension force, leg extension force, and handgrip strength.

For back extension force, at baseline, no significant differences between groups (p>0.05) were observed, and subsequently, there was no significant between time x group interaction (p>0.05). However, there was a significant difference across the four-time points (p<0.01). (See Figure 4a). However,

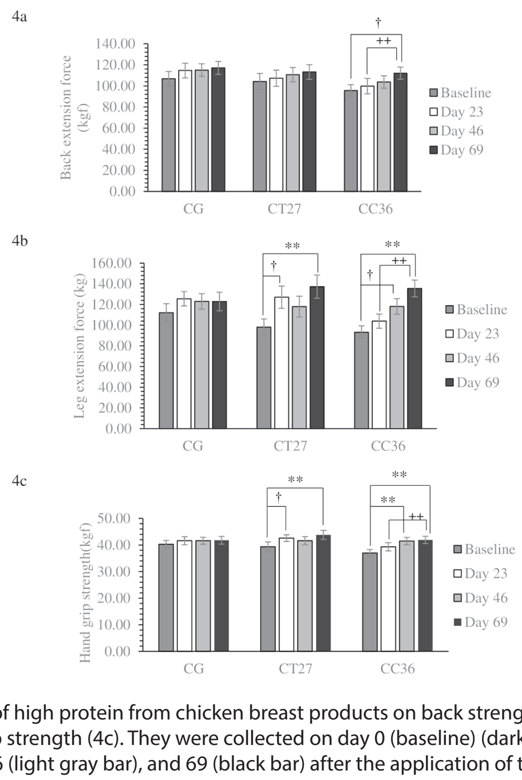

FIGURE 4. Effects of high protein from chicken breast products on back strength (4a), leg strength (4b), and hand grip strength (4c). They were collected on day 0 (baseline) (dark gray bar), 23 (white bar), 46 (light gray bar), and 69 (black bar) after the application of the tests.

the mean scores of the CC36 group significantly increased between baseline and day 69 ($p<0.05$), with a significant increase from day 23 compared with day 69 ($p<0.05$).

For leg extension force (kgf), there were significant differences across the four-time points ($p<0.01$) but no significant differences between groups ($p>0.05$). There was also a significant between time x group interaction ($p<0.05$). The mean scores for leg extension force of the CT27 group gradually increased overall from the baseline to day 69. For the CC36 group there was a similar overall statistically significant increase between baseline and day 69, with an accelerated increase from day 23 and 69 that was statistically significant. The leg extension results are shown in Figure 4b.

For the handgrip strength (kgf) data, there were significant differences across the four-time points ($p<0.01$) but no significant differences between groups ($p>0.05$) (Figure 4c). There was also a significant interaction between time x group. ($p<0.05$).

Overall, from baseline to day 69, the mean scores for handgrip strength of the CT27 group gradually increased from the baseline to day 69. For the CC36 group, there was a statistically significant increase overall, from baseline to day 69.

Discussion

Our double-blind placebo-controlled design study was one of the few studies which evaluated the effects of meat-based snacks on muscle mass and strength of people involved in a resistance-training program. The crucial finding of this study was that both high protein snacks from chicken breast in chip and chewable tablet forms consumed both before and after training at the level above RDA increased muscle mass in term of skeleton muscle percentage and arm muscle circumference as well as strength of legs, back, and hands (Hoffman et al., 2004; Negro et al., 2014).

The recommended daily intakes (RDIs) set by The Academy of Nutrition and Dietetics suggested that an average individual should consume 0.8 grams of protein per kilogram of body weight per day ($g \cdot kg^{-1} \cdot d^{-1}$) for general health (Lonnie et al., 2018), while people with regular exercise such as lifts weightlifting, running, or cycling event were advised to eat a range of 1.2-1.7 $g \cdot kg^{-1} \cdot d^{-1}$to increase muscle mass in combination with physical activity (Rodriguez et al., 2009). From nutritional intake data of this study, habitual protein intake along with protein from chicken breast products of participants was approximately 1.9 and 1.7 $g \cdot kg^{-1} \cdot d^{-1}$ in CC36 group and CT27 group, respectively. In comparison, it was 1.0 $g \cdot kg^{-1} \cdot d^{-1}$ in CG group.

Muscle mass was built when the net protein balance was positive: muscle protein synthesis exceeds muscle protein breakdown, and muscle protein turnover was the greatest after working out (Tipton et al., 2013). Additionally, it has been shown that muscle mass increased over time when resistance exercise (weightlifting, bodyweight exercises, etc.) was combined with nutrient intake (C. E. Cooper et al., 2008). With higher protein intake, participants appeared to increase the ability of necessary protein synthesis and inhibit protein degradation (Weinert, 2009). The increase in protein synthesis could be explained by an increase in mammalian target of rapamycin and 70-kDa ribosomal protein S6 kinase signaling initiated by positive regulators (e.g., insulin-like growth factor 1) and this pathway (Detzel et al., 2015). Shivani et.al. recently demonstrated that consuming animal-based protein containing essential amino acids could trigger the aforementioned signaling pathways to enhance protein accretion and muscle mass (Sahni et al., 2015).

Focusing on the body composition, baseline measurements of all parameters of the three groups showed no significant difference ($p>0.05$). For % skeleton muscle mass in the CT27 group, no significant changes were observed after 69 days of the study compared to the baseline value, while there was an increase in the CC36 group from the baseline to days 46 and 69 of consumption ($p<0.05$). This might be explained by the different serving protein content in the CC36 formula containing 20% higher amount of protein than the CT27 formula. High animal-based protein diets have also been shown to cause a significantly greater net protein synthesis because food protein quality assessed by digestibility, net protein utilization, and biological value has been better than other sources (Berrazaga et al., 2019; Hoffman et al., 2004).

Overall, for muscle strength assessment including back, leg and lower-hand muscle strength, showed that the strength gains of the CT27 and CC36 groups were significantly greater than that of the placebo group. Even though the muscle strength values for the placebo group tended to increase from baseline, this was a slower rate than the other groups indicating that protein intake was beneficial (Sahni et al., 2015; Sharp et al., 2018). In conclusion, resistance training exercise-induced muscular strength might be primarily mediated by dietary protein intake and strength training (Cooper et al., 2008). Load and specificity, training volume, and especially increased training experience might also contribute but were not studied here (Mangine et al., 2015). The International Society for Sports Nutrition also recommended protein intake at levels higher than the RDA for physically active individuals (1.4–2.0 g/kg/d).

Calf muscle circumference measurements showed no significant increase at all over the 3-month period for protein groups. However, interestingly, the placebo group experienced a significant decrease in calf muscle circumference over the 3-month period. The muscle strengthening exercises for calf muscles were performed only one day of each of the four exercise days per week, whereas the arm muscles benefited from all upper-body exercises. This might be because of the amount of exercise of the calf muscles was insufficient to achieve a significant outcome (Burd et al., 2010). For another explanation, given the decrease in calf muscle strength in the placebo group, it could be assumed that consumption of the protein supplements did have a beneficial effect on calf muscle strength, of only to maintain initial strength.

Similar outcomes have been reported not only in biceps and triceps workout that direct affected biceps and triceps muscle groups but also back, chest, and deltoid workout that minor affected biceps and triceps muscle groups (Andersen et al., 2014; Atle Hole Saeterbakken et al., 2017). The limited effect of only one exercise day on calf muscles was also noted. To build muscle more uniformly, workouts needed to be performed concurrently and consistently with all muscle groups over time (Crewther et al., 2016; Mangine et al., 2015).

However, the percentage of total fat of the CC36 significantly increased ($p<0.05$) between day 46 and day 69. Although protein offers a number of health benefits, a diet with excess calories will be converted to fat glucose (by gluconeogenesis) or ketone bodies. The leftover carbon compound is also converted into glucose, which the human body uses for energy. In a state of low energy demand, these metabolites will be stored as glycogen and fat (Bray et al., 2012).

Nevertheless, the present study had limitations, including gender, race, and source of protein, confining potential generalizability. Gender is an important consideration in responses to interventions for body composition changing and muscle adaptations. A small number of participants might provide less consistent results than a larger one. Longitudinal studies of changes in dietary protein, lean mass, and strength should be explored because future prospects for interventions will depend on identifying these physiologic pathways involved in muscle changes with age.

Conclusion

This study shows the consumption of chicken protein as a high protein snack promotes the building and strengthening of human muscle when taken during a regular strength training program. Therefore, it is reasonable to suggest that, to popularize these as desirable edible product, further research is required to be improve the smell and taste of the products.

Conflicts of interest: There are no conflicts to declare.

Acknowledgments

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ORIGINAL SCIENTIFIC PAPER

The Effect of Cinnamon Extract on Recovery and Performance of Weightlifting Athletes

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Abstract

Weightlifting is a type of sport that demands beneficial complementary supplements. This is because of the highly intensive training and tight schedules, which requires the body to be maintained at the prime condition to avoid injury. Furthermore, supplements and natural products are needed to accelerate athletes' recovery and avoid doping. Cinnamon is a good natural product that contains phenol and cinnamaldehyde antioxidant content. This study used a double-blind one-way crossover design approach on 16 male athletes with the lowest experience competing in Southeast Asia. The athletes consumed 500 mg of cinnamon extract for 8 weeks and entered a 4 and 8 week washout phase and placebo, respectively. The performance tests were conducted by match simulations, such as snatch and clean and jerk. Creatine kinase (CK), C-reactive protein (CRP), and lactate were tested to determine fatigue levels and accelerate recovery. According to the results, significant changes occurred for CK and CRP of $p<0.005$, glucose $p<0.048$, and lactate at $p<0.012$ with no effects on performance. Conclusion: Cinnamon extract significantly affects CK, CRP, lactate, and glucose without any notable effects on performance.

Keywords: *Ergogenic aid, Muscle damage, Muscle soreness*

Introduction

Young athletes go through many growth stages from an early age to become professionals and achieve peak performance (Huebner, & Perperoglou, 2019). Some athletes exercise 12 times a week, impacting their fatigue levels, recovery speed, and performance of future activities (Williams, Tolusso, Fedewa, & Esco, 2017; Poulios et al., 2019; Junaidi et al., 2020). Even in weightlifting, the risk of injury to young athletes is more or less due to imperfect technique. On the other hand, they should continue to practice regularly with the measured load. The main problem is the wrong technique when exercising often affected by fatigue condition. Fatigue experienced by weight lifters after training causes muscle soreness and damage because, after exercise, there are inflammations caused by C-Reactive Protein (CRP), and intracellular proteins, such as creatine kinase (CK) (Magal et al., 2010; Araszi & Asadi, 2013). This inflammatory state often results in muscle soreness, decreased functionality, and reduced performance (Peternelj & Coombes, 2011; Powers, Nelson, & Hudson, 2011; Chen et al., 2012).

Athletes should consume food and drinks with sufficient nutritional content to meet their body requirements. Some athletes and coaches prepare supplements from natural and synthetic ingredients to meet their needs before and after training. Athletes aim to accelerate muscle recovery and increase energy when training (Braun et al., 2009). Natural-based supplements help increase antioxidants and anti-fatigue in the body, improving an athlete's performance (Peternelj, & Coombes, 2011; Zhu et al., 2020). Cinnamon extracts can reduce muscle damage caused by insulinogenic effects when administered in 500 mg daily dosage in 6 consecutive weeks (Zhu et al., 2020). In that study, the samples were badminton athletes, who tended aerobic metabolic characteristics. Furthermore, studies on cinnamon conducted in 2020 show that it can reduce muscle inflammation and oxidative stress levels in humans (Zhu et al., 2020). That reasonable because, they study explain cinnamon contents include 3-phenyl-2 (E) -propenal aromatic aldehyde (cinnamaldehyde, trans-cinnamaldehyde) and cinnamic acid. Other benefits of cinnamon are often used for alternative and

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complementary medicine. Cinnamon intake has been used because of its therapeutic effect in treating flatulence, diarrhea, toothache, fever, vaginal discharge, flu, headaches, as well as an antitumor and anticancer (Kawarta, & Rajagopalan, 2015; Goel, & Mishra, 2020). However, other studies have shown unclear findings on muscle improvement after consuming cinnamon extract. Moreover, the physiological effects, such as CRP and glucose, are still lacking. Therefore, the effect of cinnamon extract on insulin sensitivity, inflammation, increased glucose transport in skeletal muscle, and improved recovery is unclear.

No studies have shown the effects of cinnamon extract on accelerating the recovery process with indicators of muscle soreness and damage, as well as athletic performance. Therefore, this study examined the effect of cinnamon extract for 8 consecutive weeks on physiological biomarkers such as muscle soreness and damage, as well as increased performance in weight lifters. The study hypothesized that the 8-week supplementation period of the cinnamon extract significantly improves athlete performance and reduces muscle soreness and damage.

Methods

Study design and participant

The design of this study was double-blind one-way crossover to determine the effect of cinnamon extract on muscle soreness and damage, as well as performance on 16 weightlifters. This study involved 16 male athletes under the guidance of the Gajah Lampung weightlifting club. All samples were recruited based on the different criteria, including having participated twice in national weightlifting championships, non-smoker, and no history of chronic diseases. Moreover, during the treatment, participants were prohibited from consuming anything outside the research rules, including food and drink supplements. The samples filled an informed consent to participate and all research procedures were approved by the ethics committee of the Indonesian Ministry of Health. Also, the research protocol received ethical approval from the Health Research Ethics Committee, Ministry of Health, Bandung Health Polytechnic, Letter No. 10/KEPK/EC/IV/2020.

All samples were prohibited from taking supplements 4 weeks before the initial test and the treatment stage to avoid routine consumption effects, and then the participants received 8 weeks of treatment for the first cinnamon extract supplementation. This was followed by a 4- and 8-week washout and second supplementation period with placebo respectively. In the first stage, samples consumed a 250 mg-capsule of cinnamon extract (Cinnulin PF®, 4 All Vitamins, New York, USA) every morning and evening. The second supplementation stage used a placebo without anti-fatigue and antioxidants with the same consumption time and duration, as explained in Figure 1. Cinnamon extract and placebo dosages were established based on previous study (McMorris et al., 2006).

Settings and locations of data collection

The research was conducted in Lampung, Indonesia. Testing took place on Prodia Laboratory in Bandar Lampung City. The baseline study was started in June 2020 and ended in October 2020.

Outcome measures

In this study, the training program is controlled by a team of trainers who ensure that all samples get an exercise program with the same goals customized to their respective abilities. Furthermore, a certified nutritionist provided food for all daily meals and fluids. This was to ensure that the samples were not contaminated by nutritional intake outside the control, resulting to study disruptions. Nutritional control was easier because all samples were in the same dormitory, and the research team could quickly review their daily activities.

All participant takes arthrometric tests, including body height, body weight, and body composition measured using DEXA composition before starting supplementation. Furthermore, the samples were taken for lactate and glucose levels, creatine kinase (CK), and C-Reactive Protein (CRP) measurements. After a performance test conducted comprising of clean and jerk, snatch, and 1 Repetition Maximal (1RM). Lactate and glucose levels, creatine kinase (CK), and C-Reactive Protein (CRP were taken within 24 hours after the previous tests. The samples underwent an 8-week exercise treatment, nutrition control, and extra cinnamon supplementation. After the treatment process, the second test was conducted to determine the impact of the cinnamon extract. Furthermore, the samples entered a washout stage for 4 weeks to avoid or eliminate the previous supplementation effects. The third test was then performed to determine the condition of the athlete before placebo supplementation. It was continued with the supplementation process for another 8 weeks which ended with the fourth test to determine placebo supplementation effects.

Before the test sample prime conditions were confirmed and evidenced through a doctor's health certificate by getting enough sleep, having sufficient breakfast, and not consuming caffeinated food and drinks. The test began with anthropometric measurements, followed by body composition evaluation using the DEXA tool (GE Lunar DPX Pro, Madison, WI). Moreover, 5 mL of venous blood sample was taken to measure CK and lactate levels before heating and testing. Subsequently, the samples warmed up and performed Clean and Jerk, Snatch, and 1RM and conducted lactate, glucose, CK, and C-RP test levels. The training method during the supplementation process was adopted from previous study (Hornsby et al., 2017).

Clean and Jerk

The sample performed 3 clean and jerk movements according to match rules. The first trial was performed 2-3 minutes of rest, while the second had increased load and the same resting duration. Lastly, samples were tested with the maximum force according to their ability.

Snatch

Similarly, the snatch test is part of the match simulation to determine weightlifter performance. Therefore, it was conducted 3 times by prioritizing classes from one generation to the next, which continued to increase with 2-3 minutes rest in between.

Blood analysis

In this study, we used Cobas Mira S, USA with the kinetic method, in accordance with the rules of the International Federation of Clinical Chemistry and the German Society for Clinical Chemistry, for the determination of creatine kinase activity. For the analysis, we mixed reagent (A) creatine kinase liquid, vol.=40/80 ml (consisting of Good's buffer 125 mmol/l, magnesium acetate 12 mmol/l, EDTA 2 mmol/l, D-glucose 25 mmol/l, N-acetyl-L-cysteine 25 mmol/l, NADP 2.5 mmol/l, and HK-hexokinase 6500 U/l), with reagent (B) creatine kinase liquid, vol.=10/20 ml (consisting of ADP 15 mmol/l, AMP 25 mmol/l, di-adenosine 5-phosphate 103 μmol/l, G-6-PDH 8800 U/l, and creatine phosphate 250 mmol/l) with =340 nm at the temperature of 37°C. All protocol about blood analysist measurement was similarity and identically by previous study who conducted (Junaidi et al., 2020).

Statistical analysis

The statistical analysis tests were performed with the SPSS software, V.21.0., while normal sample distribution was checked using the Shapiro-Wilk test. A 2x2 (group: Cinnamon Group and Placebo Group) (time: pre-, post-) repeated measures analysis of variance (ANOVA) was calculated for each parameter. The independent t-test was used to reveal the differences between pre-and post-supplementation results. Also, the 95% confidence interval and percentage changes were calculated, and the statistical significance was accepted at $p<0.05$.

Results

Table 1 describes the anthropometry and age of all samples involved in the study.

Table 1. Data Anthropometry

Variables	CG group
Age (years)	22.87±3.25
Weight (kg)	76.12±18.40
Height (cm)	160.56±4.79
BMI (kg/m^2)	29.32±5.71

Table 2 contains the differences in the effect of Cinnamon and Placebo on participants' performance.

Table 2. The Influence of Cinnamon on the Performance of All Participants

Variable	Cinnamon		Placebo		p-value
	Pre-Intervention	Post-intervention	Pre-Intervention	Post-intervention	
Clean and Jerk	152.63±26.69	152.88±26.97	152.25±26.42	152.75±26.34	0.789
Snatch	118.88±26.5	118.13±26.13	119.13±26.15	118.38±26.36	0.778

Table 3 contains changes in the physiological biomarkers in all participants when taking Cinnamon and Placebo.

Table 3. Cinnamon Effects on Physiological Biomarkers in All Participants

Variable	Cinnamon				Placebo				Group	Time	Group X Time
	Pre-Intervention	Post-Intervention	Δ%	P	Pre-Intervention	Post-Intervention	Δ%	P			
pre-test CK	168.62±15.68	169.37±10.19	0.44%	0.911	161.25±8.01	163.62±10.41	1.47%	0.617	0.702	0.116	0.842
post-test CK	300.37±16.50	225.50±23.11	-24.93%	0.001*	311.50±44.28	304.87±34.16	-2.13%	0.743	0.001	0.001*	0.005*
pre-test CRP	1.37±1.03	1.41±1.05	2.92%	0.944	1.33±1.19	2.37±0.77	15.04%	0.743	0.763	0.911	0.836
post-test CRP	2.52±1.15	2.82±0.56	4.37%	0.827	1.5±1.1	3.85±0.9	-1.90%	0.919	0.905	0.128	0.005*
pre-test GLU	84.25±16.73	85.75±16.03	1.78%	0.857	82.87±13.08	80.25±8.61	-3.16%	0.634	0.910	0.493	0.680
post-test GLU	92.25±11.80	98.62±13.93	6.91%	0.340	94.50±9.62	84.75±7.77	-10.32%	0.043*	0.669	0.147	0.048*
pre-test LACT	1.72±0.63	1.56±0.55	-9.30%	0.594	1.76±0.50	1.66±0.29	-5.68%	0.635	0.475	0.707	0.864
post-test LACT	9.92±0.92	8.78±0.83	-11.49%	0.021*	8.85±1.04	9.38±0.69	5.99%	0.246	0.345	0.453	0.012*

Note. CK: Creatine kinase; GLU: Glucose-Blood glucose; CRP: C-reactive protein; LACT: Lactate-Blood lactate.
*Significant differences between Cinnamon consumption and Placebo consumption

Physiological Biomarkers

There were significant changes for all physiological biomarkers after the performance tests. CK and CRP showed significant ($p<0.005$) changes in the cinnamon group compared to placebo. There were noticeable increases and differences in glucose and lactate between the two types of supplementation which were $p<0.048$, $p<0.012$ respectively. However, there were no significant effects on physiological biomarkers before the performance test.

Performance

There were slight improvements in both clean and jerk and snatch measurements. Specifically, ANOVA showed no change in Clean and Jerk (p<0.789), as well as snatch (p<0.778).

Discussion

This study assessed on how to process 500 mg of cinnamon extract supplementation per day to improve performance and alleviate muscle soreness and damage in weightlifters. According to the hypothesis, there was a noticeable performance increase in groups given cinnamon extract on these 3 indicators. It is critical to note that performance, muscle soreness, and damage are important elements for weightlifters.

Based on the results, there was a significant difference in CK after the performance test between before and after the supplementation process compared to the placebo group. Our results, in line with previous studies. For example, study who conducted by Junaidi et al. (2020), that explained cinnamon extract increases insulin activity, preventing an increase in CK (Anderson, 2008; Islam, Yorgason, & Hazell, 2016; Fayaz, Damirchi, Zebardast, & Babaei, 2019; Junadi et al., 2020). In CRP, there are significant changes that are similar to (Fedewa, Hathaway, & Ward-Ritacco, 2017). Contrastingly, other studies using different dosage content of only 300 mg per day showed different results (Davari et al., 2020). Cinnamon stimulation, increase in insulin activity, carbohydrate metabolism, and the yield on CRP while decreasing CK levels (Khan, Safdar, Ali Khan, Khattak, & Anderson, 2003; Anderson, 2008; Vallverdu-Queralt, 2013; Anderson et al., 2015; Chen et al., 2020). The glucose test data showed significant differences between cinnamon extract and placebo groups. Cinnamaldehyde content helps stimulate an increase in glycogen and glucose. Moreover, cinnamon stimulates glucose uptake, glycogen synthesis, and active glycogen synthase in 3T3-L1 adipocytes (Jarvill-Taylor, Anderson, & Graves, 2001; Bernardo et al., 2015).

The results obtained for CK, CRP, and Glucose showed similar results with previous studies. We assume that the increase in quality that occurs in CK and CRP as an indicator of an athlete's recovery is caused by an increase in glucose and insulin activity which increases the impact of consuming cinnamon extract. On the other hand, the glucose improvement is assumed to be caused by the presence of the glucose transporter, other studies suggest that cinnamon has been shown to increase in vitro glucose uptake and glycogen synthesis and increase insulin receptor phosphorylation (Khan et al., 2003; Couturier et al., 2010). Additionally, previous studies stated that this cinnamon extract tends to help trigger the insulin cascade system (Jarvill-Taylor et al., 2001; Shen et al., 2012). Since insulin also plays a key role in lipid metabolism, we postulate that cinnamon consumption will increase blood glucose and lipids in vivo.

Clean & jerk, and snatch as a indicator of performance showed no improvements, although this finding was not in line with previous studies (Islam et al., 2016). According to the research and based on field observations, it is due to the 8 years of athlete's dependence on creatine content in this supplement. Consumption of energy supplements such as creatine content that is used excessively will have an impact on psychological effects (Hagger & Montasem, 2009; Pasiakos et al., 2017). Although this study was conducted in a double-blind manner, suggestions decreased subject self-confidence, and discomfort isolating them from the supplement. According to the results, it was concluded that different types of sport characteristics can affect the result of increasing or decreasing performance in the subject. Moreover, the level of play (amateur and professional) makes a difference to the final result.

The absence of a significant impact on these performance indicators is assumed to be due to the athletes' reliance on other supplements containing content prior to joining this study. Moreover, the habits of the samples in consuming supplements containing creatine have been carried out for more than five years. On the other hand, it creates an impact on one's energy, passion. This is in line with the testimony of samples who felt weakness and less enthusiastic after 3 days of not consuming the usual supplements (creatine). On the other hand, Physical performance during exercise, creating a brief reaction to high-intensity muscle activity (Allen, 2012). Furthermore, creatine has other positive effects, such as reducing stress and improving mood (McMorris et al 2006).

Our study has a limitation. First, we realize that, the sample size still needs to be increased in future studies, thereby reducing the risk of bias in the final results. The second increase in the number of measurement variables such as: LDH, or other psychological measurement variables should be applied in future studies, to strengthen the findings in this study. These results suggest that cinnamon is suitable for accelerated long-term and not temporary recovery. This is due to its significant impact on physiological biomarkers', 24 hours after the test. Moreover, cinnamon positively affects the acceleration of recovery in muscle damage and soreness. However, there are no performance effects determined due to subjects' creatine consuming habits. Therefore, this research can be developed by combining psychological factors with cinnamon and creatine for further studies.

Conclusion

Supplementation with 500 mg of cinnamon extract per day for 8 consecutive weeks improves muscle damage shown by an increase in CK. Also, there was an improvement in muscle soreness, evident through changes in CRP. However, the cinnamon extract does not have significant impacts on athlete performance when compared to the placebo group.

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Conflicts of Interest

The authors declare no conflict of interest.

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ORIGINAL SCIENTIFIC PAPER

The Influence of Maximum Strength Performance in Seated Calf Raises on Counter Movement Jump and Squat Jump in Elite Junior Basketball Players

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Abstract

In basketball high intensity jumping and sprinting performance is of high importance. There seems to be a relationship between maximal strength (MSt) and jumping performance in general, but influence of MSt in the plantar flexors and jumping performance seems not to be investigated very well. Thus, the aim of this study was to investigate the influence of MSt in the plantar flexors on jumping performance. 37 young elite basketball players were included (age: 13.9±1.8 years; weight: 66.4±16.8 kg; height: 179.21±13.24 cm) and countermovement jump (CMJ) and squat jump (SJ) height as well as unilateral and bilateral maximal isometric contraction in the plantar flexors with bended knee joint were assessed. Pearson correlations were calculated for MSt and jumping performance and Bland-Altman Analysis was performed to determine the level of variance between bilateral MSt assessment and cumulated MSt value of unilateral measurements. This study shows a moderate influence of isometric MSt in the calf muscle on jumping performance, so it seems beneficial to include the training of the plantar flexors in the training routine of basketball players. When determining MSt, the bilateral force deficit must be considered, even though there was no influence on determined correlations.

Keywords: *Jumping performance, Athletic training, Plantar flexors, Basketball*

Introduction

There is high relevance of maximal strength in athletic performance and its influence on jumping and sprinting performance is widely investigated in many sports (Chen et al., 2022; Fry & Kreamer, 1991; Lum et al., 2020; Requena et al., 2014) such as lower-limb joint strength and the ability to rapidly generate force, may play an important role in leg-spring stiffness regulation. This study aimed to investigate the relationship between isokinetic knee and ankle joint peak torque (PT). Especially maximal strength in lower limb muscle is considered a fundamental determinant in high-intensity actions such as linear and change-of-direction (COD) sprint as well as standing long jump (SLJ) and vertical jump (Keiner et al., 2020; Möck et al., 2018, 2019). Effects of 10 months of speed, functional, and traditional strength training on strength, linear sprint, change of direction, and jump performance in trained adolescent soccer players. In basketball a high ratio of high intensity jumping and sprinting is required (Abdelkrim et al., 2007; Stojanovic et al., 2018). Players spent 8.8% (1%. Within a single game, basketball players are reported to change activity up to 3000 times. These athletes also show the highest frequency of lateral movements (up to 450 per game) in team sports (Taylor et al., 2017; Vázquez-Guerrero et al., 2019), while also performing more than 50 maximal jumps per game (Taylor et al., 2017). Consequently, vertical jump performance tests such as countermovement (CMJ) and squat jumps (SJ) are a vital

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component of most performance diagnostics in basketball (Delextrat & Cohen, 2008, 2009). On average, players demonstrating high level vertical jump performance will be picked earlier in the yearly NBA draft (Cui et al., 2019).

From this, measuring maximal strength plays an important role in monitoring batteries to investigate performance level. To investigate an athlete's performance, maximal strength testing is commonly used under isometric and dynamic conditions. While some authors point out a higher transferability of 1RM testing to the sport specific tasks such as jumping and sprinting, there are also several advantages listed for maximal isometric strength tests e.g. standardization of testing conditions (Lum et al., 2020; Lynch et al., 2021), minimizing risk of injuries (Lynch et al., 2021) and time economics (Mcguigan et al., 2010). While the influence of maximal isometric strength in the squat and isometric mid-thigh pull is well investigated, the literature search did not yield studies investigating maximal isometric strength in the plantar flexors on jumping height. Because there is a correlation of r=0.35 between 1RM testing in standing calf raise and jumping performance as well as correlations of r=-0.23-0.52 in standing calf raise and sprinting performance with distances covered up to 30m (Möck et al., 2019), inclusion of plantar flexors in sport specific tasks in basketball can be assumed. Keiner et al. (2021) as well as Möck et al., (2019) investigated the influence of calf muscle strength on jumping and sprinting performance with extended knee joint. Arampatzis et al. (2006) and Signorile et al. (2002) point out differences in involved muscle in plantar flexion dependent on knee joint angle, but, to the best of the authors knowledge, no studies could be found investigating the influence of maximal strength of the plantar flexors in bended knee joint on jumping performance.

Bilateral as well as unilateral muscle contractions can be assumed in basketball. Since task familiarity plays a crucial role in the extent of the bilateral force deficit and no studies could also be determined investigating the bilateral force deficit in basketball players, present study will examine level of variance between bilateral strength measurement and cumulated values of unilateral strength measurement (Skarabot et al., 2016). Van Dieën et al. (2003) determined an overall deficit of the bilateral knee extension of about 7%.

Jumping ability is of high relevance in basketball but there is lacking evidence regarding maximal strength measured under isometric conditions in the plantar flexors. Therefore, the aim of this study was to investigate correlations between maximal isometric strength in the plantar flexors with a bended knee joint on jumping performance, which is tested with the CMJ and SJ. Furthermore, since Skarabot et al. (2016) point out a potential influence of the bilateral force deficit on athletic performance, the presence as well as the influence of the bilateral force deficit in the plantar flexors on jumping performance is examined. Based on the literature, it can be hypothesized that there are moderate correlations between maximal strength in the calf muscle and jumping performance and, based on familiarity of basketball players with bilateral and unilateral contractions, little influence of bilateral force deficit.

Methods

The aim of this investigation was to examine the correlation between maximum isometric strength of the calf muscle and jumping performance measured via CMJ and SJ in elite youth basketball players. One week before testing, a familiarization session was performed to minimize learning effects.

Subjects

For the study 37 male high-level youth basketball players (age: 13.9±1.8 years with a range of 13-16 years; weight: 66.4±16.8 kg; height: 179.21±13.24 cm) were recruited from a German first league basketball club being part of U16 first national league or U14 league. All athletes have been involved in organized basketball training and competition since childhood and perform athletic and team training at least three times per week and were familiar with testing conditions. Also, all players did not conduct any physically demanding activities within the 48 hours before testing and were injury free for at least six months. Each participant and his parents were informed about the experimental risks involved with the research. All participants and their parents provided written informed consent to participate in the present study. Furthermore, this study was approved by the institutional review board (Carl von Ossietzky University Oldenburg, No. Drs.EK/2022/026-01). The study was performed with human participants in accordance with the Helsinki Declaration.

Testing procedure

Before testing started, the subjects performed a standardized warm up routine containing six linear runs of 15 meters each with progressive increased intensity. During the last three sideline-to-sideline runs, subjects performed ten repetitions of deep bodyweight squats when reaching the sideline. Subsequently, participants performed three sets of three squat jumps. The testing procedure contained CMJ, SJ and isometric maximal strength in seated calf raise with bended knees (90°) for both unilateral and bilateral testing. All participants had prior experience with performance diagnostics and the exercises as well as the measuring devices used.

Countermovement Jump

The force plate used to measure vertical jumping performance in this study had a surface area of 50x60 cm. The force transducer (company AST, Leipzig, model KAC) measures the vertical reaction forces. The strain gauges cover a measurement range of ± 5000N. The analog signals are amplified and subsequently converted by a 13-bit A-D converter. The specialized software (Carl von Ossietzky University Oldenburg, Germany) displays the force-time curves.

Subjects positioned themselves on the force-measuring plate with feet shoulder width apart with hands placed on the hips and an upright body meaning knee and hips fully extended. Participants were instructed to quickly descend to a self-selected depth and initiate the concentric phase with maximal-explosive effort to reach maximal height. During the flight and landing phase subjects had to keep their knees and hips fully extended, hands on their hips as well as toes elevated. CMJ height was determined via flight time. All participants had three attempts to reach maximal CMJ height with a break of one minute in between attempts.

Squat Jump

Subjects had to start from 90° knee joint angle and jump as high as possible without a countermovement. Subjects were instructed to remain motionless in this position until the starting signal was given. Equal to the CMJ, participants had to keep their knees and hips fully extended during the flight and landing phases as well as their hands on hips and toes elevated. For both jumps, height was determined via flight time using the force plate. All participants had three attempts with one-minute breaks in-between.

Maximal isometric strength in seated calf raise

To determine the isometric maximum strength in the seated calf raise, a standard seated calf raise machine was modified with small force plates on each of the footrests. Another software was used to display the force-time curves and calculate the MSt values. Subjects were placed on the seated calf raise machine with their knees and ankles in 90° positions and forefoot placed on the force plates. Subjects' knees were tightly fixed in place without any play by clamping a pad on top of their lower thighs. Participants were instructed to perform a maximal plantar flexion against the padding on top of their lower thighs after receiving an acoustic signal. Maximal isometric strength was held for three seconds. In-between attempts subjects rested for one minute. Each subject was tested until no further increases could be obtained. Therefore, maximal isometric strength in the plantar flexion was assessed in bilateral and unilateral plantarflexion with bended knee joint. All participants conducted at least five attempts.

Statistical analysis

The data were analyzed using SPSS 28.0. (IBM, IBM Corp., Armonk, New York, USA). The significance level for all statistical tests was set at <0.05. The descriptive statistics for all measures are presented as the mean (M) ± standard deviation (SD) with 95% CI. Reliability analyses were performed for test bests and the tests second best value using the Intraclass Correlation Coefficient (ICC) with 95% confidence interval (CI), the correlation coefficient (r) and the coefficient of variance (CV). Furthermore, a bivariate one-tailed Pearson correlation analysis was used to assess the relationship between maximal strength in the plantar flexors with 90° knee joint angle and CMJ and SJ height. To determine significant differences in the correlation coefficients between subgroups (different ages), the data were z'-transformed according to the Fisher method. The significant difference was calculated by the difference of the two transformed values after standardization ($z = \frac{z'_1 - z'_2}{\sqrt{\frac{1}{n_1-3}+\frac{1}{n_2-3}}}$). Benjamini and Hochberg's method was used to control the study wise false discovery rate to be 0.05 (Ferreira & Zwinderman, 2006)

To investigate the bilateral strength deficit, the maximal isometric strength measured in unilateral testing was cumulated and compared with the bilateral maximal strength test values. Comparison was performed by Bland-Altman Analysis and shown in a Plot, which is illustrated with "R". Furthermore, we performed Bland Altman analysis to show level of variance between SJ and CMJ. Correlations were analyzed via SPSS (IBM SPSS Statistics Version 28, IBM Corp., Armonk, New York, USA). Level of significance for all tests was set to p<0.005. Relationships were classified as follows: 0 = no correlation, 0<r<0.2 = very low correlation, 0.4<r<0.6=-moderate correlation, 0.6<0.8=high correlation, 0.8<r<1 = very high correlation (Cohen, 1988).Variance Exploration (r^2) was determined to clarify the influence of maximal strength in the plantar flexors on jumping performance. To examine the bilateral force deficit, variances between bilateral measurement and cumulated strength maximum for both unilateral measurements were compared with Bland-Altman-Analysis to show deviations between methods and to investigate agreement between both methods (Bland & Altmann, 1986). Mean absolute error (MAE) as well as Mean absolute percentage error (MAPE) are calculated with $\mathrm{MAE} = \frac{1}{n} \cdot \sum_{i=1}^{n} |x_i - y_i|$ and $\mathrm{MAPE} = \frac{100\%}{n} \cdot \sum_{i=1}^{n} \left| \frac{x_i - y_i}{x_i} \right|$.

Results

Testing for normal distribution using Shapiro-Wilk test shows that requirements for Pearson's product-moment correlation are fulfilled. ICC with 95% CIs, CV and correlations for the performance tests are listed in table 1.

Table 1: Reliability of used test items

	ICC (95%-CI)	CV
MSt	0.997 (0.995-0.998)	1.0±0.6% (0.8-1.18)
CMJ	0.988 (0.97-0.995)	1.6±0.9% (1.24-1.99)
SJ	0.967 (0.92-0.987)	1.9±1.5% (1.32-2.63)

With ICCs between 0.967 and 0.997 a good reliability can be assumed for maximal isometric strength measurements (Shrout & Fleiss, 1979). Table 2 shows descriptive statistics of measured values. Since the correlation coefficients age subgroups did not differ significantly, the correlations coefficients presented correspond to the entire group.

Table 2: Descriptive data for CMJ, SJ and SCR

	M±SD (95%CI)	Minimum	Maximum
MSt (in N)	2231.97±650.94 (2048.85-2456.38)	979	3649
MStR (in N)	1096.88±303.86 (997.38-1192.27)	509.77	1672.66
MStL (in N)	1049.56±300.12 (948.74-1144.3	458.13	1656.33
MStLR (in N)	2146.44±599.24 (1947.79-2333.15)	991.77	3312.98
CMJ (in cm)	34.88±6.89 (32.84-37.26)	22.7	50.00
SJ (in cm)	31.32 ±5.3 (29.67-33.34)	23.3	45.0

MSt-maximal isometric strength in bilateral measurement; MStRL-maximal isometric strength, cumulated value from right and left leg; MStR-maximal isometric strength in the right leg; MStL-maximal isometric strength in the left leg; CMJ-jumping height in counter movement jump; SJ-jumping height with the squat jump.

There are correlation coefficients between maximal isometric strength in the plantar flexors in bended knee joint and CMJ with r=0.52 (0.23-0.72) and r^2=27.04%, and SJ with r= 0.54 (0.26-0.73) and r^2=29.16%. Figure 1 and 2 showing correlations between bilateral MST and cumulated unliateral strength measurement and jumping performance to compare results and illustrate the bilateral strength deficit. Therefore, in Figure 3 results of Bland Altman Analysis are plotted to determine level of variance with 95%CI of about -200N to 400N. Bland Altman analysis shows a difference between both methods (Mean Error (ME)) of 85.53N corresponds to 4.45% and MAE=142.73, and a MAPE=6.33 %.

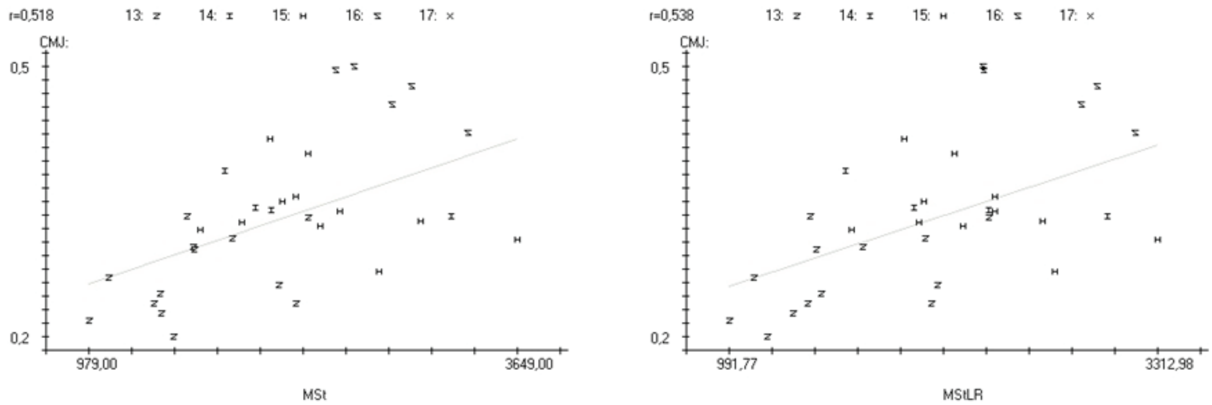

FIGURE 1: Scatterplot with linear trend line of countermovement jump with maximal strength measured bilateral (r= 0.52 [CI95%: 0.23-0.72]) and maximal strength measured with cumulated unilateral measurements (r=0.54 [CI95%:0.26-0.73])
Note MSt= maximal isometric strength in bilateral measurement, MStRL=maximal isometric strength, cumulated value from right and left leg, CMJ= jumping height with the counter movement jump.

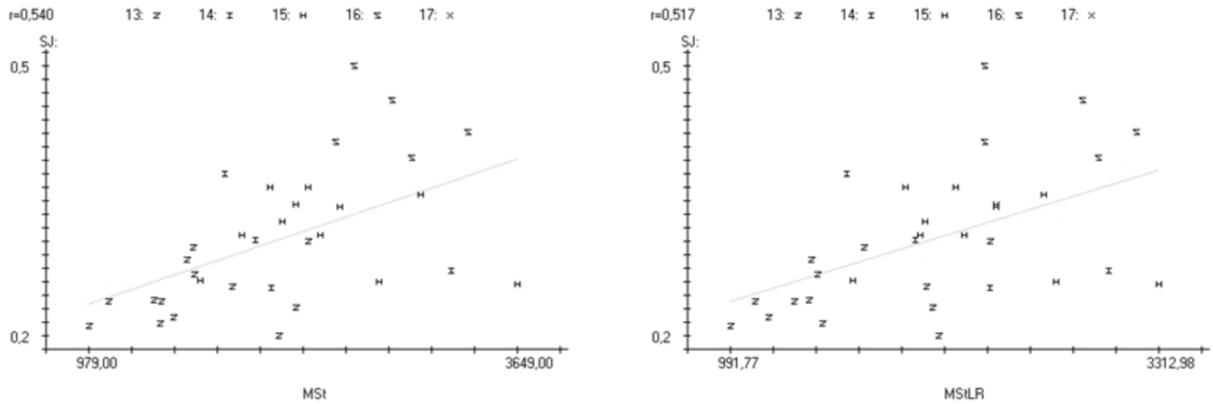

FIGURE 2: Scatterplot with linear trend line of squat jump with maximal strength measured bilateral (r= 0.54 [CI95%: 0.26-0.74]) and maximal strength measured with cumulated unilateral measurements (r=0.52 [CI95%:23-0.72])
Note MSt= maximal isometric strength in bilateral measurement, MStRL=maximal isometric strength, cumulated value from right and left leg, CMJ= jumping height with the squat jump

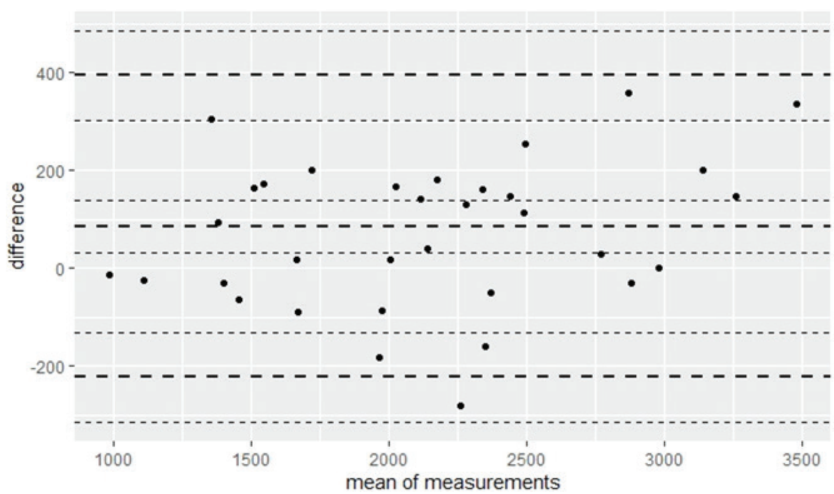

FIGURE 3: Bland Altman Plot for bilateral maximal strength measurement in the plantar flexion and cumulated unilateral maximal strength measurement

Discussion

The aim of the present study was to investigate the influence of maximal isometric strength in the plantar flexors with bended knee joint angle on jumping performance in CMJ and SJ in youth elite basketball players. Bland Altman Plot shows a variance with 95%CI of about -200 to +400N around the mean value with a mean difference between both methods of about 100N corresponding to 4.45% and MAE=142.73, and a MAPE=6.325 %

While the influence of multi joint exercises such as the squat on jumping performance is investigated in many sports, only few studies examined the influence of maximal strength in the calf muscle on jumping (Keiner et al., 2021) or sprinting performance (Möck et al., 2019). However, these studies investigated the influence of 1RM in standing calf raise. Since Arampatzis et al. (2006) and Signorile et al. (2002) showed difference between focusing muscle groups in the triceps surae while performing a plantar flexion dependent on knee joint angle, investigating the influence of calf muscle strength in different knee joint angles is relevant. It can be assumed that there is higher impact of the gastrocnemius to the power output when performing plantar flexion with extended knee joint, while there is more influence of the soleus in bended knee joint position. This is the first investigation pointing out the influence of isometric maximal strength with bended knee joint on jumping performance. Thus, it seems there is an influence of the triceps surae on sprinting (Möck et al., 2019) as well as on jumping performance (Keiner et al., 2021), independently of the knee angle. Since in SJ and CMJ a high influence of the quadriceps on strength production can be assumed, it is not surprising that correlations between maximal strength measured in the squat with r= 0.78 (Wisløff et al., 2004) and r=0.76 (Comfort et al., 2014) are higher than determined correlation in the present study, but there is still a moderate influence of the calf muscle in jumping and sprinting movements.

When performing bilateral movements, dependent on trainings status and commonly used training method, a bilateral force deficit can be assumed (Jakobi & Chilibeck, 2001; Skarabot et al., 2016). In basketball, both unilateral as well as bilateral jumping movements are commonly implemented in conditioning training (Arede et al., 2019), e.g. using barbell squats and unilateral strength exercises. Therefore, Bland Altman plot as well as Pearson correlations were performed for the bilateral measurement as well as the cumulated unilateral strength measurement. With r=0.52-0.54 and variance plotted in the Bland Altman plot in Figure 3 it can be hypothesized that the bilateral force deficit is not consistent in the measured population but comparable with previous studies determining bilateral force deficit in different muscle groups (Van Dieën et al., 2003). The present results show only little influence of bilateral force deficit in plantar flexors on jumping performance in basketball players.

The study is limited as Murphy & Wilson (1996) electro-myography data were collected from the triceps brachii and pectoralis major muscles to compare underlying neural characteristics between the isometric tests and dynamic movement. A group of 24 healthy male subjects performed two isometric tests in a bench press position, at elbow angles of 90-120%. From these data, the maximal force and rate of force development were determined. In addition, each subject performed a seated medicine ball throw as a measure of dynamic upper body performance. Correlations showed that isometric measurements of force (r =0.47-0.55 point out poor correlations between isometric and dynamic maximal strength testing. Thus, there may be some limitations in comparability between maximal isometric strength measured in the present study and maximal dynamic strength, e.g. evaluated by Möck et al. (2019) and Keiner et al. (2021). Assuming that there is higher transfer of 1RM testing because of higher agreement in central nervous aspects with athletic performance as jumping and sprinting, the correlations of this study may be underestimated. Another limitation is the age range, although the subgroup analysis makes it possible to consider the entire group.

Conclusion

Analyzed data show an influence of maximal strength of the plantar flexors on jumping performance with r^2=29.16% for the SJ and 27.04% for the CMJ in male high-level youth basketball players. From this, longitudinal studies to investigate the effects of isolated calf muscle strength training on jumping performance are requested to investigate whether an isolated strength training for the plantar flexors should be implemented in athletic training in basketball. Furthermore, attention should be paid to testing design (unilateral vs bilateral testing conditions) when the aim of the study is to examine maximum strength. Especially when monitoring performance in diagnostic in competitive sports, there is a need for valid, reliable and especially precise assessments, where ME between both methods of 100N corresponding to 4.45% and MAE=142.73, and a MAPE=6.33% with expected spread of the values between -200 to +400N in between of 95%CI seems not to be useful. From this, bilateral force deficit must be considered.

Acknowledgments
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Conflict of Interest
The author declares that there is no conflict of interest.

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SportMont

ORIGINAL SCIENTIFIC PAPER

Relationship of Pre-Season Strength Asymmetries, Flexibility and Aerobic Capacity with In-Season Lower Body Injuries in Soccer Players

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Abstract

The present study aimed to assess the differences in pre-season knee strength asymmetries, flexibility, and aerobic capacity of soccer players that sustained lower-body injuries during the in-season period compared to those that did not have a lower-body injury. A secondary purpose was to compare the aforementioned parameters between the players that sustained a knee ligament injury and hamstring strain. One hundred and thirty-three division 1 soccer players participated in the study. Fitness testing was conducted at the end of the pre-season period, and the players were followed for a total of 20 games. The anthropometric, lower body strength, flexibility and aerobic capacity parameters were compared between the players that sustained hamstring strains and knee ligament injuries and those that did not sustain any injuries. Results indicated that injured players were significantly older and less flexible than non-injured players ($p<0.05$). Additionally, injured players appeared significantly weaker on the right and left quadriceps and hamstring muscles ($p<0.05$). Furthermore, injured players had significantly greater asymmetries for the hamstrings muscle ($p<0.05$) and significantly lower VO2max values and running time than the non-injured players ($p<0.05$). Lastly, a significant difference between the players that sustained a hamstring injury compared to those who sustained a knee injury was indicated in right hamstring strength, right side ratio, and hamstring asymmetries ($p<0.05$). Our findings suggest that off- and pre-season interventions should be tailored toward increasing aerobic fitness and lower body strength and flexibility while minimizing strength asymmetries and imbalances to reduce in-season injury risk.

Keywords: *bilateral asymmetries, strength imbalances, flexibility, aerobic fitness, soccer*

Introduction

Professional soccer is generally known to be associated with a relatively high injury rate (Hawkins, Hulse, Wilkinson, Hodson, & Gibson, 2001). Research indicated that the total injury incidence in professional soccer players ranges from 2.48 (Ekstrand, Hagglund & Walden, 2011) to 9.4 injuries per 1000 hours of exposure (Walden, Hagglund, & Ekstrand, 2005). More specifically, the injury rate during competition ranges from 8.7 to 65.9 injuries per 1000 hours of exposure, whereas the injury incidence during training is between 1.37 to 5.8 injuries per 1000 hours of exposure (Ekstrand, Hagglund, & Walden, 2011, Eirale, Hamilton, Bisciotti, Grantham & Chalabi, 2012). Furthermore, an analysis of 6030 injuries in soccer players indicated that the majority of injuries were classified as strains (37%) and sprains (19%), with the lower extremity being the site of 87% of the reported injuries (Hawkins, Hulse, Wilkinson, Hodson, & Gibson, 2001). Additionally, research affirmed that soccer injuries are associated with the players' age, exercise load, professional level, and pre-season training status (Dauty & Collon, 2011; Clemente et al., 2017a; Clemente et al., 2017b; Eliakim, Doron, Meckel, Nemet, & Eliakim, 2018; Nobari et al., 2021).

It is imperative to identify the modifiable risk factors in order to prevent time-loss due to soccer-related injuries and

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maintain soccer players' health and safety. For over a decade, investigators have examined the effect of specific factors on fatigue (Clemente et al., 2017a; Clemente et al., 2017b; Nobari et al., 2021; Nobari, Fani, Pardos-Mainer, & Pérez-Gómez, 2021) and soccer-related injuries with an ultimate goal to prevent them. In this regard, it is debatable whether it is possible to use screening tests to determine who is at an increased risk for a sports injury. Nonetheless, research indicated that a combination of tests during the pre-season period that identify bilateral and ipsilateral isokinetic asymmetries and mixed rations could potentially predict the likelihood of hamstring injury in professional soccer players during the competitive season (Dauty, Menu, Fouasson-Chailloux, Ferréol, & Dubois, 2016). Furthermore, it was demonstrated that lower pre-season isokinetic hamstring strength and a lower hamstring-to-quadriceps ratio increase the risk of acute hamstring strain injury during the in-season period (Lee, Mok, Chan, Yung, & Chan, 2018). Concurrently, if the asymmetry between the knee extensors exceeds 10%, it increases the risk of musculoskeletal injuries by 16 times and ligament and meniscus injuries by up to 28 times (Liporaci, Saad, Grossi, & Riberto, 2019). Moreover, if a strength imbalance is over 10% in the knee flexors, the risk of injury increases by 12 times. Notably, soccer players have shown differences in strength and flexibility between the dominant and non-dominant limbs, which may be due to the technical elements that involve one-sided activities such as kicking, tackling and passing, performed during the games and training (Rahnama, Lees, & Bambaecichi, 2005). Research also indicated that long-term participation in soccer leads to the development of various degrees and modes of functional asymmetry (Fousekis, Tsepis, & Vagenas, 2010). While the aforementioned studies indicated an association between the forces generated at slow isokinetic speeds and lower limb injury incidence, slow-velocity strength production alone might not fully represent the forces generated during a soccer game. Notwithstanding, the rationale for assessing lower-body isokinetic strength and imbalances remains, although it must be acknowledged that the risk of injury is multi-factorial (Hughes, Sergeant, Parkes, & Callaghan, 2017).

In addition to the aforementioned factors, studies in various groups indicated that aerobic fitness might be a recognized risk factor for injury (Watson, Brickson, Brooks, & Dunn, 2017; Eliakim, Doron, Meckel, Nemet, & Eliakim, 2018). Research on female teenage soccer players demonstrated that a higher level of pre-season aerobic fitness is related to a lower risk of injury and sickness throughout the season, suggesting that the off-season training program should be tailored towards increasing aerobic fitness, which may aid in injury and illness prevention (Watson, Brickson, Brooks, & Dunn, 2017). Additionally, research indicated that improvements in VO2 max during the pre-season training period were significantly lower among injured soccer players than non-injured players, while the fitness characteristics at the beginning of pre-season training were not significantly different between the two groups (Eliakim, Doron, Meckel, Nemet, & Eliakim, 2018).

Pre-season soccer training aims to prepare the players mentally and physically to withstand the demands associated with the training and competition during the in-season. Unlike other sports, soccer is characterized by a shorter pre-season training period and a longer in-season period, especially when teams participate in international games (Francioni et al., 2016). Thus, the pre-season period is characterized by a high training load compared to the in-season period (Francioni et al., 2016). Therefore, a careful strategic periodization is required for the players to increase their aerobic capacity and strength and reduce possible asymmetries, which may result in injuries during the in-season period. The present study aimed to assess the differences in pre-season intra- and inter-limb strength knee asymmetry, flexibility, and aerobic capacity of soccer players that sustained lower-body non-contact injuries during the in-season period compared to those that did not have a lower-body injury. The study's secondary purpose was to compare the aforementioned parameters between the players that sustained a knee ligament injury and hamstring strain.

Methods

Participants

A total of one hundred and thirty-three division 1 soccer players (n=133, age 25.51 ± 5.59 years, height 179.9±17 cm) participated in the study. Fitness testing was conducted at the end of the pre-season period, and the players were followed for a total of 20 games (from Aug 20, 2021, to Feb 5, 2022). The initial sample included 155 players, but only 133 met the inclusion criteria. Players diagnosed with COVID-19 within two months before the collection of data were excluded from the study. Furthermore, players with a previous lower-body injury within the last six months or those that had an injury during the pre-season training period were excluded from the study. Additionally, players with contact injuries or injuries other than hamstring strains (grade 2 and up) and knee ligament injuries were also excluded. The injuries were included only when they were clinically diagnosed and resulted in an absence from training or competition of at least seven days. Only injuries classified as moderate (8–28 days of absence) and major (more than 28 days of absence) were included in this study (Hägglund, Waldén, Bahr, & Ekstrand, 2005). Therefore, the study included the players that sustained hamstring strains (grade 2 and up) and knee ligament injuries and those that did not sustain any injuries. Participants and the medical team of the five participating teams were asked to report any injury that occurred during a soccer game or training and resulted in the athletes' inability to continue participating. In addition, they were asked to provide the date of the injury, the body part involved, and the mechanism.

Procedures and data collection

Players were advised to abstain from any activity the days before testing, and measurements were obtained between 9:00 am and 14:00 on two different days to avoid potential fatigue from subsequent testing. Testing was part of the professional team's seasonal plan to examine the players' readiness at the end of the pre-season period, but players' participation in this study was completely voluntary. Each player was briefed on the procedures and signed an informed consent before data collection. Ethical guidelines were followed according to the Helsinki Declaration's ethical standards, and the University's ethics committee board (reference number STEMH 541) approved the study.

Anthropometric measurements

A wall stadiometer (Leicester; Tanita, Japan) was used to measure the players' stature, while a leg-to-leg bioelectrical impedance analyzer (BC418MA; Tanita) was utilized to measure body composition. Before the measurements were obtained, all players were instructed to follow the standard BIA (bioelectrical impedance analysis) guidelines (Kyle et al., 2004).

Lower body strength

The isokinetic knee strength was assessed utilizing the Humac Norm and Rehabilitation device (CSMI, Stoughton, MA, USA) according to the methods described by previous investigators (Parpa & Michaelides, 2020). Before the isokinetic testing, players had a 5-min self-paced warm-up on a mechanically braked cycle ergometer (Monark 894 E Peak Bike, Weight Ergometer, Sweden). Once the players were appropriately positioned on the device, they performed five sub-maximal repetitions of concentric knee flexion and extension for familiarization purposes. The isokinetic testing included three maximal concentric flexion and extension repetitions at an angle speed of 60°/sec.

Sit and reach test

A sit and reach box was used to assess the flexibility of the lower back and hamstring muscles according to methods described by previous investigators (Russell, 1980). Players removed their shoes and placed the soles of their feet against the box while their knees were fully extended. They were instructed to avoid fast and jerky movements while leaning forward with their hands on top of each other and palms facing downwards. They performed two practice trials, and the third trial was recorded to the nearest cm.

Cardiopulmonary exercise testing

The players completed an incremental maximal cardiopulmonary exercise testing until they reached exhaustion on a treadmill (h/p/Cosmos Quasar med, H-P-Cosmos Sports & Medical GmbH, Nussdorf-Traunstein, Germany). The players were tested utilizing the modified Heck incremental maximal protocol, which was previously validated for its reliability to test soccer players (Santos-Silva, Fonseca, Castro, & Greve, 2007; Parpa & Michaelides, 2022). A breath-by-breath analysis was performed on the Cosmed Quark CPET (Rome, Italy) system while laboratory conditions were kept constant (temperature 22±1°C and relative humidity at 50%). The test came to an end when the participant reached volitional fatigue or when there was no variation among the VO2 levels while the workload increased. The VO2max was detected following filtering the results to identify the highest value for an average of 10 seconds. The ventilatory threshold and respiratory compensation point were determined using different criteria. The ventilatory threshold was determined through the V-Slope method and was verified at the nadir of the VE/V̇ O2 curve. The respiratory compensation point was determined at the nadir of the VE/V̇ CO2 curve.

Statistics

SPSS 26.0 for Windows (SPSS Inc., Chicago) was utilized to analyze the results. The homogeneity of variance and normality assumptions were verified using Brown and Forsythe's and Shapiro-Wilk tests, respectively. Means and Standard Deviations were calculated for all the parameters. Means were compared using an independent samples t-test. Cohen's d was calculated to determine the effect size. Effect sizes were interpreted as small (0.2-0.4), medium (0.5-0.7) and large (0.8-1.4) (Cohen, 1988). For the statistical analyses, significance was accepted at $p<0.05$.

Results

The anthropometric and body composition parameters are presented in table 1. Following the twenty in-season games, 37 players suffered either a hamstring strain (n=20) or knee ligament injury (n=17).

Table 1. Demographic Characteristics of injured and non-injured players.

	Injured		Non-Injured		95% CI for the difference
	n	Mean±SD	n	Mean±SD	Lower Upper
Age (years)	37	27.08±6.32*	96	24.91±5.19	-4.29-(-0.062)
Height (cm)	37	175.02±29.98*	96	181.79±6.94	0.34-13.20
Weight (kg)	37	74.72±6.89*	96	78.29±7.22	0.84-6.30
Fat % BIA	37	10.61±3.32	96	10.57±2.94	-1.21-1.13

Note.*p<0.05; CI: confidence interval

Table 2. Flexibility and lower body strength parameters of injured and non-injured players.

	Injured		Non-Injured		95% CI for the difference
	n	Mean±SD	n	Mean±SD	Lower Upper
Flexibility (cm)	37	31.41±9.76*	96	38.52±6.69	4.18-10.04
Right quadriceps 600/sec	37	218.81±37.68*	96	236.77±33.01	4.81-31.11
Right hamstring 600/sec	37	162.68±25.02*	96	176.83±29.86	3.21-25.11
Ratio	37	74.86±12.59	96	74.83±8.84	-3.87-3.80
Left quadriceps 600/sec	37	213.62±39.43*	96	234.50±35.08	6.97-34.79
Left hamstring 600/sec	37	164.30±25.42*	96	177.06±26.86	2.63-22.90
Ratio	37	78.03±11.66	96	76.10±9.91	-5.91-2.07
quadriceps asymmetry	37	8.32±6.37	96	6.94±5.48	-3.58-0.81
Hamstrings asymmetry	37	10.43±7.14*	96	5.53±4.18	-6.88-(-2.92)

Note. *p<0.05; CI: confidence interval

It should be noted that 16 out of the 20 hamstring injuries and 14 out of the 17 knee ligament injuries occurred during a competitive game. Results indicated that injured players were significantly older [t(131)=-2.036, d= 0.375, p<0.05], while at the same time, they were significantly shorter [t(131)=-2.084, d=0.32, p<0.05] and lighter than non-injured players [t(131)=-2.59, d=0.51, p<0.05] (Table 1).

Furthermore, the examination of flexibility indicated that injured players were significantly less flexible [t(131)=-4.79, d=0.85, p<0.05] than non-injured players (Table 2). Additionally, considering lower body strength parameters, injured players appeared to be significantly weaker on both right and left quadriceps and hamstring muscles (p<0.05) compared to non-injured (Table 2, Figure 1).

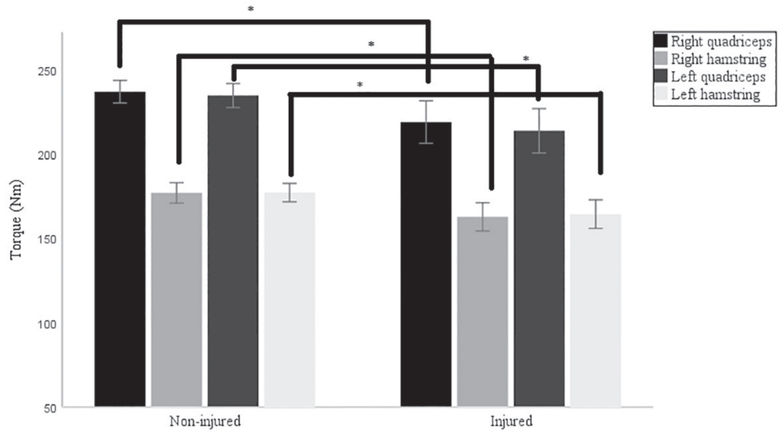

FIGURE 1. Lower body strength of injured and non-injured players
Note *p<0.05

Considering muscle asymmetries, injured players had significantly [t(131)= 4.90, d=0.84, p<0.05] greater bilateral difference for the hamstrings muscle compared to non-injured players (Table 2). Furthermore, results indicated significantly lower VO2max values [t(131)=4.64, d= 0.95, p<0.05] and running time [t(131)=5.44, d=1.07, p<0.05] for the injured players compared to the non-injured players (Table 3, Figure 2). Concurrently, VO2 values at ventilatory (VT) threshold [t(131)=2.43, p<0.05] and respiratory compensation point (RC) [t(131)=3.85, p<0.05] were significantly lower for the injured players (Table 3).

Table 3. Aerobic capacity of injured and non-injured players.

	Injured		Non-Injured		95% CI for the difference
	n	Mean±SD	n	Mean	Lower Upper
VO2max (ml/kg/min)	37	53.77±3.24*	96	57.46±4.39	2.12-5.26
Running time (min)	37	15.84±1.51*	96	17.55±1.68	1.09-2.34
VO2 at VT (ml/kg/min)	37	37.91±3.88*	96	40.49±5.97	0.83-4.33
VO2 at RC (ml/kg/min)	37	47.04±5.08*	96	50.56±4.59	1.71-5.33

Note. *p<0.05; CI: confidence interval; VO2max: maximal oxygen uptake; VO2 at LT: oxygen uptake at lactate threshold; VO2 at C: oxygen uptake at respiratory compensation point.

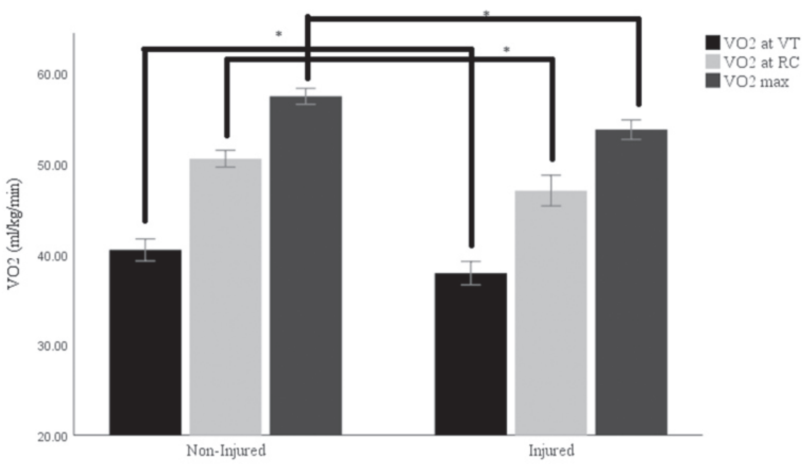

FIGURE 2. Oxygen consumption at ventilatory threshold (VO2 at VT), at respiratory compensation point (VO2 at RC) and VO2max of injured and non-injured players
Note *p<0.05

Concerning the aforementioned parameters based on the type of the injury, results indicated that the players who sustained hamstring injuries were not significantly different in aerobic performance, flexibility or anthropometric characteristics compared to those that sustained a knee injury. On the contrary, a significant difference between the two groups was indicated in right hamstring strength [t(35)=2.92, p<0.05], right side ratio [t(35)=4.43, p<0.05], and hamstring asymmetries [t(35)=-2.73, p<0.05]. A borderline significant difference was also indicated in the left hamstring strength between the two groups [t(35)=1.96, p=0.07]. More specifically, hamstring asymmetry was 13.13±7.6 for the players that sustained a hamstring injury, while it was 7.24±5.09 for the players that sustained a knee ligament injury. Furthermore, players who sustained a hamstring injury had significantly weaker right hamstring muscles (152.60±24.70 Nm) than those who sustained a knee ligament injury (174.53±20.20 Nm).

Discussion

The present study aimed to examine the differences in pre-season intra- and inter-limb strength knee asymmetry, flexibility, and aerobic capacity of soccer players that sustained lower-body non-contact injuries during the in-season period compared to those that did not have any lower-body injuries. After twenty in-season games, twenty players suffered a hamstring strain, and seventeen players suffered a non-contact knee ligament injury. Results indicated that injured players were significantly older and less flexible than non-injured players. Additionally, injured players appeared to be significantly weaker on both right and left quadriceps and hamstring muscles and had greater bilateral differences for the hamstrings muscle than non-injured players. Furthermore, results indicated significantly lower VO2max values and running time for the injured players than for non-injured players. Lastly, the players who sustained a hamstring injury were significantly weaker on the hamstring muscles and had significantly greater hamstring asymmetries than those who sustained a knee ligament injury. Whilst these results should not be a surprise, these data clearly show that injured players were significantly weaker, had greater imbalances and had significantly lower physical fitness and flexibility at the beginning of the season, which might have contributed to the development of lower-body injuries.

The role of muscle strength, imbalances and flexibility are particularly interesting because these are modifiable risk factors and potential points of engagement for hamstring injury prevention. Research indicated that a mixed ratio of less than 0.8, an ipsilateral ratio of less than 0.47, and a bilateral ratio of less than 0.85 were the most predictive of a hamstring injury (Dauty, Menu, Fouasson-Chailloux, Ferréol, & Dubois, 2016). In addition, the ipsilateral ratio of less than 0.47 allowed the prediction of the severity of the hamstring injury (Dauty, Menu, Fouasson-Chailloux, Ferréol, & Dubois, 2016). In our study, the ratios of injured and non-inured players were within normal values and did not indicate any risk when the injured players were analyzed as one group. However, when the players were compared based on the type of injury they sustained, it was demonstrated that those who sustained a hamstring injury had a mean ratio of 68, while those who sustained a knee ligament injury had a mean ratio 82.94. This finding supports that those ratios may be predictive of a hamstring injury, as indicated by other research as well (Lee, Mok, Chan, Yung, & Chan, 2018), rather than a knee ligament injury. Furthermore, the hamstring asymmetry of the injured group was over 10% which is in agreement with other studies (Liporaci, Saad, Grossi, & Riberto, 2019). More specifically, research demonstrated that a strength imbalance of over 10% in the knee flexors increases the risk of injury by 12 times (Liporaci, Saad, Grossi, & Riberto, 2019). In our study, when the injured players were analyzed based on the injury they sustained, it was indicated that hamstring asymmetry was 13.13±7.6 for the players that sustained a hamstring injury, while it was 7.24±5.09 for the players who sustained a knee ligament injury. This finding further supports that hamstring imbalances of over 10% may predict hamstring injuries rather than knee ligament injuries. On the contrary, other studies (Izovska et al., 2019) suggested that those imbalances in the flexors of the knee may predominantly be associated with the rapture of the anterior cruciate ligament and other parts of the knee. Of note is that no strength asymmetry between the knee extensors was presented in the injured and non-injured group.

Considering lower body strength and flexibility, our results align with other studies indicating that lower pre-season isokinetic hamstring strength increases the risk of acute hamstring strain injury during the in-season period (Wan, Qu, Garrett, Liu, & Yu, 2017). Our results demonstrated that injured players were significantly weaker in the quadriceps and hamstring muscles than non-injured players. Furthermore, while no significant differences were demonstrated between the players who sustained hamstring injuries and knee ligament injuries in the strength of the quadriceps, the hamstring injured group had significantly weaker right hamstring muscles (152.60±24.70 Nm) compared to those that sustained a knee ligament injury (174.53±20.20 Nm). Concurrently, our findings indicated that injured players had significantly lower flexibility assessed by the sit and reach test than non-inured players. Flexibility was not significantly different among the players that sustained a hamstring injury or knee ligament injury. These results align with previous investigators who indicated that in sports that involve sprinting, athletes with good hamstring flexibility have lower peak hamstring muscle strains than athletes with poor hamstring flexibility. In contrast, other studies suggest that hamstring flexibility cannot be used to predict a hamstring injury accurately (Gabbe, Finch, Bennell, & Wajswelner, 2005). Notably, there is conflicting evidence that older age, increased quadriceps peak torque, hamstring flexibility and strength imbalances increase the risk of a hamstring injury (Freckleton & Pizzari, 2013). The differences in the methodology utilized by the different studies might have contributed to these conflicting results. Nevertheless, lower hamstring flexibility should not be ignored as it may turn into a risk factor, especially when combined with other risk factors such as strength and asymmetries.

In addition to the aforementioned risk factors, research affirms that aerobic fitness might be a recognized risk factor for injury (Watson, Brickson, Brooks, & Dunn, 2017; Eliakim, Doron, Meckel, Nemet, & Eliakim, 2018). Our results indicated that injured players had significantly lower VO2max values and running time on the treadmill than the non-injured players. Concurrently, the injured players' VO2 values at the ventilatory threshold and respiratory compensation point were significantly lower. These results are in agreement with previous studies that demonstrated a negative association between pre-season aerobic fitness and injury risk throughout the season (Watson, Brickson, Brooks, & Dunn, 2017). In addition, research indicated that lower improvements in VO2max during the pre-season training are associated with higher injury rates during the in-season period (Eliakim, Doron, Meckel, Nemet, & Eliakim, 2018).

To our knowledge, this is the first study that evaluated lower body strength, asymmetries, flexibility and aerobic performance as risk factors for injuries in soccer players. Together, our findings suggest that off, and pre-season interventions should be tailored toward increasing aerobic fitness, lower body strength and flexibility while minimizing strength asymmetries and imbalances (especially in the hamstring muscles) in order to reduce in-season injury risk.

Limitations

Despite the significant findings, this study comes with several limitations. First, the injuries were not specified based on the players' playing position, which could be linked with different muscle strength profiles. Furthermore, hamstring injuries should have been separated into the stretch-type and sprint-type hamstring injuries. In addition, extrinsic factors such as the quality of the soccer field, insufficient warm-up, and differences in the training load of the participating teams could not be controlled.

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Conflict of Interest
The author declares that there is no conflict of interest.

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ORIGINAL SCIENTIFIC PAPER

Differential Influence of General Anthropometric and Motor Predictors on Pre-planned Agility in Pubescent Boys and Girls: A Multiple Regression Study

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Abstract

In this study, we investigated the influence of balance, jumping power, and speed as well as morphological variables for three different agility tests in early pubescent boys (n=73) and girls (n=63). The predictors included body height and mass, body fat, high jumps, the overall stability index, ankle mobility, and a 10 and a 15 m sprint. The statistical analysis included calculations of correlations, regression models for the correlated variables, and the validation of the regression models. The calculated regression models for the male group explained 38% of the variance in a Zig-Zag test, 12% in a 20-yard test (20Y), and 81% in a T-test. The significant regression model for the Zig-Zag test included body mass, high jumps, and a 10 m sprint. The 20Y test had no predictors in the male group. For the T-test, the only predictor was the 10 m sprint. The calculated regression models for the female group explained 57% of the variance in the Zig-Zag test, 32% in the 20Y test, and 42% in the T-test. The significant regression model in the female group included only the 10 m sprint for all three agility criteria. The regression models were cross-validated using the second half of the sample (boys: n=36; girls: n=31). The correlation between the predicted and the achieved scores provided a statistically significant validation for all agility tests.

Keywords: *morphology, change of direction, motor abilities, children, mobility*

Introduction

Agility is defined as the ability to undertake a fast and effective change of movement direction and speed (Sekulic et al., 2013). It consists of an explosive movement start, acceleration, deceleration, a change of direction, and the restoration of fast movement whilst maintaining a dynamic balance (Sheppard & Young, 2006). Current research shows that agility has two different forms: pre-planned and non-planned (Young et al., 2015). Pre-planned agility does not include a response to external unpredictable stimuli whereas non-planned does (Farrow et al., 2005). Both agility types occur in the majority of sporting activities. In more complex activities such as team sport games, non-planned agility is of greater importance for a successful performance (Young & Willey, 2010).

As in the adult athlete population, agility is significantly present in the physical activities of children. The majority of unstructured games and structured sports games of children abound with fast and reactive short runs, various jumps, and hops. The development of agility is influenced by biological maturation; certain phases of child development are more sensitive than others. According to Balyi & Hamilton (2004), the best age for developing agility is between the 9th and 12th year. In the study of Demirhan et al. (2017), the authors reported that agility develops rapidly until puberty and that three years after this period, agility performance decreases.

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After a period of rapid development, agility increases once more until maturity (Demirhan et al., 2017).

Due to its complexity, agility depends on motor abilities such as speed, power, coordination, or balance, but also on several anthropometric characteristics. However, a literature review shows inconsistent findings. In study of Little and Williams (2005), the authors concluded that acceleration, maximum speed, and agility were specific qualities that were relatively unrelated to one another. Similar findings were reported by Marković (2007), where the author found a poor relationship between strength and power qualities and agility performance. Conversely, Negra et al. (2017) concluded that agility performance, speed time, and jumping ability could represent the same motor abilities in competitive-level young male team sport athletes. Similarly, in the study of Barnes et al. (2007), the authors found that individuals with a greater countermovement performance also had quicker agility times, indicating that training predominantly in the vertical domain may also yield improvements in agility performance.

Following on from the above-mentioned studies, it is also important to identify the factors that influence agility performance in children. Such information could help strength and conditioning experts as well as physical education teachers to design training plans with greater efficiency for the agility development of children. Hence, the main goal of this research was to assess if speed, power, mobility, and balance as well as several anthropometric measures could be predictors of agility performance in early pubescent boys and girls. It was expected that the selected predictors would independently explain the variance in the agility criteria.

Methods

Participants

Boys (n=73) and girls (n=63) aged 12 to 13 years were recruited for this study from several schools in the same city. The average height was 170.93±8.47 for boys and 166.36±5.78 for girls (mean±SD). The average body mass was 62.49±15.21 kg for boys and 56.23±9.90 kg for girls. The testing was performed as part of the initial screening at the beginning of their sportive seasons. All participants were in good health based on an initial medical screening. Two had suffered recent musculoskeletal disorders (i.e., injury and pain prevalence) and were not included in the investigation. The participants were required to answer a questionnaire that was designed to assess the type of sports in which they had previously engaged. If participants played in agility-saturated sports, they were not included in the study (n=17). Only the participants who were not previously involved in sports or those who were involved in sports where agility was not systematically trained (e.g., swimming, track and field, and rowing) were included in this investigation (n=71). The total sample of participants was randomly divided into validation (boys: n=36; girls: n=31) and cross-validation (boys: n=37; girls: n=32) subsamples. The Ethical Board of the University of Split, Faculty of Kinesiology, Split, Croatia, provided written approval to proceed with the investigation. The participants were informed of the purpose of the study and their parents provided written consent.

Measures and Procedures

The anthropometric variables that were analysed in this study were body height, body mass, and body fat. Additional tests included an explosive power test (high jump), a balance test measurement of the overall stability index, and a 10 and a 15 m sprint test to measure running speed and ankle mobility. As different sports require different types of agility, three different agility tests were conducted: a T-shaped course test, a Zig-Zag test, and a 20Y shuttle test (Spasic et al., 2015; Sisic et al., 2015).

Body height and mass were assessed using a Seca Instruments stadiometer and a weighing scale (Hamburg, Germany). Body fat was measured using a Tanita BC-418 segmental body composition analyser (Tanita Corp., Tokyo, Japan), which provides a print-out of the calculated body fat (Pietrobelli et al., 2004). The subjects stood with bare feet on the metal sole plates of the machine. Agility and running speed were measured using a Brower timing system (Salt Lake City, UT, USA). The high jump was measured using an Optojump system, a dual-beam optical device that measures ground contact and flight time during a jump or series of jumps (Microgate, Bolzano, Italy; Schiltz et al., 2009). Balance was measured using a Biodex Balance System (Shirley, NY, USA).

For the T-shaped course test, 4 cones of 30 cm were arranged at the points of the required directional changes. When the test began, the participants were required to sprint forward along Course A (9.14 m) until they could touch the tip of the first cone with their right hand. They then side-shuffled leftward along Course B (4.75 m) until touching the tip of the second cone with their left hand. Next, they side-shuffled rightward along Course C (9.5 m) until touching the tip of the third cone with their right hand. They then side-shuffled leftward along Course D (4.75 m) until touching the tip of the fourth cone with their left hand. Finally, they back-pedalled over Course E (9.14 m) until reaching the finishing point (which was the original starting point). The trials were deemed unsuccessful if the participant failed to touch a designated cone, crossed their legs whilst shuffling, or failed to face forward at all times.

The Zig-Zag agility test consisted of maximal running throughout a 4×5 m zig-zag course. The timing began on a sound signal and stopped when the participant passed through a timing gate.

For the 20Y shuttle test, the examinee started with a three-point stance and ran along Course A (5 yd, 4.57 m), Course B (10 yd, 9.14 m), and finally along Course C (5 yd, 4.57 m). The countermovement jump test began with the participant standing in an upright position. A fast downward movement to approximately a 90° knee flexion was immediately followed by a quick upward vertical movement as high as possible, all in one sequence. The test was performed without an arm swing as the hands remained on the hips.

The overall stability index presents the average tilt in degrees from the centre of a platform. The higher the numerical value of the index, the greater the variability from the horizontal positioning; i.e., the greater the instability whilst balancing on the platform. The stability testing was performed without footwear. The participants established a foot position with a comfortable stance width that allowed them to maintain the most stable (horizontally levelled) position possible on the platform. The positioning of the feet was recorded and marked with tape using coordinates on the grid of the platform to ensure that the stance was consistent during the trials. The participants were required to maintain an upright posture whilst keeping the arms to the sides and looking straight ahead at the Biodex LCD monitor, which was approximately 0.3 m away. One practice trial was allowed before the three test trials. Each testing trial lasted 20 s. The resistance level was set at number 9 on a scale with anchors of 1 (least stable) and 12 (most stable).

For the 10 m sprint, the start-line position was placed 1 m before the first timing gate. The timing was only triggered when the infrared beams were disrupted. A second electronic timing gate was positioned 11 m from the start line. The participants were instructed to begin with their preferred foot forward placed on a line marked on the floor and to run as quickly as possible along the 11 m distance. The times were recorded in hundredths of seconds. The same procedure was conducted for the 15 m sprint, with timing gates positioned 1 and 16 m from the start line (Duthie et al., 2006).

All of the tests were performed indoors on a wooden gymnasium floor. Before testing, the participants completed a 15 min warm-up, which included jogging, lateral displacement drills, dynamic stretching, and light jumping. The sequence of testing was the same for all the participants. The first day of data collection consisted of an anthropometric assessment and power and speed measurements. During the second day, the participants performed the balance test and the three agility tests. During the course of the testing, the participants were asked to maintain their normal diet. To account for a diurnal variation in fitness abilities, all of the tests were performed at the same time of the day (9 to 11 a.m.) from April to June. Before the data collection began, the participants were familiarized with the testing procedures and allowed one practice trial of each test at a slow tempo. The participants performed three trials of each test with 3–4 min rest between the trials except for the balance tests, where 1 min of rest was allowed between the trials. In the case of evident fatigue, a longer rest period was allowed. The participants performed the tests wearing their choice of running shoes (excluding the balance testing, which was completed with bare feet). For tests automatically measured by the Brower timing system, Optojump, and the Biodex balance system, the same examiner assessed all participants.

Statistical Analyses

The statistical analyses included the calculation of the descriptive statistical parameters (means and standard deviations) and the calculation of the Pearson correlation to assess the associations between the variables. The results of the correlation analysis determined the pick of the variables for the multiple regression analysis; only significantly correlated variables were included. All other variables were excluded from the regression analysis. The predictors that were included in the regression analysis were the body height, vertical jump, and 10 m sprint. The successful regression models were then applied to the cross-validation group. The regressions were cross-validated by Bland–Altman plots of the average between the calculated and the achieved scores (abscise) and the differences between the achieved and the calculated scores (ordinate). For all the analyses, Statistica 14.0 (TIBCO Software Inc, USA) was used, and a p-level of 95% was applied.

Results

Significant linear correlations were found between the vertical jump height (VJH) and the 10 m sprint (S10m) as motor predictors and agility criteria (Table 2).

Table 1. Descriptive statistic results

Variables	M	F
	Mean ± SD	**Mean ± SD**
BH	170.93 ± 8.47	166.36 ± 5.78
BM	62.49 ± 15.21	56.23 ± 9.90
BFat	20.63 ± 8.20	24.24 ± 7.32
VJH	26.16 ± 7.22	22.09 ± 4.17
S10m	1.42 ± 0.59	1.70 ± 0.34
S15m	2.42 ± 1.00	2.91 ± 0.57
LOS	34.57 ± 10.33	35.52 ± 11.36
TTest	12.15 ± 1.21	12.65 ± 0.99
ZigZag	6.37 ± 0.55	7.02 ± 0.56
20Y	5.87 ± 0.53	6.30 ± 0.47
ADD	33.84 ± 14.63	38.97 ± 7.79
ABD	36.52 ± 15.91	42.10 ± 8.36
DFlex	21.70 ± 10.16	27.41 ± 7.43
PFlex	36.38 ± 15.67	44.03 ± 8.52

Legend: BH - body height; BM - body mass; BFat - body fatt; VJH - vertical jump height; S10m - sprint 10m; S15m - sprint 15m; LOS - balance test; TTest - T course agility test; ZigZag - zig zag agility test; 20Y - 20 yards agility shuttle test; ADD - ankle adduction; ABD - ankle abduction; DFlex - dorsiflexion; PFlex - plantarflexion

Body mass (BM) and body fat (BFat) as morphological predictors also showed significant correlations with the agility tests. Body height showed no significant correlations with the agility criteria in both groups. The balance test (LOS) only correlated with the 20Y agility test in the male group. The ankle mobility tests showed no correlations with the agility criteria in the male group, but ankle adduction (ADD) and ankle abduction (ABD) showed significant correlations with the ZigZag agility test in the female group (Table 2).

The calculated regression models for the male group ex-

Table 2. Pearson correlation between studied variables

Predictors	M			F		
	Zig-Zag	20Y	T-test	Zig-Zag	20Y	T-test
BH	0.17	-0.07	-0.01	0.10	-0.02	0.00
BM	0.37*	0.21	0.28*	0.38*	0.27*	0.40*
BFat	0.28*	0.27*	0.33*	0.31*	0.51*	0.51*
VJH	-0.37*	-0.51*	-0.47*	-0.33*	-0.47*	-0.47*
S10m	0.55*	0.79*	0.81*	0.40*	0.54*	0.37*
LOS	-0.21	-0.26*	-0.25	0.01	-0.15	-0.10
ADD	0.02	-0.10	-0.08	0.27*	0.04	0.08
ABD	0.08	-0.01	-0.06	0.27*	-0.07	-0.06
DFlex	0.02	-0.16	-0.15	0.26	0.05	0.04
PFlex	0.05	0.03	-0.00	-0.01	-0.13	-0.15

Legend: BH - body height; BM - body mass; BFat - body fatt; VJH - vertical jump height; S10m - sprint 10m; S15m - sprint 15m; LOS - balance test; TTest - T course agility test; ZigZag - zig zag agility test; 20Y - 20 yards agility shuttle test; ADD - ankle adduction; ABD - ankle abduction; DFlex - dorsiflexion; PFlex - plantarflexion

plained 38% of the variance in the Zig-Zag test, 12% in the 20Y test, and 81% in the T-test (Table 3). The significant regression model for the Zig-Zag test included the body mass (BM), high jump (VJH), and 10 m sprint (S10m). The 20Y test had no predictors in the male group. For the T-test, the only predictor was the 10 m sprint (S10m).

Table 3. Regression summary for dependent variables for male participants

Predictor Zig-Zag	Beta	SE (beta)	b	SE (b)	t	p
Intercept			1.58	0.88	1.79	0.08
BH	0.32	0.12	0.02	0.01	2.64	0.01
VJH	0.38	0.10	0.08	0.02	3.74	0.00
S10m	0.32	0.11	0.84	0.29	2.89	0.01
R= .64; R2= .38; F=4.68; p=.00; SE=1.22						
Predictor 20Y	**Beta**	**SE (beta)**	**b**	**SE (b)**	**t**	**p**
Intercept			5.88	0.67	8.83	0.00
R= .34; R2= .12; F=2.35; p=.06; SE=.83						
Predictor T-test	**Beta**	**SE (beta)**	**b**	**SE (b)**	**t**	**p**
Intercept			5.88	0.67	8.83	0.00
S10m	0.92	0.06	7.30	0.47	15.42	0.00
R= .91; R2= .81; F=82.96; p=.00; SE=1.97						

Legend: BH - body height; VJH - vertical jump height; S10m - sprint 10m

The calculated regression models for the female group explained 57% of the variance in the Zig-Zag test, 32% in the 20Y test, and 42% in the T-test (Table 4). The only significant regression model in the female group was the 10 m sprint (S10m) for all three agility criteria.

The correlations between the obtained regression models

Table 4. Regression Summary for dependent variables for female participants

Predictor Zig-Zag	Beta	SE (beta)	b	SE (b)	t	p
Intercept			0.16	1.21	0.1	0.90
S10m	0.76	0.10	3.54	0.46	7.8	0.00
R= .78; R2= .57; F=15.02; p=.00; SE=1.04						
Predictor 20Y	**Beta**	**SE (beta)**	**b**	**SE (b)**	**t**	**p**
Intercept			2.23	1.11	2.00	0.05
S10m	0.43	0.11	1.52	0.40	3.79	0.00
R= .61; R2= .32; F=8.62; p=.00; SE=.98						
Predictor T-test	**Beta**	**SE (beta)**	**b**	**SE (b)**	**t**	**p**
Intercept			0.49	2.35	0.21	0.83
S10m	0.71	0.10	6.00	0.85	7.05	0.00
R= .71; R2= .47; F=15.20; p=.00; SE=2.08						

Legend: S10m - sprint 10m

and the achieved test results are shown in Tables 5 and 6. The regression models were confirmed because all the correlations were significant in both groups. In the male group, the highest correlation between the achieved and the predicted test results was noticed for the T-test (0.85) and the lowest was for the 20Y test (0.44). Similar to the male group, in the female group, the highest correlation between the achieved and the predicted test results was noticed for the T-test (0.71) and the lowest was for the 20Y test (0.61).

Bland–Altman plots were presented for all three agility tests. The plots showed that almost all cross-validation scores were positioned within the 95% CIs in the agility score differences (the observed minus the predicted scores). The biggest diversity was noticed in the Zig-Zag test for the female group.

Table 5. Comparisons between calculated and achieved scores for female and male students

Predictor	Female		r	Male		r
	Achieved	Predicted		Achieved	Predicted	
T-test	12.65±0.99	12.37±2.09	0.71*	12.15±1.21	10.55±4.28	0.85*
Zig-Zag	7.02±0.56	5.56±0.40	0.70*	6.37±0.55	5.82±0.95	0.82*
20Y	6.30±0.47	6.16±0.72	0.61*	5.87±0.53	5.54±0.28	0.44*

Legend: TTest - T course agility test; ZigZag - zig zag agility test; 20Y - 20 yards agility shuttle test

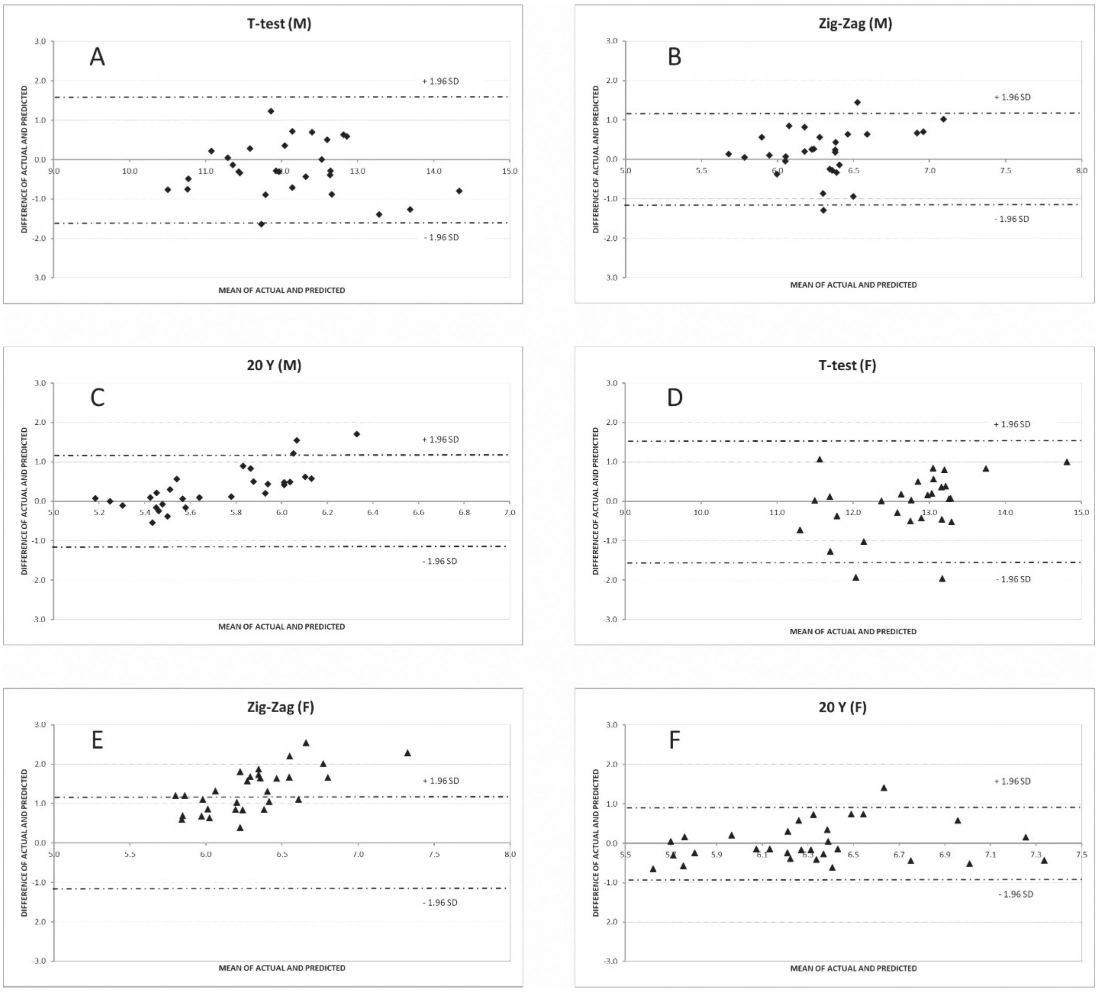

FIGURE 1. Bland-Altman plot for the calculated and achieved scores on the T-test. Zig-Zag and 20Y test for the cross-validation sample.

Discussion

This study had two major findings: (1) the 10 m sprint was found to be the most important predictor of agility performance; and (2) the body height and vertical jump were found to be predictors of the Zig-Zag agility test in the male group.

A literature review showed that BH can be an advantage as well as a disadvantage whilst performing agility tasks. According to Mathisen and Pettersen (2015), agility is significantly correlated with body height at the age of 13–14 years, but not in pre- and post-peak height velocity groups. Our cohort was in the stage of development where BH has the fastest growth and can disturb coordinative skills; thus, a negative influence on agility performance was expected (Philippaerts et al., 2006). Nevertheless, we found no negative correlations with agility performance. The negative influence of body mass and body fat on agility is well-recorded in the literature, especially in agility-untrained cohorts such as ours (Dhapola & Verma, 2017).

Despite the importance of balance in agility movements, we found this only in one test in the male group (Sekulic et al., 2013; Acar & Eler, 2019; Cengizhan et al., 2019). The reasons for this could be found in the structure of the balance test used in our study. The LOS is a test that assesses dynamic balance in a stationary position. Conversely, in agility tests subjects have to maintain their balance through constant and fast movements. A lack of strong correlations between the specific measures of static and dynamic balance and agility was also reported by Sibenaller et al. (2010). Balance has a specific appearance during agility performance. This was proven in the study of Stirling, Eke & Cain (2018), where the authors reported that athletes with a higher agility score also had a higher balance score whilst undertaking an agility course and wearing inertial measurement units on their body. Hence, regression modelling should include more specific or surrogate agility balance tests. This was not the case in our study.

Girls had greater mobility in all ankle mobility tests. This could be connected to a lower muscle mass and muscle tone in girls compared with boys of an early puberty age (Round et al., 1999). We speculated that the weaker muscles in girls produced a less stable ankle. As the ankle is one of the most engaged joints in agility movements, its instability or over-mobility can negatively influence agility performance. This was our prediction for the female group. This type of correlation was noticed in the Zig-Zag test for the female group.

As reported in the Results section, the 10 m sprint was the variable that predicted agility performance in almost all agility tests. However, other criteria oscillated among the regression models of the tests for the different genders. Specifically, the regression model for the Zig-Zag test in the boys included BH, VJH, and S10m whereas in the girls, the Zig-Zag agility was predicted only with S10m. As presented in the Bland–Altman plots, the predicted scores for the girls in the Zig-Zag test were poorer than the achieved scores (Figure 1). As the Zig-Zag test was complex and had many “stop-and-go” manoeuvres, cuts, changes of movement direction, accelerations, and decelerations, it was reasonable to expect that its prediction would be associated with other anthropological criteria (Sisic et al., 2015; Begu et al., 2018). This was not the case for the female group. Although we could only speculate why the regression model for the Zig-Zag test for the girls did not include other variables, it was clear that Zig-Zag agility performance was influenced by characteristics and abilities other than those studied (e.g., stride length, reactive speed, and leg and foot dimensions). Similarly, the regression model for 20Y in the male group did not exclude any predictor of agility performance. This finding should be considered taking into account the movement demands during the 20Y performance and the predictors used in this study. This was the only test that had a 180° turn and in which the eccentric strength of the lower extremities was extremely important during the deceleration phase (Hewit et al., 2011; Graham-Smith et al., 2018;). As no eccentric strength variables were used in this study, a lack of predictors for 20Y agility performance was expected. The findings from the T-test regression modelling were the opposite. Although the T-test had significant lateral movement demands (in total, 20 m of lateral movement) and a change of direction during the lateral movements, the only predictor in both groups was S10m, which was more characteristic of forward movement patterns. The T-test performance also consisted of 10 m forward running; the regression modelling did not incorporate any variables connected to lateral movements (such as leg length, lateral jump power, full-body coordination, and adduction and abduction muscle strength). Hence, S10m was our logical predictor of T-test agility performance in early puberty-age children.

Conclusion

The calculated linear correlations agreed with the findings of our research conducted on early puberty-age children. All three agility tests had valid regression models for both genders. From all the anthropological variables used in the regression modelling, speed was found to be the most important predictor of agility performance. Body measures, balance, power, and mobility tests used in the study were not reliable predictors of agility performance in early puberty. A major limitation of this study was the lack of inclusion of other abilities that could significantly contribute to a prediction model of agility performance in early pubescent boys and girls; e.g., cognitive qualities, coordination, reactive speed, and flexibility. In future studies, regression modelling should include more specific and/or surrogate tests that are similar to agility test movement demands. The results of this study indicate that agility is a complex ability. Accordingly, agility research, assessment, and training should be extensive in early puberty-age children.

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Conflicts of interest

The authors declare that there are no conflicts of interest.

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ORIGINAL SCIENTIFIC PAPER

Motor Status of Military Pilots in Montenegro

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Abstract

The results of numerous kinesiological studies in contemporary armed forces of today indicate the considerable role that the motor skills of soldiers play in the performance of multi-purpose specific tasks. The aim of this research was to determine targeted motor profiles of military pilots. The sample of participants consisted 20 military pilots of the Armed Forces of Montenegro, aged 36.3±11 years. The sample of measurements included 18 indicators of motor skills for the evaluation of precision, balance, flexibility, speed, coordination, explosive power, repetitive strength, aerobic and anaerobic endurance. The central and dispersion parameters of the variables were calculated. It was determined that the motor profile of military pilots was not at a satisfactory level, except for indicators of aerobic endurance, and explosive and repetitive strength. The results obtained indicate the need to carry out further research to predominantly study the impact of a broad spectrum of motor predictors on the criterion in the form of simulation movements of military tasks typical for certain military specialties. This would provide important data pertaining to military organization in the sense of improving the assessment and development of the conditioning potentials of soldiers.

Keywords: *motor profile, motor skills, physical fitness, army, air force*

Introduction

The level of conditioning potential to a great extent reflects one's state of health and ability to perform different forms of physical activity related to everyday life, sport, or professional activities (Grygiel-Górniak et al., 2016). Motor skills in the military are important for performing tasks specific to its various units, or its more specifically determined military specialties. What this primarily refers to is the following: flying, diving, weighted and non-weighted marching as a part of conditioning, the evacuation and transport of the wounded, tactical procedures in offense and defense, saboteur anti-terrorist activities, alpine and mountain terrain activities, skiing and outdoor stay in winter conditions, search and rescue on land and at sea, and evacuation activities and rescue missions in case of natural and man-made disasters and catastrophes. It is clear that each of these activities requires a certain level and specific manifestation of the motor potential of soldiers (Banjević, 2021).

The military pilots should be ready to perform tasks that include survival training in extreme conditions, such as after a forced landing, crossing long distances on foot, etc. (Rintamäki et al., 2005; Tomczak, 2013). On the other hand, physical preparation is necessary in order to perform work tasks. Numerous studies indicate that physically fit pilots suffer significantly less from various disability than their less able colleagues (Rintala, Häkkinen, Siitonen, & Kyröläinen, 2015). Therefore, physical training seems to be very useful for a military pilots who aim to maintain adequate professional competence and health (Willardson et al., 2010; Rintala et al., 2015).

The profession of a military pilot is a privilege for certain individuals with highly developed psycho-physical characteristics. They require specially developed abilities, so as to be able to efficiently and safely operate aircrafts in various stressful and dangerous situations (Meško, 2008). The detection and development of special pilot skills is a very important factor in contemporary flight preparations (Carretta, 2000). The level of difficultly which dictates the work environment of a military pilot requires efficiency in manifesting their motor skills. This primarily refers to the time needed to receive and process information, as well as the specific motor response which is usually very complex (Temme et al., 1995). In that sense what is also required is the need to assess the dominant motor skills in the movement activity of military pilots.

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Motor status of Air Force pilots was assessed by vary motor tests in different armies (Jukić et al., 2008; Meško et al., 2013; Tomczak & Haponik, 2016). These motor tests are assessed on the basis of exercises measuring the strength of abdominal muscles and shoulders, speed, agility and running stamina (Tomczak, & Haponik, 2016). Military pilots are characterized by a medium level of physical fitness and a medium level of aerobic capacity (Tomczak, & Haponik, 2016).

However, the motor status of military pilots, is insufficiently researched, and also there are no previous studies that have investigated motor status of Montenegrin military pilots. Therefore, the aim of this research was to determine the target motor profiles of pilots of the Armed Forces of Montenegro. The achieved aim will provide feedback relevant for the aspect of gaining insight into the current state of the motor status of the participants, which will have a clear practical importance in the sense of the construction of effective training-transformational processes. In addition, the possible errors when defining and applying the current batteries for the evaluation of the conditioning potential of the members of the Armed Forces of Montenegro will be determined, whereby clear guidelines will be given to the military in the sense of improvements made to the evaluation system of the motor potential of soldiers.

Methods

Participants

This is a transversal study and consists of a one-time evaluation of the relevant motor indicators of military pilots. The sample of participants consisted of 20 military pilots of the Armed Forces of Montenegro, aged 36.3±11 yrs. The research was carried out in accordance with the Declaration of Helsinki.

Procedures and measures

The evaluation of the state of the participants' motor skills was carried out based on the performance and analysis of the following motor tests: pointing with a long implement, overhand horizontal throw at a wall target, the static tandem balance test in the eyes closed position, the seated forward bend test, the shoulder pole stretch, hand tapping, the 20m sprint with a high start, climbing up and down on a bench and the Swedish ladder wall bar, the figure eight running drill bending, seated medicine ball throw from the chest, the standing broad jump, pull-ups, 60 second squats, two-minute torso lifts, two-minute push-ups, the 300 yard dash with a change in direction, and the 3200 m run. The motor tests were used in accordance with the Protocol for the assessment of motor skills in the armed forces (Jukić et al., 2008).

Statistical analysis

The results were first systematized, then statistically processed on a PC using the SPSS 20.0 software (Statistical Package for Social Sciences, v20.0 SPSS Inc., Chicago, IL, USA). For all the applied indicators of motor status, the descriptive statistical parameters of the central tendency and measures of variability were calculated: the means, standard deviation, minimum result, maximum result, variation width, coefficient of variation, and standard error. Testing the normality of the distribution of the frequencies of the applied variables was carried out using the coefficient of asymmetry, skewness, and coefficient of flatness, kurtosis.

Table 1. The central and dispersion parameters of the motor skills variables of military pilots

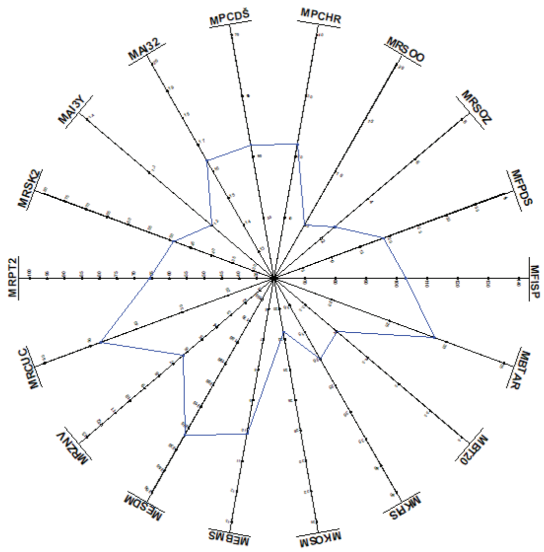
Variables	Min	Max	VW	M	Se	SD	KV	Sk	Ku
MPCDŠ	55.0	67.0	12.0	60.9	0.92	3.6	5.91	0.38	-0.71
MPHCR	13.0	28.0	15.0	21.8	1.18	4.6	21.10	-0.57	-0.30
MRSOO	2.8	8.5	5.7	5.0	0.37	1.4	28	0.77	1.13
MRSOZ	1.4	6.0	4.6	2.6	0.32	1.3	50	1.69	3.12
MFPDS	7.0	28.0	21.0	18.9	1.69	6.6	34.92	-0.54	-0.78
MFISP	58.0	134.0	76.0	103.3	4.45	17.2	16.65	-0.88	2.96
MBTAR	18.0	36.0	18.0	28.4	1.23	4.8	16.90	-0.47	0.31
MBT20	3.5	4.8	1.3	4.0	0.10	0.4	10	0.74	-0.42
MKPIS	14.7	33.2	18.5	19.9	1.42	5.5	27.63	1.71	2.08
MKOSM	19.3	25.2	5.9	21.8	0.46	1.8	8.25	0.38	-0.52
MEBMS	7.2	13.1	5.9	10.1	0.39	1.5	14.85	-0.04	0.05
MESDM	176.0	245.0	69.0	223.0	4.95	19.2	8.60	-0.97	1.00
MRZNV	1.0	11.0	10.0	6.3	0.78	3.0	47.61	-0.14	-0.99
MRČUČ	30.0	63.0	33.0	47.8	2.94	11.4	23.84	-0.18	-1.40
MRPT2	31.0	100.0	69.0	65.2	4.63	17.9	27.45	0.12	-0.09
MRSK2	28.0	77.0	49.0	49.1	3.63	14.1	28.71	0.10	-0.45
MAI3Y	1.1	1.4	0.3	1.2	0.03	0.1	8.33	0.37	-0.92
MAI32	13.2	19.5	6.3	16.4	0.46	1.8	10.97	-0.38	-0.30

Legend: Min – minimum result; Max – maximum result; VW – variation width; M – mean; Se – standard error; SD – standard deviation; KV – coefficient of variation; Sk – Skewness; Ku – Kurtosis; MPCDŠ – pointing with a long implement; MPHCR – overhand horizontal throw at a wall target; MRSOO – the static tandem balance test in the eyes open; MRSOZ – the static tandem balance test in the eyes closed; MFPDS – the seated forward bend test; MFISP – the shoulder pole stretch; MBTAR – hand tapping; MBT20 – the 20m sprint with a high start; MKPIS – climbing up and down on a bench and the Swedish ladder wall bar; MKOSM – the figure eight running drill bending; MEBMS – seated medicine ball throw from the chest; MESDM – the standing broad jump; MRZNV – pull-ups; MRČUČ – 60 seconds squats; MRPT2 – two-minute torso lifts; MRSK2 – two-minute push-ups; MAI3Y – the 300-yard dash with a change in direction; MAI32 – the 3200 m run.

Results

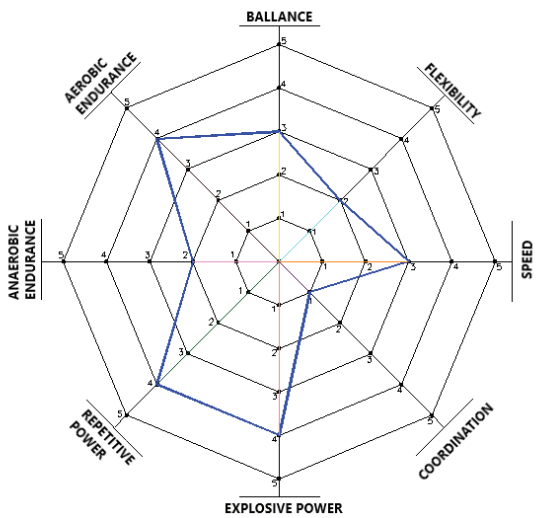
Table 1 shows the basic descriptive parameters of the motor skills of military pilots.

Based on the analysis of table 1, it can be concluded that the obtained distribution frequencies indicate that the applied motor tests consist of movement tasks of varying difficulty, but also that this did not lead to a significant dispersion of the results. An epikurtic asymmetry was noted for half of the motor tests. In that sense, two balance tests stand out predominantly, which is not surprising considering that pilots need to have precisely those features and abilities which were studied using the aforementioned measuring instruments. The negative asymmetry (hypokurtic) is moderate, which indicates a mild dominance of numerically greater results in the statistical series, and was determined in the distribution of frequencies of the remaining variables. The determined values of the motor status of the pilots of the AF of Montenegro are shown in graph 1.



GRAPH 1. The values of the motor status of military pilots

According to the standardized model (Jukić et al., 2008), estimates of individual motor skills of military pilots of the Montenegrin Air Force were obtained, which are shown in Graph 2.



GRAPH 2. Evaluations of the motor skills of military pilots

By analyzing the numerical values shown in graph 2, the motor skills of the military pilots of the AF of Montenegro were evaluated based on the following: balance – 3; flexibility – 2; speed – 3; coordination – 1; explosive power – 4; repetitive strength – 4; anaerobic endurance – 2; aerobic endurance – 4.

Discussion

It is of exceptional importance, when accepting a candidate into the armed forces, that the forces "get" members with those motor skills profiles are closest to those of an imaginary model of a soldier, who will spend the first few years of service performing jobs and tasks which are psychologically and physically very demanding. In addition, the members of the armed forces need to be in a constant "good form", their military readiness during the year as well as during several years must not be questioned, nor can it fall below the optimum level, which is a considerable difference from the "timing" of achieving top form characteristic of athletes (Banjević, 2012).

Members of the armed forces, unlike the individual athlete or members of a sports team, have an exceptionally broad range of activities which require of them to make use of all their human resources. This should be borne in mind, as it is not possible to use a unique criterion for the assessment and evaluation of the level of physical abilities for all structural segments of the military. However, that is the current state of affairs, even though we know that the air force, navy, or ground forces have different requirements, as do special units and the military police.

Although the results show variability in different motor skills, the level of physical performance of military pilots is not great. However, previous studies report a good level of performance of military pilots (Fogelholm et al., 2006; Sovelius, Salonen, Lamminen, Huhtala, & Hämäläinen, 2008; Meško et al., 2013; Rintala et al., 2015). It is expected that military pilots achieve significantly better results in relation to civilians on motor tests of coordination, speed and repetitive strength (Meško et al., 2013). The study (Tomczak, 2010) should also be pointed out, in which the level of motor skills between military pilots and students of the Faculty of Sports was compared. It was established that the students of the Faculty of Sports were better only in the speed of running at 15 m, and it should be added that the pilots were on average 14 years older. However, it should be noted that the results given are hardly satisfactory compared to typical athletic levels of endurance or strength sports (Montgomery, 2006). Also, Shin & Jee (2019) point out that the motor skills of military pilots have declined today compared to the results of their colleagues from 20 years ago. Compared to data collected in 2000, back force and explosive power decreased by 33% and 20%, respectively. Leg strength and balance parameters decreased by 10% and 30%, respectively (Shin & Jee, 2019).

One study (Idrizović & Banjević, 2013) has shown that, considering the determined association between individual predictor motor variables and the defined criterion in the form of a polygon used to simulate the movement activities of military pilots, the dominant motor skills in their case are: speed, coordination, anaerobic endurance, and explosive power of the lower extremities. Guided by these very significant findings, this study evaluated precisely these abilities, whereby it was concluded that in the case of military pilots, with the exception of aerobic endurance, and explosive and repetitive strength, they were at not at all at a satisfactory level. One of the main causes of such a state is precisely the development of those motor skills which are currently being tested in the military, that is, repetitive strength and aerobic endurance in particular.

Based on the achieved results, it is noticeable that Montenegrin military pilots achieved high results on explosive and repetitive strength tests, as well as on the aerobic endurance test, which is in line with previous research (Meško et al., 2013; Rintala et al., 2015). Also, the authors point out that good strength and endurance of the extensor muscles of the torso can prevent problems with the spine related to flying (Honkanen, 2019).

Average results were achieved in balance and speed tests and according to Shin & Jee (2019) these parameters have a negative growth in the last twenty years in the population of military pilots. Poor results achieved on tests of flexibility, anaerobic endurance and coordination. Although flexibility and anaerobic endurance are not considered crucial motor skills, on the other hand Tomczak (2015) points out that coordination skills are very important when it comes to military pilots.

This conclusion draws with it a series of facts which should be presented to the military, and one in particular is essential in the sense of improving the conditioning potential of soldiers of different specialties. It reads as follows: The current battery of tests for the evaluation of the conditioning potential of soldiers cannot be valid since it is identical for every unit within the armed forces and for military specialty. In fact, by applying it in its current form, no adequate feedback can be obtained on the state of important motor qualities which dominate the various movement tasks of soldiers. This could certainly be connected to the various energy balances in certain military specialties, which to a great extent dictate the level and quality of the manifestation of individual motor potentials. Specifically, years of research and experience from the field obtained by numerous armed forces have indicated that the conditioning preparedness for the performance of military activities consists of the following two basic elements of physical ability: the ability to do aerobic work (endurance) and muscle power (Sharp, Knapik, & Wallker, 2008). They represent two basic elements of the overall energy balance in the bodies of soldiers (Shvartz, & Reibold, 1990). The decrease in the values of these abilities due to age, and thus a considerable decrease in energy consumption, emerges as a result of morphological and functional changes in the cardiovascular system and skeleto-muscular system, while the speed of the decrease is influenced by numerous factors, primarily changes in body mass and the percentage of body fat during the course of one's lifetime (Buskirk, & Hodgson, 1987). According to the current Guidelines for testing the physical abilities of professional soldiers of the Armed Forces of Montenegro, for all the elements of the conditioning preparedness the tests and norms differ only in relation to age. This has provided support for the fact that the abilities of the human body decrease with age, but these norms are not associated with the requirements of various military duties.

Conclusion

Based on the obtained data, it was determined that the motor profile of military pilots is not at a satisfactory level, with the exception of indicators related to aerobic endurance, and explosive and repetitive strength. Also, the currently dominant battery of tests for the evaluation of the conditioning potential of the soldiers is not adequate from the aspect of the inability to perform a target evaluation of those motor skills which dominate the movement tasks of various military specialties.

The results of this research provide a contribution to shedding light on the state of the motor skills of military pilots and the validity of implementing the current battery of tests for the evaluation of the conditioning potential of soldiers. It is important to carry out more extensive research which would include the remaining military specialties, whereby primarily, based on determining the effects of a broad spectrum of motor predictors on the criterion in the form of a polygon for movement simulation, it would be possible to precisely define those motor skills which should be subjected to the processes of contemporary training technology. This would undoubtedly contribute to the improvement of the conditioning potential of the soldiers, and thus the increase in their overall combat readiness.

The special significance of this paper lies in the type of sample of participants, which could in a way also account for the limitation in the study in terms of any generalizations of the results. Still, bearing in mind the considerable significance of the army as a special part of the community, the theoretical and practical impact of this research is undeniable.

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Conflicts of interest
The authors declare that there are no conflicts of interest.

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ORIGINAL SCIENTIFIC PAPER

Job Satisfaction of Physical Education Teachers in Slovakia

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Abstract

Many studies have confirmed that job satisfaction is one of the important factors that maintain a high level of performance. The aim of this study was to analyze job satisfaction among physical education teachers in Slovakia. This was a cross-sectional intraindividual ex post facto research. 139 male and 173 female Slovak physical education teachers participated in this study, 165 of them were employed at primary schools and 147 of them worked at secondary schools. To get the empirical data, the method of questionnaire and interview was used. It has been shown that job satisfaction of physical education teachers in Slovakia are differentiated in terms of gender, but are not differentiated from the point of view of age and of the type of school. The obtained results shows that male physical teachers working in schools have better job satisfaction than their female counterpart ($\chi2=10.308$, $p<0.01\%$). The findings suggest that job satisfaction of physical education in Slovak teachers is low. This research was realized out within the project VEGA, No. 1/0523/19 „Telesná a športová výchova a jej kvalita a potenciál v podpore zdravia z pohľadu žiakov, učiteľov a rodičov" ["Physical and Sports Education and its Quality and Potential in Promoting Health from the Perspective of Pupils, Teachers and Parents"].

Keywords: *job satisfaction, PE teachers, workload, financial evaluation*

Introduction

Teachers have undoubtedly a key role to play in providing of quality education. The majority of teachers in OECD countries and economies in TALIS (Teaching and Learning International Survey) (90%) are satisfied with their job, and most of them (91%) do not regret becoming a teacher (OECD, 2020). However, several data show that the attractiveness of this profession is relatively low in Slovakia and teachers perceive their profession from a public point of view rather negatively, while abroad teachers feel more valued. According to the 2018 International Study TALIS, only 26% of teachers and 37% of OECD principals involved in research agreed with the claim, that profession of the teacher is valued in society. In the Slovak Republic, this share was even the smallest of all OECD countries (the average of the countries is 19.7%), as only 4.5% of teachers and 2.1% of principals in Slovakia believe that the teaching profession is valued in society. It was the lowest evaluation rate among the most economically developed countries. Compared to the previous cycle of TALIS 2013, there was no significant difference in the perception of Slovak teachers or principals in their perception of how their profession is valued in society. Longer-serving teachers are also more likely than their younger colleagues to say that the profession is undervalued, suggesting a degree of professional disillusionment as teacher´s progress along the career path (OECD 2020).

Basically, job satisfaction is about liking your job and finding fulfilment in what you do. It combines an individual's feelings and emotions about their job and how their job affects their personal lives (Hundito, 2015). TALIS defines job satisfaction as the sense of fulfilment and gratification that teachers get from their work. Job satisfaction may have

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a positive association with teachers' attitudes towards their work and with their performance (OECD, 2020). Fisher & Hannah in another definition see job satisfaction as a psychological factor and define it as an emotional adaptation to job conditions i.e., if a job provides ideal conditions for the individual, he will be satisfied with his job, but if it does not, he will start to blame his job and if possible will leave it. Job satisfaction causes an increase in the employee's productivity and organizational commitment; his physical and mental health is guaranteed; he is motivated; he is satisfied with life; and he learns new professional skills quickly (Tajnia et al., 2014). Nascimento et al. (2016) stated that job satisfaction is defined as an emotional state resulting from interaction of professionals, their personal characteristics, values and expectations about labor environment and organization, which can have an influence on a worker's perception of quality of life and wellbeing.

Considering specifically the teaching profession, it is possible to state that the notion of professional satisfaction of teachers is complex, finding, beyond that, an endless amount of factors responsible for their (dis)satisfaction with teaching. For this reason, one should consider abrupt cultural, social, political and economic changes occurred within the school sphere that impact teaching activity over time, generating, in turn, the confrontation of teacher with problems and difficulties currently faced as they exercise their profession, since school, as a public institution and space for professional intervention, has a direct influence on teaching performance and on a teacher's satisfaction with his professional activity (Nascimento et al., 2016). Since the teaching of physical education (PE) is a specific process that differs from other teaching processes at school, the teacher's work is specific in terms of workload, which Kyriacou (2001) defined as the experience of unpleasant and negative emotions of the teacher resulting from his profession and can manifest as anger, anxiety, tension, frustration, and can result in depression. The workload can cause a teacher to perceive his or her work situation as a threat to his or her mental health and to underestimate himself or herself.

What factors could be shaping teachers' satisfaction? There are many factors which affect the job satisfaction level of teacher such as age, seniority, education level, gender, marital status, salary, the attitude of school principal, physical structure, colleagues and that can be categorized as internal aspects (personality traits, feelings and emotions) and external aspects (organizational, social and cultural conditions and characteristics) (Xiaofu & Qiwen, 2007; Saygi et al. 2011; Tajnia et al., 2014; Dogan et al. 2018). There are some variables that provide satisfaction for PE teachers such as having job security, going on vacation, being physically active during the PE lessons, and facilitating satisfactory lifestyle (Bizet et al., 2010). High job satisfaction among teachers has been associated with an increase in overall school effectiveness (Hung, 2012) and a decrease in the desire to leave one's job (Johnson et al., 2012). Machado-Taylor et al. (2010) found that job satisfaction and motivation played an important role in contributing to positive outcomes in the quality of the schools and the students' learning.

Many studies have confirmed that job satisfaction is one of the important factors that maintain a high level of performance. Some researchers have pointed out that the low levels of job satisfaction may lead to lower productivity, associated apathy and loss of interest, as well as, the low level of organizational commitment, because this relationship affect the quality of education and student achievement (Mouloud et al., 2016). Wage income is an important factor influencing job satisfaction and low income has a dramatic effect on job satisfaction. Therefore, the items in the questionnaire asked teachers also about their satisfaction with the salary evaluation because salary has a direct relationship with job satisfaction.

In the Slovak Republic 18% of teachers report being satisfied with their salaries, which is lower than the OECD average (39%) (OECD 2020). But what is the satisfaction of PE teachers? It is known that PE teachers face with many problems and stress about their duties in their professional lives. Identification of problems faced by PE teachers will play an important role in solving problems related to PE. Kul et al. (2018) stated that in order to be able to create a good learning environment, it is necessary to establish a good learning environment first and in order to be able to create this environment, it is necessary to first identify the problems faced by the PE teachers and to offer solutions.

The prestige of the teaching profession is often reflected in the satisfaction of the teachers themselves with the job. In the context of previous findings, the aim of this study is to find how physical and sports teachers in Slovakia evaluate their workload and financial evaluation and what are their complaints.

Methods

Participants

The research group consisted of PE teachers who teach this subject at several types of schools (primary schools, secondary schools - general focus, bilingual grammar schools, secondary vocational schools, united schools and others). A total of 312 teachers of physical and sports education in Slovakia were involved in the research. The numbers of men and women in our sample do not match. In this total number (n=312), 139 were men (44.6%) and 173 women (55.4%). In terms of individual types of schools, more than half were PE teachers from primary schools (52.9%), who were slightly more represented than teachers teaching at secondary schools (47.1%). In terms of age, the largest group (28.8%) were teachers aged 31-40. Less than one percent less (27.9%) were teachers aged 41-50. The smallest group is the oldest teachers aged 61 and over (9%). In our research group, there was not only beginning teachers with a length of practice of up to 5 years, who accounted for 20.8% of the total number, but also PE teachers with many years of practice and experience (30 years and more), who formed the largest group (21. 2%) of the total.

Slovakia currently distinguish in terms of administrative division 8 self-governing regions, which are concentrated around the largest cities and differ in population, population density, age structure, natural and cultural specifics, as well as folklore customs. Each region consists of districts. There are currently 79 districts in Slovakia. The number of teachers participating in the research by individual regions and districts is showns in Figure 1. During the obtaining data an effort was to obtain the opinions of teachers from every region of Slovakia, which almost successful. Out of 79 districts, teachers from up to 70 districts are represented in our group.

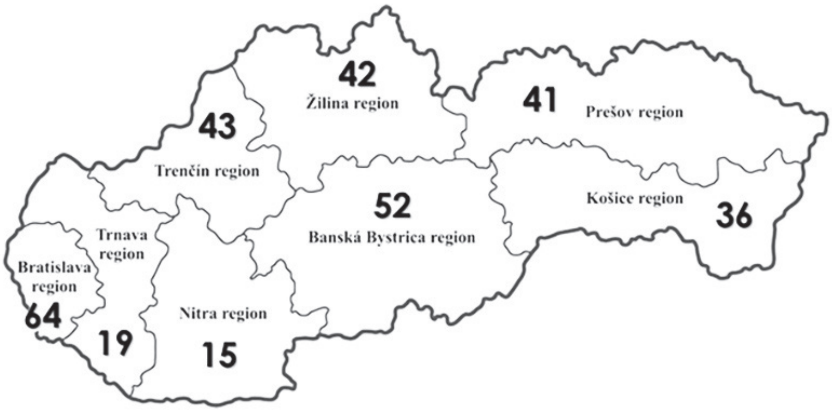

FIGURE 1. Number of teachers according to the region.

Procedures

A questionnaire and interview method was used to obtain the data. The questionnaire was compiled using research works dealing with the same or similar issues carried out in the recent past (Procházka, 2013; Fialová et al., 2014), supplemented with own questions and adjusted according to our goals and tasks to address the research problem. The questionnaire underwent an expert assessment by several experts working in the field and was divided into the following seven parts: 1) The position of PE among other subjects, the prestige of the teaching profession; 2) Problems of non-training students, 3) Number of PE hours, competitions, tournaments; 4) The issue of evaluation/classification of the subject PE; 5) Problems of spatial and material conditions; 6) Information and communication technologies; 7) Quality of teaching physical and sports education.

The total number of questions in the questionnaire was 45, with both closed and open answers, but paper bring only some results from our research regarding job satisfaction. The teachers' opinions was also supplemented with interviews.

The research was conducted during in the years 2019-2021 and data collection took place in the third phase from April 2019 to the end of 2019. The distribution and administration of the questionnaires was ensured at trainings within the project "Use of motivational factors in teaching physical and sports education in primary and secondary schools", which focused on educational activities in physical and sports education with an emphasis on the development of key competences, knowledge and skills of primary and secondary school teachers.

In all the cases, the questionnaires were filled anonymously, and participation in the study was entirely voluntary. This study was approved in advance by the Ethics committee of the Faculty of physical education and sport, Comenius University (no. 9/2019). All participants were informed about the aims, methods of data collection, and their use for research purposes.

Statistical analysis

Descriptive statistics (frequencies) were used to describe the basic features of the data, providing simple summaries about the measures to identify the opinions and complaints of physical education teachers concerning their job satisfaction and financial evaluation. The results of the questionnaires were evaluated by the percentage analysis and in the search for correlations between the selected indicators we applied the correlation analysis and Chi-square test ($\chi 2$). P-values of ≤ 0.05 were considered statistically significant. The data were analyzed by using the statistics software SPSS 23.0. (Statistical Package for Social Sciences, v23.0 SPSS Inc., Chicago, IL, USA).

Results

138 teachers (44.2%) stated complaints about the workload. However, the negative finding is that not a third of PE teachers (30.4%) are satisfied with the workload (answers are yes, absolutely yes). When comparing the answers of primary and secondary school teachers, we see (Figure 2) that 1% only more satisfaction with the workload was expressed by PE teachers from primary % schools (30.9%) then from second-

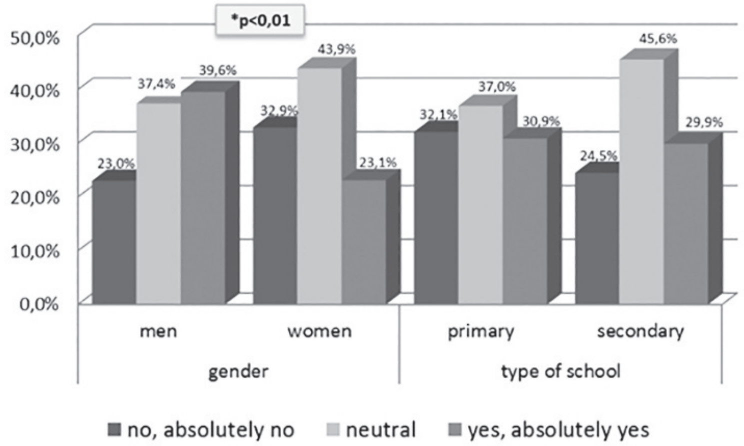

FIGURE 2. Satisfaction of PE teachers with workload.

ary schools (29.9%). There were no significant differences in terms of school type [χ2(2, N=312)=3.02, p=0.221]. In terms of gender, men (39.6%) expressed significantly greater satisfaction then women (23.1%) [χ2(2, N=312)=10.3, p=0.006]. It turned out that up to one third of women are not satisfied with their workload (32.9%). On the contrary, in the evaluation job satisfaction there were significant differences neither in terms of in terms of age [χ2(4, N=312)=1.9, p=0.753] nor school type, and school location.

There are almost no differences (Figure 3) in satisfaction with salary evaluation between primary and secondary school teachers [χ2(2, N=312)=0.15, p=0.926]. Although women (12.7%) were slightly more satisfied than men (10.8%), we did not notice statistically significant differences in terms of gender [χ2(2, N=312)=0.71, p=0.702]. We did not notice much differences in terms of age either [χ2(4, N=312)=1.68, p=0.795]. The youngest teachers under 30 were the least satisfied with the salary (71.1%). The greatest dissatisfaction is among teachers in the Bratislava region, where more than ¾ teachers (76.6%) are not satisfied with the salary evaluation.

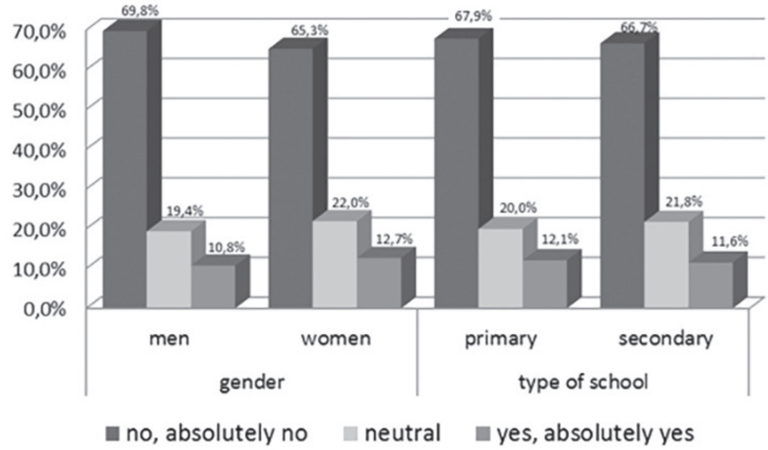

FIGURE 3. Satisfaction of physical education teachers with salary evaluation.

Discussion

Teachers undoubtedly have a key role to play in providing quality education. As the teaching of physical and sports education is a specific process that differs from other teaching processes at school, the teacher's job is also specific in terms of workload.

The basis of the results of this research is noticeable that most teachers are dissatisfied with their work and salary. Teachers are most annoyed by the amount of bureaucracy and administrative duties they have to perform during breaks, which they consider unnecessary. To a large extent, they also complain about overload and a number of outside teaching duties such as supervision in the corridors. Among the other most frequently mentioned complaints was their frequent participation in competitions, which affects the standard teaching of physical and sports education at school, and in addition, these competitions are often attended by a narrow circle of students. Their dissatisfaction with the workload is often related to the high number of students in the class. They also drew attention to high hours and overtime, which they consider to be inadequately assessed. On the other hand, teachers have complaints about the current number of PE hours, which they consider insufficient to manage the school curriculum. Some teachers also complain about the lack of space (learning in other areas such as the gym), high noise and, in particular, the high psychological demands and responsibility for health and safety during exercise.

Reservations for salary evaluation were specified in the questionnaire by up to 220 teachers. PE teachers have the greatest objection to the low evaluation of teachers, which in their opinion is financially underestimated, insufficient and underappreciated due to the work done. A significant number of teachers also stated that their evaluation is inadequate in comparison with other professions with a university degree, or other EU or OECD countries. One of the PE teachers from a secondary vocational school remarked that pupils earn a teacher with an apprenticeship certificate in the same way as a teacher with a university degree himself.

Several teachers also said that in addition to working at school, they also had to work in the afternoon to improve their financial income, suggesting that they would earn more as coaches in less time. According to teachers, this is a really low ratio of salary to time they have to spend preparing for lessons, competitions, students during breaks and they state that their current salary does not reflect and adequately reward their overall effort, physical and mental effort, great responsibility for the safety of trainees and overall difficulty. Noordin & Jusoff (2009) state that salary have a positive effect on job satisfaction. In recent years, the number of PE teachers in Slovakia who were dissatisfied with their financial evaluation has increased, which is in line with our results. In 1992 it was 75% and in 2006 even 94.1% of PE teachers (Baginova et al., 1992; Lakóová, 2006). The international study TALIS 2018, which aimed to monitor the working environment and conditions of teachers and school principals, similarly showed that in Slovakia there is a low percentage of teachers (17.9%) who are satisfied with the salary evaluation. At the time of the study in 2018, on average, in OECD countries, 39.4% of teachers agreed or strongly agreed with the statement that they were satisfied with the salary they received for their work (OECD, 2020).

Findings suggest that satisfaction with the salary assessment is low even today (Figure 3), as only 11.2% of our research teachers are rather satisfied with their salary, and only 2 teachers (0.6%) from the whole group stated that they are completely satisfied with the salary. PE teachers clearly agreed that their current financial reward is not adequate for their teaching profession and is not a dignified reward for their work in society, despite recent salary increases. Logically, they had the biggest complaint about their low salary and also drew attention to the problem of financing rewards during the hours they spend with students on extracurricular activities, especially ski courses or competitions, in which they participate or even organize themselves, but also the hours they have to devote to classroom, or by substituting other subjects and stating that these hours are not properly reimbursed.

The majority of teachers in OECD countries and in the TALIS (Teaching and Learning International Survey) economies (90%) are satisfied with their work and most (91%) do not regret becoming a teacher (OECD, 2020). However, the findings of current research suggest that the attractiveness of this profession is relatively low in Slovakia and teachers perceive their profession from a public point of view rather negatively, as only 30.4% of physical education teachers are satisfied with their workload and only 11.8 teachers are sooner or completely satisfied with their salary. Topič and Mujanović (2012) achieved much more positive results in Slovenia, according to which job satisfaction of physical education teachers in Slovenia is generally at a very high level. The results of their study showed that Slovenian PE teachers are very satisfied with their current profession, but are more likely to expect their retirement due to the extension of their years of service. The authors also noted a statistically higher satisfaction with management in schools where the principal was a PE teacher compared to other schools where the principal taught other subjects.

In this study, a significant difference was found in the comparison of satisfaction level of male and female PE teachers. Male PE teachers job satisfaction levels were higher than female PE teachers. In similar studies (Topič & Mujanović, 2012; Hundito, 2015; Ünlü & Filiz, 2019), they stated that male PE teacher' job satisfaction level was higher than the level of females. This results was consistent with present study. However, in another study, Tajnia et al. (2014) determined that female PE teachers had higher job satisfaction than males did. As it was seen there were different results related to the job satisfaction according to gender. It was indicated that job satisfaction of male employees was mainly based on enthusiasm and dynamism as a characteristic of their earlier age phase. On the other hand, the job satisfaction of women was apparently based on the capability of quick recognition with the work content induced by the experience accumulated with age (Bekiari & Ntakou, 2018).

In the comparison of job satisfaction level of PE teachers with their current job considering their ages, there were not any significant differences. The findings of the present research suggest that age did not affect the overall job satisfaction of PE teachers in Slovakia. However, some of the studies revealed the significant differences between age and job satisfaction (Tajnia et al., 2014; Bekiari & Ntakou, 2018). Bernabe et al. (2016) stated that experienced teachers aged 45 years or older had higher levels of job satisfaction. In our research, we did not find differences in the job satisfaction of teachers in terms of age.

There are some variables that provide satisfaction for physical education teachers such as having job security, going on vacation, being physically active during the PE lessons, and facilitating satisfactory lifestyle (Bizet et al., 2010). Job satisfaction is thus a very important factor, as it is the basis for maintaining quality PE classes and well-designed PE programs, although there are many factors responsible for (dis) satisfaction with workload. Therefore, preventive measures should be developed to increase teachers' satisfaction with the workload, where, in addition to the financial area, promotional and educational opportunities could be improved. On this basis, it can be stated that the current financial evaluation of teachers does not meet the qualification requirements of their profession or its importance for society. At the same time, it has a negative impact on the attractiveness of the profession. This can result not only in low interest in the teaching profession, but also in the abandonment of it by those who already practice it. We are of the opinion that countries' education systems should offer their employees salary conditions that are also attractive in relation to other jobs that require similar qualifications.

This study included PE teachers who were working in public schools in Slovakia. There were also PE teachers who were working in private schools. These PE teachers were not included in this study. Also, the sample of the study consisted of Slovakia PE teachers may not be comparable to other contexts or countries. In the research, only the satisfaction with workload and with salary evaluation of PE teachers was examined and compared according to gender, age and type of school variables. In further research, it can be examined comparatively with different branches of teachers and variables including; working hours, teaching experience, working conditions and working environment.

Future research should include factor analysis and bigger, more representative sample. PE teachers' job satisfaction should be also investigated through longitudinal study. In the future, we recommend comparing the state of PE before the pandemic, during, resp. after its completion, and therefore we recommend repeating similar research and watching how the corona virus pandemic affected teachers' opinions and their view of job satisfaction.

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Conflicts of interest
The authors declare that there are no conflicts of interest.

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ORIGINAL SCIENTIFIC PAPER

Objective Outcomes of All-inside Anterior Cruciate Ligament Reconstruction with and Without Internal Suture Augmentation Technique: Randomized Controlled Trial

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Abstract

To report and compare patient outcomes (PROs) (IKDC score, Lysholm Score) and knee laxity using Lachmeter -The digital Rolimeter ® - among patients who underwent hamstrings autograft anterior cruciate ligament reconstruction (ACLR) with and without internal tape augmentation. Randomized trial of 41 patients in which 21 patients underwent all-inside ACLR with internal suture augmentation (Group I, Brace group) and 20 patients underwent all-inside ACLR without internal suture augmentation (Group II, non-brace group). Primary outcomes Lachmeter examinations and PROs were analyzed at 3,6,9 months postoperative. Secondary outcomes were graft failure, synovitis, and infection. Mean follow-up duration was 18 months ± 3.4. Date was expressed as Mean±SD for quantitative parametric data or number and percentage for categorized data. Delta change (dC) principle was used to test the actual mathematical change in the outcomes between 0-9 months and 3-9 months intervals postoperative. Lysholm score at 9-months was significant and better in brace group mean: 94 (92.4-96.5), p<0.005. Postoperative Lachmeter at 3,9 months was significant with less laxity in brace group mean: 1.98 (1.89-2.07), 2.14 (2.06-2.22) p<0.005. dC Lachmeter in both intervals was significant with less laxity in brace group mean: .09 (.06-.11) p<0.001. dC IKDC score was significant in 3-9 months interval mean: .31 (.28-.35) p<0.001. dC Lysholm score was significant in 0-9 months interval mean: .86 (.72-.99) p<0.001. Both scores were better in brace-group. One graft failure was reported in Group II and one case of synovitis in Group I. All-inside ACLR with brace showed better laxity measures and lower failure rate at 9-months postoperative. However, the subjective functional outcomes did not show clear evidence of superiority in the suture tape augmentation group.

Keywords: *Lachmeter, IKDC, Lysholm, all-inside ACLR, internal suture augmentation, randomized controlled trial*

Clinical trial registration number (TRN): NCT04906538 on 05/28/2021

Introduction

Anterior cruciate ligament injury is one of the most common knee injuries, with approximately 250,000 ACL tears occurring in the United States annually (Wang et al., 2018). Revision rate is 1.7% to 7.7% of cases with 35% of first-time graft failures are due to isolated trauma (Adams, Logerstedt, Hunter-Giordano, Axe, & Snyder-Mackler, 2012). In the absence of technical errors and traumatic events; "Biological failure" is a used term to describe such failures because of inadequate graft "ligamentization" during this period while the graft is highly sensitive. (Samitier et al., 2015) The graft usually pass through multiple histological stages; necrosis, revasculariza-

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tion, cellular repopulation and proliferation and remodeling (Ménétrey, Duthon, Laumonier, & Fritschy, 2008). Finally, collagen remodeling continues to happen during the first year after surgery by changing the non-reducible/ reducible crosslink ratio in collagen fibrils (Marumo, Saito, Yamagishi, & Fujii, 2005). Therefore, protection of the graft during these phases in a controlled manner to apply within limit mechanical loads over the graft could offer lower chances for mechanical and biological failure. This could act as “safety belt” for the graft and confirm the theory of internal suture augmentation (van Eck, Limpisvasti, & ElAttrache, 2018).

In 2006, Lubowitz described the all-inside technique using a dual retro-cutter (Arthrex, Naples, FL) that after its intra-articular assembly allows for both anatomical antegrade and retrograde femoral and tibial tunnels drilling respectively (Lubowitz, 2006). Recently, (FlipCutter; Arthrex) simplified the inside out tunnel drilling (Lubowitz, Amhad, & Anderson, 2011).

Suture tape – a braided ultra-high-molecular-weight polyethylene material – reinforcement has been described in effort to provide biomechanical support during the graft healing phases (Parkes et al., 2021). This suture tape was used successfully to augment Brostrom repair, and posteromedial corner repair (Viens, Wijdicks, Campbell, LaPrade, & Clanton, 2014) (Lubowitz, MacKay, & Gilmer, 2014). Samuel Bachmaier et al. concluded in his study testing biomechanical full construct hamstrings tendons model with internal suture augmentation that the reinforcement with suture tape increases the dynamic stiffness and ultimate load failure and decreases the dynamic elongation in the augmented sample (Bachmaier, Smith, Bley, & Wijdicks, 2018).

Arthrometric testing represents a useful objective tool that used ACL examination. The KT-1000 and KT-2000 (MEDmetric Corp, San Diego, Calif., USA) have been developed to provide acceptably accurate and reproducible laxity measurements (Daniel et al., 1985). Furthermore, the Rolimeter (Aircast, Europe) is a simple, new device that provides a comparable measurement to KT- devices (Ganko, Engebretsen, & Ozer, 2000). Lachmeter - The digital Rolimeter® is the selected device in our study that follows all the principles, validation, and technique of the Rolimeter, while providing its measured values of laxity on a digital screen rather than a metered scale as in the original Rolimeter.

The purpose of this study was

1. To report, compare and corelate the patient reported outcomes (PRO) (IKDC score, Lysholm Score) and range of motion (ROM) among patients following hamstring autograft ACLR with and without independent suture tape reinforcement against objective laxity test using Lachmeter.

2. Rate of complications and reoperations.

We hypothesize that Internal suture augmentation technique decreases post-operative graft failure rate, improves the knee stability and the patients reported functional outcomes of the knee.

Materials and methods

Study design

This randomized control trial was conducted in Ain Shams University Hospitals, following the Ethical Committee of Orthopedic Surgery Department approval, reference number: FMASU MD 310 2018 and was registered in ClinicalTrial.gov, Identifier: NCT04906538 on May 28, 2021. All surgeries were operated by two senior surgeons (Sobhy. M and Khater. A). Pre-operative and post-operative examinations, evaluations, and subjective assessment by Lachmeter were performed by Ramadan A and Haroun Y. CONSORT flow diagram was used throughout the study steps.

Study population

October 2018 until June 2020, 41 patients with torn ACL met the inclusion criteria. 21 of patients underwent all-inside ACL reconstruction with internal suture augmentation technique (Group I) and the other 20 patients underwent all-inside ACL reconstruction without internal suture augmentation technique (Group II).

- Inclusion criteria:

Age 20-35 years.

Subjects diagnosed as ACL tear according to:

(a) History of knee trauma

(b) Clinical examination (ant. Drawer test, Lachman test and pivot shift test).

(c) Radiological evidence of ACL tear by MRI.

- Exclusion criteria:

(1) Other intra or extra articular knee injuries.

(2) Previous ACL surgery on the affected knee.

(3) Bilateral ACL injuries.

(4) Significant Articular surface injury.

(5) Patients with malalignment (Genu varum, Genu valgum and Genu recurvatum).

(6) Neuromuscular disorders.

Study outcomes

Primary study outcomes: Lachmeter laxity test, IKDC score and Lysholm score. Supported by clinical examinations (pre and postoperative anterior Drawer test, pre and postoperative Lachman test, pivot shift test and ROM). These outcomes and examinations were tested for each patient preoperative, immediate postoperative and 3,6,9 months postoperative.

As secondary outcomes, we recorded any case of failure, infection, synovitis or limited ROM.

Study intervention (Surgical technique)

All the patients included in the study underwent primary ACLR using all-inside technique with quadruple semitendinosus autograft employing the GraftLink® (Arthrex, Naples, FL) with suspensory fixation Tightrope®, (Arthrex, Naples, FL) on the femoral side. The graft is pretensioned for 15 minutes at approximately 70 N to eliminate creep. Group 1 grafts were augmented by FiberTape® (Arthrex, Naples, FL) suture – ultra-high molecular weight polyethylene core with a braided polyester jacket which passed through the femoral Tightrope® loop while the fiber tape tibial free ends are kept free in the opposite direction.

The graft’s tibial end is sutured with no. 2 FiberWire sutures (Arthrex) while FiberTape® suture is outside the construct to avoid sutures loop incorporation. The femoral tunnel was created by antegrade drilling using accessory antromedial portal for at least 20-25 mm intraosseous depth. The tibial socket is created in retrograde fashion utilizing a FlipCutter® for an intraosseous depth of at least 25 mm to keep the medial tibial cortex intact. Then, the graft is passed inside the joint from the accessory antromedial portal and the femoral Tight Rope® is introduced inside the knee until it flips on the lateral femoral cortex.

The shortening sutures are pulled in an alternating fashion to hoist the graft in the femoral tunnel for 15 mm. Special mark is added to the graft using no. 2/0 Vicryl suture (Ethicon Inc.) 15 mm from both ends to ease graft manipulation inside the knee Figure 1.

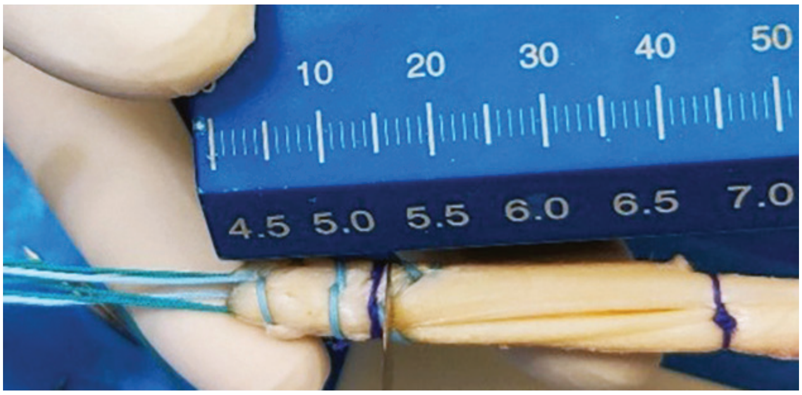

FIGURE 1. Special mark using 2/0 Vicryl suture 15 mm from each graft's side to facilitate intra-articular adjustmen

The graft's and FiberTape sutures are passed and pulled through tibial socket using no. 2 Ethibond nonabsorbable sutures (Ethicon Inc., Somerville, New Jersey, USA), as a shuttle suture, and then secured over Attachable Button System (ABS) (Arthrex, Naples, FL) Figure 2. Multiple knee cycling is routinely performed to add more tension to the construct.

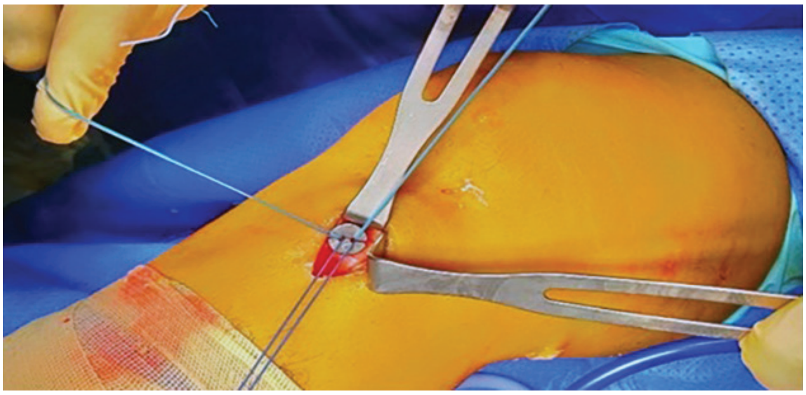

FIGURE 2. Attachable Button System (ABS) (Arthrex, Naples, FL) is fixed on the intact medial tibial cortex. The graft sutures free ends and the FiberTape® are passed through ABS button to be tightened independently.

Final sutures fixation steps are performed in the following sequence: Firstly, the free ends of the FiberTape® are sutured manually whilst the knee is in full extension. Secondly, the free ends of graft's sutures are fixed whilst the knee in 30-degree flexion. Finally, more graft tension is achieved through the femoral Tightrope® and all the construct is checked arthroscopically ensuring that the FiberTape® is slightly more lax than the graft after final tensioning figure 3. This is a modification of the original technique where the fiber tape is fixed by knotless anchor. Tensioning of the graft depends on tight manual fixation of both graft's sutures and FiberTape® free ends over ABS button on tibial side by the same surgeon. More tensioning is achieved by final femoral Tightrope® sutures shortening.

Postoperatively, full range of motion is allowed with full weight-bearing as tolerated once the patient demonstrates a well-functioning quadriceps muscle and good leg control. Closed chain strengthening exercise is emphasized and return to full activity is allowed between 6 to 9 months postoperatively.

Randomization and power analysis

Power analysis was performed using MedCalc1 Statistics Software v.15.8 (bvba, Ostend, Belgium) with a 20 subjects sample size for each group. 44 patients received for intervention and were classified by computer-generated randomization into 2 groups using Random Allocation Software V.4.5 (Asfahan, IR): (Group I) "Brace group" and (Group II) "non-Brace group". Unfortunately, 2 patients were lost during their early follow up due to COVID- 19 outbreak.

Statistical analysis

Collected data was stored in Microsoft Excel (2010; Microsoft Corp.), and analyzed using IBM® SPSS® Statistics version 23. Data was subdivided to parametric and non-parametric data using Kolgomorov and Shapiro tests.

Date was expressed as Mean±SD for quantitative measures (Lachmeter, IKDC score, Lysholm score, ROM, demographic data) and in both number and percentage for categorized data (pre-pivot test, pre-Lachman test).

The following tests were done:

1. Comparison between two independent mean groups for parametric data using Student t test.
2. Comparison between two independent groups for non-parametric data using Mann-Whitney U test.
3. Chi-square test to study the association between each 2 variables or comparison between 2 independent groups as regards the categorized data.

The degree of change during follow-up variable (delta change or dC) reflects the actual mathematical difference that

FIGURE 3. Intra-operative arthroscopic view from viewing anterolateral portal showing tightened graft and a slightly lax fiber tape while the knee in 300 flexion..

happened during the follow-up period (0 – 9 months postoperative) and can be calculated for each patient, from which, the mean delta change can be compared with other group or correlate with other variables. It is defined as follow: Delta change (dC) = (Post-Pre)/Pre. The probability of error at 0.05 was considered significant.

Results

The mean duration of follow up in our study was 18±3.4 months (range: 12-24 months). All patients were males, mean age of 29.9±5.1 years (range: 22-35 years) for Group I and the mean age of 26.7±4.09 years (range: 22-35 years) for group II. There was no significant difference between both groups regarding demographic data (age, side of injury, time since injury) Table 1 and initial manual assessment tests (pre-pivot test, pre-lachman test) Table 1.

Patient reported outcomes PROs (IKDC score, Lysholm score) and the objective knee laxity measurement by Lachmeter were reported at preoperative time, immediate postoperative and 3,9 months postoperative. There was no significant difference between the two groups at initial assessment (Lachmeter for non-injured knee and Preoperative IKDC) (P values are .87 and .819 respectively). As a reference value, Lachmeter test was done for the injured knee immediately postoperative and labeled as Lachmeter 0, which showed no significant difference between the two groups (P value .5). At 3-month postoperative assessment, laxity assessment showed significant difference between the two groups (P value .000) to be lower in Brace group, but it was insignificant regarding IKDC and Lysholm scores (P values .696 and .171 respectively). At 9-months postoperative assessment, Lysholm score showed significant difference between the two groups (higher in Brace group) and Lachmeter examination (lower in Brace group) (P values .000 and .000 respectively). However, it was not significant regarding IKDC score (P value .239) Table 2.

Table 1. Demographic characteristics of included patients and initial manual assessment

	Brace group	Non-brace group	P value
N	21	20	------
Age (years)[a]	29.9 ± 5.1(range: 22-35)	26.7 ± 4.09 (range: 22-35)	0.477
Side of injury	Right (18), Left (3)	Right (9), Left (11)	0.516
Time since injury (months)a	8.57 ± 9.91 (range: .6-36)	8.94 ± 4.91 (range: 2-15)	0.500
Pre-pivot test			
Grade 1 [b]	2 (10%)	3 (15%)	0.010 *
Grade 2 [b]	12 (57%)	11 (55%)	
Grade 3 [b]	7 (33%)	6 (30%)	
Grade 4 [b]	0 (0%)	0 (0%)	
Pre-Lachman test			
Grade 1[b]	1 (5%)	1(5%)	0.100
Grade 2[b]	13 (62%)	12(60%)	
Grade 3[b]	7 (33%)	7 (35%)	
Grade 4[b]	0 (0%)	0 (0%)	

[a] Values are expressed in terms of (Mean ± SD (Range)); [b] values are expressed in terms of (Count(%)); *Significant at p<0.05 level.

Range of motion (ROM) was measured throughout the study at preoperative time and 3,9 months postoperative. Normal ROM is considered from 0 (full extension) to 135 knee flexion. There is no significant difference between the two groups in pre-ROM, 3,9 months postoperative (P values .851,.431,.133 respectively) (Table 3).

Delta change or (dC) was tested extensively throughout the three main outcomes in this study (Lachmeter, IKDC score,

Table 2. Lachmeter Test and PROs (IKDC, Lysholm)

	Brace group	Non-brace group	P value
Lachmeter test			
Normal side Lachmeter	1.98 (1.87-2.08)	2.09 (1.97-2.21)	0.870
Injured side Lachmeter	5.55 (5.08-6.02)	6.9 (6.1.3-7.66)	0.001*
Lachmeter 0	1.96 (1.88-2.04)	2.13 (2.02-2.25)	0.560
Lachmeter 3	1.98 (1.89-2.07)	2.3 (2.19-2.4)	0.000*
Lachmeter 9	2.14 (2.06-2.22)	2.81 (2.52-3.09)	0.000*
IKDC score			
Pre-operative	49.7 (47.3- 52)	50.5 (47.9-53.2)	0.819
IKDC 3	68.9 (67.3-70.4)	68 (65.3-70.7)	0.696
IKDC 9	90.6 (89.6-91.5)	88.2 (85.3-91)	0.239
Lysholm score			
Pre-operative	51.3 (48.6-53.9)	60.9 (58.1-63.7)	0.000*
Lysholm 3	74.5 (71.5-77.5)	70.6 (68-73.2)	0.171
Lysholm 9	94 (92.4-96.5)	89 (85.7-92.2)	0.000*

Values are expressed in terms of (Mean (95% CI)), *Significant at p<0.05 level.

Lysholm score). There is no significant difference between the two groups regarding dC IKDC 0-9 months and dC Lysholm 3-9 months (P values .819, .919 respectively). However, there was significant difference in the following parameters: dC IKDC 3-9 months, dC Lysholm 0-9, dC Lachmeter 0 – 9 months and dC Lachmeter 3 - 9 months (P values .001, .001, .001, .000, .001 respectively) Table 3.

Finally, the only reported failed ACLR case was one patient in the non-Brace group. The reported traumatic event was knee twisting injury inside home at 9 months postoperative.

Table 3: Range of Motion (ROM) Assessment and Delta Change (dC) Assessment

	Brace group	Non-brace group	P value
Range of motion (ROM)			
Pre-operative ROM	131 (126.2-135.7)	133 (131.6-135)	0.851
ROM 3	100.2 (97.3-103.1)	102 (99-104)	0.431
ROM 9	129.7 (127.2-132.2)	126.9 (124.3-129.5)	0.133
Delta change (dC) assessment			
dC Lachmeter			
0 -9 months (injured side)	0.09 (0.06-0.11)	0.32 (0.18-0.46)	0.000*
3 – 9 months (injured side)	0.09 (0.06-0.11)	0.32 (0.18-0.46)	0.001*
dC IKDC score			
0-9 months	0.84 (0.75-0.94)	0.55 (0.47-0.64)	0.819
3-9 months	0.31 (0.28-0.35)	0.22 (0.18-0.26)	0.001*
dC Lysholm score			
0-9 months	0.86 (0.72-0.99)	0.46 (0.38-0.54)	0.001*
3-9 months	0.26 (0.22-0.31)	0.26 (0.20-0.33)	0.919

Values are expressed in terms of (Mean (95% CI)), *Significant at p<0.05 level.

This failure was confirmed by clinical examination and MRI examination. Revision surgery was performed 3 months later, and the failed graft was elongated and lax throughout its intra-articular course. Another case in non-Brace group suffered from arthrofibrosis 2 months postoperative and improved by arthroscopic arthrolysis. Synovitis occurred in two cases from Brace group at 3, 5 months postoperative which resolved without further surgical intervention. The risk of low-grade infection was excluded by serial normal ESR, CRP and WBCs levels. Only one case in non-brace group was a professional player who returned to sport after one year.

Discussion

All-inside ACLR technique is a well-established technique with several studies to test and review its principles and outcomes (Cerulli, Zamarra, Vercillo, & Pelosi, 2011; Blackman & Stuart, 2014; Connaughton, Geeslin, & Uggen, 2017). To our knowledge, no published study used an objective tool to judge the results and compare them with functional outcome.

The used graft tensioning sequence depends on the fact that knee joint space experienced consistent length decreases of 1 mm at 30o flexion (Li, Defrate, Rubash, & Gill, 2005; Bachmaier et al., 2018).Therefore, fixing the graft in 30o flexion will make it shorter by 1 mm than the brace that is fixed in full extension. This is ideal to prevent brace stress shielding and promotes graft ligamentization. This is aided by the fact that graft and suture tape are fixed "independently" as each has its own knot over ABS button. Final tensioning from femoral adjusts any loosening after manual tibial fixation and to standardize construct tension (Smith, Bradley, Konicek, Bley, & Wijdicks, 2020). This could be an alternative sutures fixation technique that depends on innate knee kinematics instead of using hemostat as Patrick et al described (Smith & Bley, 2016) to prevent brace- graft stress shielding. The demographic data in both groups showed no significant difference and this omit any influence of these factors on the results.

The core value in this study is an objective measurement of knee laxity using the Lachmeter whose higher value (higher mean) indicate more laxity. The used validated scores scale from 0 to 100, where score 100 is the best outcome in both scales. Functional scores were not conclusive regarding difference; as only Lysholm score 9 months postoperative was significant and its mean was higher (better) in brace group. Additionally, 3, 9 months postoperative Lachmeter assessments showed significant difference between groups with lower means (less laxity) in brace group. These functional scores are consistent with Parkes CW et al. results (Parkes et al., 2021).

Do these reported values change enough to make a real difference? In functional scores assessment; the higher the dC the better outcome at the end point. On the other hand, in Lachmeter examination the lower the dC the better outcome and less laxity at the end point. This is judged via means values across the two groups. IKDC score showed significant change in 3-9 months interval. Whereas Lysholm score was significant in 0-9 months interval. Both have higher mean scores in brace group. Furthermore. Lachmeter examination dC was significant in both tested intervals (0-9 months, 3-9 months postoperative) with lower mean dC in brace group (less laxity) as shown in Table 3. This last finding could potentiate the principle "safety belt" as suture tape augmentation ACLRs statistically showed less laxity at 9- month postoperative.

Finally, the reported knee effusion in brace group may raise the question about suture tape material biocompatibility. However, this case was treated conservatively and did not need any further intervention. On the other hand, the only failed case that was in non-brace group, occurred at 9 months postoperative, have a great influence in understanding the importance of bracing the vulnerable graft during the ligamentization period. This is supported by the fact that without technical error, biological failure is the chief type of failure in early ACLR operations (George, Dunn, & Spindler, 2006).

Limitations

The operated cases were middle aged persons without professional sports involvement. Thus, return to sport entity was not well presented. The correlation between detailed operative data such as graft thickness and type was not conducted and compared .

Conclusion

All-inside ACLR technique with hamstrings autograft and independent suture tape augmentation showed better outcomes regarding objective knee laxity testing at 9 months postoperative and lower failure rate when compared to the same technique without independent suture tape augmentation. However, the subjective functional outcomes show no suture tape augmentation superiority.

Recommended further studies

This study protocol and methodology could be more informative if conducted over larger study group of professional athletes to find out the actual efficacy of suture tape augmentation technique to protect ACL grafts.

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Conflict of Interest
The author declares that there is no conflict of interest.

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ORIGINAL SCIENTIFIC PAPER

Association Between Hamstrings' Eccentric Strength and Sprint Performance in Football Players

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Abstract

Sprint is essential for successful sport performance. Acceleration is necessary for every position in football. The ability to successfully accelerate is also an important determinant for more carried gaming activities. The eccentric strength of the hamstrings is an important task in sprint. The aim of our study was to test the correlation between the 30 m sprint and the eccentric strength of the hamstring by NordBord. The sample consisted of 48 professional football players (23.15±4.78 yr.; 180.5±5.42 cm; 76.5±7.94 kg) of the highest Slovak football league. The correlation between 30 m performance and average eccentric hamstring strength has been -0.0826. The correlation suggests that the sprint speed and eccentric strength of the hamstrings have not been associated 0 (t=-0.5619; df=46; p=0.5769). Correlation between 30 m performance and AVG/kg was -0.1317, indicating that the correlation between average weight and speed was not been significant. The eccentric strength has not been associated with a higher speed in the 30-m sprint test. However, more intervention studies are warranted.

Keywords: *speed, eccentric muscle strength, hamstring, football*

Introduction

Football is one of the most popular sports. Movement of the football player is composed of more components, including jogging, running, and sprinting. During a match, an elite football player runs approximately 10-11 km, of which 25-27% is walking, 37-45% is jogging, 6-8% is backward running, 6-11% is sprinting and the rest 20% is movement in solving individual game activities (Dolci et al., 2018). Successful performance in football depends on physiological, nutritional, technical, tactical, social and psychological parameters (Gonçalves et al., 2014; Randers et al., 2018)modified training impulse, body load and movement behaviour between defenders, midfielders and forwards, during an 11-a-side simulated football game. Twenty elite youth male footballers from the same squad participated in this study (age: 18.1 ± 0.7 years old, body mass: 70.5 ± 4.3 kg, height: 1.8 ± 0.3 m and playing experience: 9.4 ± 1.3 years. Sprint is a significant part of overall performance. The ability of a football player to sprint significantly interferes with the successful completion of gaming activities. Every position of a football player requires acceleration. The ability to accelerate successfully is also an important determinant of several tactically performed gaming activities. The eccentric strength of the hamstrings plays an important role in sprinting (Stanton & Purdam, 1989). Sprint biomechanics requires significant activation of eccentric muscle strength during the swing phase. Sprinting is essential for successful sports performance. Sprint in football consists of alternating concentric and eccentric muscle activity, especially of the lower limbs. However, the involvement of a large number in muscles of the whole body is required for sprinting in football (Howard et al., 2018). Biomechanical variables that affect sprint include reaction time, technique, force production, neuromuscular factors, and muscle architecture. The technique represents the sprinter's ability to accelerate by increasing stride length and stride speed. High neuromuscular muscle activity during the acceleration phase means that the sprinter can reach its maximum nerve activity during the acceleration phase, which subsequently decreases (Higashihara et al., 2015). Sprint requires

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a comprehensive sequence of muscle activation throughout the body. Several types of exercises are used in speed training for athletes. Eccentric exercise is known to be important in injury prevention (van der Horst et al., 2015). Theoretically, the resulting increased hamstring power and neuromuscular activity could improve sprint performance and help a football player accelerate his performance. Therefore, the objective of our study is to test the correlation between the 30-m sprint and the eccentric muscle strength of the hamstrings.

Methods

The sample consisted of 48 football players of the highest Slovak football league (23.15±4.78 yr.; 180.5±5.42 cm; 76.5±7.94 kg). Research was carried out in February 2020 after finishing the first part of the preparation season. The criteria for the inclusion of football players have been the following: age over 17, participation in the highest national league, regular participation in training. Research has not conducted players younger than 17 years of age, with injury of the muscular system or acute infection.

Subsequently, all athletes have undergone a 30 m linear sprint test measured by Witty Microgate photocells. Microgate Polifemo photocells work as a coaxial optical system. Additionally, the Polifemo line employs an intelligent link to the timer using the standard 2-wire banana connection. NordBord has implemented a maximum eccentric hamstring test (Figure 1). The NordBord Hamstring Testing System is a device based on measurement of eccentric and isometric hamstring strength. NordBord was invented by Vald Performance company established in Australian Newstead. The majority of NordBord consists of an area for athletes to kneel on. Once kneeling, athletes insert their ankles into padded ankle hooks and then perform a movement to measure eccentric and isometric hamstring strength. Ankle hooks include a sensor which measures the force of muscle activity (in Newtons). NordBord sensors must be in a perpendicular position towards the ground for successful test completion. The NordBord device allows testing of eccentric and isometric muscle activity. NordBord also allows testing in other positions, such as Razor Curl. The main advantage of NordBord is that testing is performed quickly.

Testing process

Before testing, all athletes have undergone a uniform form of warm-up, according to the RAMP protocol (Raise - Activation - Mobilization - Potentiation) with a duration of 15 minutes. Collective warm-up has been followed by individual 5-minute warm-up and the start of the test. The 30 m distance has been labeled by photocells (as well as 5 m, and 10 m, 15 m) and set at the average height of the hip joint. The starting line has been located 0.5 meters in front of the position of the first photocell, where the players have started on their own initiative. The test has been performed on artificial grass and each athlete has had 2 attempts to give their maximum performance. Immediately after passing the sprint test, the NordBord device measured the eccentric force of the hamstrings.

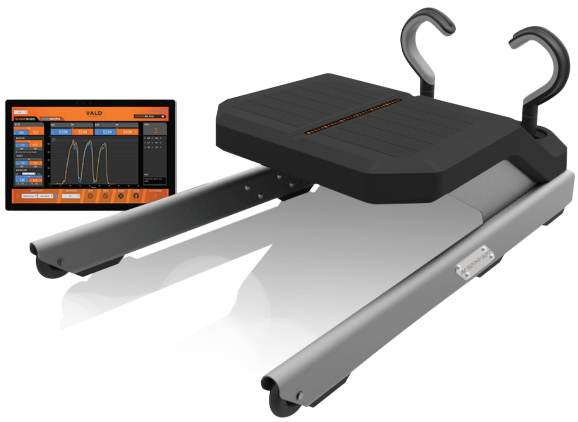

FIGURE 1. NordBord Hamstring Testing system

For research purposes, the maximum strength (N) (average of the lower limbs) that a player has been able to generate according to the sensors has been recorded. To determine the relative strength of the hamstrings, the obtained data were divided by the weight and athlethes' BMIs.

Before performing the test, itself, the athletes were in-

FIGURE 2. NordBord Testing

formed about its optimal design, pointed out its specifics, and showed the demonstration. After taking the correct position in the scoreboard section, the information about the position of the knees has been filled in, the sensors have been switched on, and the testing using the appropriate device with iOS software has started. The tested athletes have had a preview of the current test progress visible on the iPad screen throughout the testing. Athletes were required to maintain their knee, lumbar, and shoulder joints level for successful movement performance throughout implementation of the Nordic Hamstring Eccentric Test. In case of deviation from the optimal technique, increased attention has been paid to the athlete during the testing, resp. the test has had to be repeated. The players performed two repetitions of the required technical design.

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants involved in the study.

Statistical analysis

Pearson's correlation has been used for statistical processing. The correlation relationship between the variables has been clarified using a correlation matrix and graphically. For selected dependencies of variables, a graphical representation has been created using separate diagrams. Using the significance test of the correlation coefficient, it was tested whether the correlation between the 2 variables differs significantly from 0 or not. The distribution of the measured data, the regression curve, and the confidence interval of the regression curve are visible in the diagrams. In addition, for the individual axes, there is a box diagram according to the frequency of the occurrence of data on the axis. A significance level has been used, which is equal to α=0.05. A correlation analysis has been used via RStudio statistical software.

Results

The eccentric strength of the hamstrings has not been correlated with the higher sprint speed on the right side (r=-0.04; p>0.05) and on the left side (r=-0.13; p>0.05). No high level of correlation has been discovered, not even between BMI and the eccentric strength (r=0.4; p=0.118). A higher correlation rate has been discovered between eccentric strength and weight (r=0.48; p=0.019). The weight of the football players on the right side has not been associated with a sprint speed of 30 m (r=0.61; p<0.001) and on the left side (r=0.58; p<0.001). Another factor that has not been linked to hamstrings' eccentric strength of the hamstrings was age

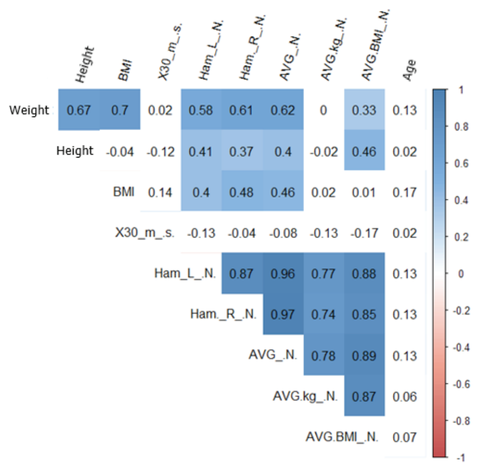

FIGURE 3. Correlation matrix

(r=0.13; p>0.05).

Part of the diagram is the value of the correlation coefficient, its significance, and a graphical representation of the variables in pairs, by pair comparison.

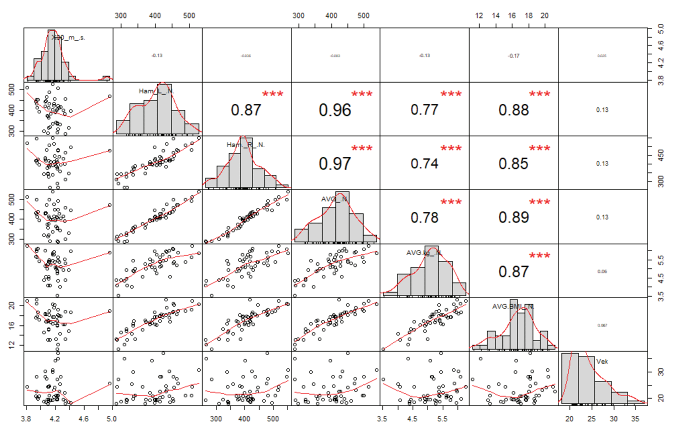

FIGURE 4. Hamstrings' eccentric strength with more factors

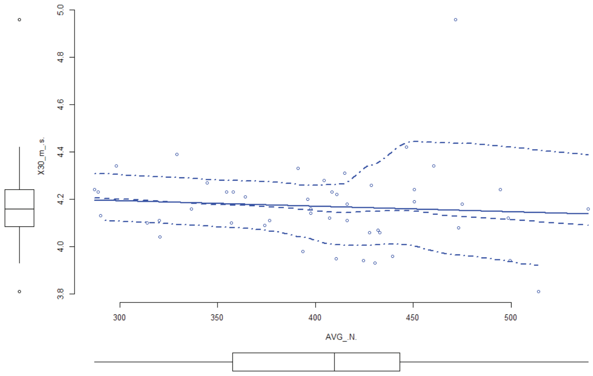

FIGURE 5. Comparison of 30m (s) and AVG (N)

Pearson's correlation between 30 m performance and AVG is -0.0826. The significance test of the correlation coefficient indicates that the sprint speed and the magnitude of the eccentric force of the hamstrings have not been associated with 0 (t=-0.5619; df=46; p=0.5769).

Pearson's correlation between 30 m performance and

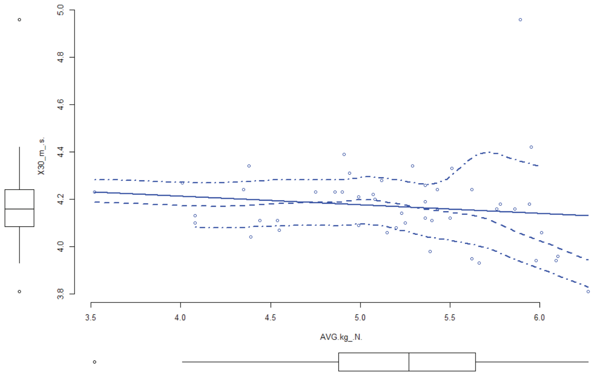

FIGURE 6. Comparison of 30 m (s) and AVG/kg (N)

AVG/kg is -0.1317, indicating that the correlation between average weight and speed is not significant. The test of significance of the correlation coefficient is equal (t=-0.90125; df=46; p=0.3722).

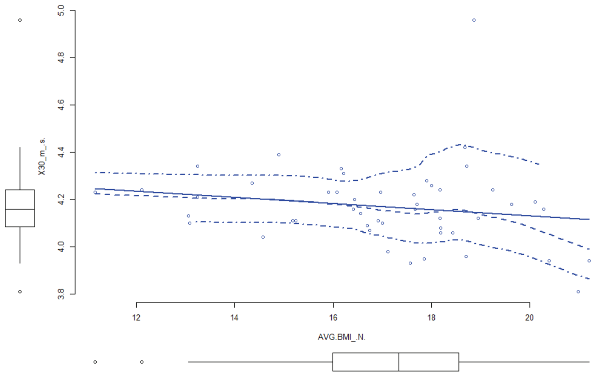

FIGURE 7. Comparison of 30 m (s) and AVG/BMI (N)

Pearson's correlation between 30 m performance and AVG/BMI is -0.1748, which means that the correlation value is only low. The significance of the correlation coefficient is equal to 0 (t=-1.2042; df=46; p=0.2347).

Pearson's correlation between age and AVG is 0.0248, which means that the 2 variables compared are independent. The significance of the correlation coefficient is equal to 0 (t=0.16802; df=46; p=0.8673). The combination of Pearson correlation coefficients and correlation coefficients' tests of significance can be given in one summary table (Table 1). Table 1 provides, among other information, the correlation coefficients, and the result of the correlation test (95% confidence interval and p values) for all pairwise comparisons of variables. Correlations of which p value (in the column named "p") is lower than a significance level 0.05, significantly differing from 0. In the last column, the level of significance has been marked with the number of stars.

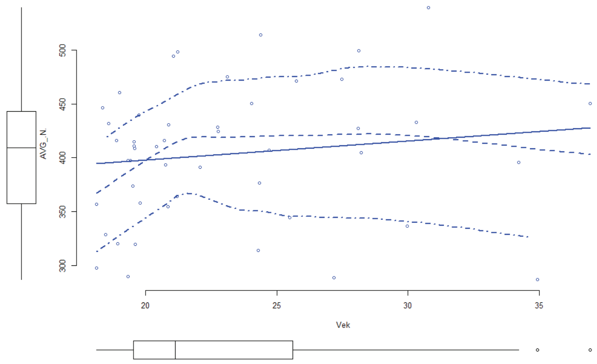

FIGURE 8. Comparison of Age and AVG (N)

Table 1. Comparison of Age and AVG (N)

Parameter1	Parameter2	r	95% CI	t(46)	p	Significance
Weight	Height	0.67	[0.48, 0.80]	6.13	<.001	***
Weight	BMI	0.70	[0.52, 0.82]	6.66	<.001	***
Weight	30m (s)	0.02	[-0.26, 0.30]	0.15	>.999	
Weight	Ham L (N)	0.58	[0.35, 0.74]	4.81	<.001	***
Weight	Ham R (N)	0.61	[0.40, 0.77]	5.29	<.001	***
Weight	AVG (N)	0.62	[0.40, 0.77]	5.32	<.001	***
Weight	AVG/kg (N)	-0.0045	[-0.29, 0.28]	-0.03	>.999	
Weight	AVG/BMI (N)	0.33	[0.05, 0.56]	2.40	0.474	
Weight	Age	0.13	[-0.16, 0.40]	0.87	>.999	
Height	BMI	-0.04	[-0.32, 0.25]	-0.27	>.999	
Height	30m (s)	-0.12	[-0.39, 0.17]	-0.83	>.999	
Height	Ham L (N)	0.41	[0.14, 0.62]	3.01	0.115	
Height	Ham R (N)	0.37	[0.10, 0.59]	2.71	0.227	
Height	AVG (N)	0.40	[0.13, 0.61]	2.96	0.121	
Height	AVG/kg (N)	-0.02	[-0.30, 0.27]	-0.11	>.999	
Height	AVG/BMI (N)	0.46	[0.21, 0.66]	3.55	0.026	*
Height	Age	0.02	[-0.27, 0.30]	0.13	>.999	
BMI	30m (s)	0.14	[-0.15, 0.41]	0.99	>.999	
BMI	Ham L (N)	0.40	[0.13, 0.62]	2.98	0.118	
BMI	Ham R (N)	0.48	[0.22, 0.67]	3.66	0.019	*
BMI	AVG (N)	0.46	[0.20, 0.65]	3.47	0.032	*
BMI	AVG/kg (N)	0.02	[-0.26, 0.30]	0.14	>.999	
BMI	AVG/BMI (N)	0.00623	[-0.28, 0.29]	0.04	>.999	
BMI	Age	0.17	[-0.12, 0.43]	1.18	>.999	
30m (s)	Ham L (N)	-0.13	[-0.40, 0.16]	-0.87	>.999	
30m (s)	Ham R (N)	-0.04	[-0.32, 0.25]	-0.25	>.999	
30m (s)	AVG (N)	-0.08	[-0.36, 0.21]	-0.56	>.999	
30m (s)	AVG/kg (N)	-0.13	[-0.40, 0.16]	-0.90	>.999	
30m (s)	AVG/BMI (N)	-0.17	[-0.44, 0.12]	-1.20	>.999	
30m (s)	Age	0.02	[-0.26, 0.31]	0.17	>.999	
Ham L (N)	Ham R (N)	0.87	[0.78, 0.93]	12.13	<.001	***
Ham L (N)	AVG (N)	0.96	[0.94, 0.98]	24.79	<.001	***
Ham L (N)	AVG/kg (N)	0.77	[0.62, 0.86]	8.16	<.001	***
Ham L (N)	AVG/BMI (N)	0.88	[0.79, 0.93]	12.48	<.001	***

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Table 1. Comparison of Age and AVG (N)

Parameter1	Parameter2	r	95% CI	t(46)	p	Significance
Ham L (N)	Age	0.13	[-0.16, 0.40]	0.92	>.999	
Ham R (N)	AVG (N)	0.97	[0.95, 0.98]	27.40	<.001	***
Ham R (N)	AVG/kg (N)	0.74	[0.58, 0.85]	7.54	<.001	***
Ham R (N)	AVG/BMI (N)	0.85	[0.74, 0.91]	10.77	<.001	***
Ham R (N)	Age	0.13	[-0.16, 0.40]	0.86	>.999	
AVG (N)	AVG/kg (N)	0.78	[0.64, 0.87]	8.47	<.001	***
AVG (N)	AVG/BMI (N)	0.89	[0.81, 0.94]	13.26	<.001	***
AVG (N)	Age	0.13	[-0.16, 0.40]	0.92	>.999	
AVG/kg (N)	AVG/BMI (N)	0.87	[0.78, 0.93]	12.06	<.001	***
AVG/kg (N)	Age	0.06	[-0.23, 0.34]	0.41	>.999	
AVG/BMI (N)	Age	0.07	[-0.22, 0.34]	0.45	>.999	

Note AVG = average; Ham L = hamstrings' strength (left leg); Ham R = hamstrings' strength (right leg); r

Discussion

In the study, the eccentric strength has not correlated with the sprint speed according to the 30-m sprint. A potential explanation may be that an isolation of one factor that would relate to the speed is difficult (Nikolaidis et al., 2016). In our study, a low correlation between the eccentric strength and speed has been observed according to the 30 m sprint. The speed of a football player is made up of several factors that can contribute to a higher speed of a football player. The critical factors that have been correlated together were weight and eccentric strength. This can be explained by the design of the device due to the effect of weight on the optimal performance of the Nordic hamstring exercise with the NordBord device. The inability to take the athlete's weight into account may result in distortion results in terms of the eccentric strength. An athlete with a lower weight is more likely to have a lower eccentric final hamstring strength than an athlete with a higher weight. However, it is not the rule that the athlete with the higher weight will have the strongest eccentric hamstring strength. Another important limitation was correlation testing and not intervention by footballers. The correlation indicates the possible association of two or more variables.

The benefit of performance improvement is better to be verified with intervention studies aimed at improving the speed of footballers. When measuring the eccentric strength on the NordBord, the athlete performs a Nordic hamstring exercise. The effectiveness of the Nordic hamstring to sprint speed has been tested by Ishoi et al. (I2018). The exercise protocol lasted 10 weeks. The group consisted of 35 footballers, who were divided into an intervention group (n-18) and a control group (n-17). The intervention group has improved its eccentric hamstring strength (62.3 N, p=0.006, d=0.92). The effectiveness of Nordic hamstring exercise has also been tested in a study by Krommes et al. (Krommes et al., 2017). The group consisted of 19 football players with the Nordic hamstring exercise, which was included 27 times in the training unit. An improvement in short-distance sprint performance has been recorded in the intervention group compared to the control group. A smaller decrease in sprint speed has been recorded after 30 m. Counter movement jump (CMJ) has improved in both groups. According to Krommes et al., the use of eccentric exercises does not lead to worsening of football players and, on the other hand, it can be beneficial in improving explosive abilities.

Siddle et al. (Siddle et al., 2019)10m sprint speed, and change-of-direction (COD have tested the acute effect of Nordic hamstring exercise on speed and strength. The group consisted of 14 footballers, who were randomly divided into an intervention group (n-7) and a control group (n-7). An improvement in eccentric strength has been observed in the intervention group (31.81 Nm-1 vs 6.44 Nm-1, P=0.001) speed according to the change of direction test (-0.12s vs. 0.20 s; p=0.003) and the sprint (-0.06 s). vs. 0.05 s; p=0.024). The aim of the study by Mendiguchia et al. (2020) was to compare the effect of eccentric exercise with sprint training on sprint performance and its mechanical foundation, as well as on the architecture of the long head of the biceps femoris. The group consisted of 32 footballers, who completed a 6-week programme before the season - the „soccer group" (n =10), the „nordic group" (n=12), and the „sprint group" (n=10). The most significant changes occurred in the 'Sprint group'; small negative changes have been recorded in the 'Soccer group' and 'Nordic group'. In the group that underwent sprinting exercises, the training has led to an extension of the muscle fascicles of the hamstrings. In the group practicing the Nordic hamstring, an increase according to the pennation angle. Sprint training was more effective than eccentric exercise in improving speed. Freeman et al. (2019) have also tested the effectiveness of the Nordic hamstring to sprint speed and the size of the eccentric strength has also been tested by Freeman et al. (2019). The group consisted of 28 athletes, who have been randomly divided into a group that practiced sprint training and a group that underwent eccentric Nordic hamstring exercises. Improvements have been observed in eccentric muscle strength (ES=0.39, P<0.05) and sprint speed (ES=0.29, P<0.05) have been observed in both groups. The meta-analysis by Cuthbert et al. (2020) has tested the effect of the Nordic hamstring on the size of the eccentric muscle strength and the hamstring architecture. Thirteen studies have been included in the analysis. An improvement in the hamstring eccentric strength has been reported in athletes. Similar results have been reported for changes in fascicle length (g 2.58) and a large-to-very large positive reduction in pennation angle (g≥1.31). The differences have been estimated to be of magnitude of 0.374

(p=0.009) for strength and 0.793 (p<0.001) for architecture. A meta-analysis by Seitz et al. (2014)whether increases in lower-body strength transfer positively to sprint performance remain unclear.\nOBJECTIVES: This meta-analysis determined whether increases in lower-body strength (measured with the free-weight back squat exercise has evaluated the association between increased lower limb muscle strength and speed. The analysis has included 15 studies (n-510). An increase in lower limb strength has been associated with an increase in athlete speed (r=-0.77; p=0.0001). The effectiveness of eccentric muscle exercise is known from the point of view of preventing hamstring injury. The aim of the study by Van der Horst et al. (2015) was to test the effectiveness of Nordic hamstring exercise on the incidence and severity of hamstring injuries. The intervention group consisted of 292 football players and the control group consisted of 287 football players. The Nordic hamstring exercise lasted 13 weeks. There has been a significant reduction in the incidence of hamstring injuries in the regular exercise group, but Nordic hamstring exercise has not affected the severity of the injury. The effectiveness of Nordic hamstrings on prevalence and incidence has also been tested by Petersen et al. (2011) who have tested 461 footballers compared to 481 footballers who did not train Nordic hamstrings. The exercise lasted for 10 weeks. There were 52 hamstring injuries in the control group and 15 injuries in the intervention group. According to Petersen et al., the inclusion of eccentric exercises leads to a significant reduction in hamstring injuries. The purpose of the study by Líška et al. (2019)which is associated with significant economic costs and high demand for sport rehabilitation. Exercise for eccentric muscle strength of the posterior thigh muscles plays an important role in prevention. Objective: The main goal of our study is to compare eccentric muscle strength of the posterior thigh muscles in elite hockey players and elite football players, and also to identify the risk of injury in both groups. Methods: NordBord Hamstring Testing System is an equipment designed to measure eccentric and isometric strength of hamstrings. Nordbord's main focus is on the eccentric muscle strength in exercise which is called Nordic Hamstring. Sample: Our sample included professional hockey players (n = 30 was to test the size of the eccentric muscle strength in professional hockey players and football players. The tested group consisted of 30 professional hockey players and 30 football players. The average values of eccentric muscle strength in hockey players were 419.8 N on the left hamstring and 420.9 N on the right hamstring. For football players, the average values of eccentric muscle strength have reached the following values: left hamstring 419.6 N, right hamstring 428.6 N. There were no statistically significant differences between football players and hockey players in terms of the size of the eccentric strength.

Conclusion

The hamstrings' eccentric strength has not been associated with a higher speed in the 30 m sprint test. However, more intervention studies are warranted.

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Conflict of Interest
The author declares that there is no conflict of interest.

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ORIGINAL SCIENTIFIC PAPER

Fitness Profiling in Top-Level Youth Sport Climbing; Gender Differences

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Abstract

Sport climbers should possess specific anthropometric characteristics and conditioning capacities to reach a top level in this sport. PURPOSE: The purpose of this study was to determine gender differences in the fitness status of the top-level youth sport climbers. METHODS: The study was conducted on 20 elite Croatian youth sport climbers (all members of the national team, ten females; 13-18 years of age). The variables included anthropometric status (mass, height, arm span, and body fat percentage), generic- (countermovement- and squat-jump, grip strength), and specific-fitness tests (power slap test and Draga foot lift). RESULTS: Boys were taller than girls (t-test=2.51, p=0.02, moderate effect size (ES)), and had lower body fat percentage (t=-5.66, p=0.001, very large ES). Boys achieved better results in countermovement- (t=5.39, p=0.001, very large ES) and squat-jump (t=2.19, p=0.04, moderate ES), while there were no gender differences in the specific fitness tests. CONCLUSION: Gender differences were observed in generic but not in specific fitness, which may indicate that climbing is a specific sport that requires and develops specific abilities in a similar way in boys and girls.

Keywords: *climbers, generic tests, sport-specific tests, conditioning capacities, youth athletes*

Introduction

Sport climbing is a new Olympic sport that involves climbing variable rocks using only the athlete's body (Sanchez et al., 2019). According to international standards, professional sport climbers compete exclusively on artificial walls. The popularity of sport climbing is growing rapidly; according to the International Federation of Sport Climbing (IFSC), 35 million people worldwide participate in sport climbing (International Federation of Sport Climbing, 2015). Sport climbing is a polystructural acyclic activity that requires specific psycho-tactical, physiologic-anthropometrical, and coordination-technical aspects for successful performance (Magiera et al., 2013).

Previous studies point to multiple characteristics that define performance in elite sports climbers (Fuss & Niegl, 2010; Michailov et al., 2015; Assmann et al., 2020). Anthropometric parameters like body mass, height, arm span, forearm diameter, and body fat percent are essential determinants of climbing success (Laffaye, Collin, et al., 2014). Specifically, according to MacKenzie et al. (2020), low body fat percentage is the anthropometric parameter that correlates with success the most. In a study by Laffaye et al. (2016), better climbers had higher ape index (arm span to height ratio). However, general fitness tests (Countermovement jump, isometric Sorensen test, Bench press test) showed no connection to climbing performance, associated with success or gender (Laffaye, Collin, et al., 2014). Nevertheless, handgrip strength to body mass ratio is the only general fitness predictor of sport climbing success (Laffaye et al., 2016; Assmann et al., 2020).

It is generally accepted that climbing-specific tests are good predictors of climbers' performance and can differen-

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tiate them based on their success (Saul et al., 2019; Draper et al., 2021). One parameter that differentiates elite climbers from the general population and novice climbers is finger strength and forearm flexor endurance (MacLeod et al., 2007). Namely, sport climbing requires constant and long-term loading of the finger and forearm flexors. Therefore, the endurance of the se muscle groups is one of the most important factors for climbing performance (Valenzuela et al., 2015). The endurance of shoulder girdle muscles is also connected with climbing success (MacKenzie et al., 2020). Modern competitive climbing requires various dynamic-acrobatic movements and exceptionally difficult motions. For this reasons, climbers must have explosive power and highly developed movement coordination (Fuss & Niegl, 2010). In addition, better climbers have better hip flexibility and mobility for more efficient movements (Draper et al., 2017). The above parameters are equally important in both genders (Philippe et al., 2012).

In order to objectively define the state of important climbing skills, it is necessary to determine a gender-specific model that athletes strive for in the training process. However, the studies that investigate the gender differences are scarce, and the studies that have been conducted show contradictory results. According to the study of Philippe et al. (2012), there are no differences between male and female elite and high-level performance climbers (21-32 years old) in terms of forearm and finger flexor muscle fatigue. Furthermore, differences among male and female elite climbers (24-37 years old) were not found in general fitness tests (sit & reach relative handgrip strength) (Espana-Romero et al., 2009). However, Wu et al. (2011) show the results from Chinese elite climbers (23-38 years old), where gender differences in handgrip strength are found (males have better results). Regarding anthropometric characteristics, male climbers had lower body fat percentage, longer arm length, and higher BMI compared to females (Espana-Romero et al., 2009).

From the overview of previous research, it can be seen that most of the studies on anthropometric and fitness determinants were conducted on older climbers (>20 years old) (MacKenzie et al., 2020; Saul et al., 2019). Considering that competitions in sport climbing are held from <10 years old, it is clear that there is a need to determine fitness profiles for younger age categories. Finally, there are few studies that examine gender differences, with contradictory findings (Philippe et al., 2012; Schoffl et al., 2011). This purpose of this study was to determine the gender-specific fitness profile of elite youth sport climbers (13-18 years old). More specifically, it aimed to determine the gender differences in anthropometric, general, and specific measurements of conditioning capacities among top-level youth sport climbers in Croatia (members of the national team). By determining the fitness profile of youth sport climbers, it could be possible to develop better training programs and optimally develop their performance.

Methods

Participants

This study included 20 youth sport climbers aged 13-18 years, all Croatian members of the national climbing team. All climbers were neither ill nor injured during the study. Athletes were informed about the procedures, risks, and aims of the research and signed the informed consent before initiating the study. Parents or legal guardians signed the informed consent for participants under the age of 18. The Ethical Board of the University of Split, Faculty of Kinesiology, Split, Croatia, approved the study (Ref. no:2181-205-02-05-22-001, Date of approval: 05/01/2022).

Variables and procedures

This research included anthropometric variables, as well as generic and specific fitness tests.

Anthropometric variables included body mass (BM), body height (BH), body mass index (BMI) calculated as BMI=BM(kg)/BH(m)2, arm span (AS), ape-index (AS to BH ratio), body fat percentage (BF%) calculated by Durnin and Womersley formula measuring four skinfolds with using Harpenden skinfold calliper (British Indicators, Burgess Hill, England).

Generic-fitness tests included countermovement jump (CMJ) test, squat jump (SJ) test, and handgrip strength (HGS).

CMJ and SJ tests were used for measuring the explosive strength of lower limbs and were assessed by the Optogate System (Microgate, Bolzano, Italy). CMJ was performed by climbers standing upright between two photoelectric beams with hands placed on their hips. They moved downwards with knees bending to approximately 90° and performed maximal upward movement-jump. SJ was conducted in the same setting, but athletes started the jump from a position with approximately 90° bent knees and without any downward movement. Athletes performed three trials for CMJ and SJ, with one-minute rest between the trials and 5 minutes rest between the tests. The best score (cm) from CMJ and SJ was taken for analysis.

HGS was measured by the electronic hand dynamometer Camry (Model EH101, Zhongshan Camry Electronic, China). Athletes were sitting on the chair with arm fully adducted and 90° flexed elbow. The use of the thumb and other hand was not allowed while applying the maximal pressure. Each athlete performed three trials of maximal handgrip pressure with each hand, separated by one minute of rest. The highest produced force from three trials was recorded. Maximal results from both hands were averaged as one score and used for further analysis (Medernach et al., 2015).

Specific fitness tests included: (i) Power slap test (SLAP) and Draga foot lift (DRAGA).

SLAP was used to assess the climbing-specific power of shoulder girdle muscles (Figure 1). The test was performed on the 20° overhang board 150 cm high and on the positive 35 mm deep wooden rung. Before the test initiation, the maximal arm reach was recorded for each hand. The test started with the participants hanging on the rung with straight arms and legs off the ground. The climber had to perform an explosive pull-up and slap with one arm as high as possible (Draper et al., 2021). The test result was calculated by subtracting the supported arm reach from maximal jump height. Participants performed three jumps on each hand, separated by 1.5 minutes of rest between the trials. The highest jump height on each hand was taken in further analysis.

DRAGA was used to evaluate climbing-specific hip joint mobility (Figure 2). Participants stood upright with their back

FIGURE 1. Power slap jump test: starting (A) and ending (B) position.

supported on the gymnastic wall bar and pelvis stabilized with a belt attached to the bar. Participants held their hands on the bar to stabilize their trunks. They performed outside rotation with the foot and maximally raised leg with a bent knee. The result of the test was the distance in centimetres from the ground to the heel of the lifted leg (Draga et al., 2020).

FIGURE 2. Draga foot lift test: starting (A) and ending (B) position.

Testing protocol

Sport climbers were tested during two testing sessions. The first testing session consisted of anthropometric measurements, HGS, CMJ and SJ tests. The second testing session consisted of climbing-specific tests: SLAP and DRAGA. Climbers performed universal warm-up before the climbing-specific tests, which consisted of 5 minutes running, 5 minutes of mobility drills, 5 minutes climbing easy boulders. Prior to the actual testing procedure, climbers underwent familiarization trials. SLAP was first explained, demonstrated and then climbers had two submaximal trials on the left and right hand to get the proper form of the test execution. Similarly, DRAGA was explained, demonstrated and climbers tried twice on each leg to feel the test procedure.

Statistical analyses

The non-uniformity of error was reduced by log-transforming the data. Statistical analyses were conducted on log-transformed data, but the results in the tables are presented as actual values (non-log-transformed). The Kolmogorov Smirnov test tested the normality of the variables. Descriptive statistics (means and standard deviations) were calculated for all variables. T-test for independent samples was calculated to determine gender differences in the studied variables. Additionally, Cohen's d effect sizes (ES) were calculated for gender differences in the studied variables, and they were interpreted as: <0.2 = very small; 0.21–0.49 = small; 0.50–0.79 = moderate; ≥0.8 = large; ≥1.2 = very large ES (Cohen, 2013).

The inter-item reliability was checked for fitness tests by calculating Inter-Item Correlation (IIC) and Cronbach's Alpha (CA) from three testing trials. Additionally, repeated-measures ANOVA was analysed for checking the differences among three trials.

All statistical analyses were performed using Statistica ver.13 (Tibco, Palo Alto, California), and a p-level of 0.05 was applied.

Results

The reliability of the generic and specific fitness variables is shown in Table 1. All fitness variables had very high reliability, with Cronbach's alpha coefficients ranging from 0.95 to 0.99. in addition, repeated-measures ANOVA showed no differences between the testing trials in all tests, except for the CMJ test.

Table 1. Reliability of the fitness variables for the total sample

	Inter-Item correlation	Cronbach's Alpha	ANOVA F-test (p)
Countermovement jump	0.99	0.99	3.84 (0.03)
Squat jump	0.95	0.95	0.21 (0.81)
Handgrip left hand	0.99	0.99	1.58 (0.22)
Handgrip right hand	0.97	0.97	3.12 (0.06)
Power slap left hand	0.99	0.99	3.24 (0.05)
Power slap right hand	0.99	0.99	1.95 (0.16)

Descriptive statistics and differences between male and female climbers are shown in Table 2. Boys are taller than girls (t-test=2.51, p=0.02, ES=1.12), and have lower body fat percentage (t=-5.66, p=0.001, ES=2.53). Boys performed better in the countermovement (t=5.39, p=0.001, ES=2.41) and squat jump (t=2.19, p=0.04, ES=0.98). There were no differences between male and female climbers in specific motoric tests.

Table 2. Descriptive statistics (means and standard deviations) and gender differences in anthropometric characteristics and fitness indices.

	Boys		Girls		t-test	
	Mean	SD	Mean	SD	t-value	p
Body mass (kg)	59.99	10.68	53.03	5.98	1.79	0.09
Body height (cm)	171.76	9.06	162.72	6.93	2.51	0.02
Body mass index	20.16	1.78	19.99	1.41	0.23	0.82
Ape index	1.02	0.02	1.03	0.02	-0.84	0.41
Body fat (%)	9.48	2.64	16.99	3.27	-5.66	0.001
Countermovement jump (cm)	33.88	5.88	22.75	2.82	5.39	0.001
Squat Jump (cm)	25.93	4.30	22.51	2.44	2.19	0.001
Handgrip strength (kg/kg)	0.77	0.09	0.74	0.07	0.85	0.40
Power slap (cm)	27.30	12.73	19.50	8.60	1.55	0.14
Foot lift (cm)	74.20	4.80	76.53	8.31	-0.77	0.45

Discussion

There are several important findings in this study. First, males are taller and have lower body fat than females. Regarding the generic tests, males performed better in CMJ and SJ tests than females. However, we found no gender difference in the applied sport-specific tests of conditioning capacities.

Anthropometric characteristics

Males are taller and have lower body fat compared to females. These results are logical and have been confirmed in numerous previous studies on the non-trained population and athletes (Watts & Jensen, 2003; Schoffl et al., 2011). This is primarily due to the secretion of sex hormones and genetic imprint (puberty is manifested by an increased secretion of testosterone in boys, followed by the development of muscle mass and the lower accumulation of fat tissue) (Karastergiou et al., 2012). For the purpose of our study, it is important to note that previous studies from the USA show a significantly lower body fat percentage in competitive climbers (13.0%) than in their 10-15 year old non-climber peers (18.7%) (Watts & Jensen, 2003). The same study showed that climbers are slightly shorter than non-climbers (158.5 cm and 167.1 cm, respectively). Supporting this, our study showed that the height of Croatian climbers is in the 50th percentile for females and males of the same age in Croatia (Juresa et al., 2012), while Croatian male climbers are in the 15th, and female climbers in the 25th percentile. This suggest that the anthropometric fitness profile of climbers is characterized by a slightly lower body height.

The results of the Croatian climbers show no differences between genders in body mass, ape-index, and arm span. A possible explanation is that the studied climbers are still in the growth and development period and have not yet reached their final body dimensions (Malina, 1994). However, regardless of the non-significant differences between genders, the reported anthropometric parameters of young climbers are important determinants of climbing performance.

Generic conditioning capacities

Although the importance of the vertical jump for climbers is not often emphasized, the specificity of modern sport climbing requires lower body power (i.e., powerful movements and jumps on large surfaces on the climbing wall). Thus, the importance of developing and testing generic jumping performance should be addressed. In our study, male climbers achieved better results than females in vertical jumps. It is regularly confirmed that males achieve better results in the vertical jump test because they have higher muscle mass, followed by hormonal functions (Laffaye, Wagner, et al., 2014). The better vertical jump performance in males is confirmed by previous studies comparing athletes in various sports (Laffaye, Wagner, et al., 2014). Our results are generally consistent with previous reports where adult climbers were examined. In particular, the study by Espana-Romero et al. (2009) found differences between male and female climbers aged 25-30 years in the CMJ test (34.1±4.43 cm for males, 28.6±3.08 cm for females). Similar results were also found in our study in the CMJ test (33.88±5.88 cm for males and 22.75±2.82 cm for females).

We found no gender differences in HGS measured by a dynamometer. This finding is not consistent with common data, which shows that males generally perform better than females in HGS (Ahrenfeldt et al., 2018). Therefore, it could be assumed that male and female climbers are equally developing HGS, unlike the general population. Irrespective of the lack of gender-differences, the results of Croatian climbers (42.7 kg) are similar to those of French novice climbers (45.8 kg) (Laffaye et al., 2016). The previously cited French study showed that HGS in the dynamometer test does not correlate with performance in sport climbing as it is not a specificity of the sport (i.e. climbing grips involve more strength of the finger flexor muscles than forearm strength). However, climbers have a much higher HGS than the general population (34,6 kg) (Ahrenfeldt et al., 2018). Therefore, it could be assumed that the assessment of HGS contributes to the modeling of the young climbers' fitness profiles.

Sport-specific tests of conditioning capacities

Although numerous studies show that sport-specific tests in climbing are good indicators of climbing performance (Michailov et al., 2015; Laffaye et al., 2016), specific tests applied in our study did not discriminate boys from girls.

First, DRAGA mobility test did not distinguish boys and girls in our research, which is in contrast to a previous Spanish study that showed better flexibility results for female climbers compared to male climbers (Espana-Romero et al., 2009). The better mobility and flexibility of the hips is explained by a wider pelvis and greater hip and pelvic angles in females (Mier & Shapiro, 2013). However, we included youth climbers who are still in the growth and development phase. Thus, the gender differences may not have occurred yet. Therefore, the results of the DRAGA test should be observed only from the perspective of youth climbers and should not be related to older climbers.

In addition, boys would be expected to achieve better results in the SLAP test than females simply because of the differences evidenced in generic jumping capacities, but also due to the greater percentage of lean body mass, body dimensions, and hormonal influence (Draper et al., 2021). Indeed, the SLAP test evaluates the (upper) body power; therefore, the listed characteristics should significantly affect differences between males and females. The reasons for the lack of gender differences in the SLAP test in our study could be explained in several ways. First, according to a database of the Croatian Federation of Sport Climbing, there are more females than males among competitive climbers in all age categories (63.63% females) (Hrvatski Sportsko Penjački Savez, 2021). Therefore, the better sport-selection among females could be the reason why the girls in our study achieved similar results as boys. Second, climbing is not a sport exclusively performed by males. Females achieve similar climbing results. Namely, according to Carroll (2021), three females are among the top 90 climbers of all time. For a simple comparison, in the 100m-dash sprint, the best female result is at 2000th position when males and females are combined. Therefore, it is possible that girls achieve similar results as males in sport-specific tests at top youth level, as the one we studied here.

Regardless of the lack of gender differences, it is also important to note that the Croatian climbers perform worse than other elite climbers in specific tests (SLAP and DRAGA) (Draper et al., 2017; Draper et al., 2021). However, as most previous studies examined older athletes (Espana-Romero et al., 2009; Draper et al., 2021), it could be assumed that our climbers have not yet reached their final stage of development and consequently their maximum performance in specific tests. Therefore, it is possible that with advanced years and with the final morphometric development, gender differences will become more pronounced. Thus, the results of this study should be observed and interpreted with caution, as the climbers have probably not developed their full potential yet.

Conclusion

Young elite climbers differed in body height (boys were taller) and body fat percentage (boys had a lower percentage) but not in body mass and ape index. Differences were recorded in general fitness tests (vertical jump), while boys and girls did not differ in any climbing-specific tests. The results may suggest that climbing is a specific sport that requires and develops specific abilities in a similar way in boys and girls. Since we also included youth climbers, the absence of gender differences could be explained by the fact that climbers have not yet reached their final stage of development and their full capacity to perform sport-specific tests.

Future studies should examine the fitness profile of top-level youth climbers in more detail to determine anthropometric characteristics and conditioning capacities that are crucial for success in this sport.

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Conflict of Interest
The author declares that there is no conflict of interest.

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ORIGINAL SCIENTIFIC PAPER

Establishing Levels of Perceived Benefits and Barriers from Exercising By Female Students at University of "Ss. Cyril & Methodius" – Skopje

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Abstract

Many individuals are not engaged in sufficient physical activity due to low perceived benefits and high perceived barriers to exercise. Given the increasing incidence of obesity and obesity-related health disorders, this topic requires further exploration. The research goal was to establish what factors, according to students' perceptions, appear as the greatest benefits from and heaviest barriers for exercising, as well as establish the correlation between these perceived benefits and barriers, and the level of physical activity. Exercise Benefits/Barriers Scale was used to assess perceived benefits and barrier intensities to exercise in 514 female university students (mean age 19.3 years, SD=1.06), taken from several faculties at the University of "Ss. Cyril and Methodius" in Skopje. The research results show that the female respondents who study at the university perceive much more benefits than barriers to exercising. The calculated relation of benefits/barriers with this sample presents 1.39. The observed highest benefit that the female respondents have perceived is the "psychological benefit", followed by the advantage related to the improved physical performance, improvement of life quality, social interaction, and health prevention. Physical tension and lack of time were graded considerably higher against the other two subscales of assessing the perceived barriers to exercising. The respondents with high physical activity have significantly higher results in the scales and subscales of assessing the perceived benefits and lower results in the scales and subscales of assessing the perceived barriers to exercising than those with a moderate and low level of physical activity. The implications of the research in elaborating the strategies and educative programs for promoting physical activity show the importance of increasing the relation benefits/barriers with the female respondents. The applied interventions should help female students to overcome the feelings of discomfort of physical tension during exercising (reducing the perceived barriers) and to emphasize health and other benefits of regular exercising (increasing the expected benefits).

Keywords: *physical activity, female students, motivation, benefits, obstacles, healthy behavior*

Introduction

Physical activity is a complex behavior that is influenced by several internal and external factors such as socio-cultural, psycho-cognitive, and physical as well as social environment of the person. Explaining how factors influence the changes in behavior is crucial for elaborating interventions, strategies, and educative programs which will contribute to increasing the level of physical activity among young people (Sallis et al., 2000).

So far, the long-term success of strategies for increasing the physical activity with the female population has not been reached, and, to develop effective health strategies, an additional examination is required about the female motives for physical activity and the challenges they face during they try to stay active (Zunft et al., 1999). In this context, the per-

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ceived benefits and obstacles appear as important mediators in changing physical activity as a complex behavior (Nahas, Goldfine, & Collins, 2003).

Although the former research work suggests that the perceived barriers are essential in predicting health behavior (Janz & Becker, 1984), the later studies of El. Ansari and Phillips (2004) suggest that this issue is more complex, implying the relation of the perceived barriers and benefits as a better predictor ofthe direction which the behavior would take. Further, it should be taken into consideration that the psycho-social factors such as self-efficacy, demographic characteristics, age, the pressure on the individual from his/her peers, and some other factors, such as the knowledge, also play important roles in engaging and sticking to the interventions for changing the physical activity as a type of behavior (Rosenstock, Strecher, & Becker, 1988).

Despite having over 50 studies that have examined the change in health behavior, it has been established that the perceived barriers were the most powerful predictor of changing the health behavior (Janz & Becker, 1984), the perceived barriers to exercising have been not examined enough yet (Ransdell et al., 2004). Along with this, the limited number of studies that examined the perceived benefits and barriers for women when doing exercises often did not take into consideration different factors of development and specific environmental conditions within different phases of female lives – how they influence their interest in exercising and their ability to be more active (King et al., 2000; El Ansari, & Lovell, 2009; Frederick et al., 2020). Further, a specific characteristic of many developed countries is the relatively high percentage of the population that go to university, most of who are women (Leslie & Owen, 2001). Yet, apart from the limited studies which have examined the female university student population, it can be concluded that just between 28% and 50% of that population regularly participate in physical activity, as against the 40% and 68% of the male university student population (Irwin, 2004; Kgokong & Parker, 2020).

Also, the recent research works point out that almost a quarter of all students who start their studies gain considerable weight during the first semester – a fact suggesting the need for effective strategies to help those young people to keep their healthy body weight (Wengreen & Moncur, 2009). The university has a similar impact in promoting physical activity as the school does (Armstrong & McManus, 1994), that the models of physical activity remain stable up to five years after graduation from university (Sparling & Snow, 2002).

The purpose of this study was to examine the perceived exercise benefits and barriers of female university students, measured by the Exercise Benefits/Barriers Scale (EBBS) (Sechrist, Walker, & Pender, 1987). Findings from the current study should assist health and fitness practitioners, researchers as well as policymakers, to design more appropriate initiatives to better suit the individual needs of female university students to ultimately increase their PA levels. The specific objectives were to: (1) Describe the sample's general levels of perceived benefits and barriers to exercise; (2) Assess whether female university students had greater total perceived benefits or barriers to exercise; (3) Identify what female university students perceived to be the biggest benefits of exercise; (4) Assess what female university students perceived to be the biggest barriers toexercise; (5) Identify how female university students' perceptions of benefits from exerciserelated to their perceptions of barriers to exercise; and (6) Establishing the correlation between the perceived benefits and barriers and the level of physical activity.

Methods

Sample of respondents

The research has been conducted on a sample of 514 female respondents randomly selected from several faculties of the University of "Ss. Cyril and Methodius" in Skopje. The average age of the respondents was 19.3 years, (SD=1.06). The respondents were treated following the Helsinki Declaration (revision of Edinburgh 2000). The protocols were approved by the Ethics Committee (Number 549, 10.05.2021) at the Ss. Cyril and Methodius University of Skopje.

Sample of variables

The data are collected using the structured questionnaire method of research. The variables are defined based on questionnaires and were categorized into two groups:

Exercise Benefits/Barriers Scale (EBBS): The perceived benefits and barriersto exercising were established with the questionnaire EBBS (Sechrist, Walker, & Pender, 1987). The established internal consistency (alpha) of the scales for assessing the benefits and barriersof exercising in former research works ranges between 0.95 and 0.86, and the reliability established by the test-retest method is from 0.89 and 0.77 (Gyurcsik et al., 2006). With this sample of respondents the internal consistency of the assessing scale was 0.91, and for assessing the perceived obstacles to exercising from 0.83. All the determinations of the scale for assessing the perceived benefits and barriers to exercising were evaluated by the Lickert system of marks from 1 to 4 grades.

Physical Activity Questionnaire (IPAQ):In assessing the physical activity it was applied a short version of the standardized International Physical Activity Questionnaire (IPAQ). Based on the standard instruction and standardized algorithms for analyzing the total volume and number of days for assessing the physical activity, the students were classified into three categories, such as students having a high level, moderate level, and low level of physical activity (IPAQ Research committee, 2005).

Methods of processing the data

Each respondent was considered by calculating standardized results of the scales for assessing total benefits and total barriers, as well as the same, was done with each subscale (the total evaluation of the scales and subscales is the average value of the determinations which were included in the scale or subscale). This adjustment aimed to provide a direct comparison between the scales and subscales. The possible results ranged from 1 to 4; 4 is the highest perception of benefits and barriers. Research objective one (to describe the sample's general levels of perceived benefits and barriers to exercise) was achieved by computing the means of the individual EBBS items. Research objective two (whether female university students had greater total perceived benefits or barriers to exercise) was assessed by a single paired samples t-test.The third and fourth research objectives (what female university students perceived to be the biggest benefits and barriers of exercise) were assessed by multiple paired sample t-tests to identify any significant differences between subscales (10 comparisons for the benefits scale; 6 comparisons for the barriers scale). The Bonferroni method was used to correct critical p values ($p<0.005$ for the benefits scale; $p<0.008$ for the barriers scale), while maintaining an alpha of 0.05 to control against an inflated alpha and the increased possibility of type I errors due to these multiple comparisons. The fifth research objective (how female university students' perceptions of benefits from exercise related to their perceptions of barriers to exercise) was assessed by the calculation of correlations between each of the benefit sub-scales with each of the barrier subscales (20 correlations). Again, to control against potential type I error due to multiple comparisons, the Bonferroni method was used to correct critical p values ($p<0.002$) while maintaining an alpha of 0.05%. The sixth and final goal of the research was established by applying a one-factor analysis of the variance, and posthoc tests were applied (Bonferroni-tests). The data was processed by statistical packet SPSS for Windows Version 26.0 (IBM Corporation, New York, NY, United States).

Results

Table 1 presents the arithmetical means and standard deviations for each statement (item) from the scale for assessing the perceived benefits of exercising with the female respondents. Generally, the female respondents either agree or completely agree with most of the statements on this scale, namely they think many of the statements are benefits of regular exercise. However, concerning some statements, the female respondents show neutral results (for example "exercising improves the quality of my work", "exercising increases my mental alertness", "I have a feeling of welfare when I take exercises", and 'exercising enables me to do normal activities without getting tired"). The female respondents agree the lest with the statements: "exercising is a good way to meet new people", "I will live longer if I take exercises", "exercising helps me to reduce the tiring", "exercising provides me contacts with friends and persons I enjoy to be with", "exercising increases my acceptance by others", "exercising will keep me from having high blood pressure" and "exercising will help me to prevent heart attacks".

Table 1. The exercise benefits scale: mean and standard deviation of each questionnaire item.*

Perceived Benefit Items	M	SD
Life Enhancement Sub-scale		
25: My disposition is improved by exercise	3.09	0.72
26: Exercising helps me sleep better at night	3.27	0.68
29: Exercising helps me decrease fatigue	2.78	0.76
32: Exercising improves my self-concept	3.13	0.69
34: Exercising increases my mental alertness	3.03	0.70
35: Exercising allows me to carry out normal activities without becoming tired	3.00	0.68
36: Exercising improves the quality of my work	3.05	0.70
41: Exercising improves overall body functioning for me	3.26	0.65
Physical performance Sub-scale		
7: Exercise increases my muscle strength	3.38	0.68
15: Exercising increases my level of physical fitness	3.30	0.67
17: My muscle tone is improved with exercise.	3.23	0.69
18: Exercising improves the functioning of my cardiovascular system	3.21	0.70
22: Exercising increases my stamina	3.20	0.69
23: Exercising improves my flexibility	3.25	0.69
31: My physical endurance is improved by exercising	3.33	0.63
43: Exercising improves the way my body looks	3.42	0.71
Psychological Outlook Sub-scale		
1: I enjoy exercising	3.47	0.62
2: Exercising decreases feelings of stress and tension for me	3.51	0.62
3: Exercising improves my mental health	3.52	0.63
8: Exercisinggives me a sense of personal accomplishment	3.23	0.75
10: Exercising makes me feel relaxed	3.30	0.71
20: I have improved feelings of well-being from exercise	3.02	0.73
Social Interaction Sub-scale		
11: Exercising lets me have contact with friends and persons I enjoy	2.73	0.86
30: Exercising is a good way for me to meet new people	2.92	0.76
38: Exercising is good entertainment for me	3.20	0.67
39: Exercising increases my acceptance by others	2.66	0.83
Preventive Health Sub-scale		
5: I will prevent heart attacks by exercising	2.10	0.84
13: Exercising will keep me from having high blood pressure	2.10	0.84
27: I will live longer if I exercise	2.87	0.88
All Benefit items of all subscale	3.05	0.36

* Adapted from the Exercise Benefits/Barriers Scale (EBBS)

Table 2 presents arithmetical means and standard deviations for each statement of the scale for assessing the perceived barriers to exercising with female respondents. Generally, the respondents agree with many statements from the scale for assessing the perceived barriers to exercising. However, the respondents do not completely agree with some of the statements, which suggests that those statements do not function as barriers for them to do exercises (for example, "I think people in exercise clothes look funny", "my family members do not encourage me to exercise"). The female respondents agree the less with the statement: "I am too embarrassed to exercise", while most of them agree with the statements: "exercising takes too much of my time", "exercising tires me" and "places for me to exercise are too far away".

Table2. The exercise barriers scale: mean and standard deviation of each questionnaire item*

Perceived Barriers Items	M	SD
Exercise Milieu Sub-scale		
9: Places for me to exercise are too far away	2.47	0.89
12: I am too embarrassed to exercise	1.70	0.86
14: It costs too much money to exercise	2.15	0.84
16: Exercise facilities do not have convenient schedules for me	2.28	0.82
28: I think people in exercise clothes look funny	1.74	0.83
42: There are too few places for me to exercise	2.23	0.80
Time Expenditure Sub-scale		
4: Exercising takes too much of my time	2.41	0.81
24: Exercising takes too much time from family relationships	2.23	0.78
37: Exercising takes too much time from my family responsibilities	2.22	0.74
Physical Exertion Sub-scale		
6: Exercise tires me	2.49	0.83
19: I am fatigued by exercise	2.41	0.75
40: Exercising is hard work for me	2.10	0.77
Family Discouragement Sub-scale		
21: My spouse (or significant other) does not encourage exercising	2.15	0.89
33: My family members do not encourage me to exercise (lack of family support)	2.04	0.87
All Barriers items of all subscales	2.20	0.45

* Adapted from the Exercise Benefits/Barriers Scale (EBBS)

Findings to the second research objective showed that this sample of femaleuniversity students felt significantly higher perceived benefits (M=3.05, SD=0.45) than barriers (M=2.20, SD=0.45)to exercise (t(513)=31.47, p<0.001). This equated to a benefit/ barrier ratio of 1.39; the ratio being >1 demonstrated that these females perceived greater benefits than barriers (Table 3).

Table 3. Standardized perceived benefit and barrier sub-scale means and standard deviations and t-test values for multiple comparisons.

Sub-scale	Mean	SD	Sub-scale†				
			1	2	3	4	5
Benefits (M = 3.05. SD = 0.36)							
Psychological Outlook	3.34	0.45	--	0.004*	0.000*	0.000*	0.000*
Physical performance	3.29	0.46		--	0.000*	0.000*	0.000*
Life Enhancement	3.08	0.45			--	0.000*	0.000*
Social Interaction	2.88	0.54				--	0.000*
Preventive Health	2.66	0.50					--
Barriers (M = 2.20. SD = 0.45)							
Physical Exertion	2.33	0.57	--	0.094	0.000*	0.000*	
Time Expenditure	2.29	0.58		--	0.000*	0.000*	
Exercise Milieu	2.10	0.54			--	0.991	
Family Discouragement	2.10	0.70				--	

For all subscales; possible scores range from 1 to 4. where 4 represents the highest perception of both benefits and barriers; †Values in the cells of these columns are actual t-test values; * Indicates that the means of the subscales that are being compared were significantly different, using Bonferroni corrected critical p values for benefits (p<0.005) and for barriers (p<0.008).

Analyzing individually the subscales for assessing the perceived benefits from exercising (Table 3), there can be noticed that the dominant benefit of exercising which the female respondents perceive is the psychologic benefit (M=3.34), and then follow the benefit connected with improving the physical performances (M=3.29), improvement of life quality (M=3.08), social interaction (M=2.88) and health prevention (M=2.66). Statistically, significant differences are established between all the subscales for assessing the perceived benefits of exercising. It is only the subscales of psychologic benefit, the benefit related to improving physical performances and improving the life quality that showed arithmetic means higher than 3, which is a "real" consent that those subscales consisting of mere than one statement are considered by the sample as benefits from the exercising.

Inspection of Table 3 shows that the greatest barriers to exercising with this sample of female respondents are the physical tension, then follows the lack of time, the exercising environment, and the lack of family support. The physical tension and lack of time were evaluated considerably higher as compared to the other two subscales for assessing the barriers to exercising. There were no established statistically significant differences between the subscales physical tension and lack of time, the exercising environment, and lack of family support. Arithmetic means of all the four subscales for assessing the barriers to exercising varied between 2 and 3, which is equal to the answers "I agree" and "I do not agree" onthe EBBS scale of rating, which can be regarded as a neutral attitude of the respondents.

Table 4. Correlation coefficients between perceived barriers and benefits of exercise subscales

	Barrier Sub-scale			
Benefit Sub-scale	Exercise Milieu	Time Expenditure	Physical Exertion	Family Discouragement
Life Enhancement	-0.187*	-0.110	-0.192*	-0.167*
Physical performance	-0.337*	-0.189*	-0.219*	-0.260*
Psychological Outlook	-0.201*	-0.132	-0.255*	-0.168*
Social Interaction	0.047	0.024	-0.066	0.029
Preventive Health	0.257*	0.171*	0.143*	0.222*

* Significant correlations using Bonferroni corrected critical p value (p<0.002).

The analysis of the matrix of cross-correlation between the subscales for assessing the benefits and barriers to exercising (Table 4) presents a low and statistically significant negative correlation between the subscales of physical performances with all four subscales for assessing the barriers to exercising. The subscales "life quality" and "psychologic benefit" are in low and statistically significant negative correlations with the subscales of "living environment", "physical tension" and "lack of family support". At the same time, the subscale of "health prevention" is in a low and statistically significant positive correlation with all the four subscales of assessing benefits from exercising.

Aiming to establish if the values of the two scales, the five subscales of assessing the perceived benefits and the four subscales of assessing the perceived barriers to exercising differ between the respondents having a different level of physical activity (low, moderate, high), where one-factor analysis of variance was applied. The analysis results (Table 5) show that those respondents classified as highly active statistically have significantly higher results on the scales and more subscales (psychologic benefit, benefit connected with improving the physical performances, improving the life quality and the social interaction) of assessing the perceived benefits of exercising and lower results in the scales and subscales (physical tension, lack of time, environment of exercising and lack of family support) of assessing the barriers for exercising in comparison

Table 5. The difference in scales and subscales of assessing the perceived benefits and barriers to exercising among the respondents classified by different levels of physical activity

	Low (1)		Moderate (2)		High (3)		F	Sig.	Post hoc pairwise comparison*		
	Mean	SD	Mean	SD	Mean	SD			1-2	1-3	2-3
Life Enhancement	2.97	0.44	3.03	0.38	3.18	0.51	9.15	0.000	ns	<	<
Physical performance	3.14	0.40	3.24	0.39	3.41	0.51	15.37	0.000	ns	<	<
Psychological Outlook	3.24	0.41	3.28	0.43	3.45	0.47	10.74	0.000	ns	<	<
Social Interaction	2.81	0.47	2.74	0.50	3.04	0.57	17.58	0.000	ns	<	<
Preventive Health	2.64	0.53	2.66	0.51	2.67	0.48	0.20	0.817	ns	ns	ns
All Benefit	2.96	0.31	2.99	0.32	3.15	0.39	15.48	0.000	ns	<	<
Exercise Milieu	2.30	0.58	2.08	0.51	2.01	0.51	11.08	0.000	>	>	ns
Time Expenditure	2.42	0.64	2.31	0.53	2.20	0.58	5.42	0.005	ns	>	ns
Physical Exertion	2.40	0.58	2.39	0.56	2.24	0.56	4.58	0.011	ns	>	>
Family Discouragement	2.31	0.74	2.12	0.63	1.96	0.70	9.19	0.000	ns	>	ns
All Barriers	2.36	0.53	2.23	0.41	2.10	0.42	12.07	0.000	>	>	>

*Example of pairwise comparison: the symbol > in column 1–2 indicates a significant difference (P<0.05) in the direction 1>2; ns: non-significant.

with those respondents classified as being moderate and low physically active. There were no established statistically significant differences between those respondents having a different level of physical activity only in the subscale of health prevention. With the respondents having a high level of physical activity, the correlation benefits/barriers was 1.50; with those respondents having moderate physical activity, the correlation benefits/ barriers was 1.34; whereas with those having a low level of physical activity. The correlation between benefits/barriers was 1.25.

Discussions

Proper physical activity plays a key role in the welfare and life quality (McAuley & Rudolph, 1995). Therefore, the university environment is of essential importance for promoting good physical health and behavior.However, the lack of enough data related to the perception and attitudes of the university student population about exercising puts a limit on designing effective interventions for promoting physical activity. This research aims to establish how university female students perceive the benefit of doing exercises and to establish what prevents them most often from having physical activities.

Regarding the first aim of the research, the results of our study show that the respondents either agree or completely agree with a great number of the statements from the scale of the perceived benefits, whereas they show neutral results or are close to accepting most of the statements from the scale of assessing the perceived barriers from exercising.

As for the benefits of doing exercises, the respondents agree the least with the statements: "exercising is a good way for me to meet new people", "I will live longer if I exercise", exercising helps me decrease fatigue", and "exercising lets me have contacts with friends and persons I enjoy", exercising is a good way for me to meet new people", exercising will keep me from having high blood pressure" and "exercising will prevent me from having heart attacks".

As for the barriers from having exercise, the respondents mainly agree with the statements: "exercising tires me", "places for me to exercise are too far", and exercising takes too much of my time", whereas they agree the least with the statements about the barriers: "I think people in exercise clothes look funny", my family members do not encourage me to exercise" and "I am too embarrassed to exercise".

As for the second goal of this study, the results point out that the respondents perceive more benefits rather than barriers from exercising, which also implies the correlation between benefits/barriers, which is 1.39. This corresponds with previous research works which showed that the perceived benefits were higher than the perceived barriers (Nahas, Goldfine & Collins, 2003).

Regarding the third goal, where the items of each subscale are analyzed in summing, the research results point that the dominant benefits from doing exercises that the respondent perceive is the psychologic benefit (better mental and psychologic welfare) and the benefit related to improving physical performances; whereas the benefits related to improving life quality, the social interaction and health prevention were ranged considerably lower.

The finding that benefits connected with the performance improvement (which covers improving physical readiness, muscular strength, cardiovascular functioning, endurance, flexibility, and physical appearance) are one of the most highly perceived benefits of exercising, which is not to be a surprise, because the importance of these qualities with the female respondents is constantly emphasized by a wide range of media canals (Kgokong & Parker, 2020). Similarly, the psychological benefit as dominant from exercising is following the research of Biddle and Bailey (1985), who established that the female respondents highly estimated the benefits related to mental and psychological welfare resulting from exercising. The surprising thing was that the respondents had the least perception of those benefits related to health, which implies that the university students population is not aware of the fact that exercising can help them in preventing and improving their health, which is contrary to the model of health belief (Janz & Becker, 1984), which to a large degree can influence the change of behavior of this population group. Therefore, in the future, this population group should be acquainted with the health benefits of exercising, through which an influence on positive behavior changes could be carried on.

The respondents' perception of having fewer benefits related to the factors of improving life quality and social interaction is contrary to the previous research, though they have been expected. Namely, the former research works (Wankel, 1980) and motivation theories (Deci & Ryan, 1980) suggest that the social issues are key motives for a person to continue doing physical activities. However, our sample presents a specific kind of population (students) which is different from the populations researched in former studies. Namely, at that age respondents have a greater opportunity for socialization, friendships, and communication, which is a constituent part of their university life. These various possibilities of socialization can "undermine" the noticed importance of social benefits that might result from exercising. The results are following the research works conducted on female respondents that did not bring recommendations for physical activity from universities in Great Britain, which also have perceived fewer benefits from the exercises related to these factors (Lovell et al., 2010).

Regarding the fourth goal, the research results point out that the lack of encouragement from the family is a barrier that prevents them the least from exercising. Although the research results suggest that the exercise environment does not appear as a significant barrier to exercising, which is inspiring, the isolated statements "Places for me to exercise are too far", which is a component of this subscale, is too highly ranged. This is following the research works of King et al. (1992), who determined that young old women have difficulties in doing exercises because of the limited reach to the spots. Further, the results of this research negate traditional attitudes that women have in situations when they feel embarrassed or uncomfortable (O'Neill & Reid, 1991; Gyurcsik et al., 2006). After all, our results can be generalized only to the university student population, which usually feel confident in their social context and have a greater possibility (and often for free) for access to exercise premises and chances for physical activity.

Based on the obtained data, there can be concluded that the subscale "lack of time" is ranged highly than the subscales of "exercise environment" and "lack of family support". Although our research points out that the lack of time is considered a neutral barrier, there still can be said that the lack of time is a bigger barrier than that of an exercise environment. This is following the studies of Gyurcsik et al., who examined the barriers to physical activity with 198 candidatestudents (Gyurcsik et al., 2006). Gyurcsik et al (2006) established that 52% of the university students mentioned their social invitations overlapping the terms for exercising (for example "I was invited to a party") as a barrier to physical activity, and 74% pointed out that their loading at the university is too large to be able to get engaged into physical activity, which reveals that both aspects are, to some extent, barriers connected with the lack of time.

Gyurcsik et al. (2006) have established that the problems referring to the exercise environment as a barrier are pointed out by a small number of students; 3% of the students mention the lack of money as a barrier to exercising, and 6% point the transport as a barrier for exercising. To overcome this barrier, female students need to be educated about skills of efficacy in handling their time (time management). Student girls could spear some time from the time spent on the computer or in front of the television, or instead of going to the cafe with friends to go to some fitness center or sports hall and have equal fun.

Physical tension was by far the highest perceived barrier to exercising with the tested university population. This is following some of the former studies (Kgokong & Parker, 2020; Shaikh, Dandekar, & Hatolkar 2020). The perception of physical tension, as a major barrier to exercising, comes from the fact that physical activity is exhausting and tiresome activity, which is to a great extent an alarming signal. That can lead to a vicious circle: the more the students' physical activity decreases, the harder and harder it is going to be for them to engage in the recommended regular physical activity. The physical dis-activity will increase the physical tension as a barrier to exercising, which will cause a drop in their activity, and as a result their condition of physical readiness. The perception of the physical tension as the main barrier to exercising can also reflect a cultural or social problem. According to the theory of planned behavior (Ajzen & Madden, 1986), attitudes are influenced by the social norms which, on their part,have an impact on intentions, and consequently on behavior. If the social norm is the absence of desire to be physically active and not to enjoy the physiologic results accompanying physical activity (for example rapid heartbeat, increased sweating, feeling of activating), then the attitude of the person can become more negative, having the effect of decreased wish for exercising and finally this could influence the behavior as well.

As for the fifth research goal, the results show that most of the subscales for assessing the barriers are in negative correlation with the subscales of assessing the benefits. The subscales of "life quality" and 'psychological benefit" are in low and statistically significant negative correlation with the subscales of "exercise environment", "physical tension" and "lack of family support". At the same time, the subscale of "health prevention" is in a low and statistically significant correlation with all of the four subscales of assessing the barriers for exercising. Further, these relations suggest that the intervention that is focused on increasing the perceived benefits of physical activity can as well have a positive effect on the changes of some barriers.

Regarding the sixth research goal of assessing the relationship between the perceived benefits and barriers to the level of physical activity, the results showed that the respondents, having a high level of physical activity, display significantly higher results in the scales and subscales of assessing the perceived benefits and lower results in the scales and subscales of assessing the perceived barriers from exercises in comparison with the respondents of a moderate or low level of physical activity. This illustrates that these students showed a positive attitude towards exercising, which, on its part, resulted in positive health behavior (i.e.exercising). These results are following former research works which have presented that the higher the perceived benefits are, the more active the person is личност (El Ansari & Lovell, 2009).

Along with this, according to the socio-cognitive theory individuals tend to act in ways that they perceive as possible to lead to positive results, but avoid behavior that they expect to bring negative results (Young et al., 2014). Perhaps it is the physical activity that had influenced the students who became classified as highly physically active to have more satisfying results in the scales and subscales which were a constituent part of the EBBS questionnaire. In other words, the relationship between them can be two-way. Those students having exercises can have a good attitude towards the physical activity, because doing the regular physical activity themselves feel the benefits of it. This concept of learning through personal experience is a key moment in the change of behavior.

The research has some limits as well. The present research design was transversal, due to which the cause-and-effect relation could not be established. Another weakness of the study refers only to the female student population of the "Ss. Cyril and Methodius" University in Skopje. In the future, there should be organized surveys that would cover the whole student population of the Republic of North Macedonia, when individual treatments would be provided for the young living in rural, sub-rural, and urban regions, and the sample would include respondents from different ethnic communities, as well as the economic-social status, would be taken into consideration. Future studies will have to answer the question about how these different factors of benefits/barriers function in influencing each other and/or how the variables should be shaped. Longitudinal studies can also provide pieces of evidence about the directions of causality.

Conclusion

On the bases of obtained results, there can be concluded that the respondents who were tested in the present research perceived the exercise as more beneficial and far fewer barriers. The perceived correlation of benefits/barriers of 1.39 may appear insufficient to motivate these respondents to be more active. The initiatives on health education and promotion of physical activity at universities can have greater efficiency if the mentioned efforts are directed at the education of those respondents who do not take exercise to increase the correlation of benefits/barriers, which would stimulate them to maintain a physically active lifestyle which, on its part, will have a better effect on their health. For example, in the context of health and social partnership participation in South Africa, El Ansari and Phillips (2004) point out that people will much more take participation in programs and interventions if they believe that the benefits of such participation are much higher than their expenses (barriers) on the same. Involvement, devotion, and feeling of ownership have always been connected with high benefits and mostly with low expenses (barriers). For a favorable correlation between expenses and benefits, the benefits should be at least 80% higher than the expenses (El Ansari & Phillips, 2004; Lovell et al, 2010). There might be necessary a similarly high correlation of benefits/barriers for the exercising to be initiated and kept on regular terms of participation by the students' population in physical activity programs.

The implications of this study include the importance of interventions that should have a twofold approach. Interventions could help in reducing the perceived barriers of "attention distraction" or "detaching" the student-girls from every perceived "unpleasantness" from the physical effort during having a physical activity (for example, by using cognitive strategies or music the respondents' attention is re-directed away from the inter-physical signs connected with the physical efforts). Along with this, interventions should be adapted into motivating the students to overcome the physical tension by providing education and the need of setting positive goals and focusing on the potential benefits of exercising. The interventions that are directed towards the one or (if possible) both targets can contribute to increasing the possibility of involving physical activity with this population group. In addition, the research results suggest that both the age and gender specificities of respondents should be taken into consideration when trying to get inside the attitudes toward exercising and physical activity.

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Conflicts of Interest
The authors declare no conflict of interest.

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ORIGINAL SCIENTIFIC PAPER

Analysis of the Associations between Contextual Variables and Match Running Performance in Croatian First Division Soccer

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Abstract

It has been hypothesized that contextual variables (i.e. match location, opponents' level) could be important determinants of running performance (RP) in soccer matches, but empirical studies provided inconsistent evidences. This study aimed to investigate the associations between contextual variables (CV) and RP in Croatian soccer players. Players' RP (n=193) were evaluated, and used as cases in this study. CV included match outcome (win-draw-loss), opponent's level (higher vs. lower ranked), and match location (home-away). RP were measured by global positioning system during the soccer matches in seasons 2018/19 (n=14) and 2019/20 (n=15) of Croatian first division, and included: the total distance covered, low-intensity (<14.3 km/h), running (14.4–19.7 km/h), high-intensity running (>19.8 km/h), high-speed running (19.8–25.1 km/h) and sprinting (>25.2 km/h). Results indicated significantly greater amount of distance covered in running zone for away matches (F-test: 7.83, p<0.01, small effect size; 1392±353 m and 1262±294 m, for home and away matches, respectively). Similar RP were observed irrespective of opponents' level (F-test: 0.05 to 1.53, p>0.05). Lowest total-, low- and running-zone distances were evidenced in won matches (9893±896 m, 8035±614 m and 1241±312 m, respectively), followed by drawn matches (10298±913 m, 8287±838 m and 1363±320 m, respectively) and lost matches (10355±1052 m, 8279±742 m and 1406±343 m, respectively). This study demonstrated that (i) won matches were characterized by lower RP, (ii) association between RP and match location was limited, (iii) RP was not related to the opponents' level.

Keywords: *situational factors, football, physical performance, match outcome, match location*

Introduction

Running performance (RP) in soccer has been extensively researched in last decade what ultimately led to their better understanding (Paul, Bradley, & Nassis, 2015; Barrera, Sarmento, Clemente, Field, & Figueiredo, 2021). Today is well known that soccer player can cover between 9 and 14 km during the matches, performing 5–15% of that distance in high intensity running (Andrzejewski, Chmura, Pluta, & Konarski, 2015; Modric, Versic, Sekulic, & Liposek, 2019). This wide ranges are determined by different variables that are associated with RP. For example, playing position in the game (Konefał et al., 2019; Modric, Versic, & Sekulic, 2020a; Chmura et al., 2021), players' physical abilities and technical level (Sæterbakken et al., 2019; Modric, Versic, & Sekulic, 2021a), team's tactical formation (Modric, Versic, & Sekulic, 2020b), competitive level or league ranking (Bradley et al., 2013; Aquino et al., 2017) have all been associated with RP. These relationships can also be influenced by contextual variables (CV) such as match location, opponents' level and match outcome (Lago-Peñas, 2012; Paul et al., 2015; Trewin, Meylan, Varley, Cronin, & Ling, 2018; Barrera et al., 2021; Modric, Versic, & Sekulic, 2021b).

Authors regularly quantified RP according to the match outcome (e.g., winning, drawing, losing). However, empirical studies provided inconsistent evidences. Specifically, Barrera

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et al. (2021) investigated association between match outcome and RP of Portuguese players, and indicated greatest total distance covered in teams that were drawing (10395±875 m), followed by winning (9978±1963 m) and losing (9415±2050 m). Andrzejewski et al. (2016) analysed RP in context of match outcome and reported similar values of total distance covered irrespective of the match outcome for central defenders, fullbacks, central midfielders and wide midfielders, while only forwards achieved higher total distance covered in won matches. In terms of high intensity distance covered (>19.8 km/h), some older studies demonstrated that soccer players perform significantly less high intensity activities when winning than when losing (Bloomfield, Polman, & O'Donoghue, 2005; Castellano, Blanco-Villaseñor, & Alvarez, 2011; Lago-Peñas, 2012). Contrary, recent studies reported no differences in distance covered at higher speeds regardless of the match outcome (García-Unanue et al., 2018; Barrera et al., 2021).

Although home advantage in soccer is a well-known and well-documented fact (Lago-Peñas, 2012), literature overview indicates contrast findings regarding the associations between RP and match location. For example, authors quantified RP of Spanish and Brazilian players according to the match location, and reported that away matches accumulated significantly more of total distance than those played at home (García-Unanue et al., 2018; Aquino et al., 2020). Contrary, Barrera et al. (2021) evidenced greater total distance covered in home then in away matches (10208 and 9470 m, respectively). On the other hand, authors mostly reported similar values of high intensity distance covered irrespective of match location (Lago, Casais, Dominguez, & Sampaio, 2010; Aquino et al., 2020; García-Unanue et al., 2018)

It is often hypothesized that total distance covered and the amount of high-intensity running during soccer matches were higher when teams competed against higher ranked than against lower ranked opponents (Rampinini, Coutts, Castagna, Sassi, & Impellizzeri, 2007; Lago-Peñas, 2012). In contrast, Aquino et al. (2020) investigated RP in Brazilian professional soccer players, and revealed that teams covered greatest total distance when competed against lower ranked. Furthermore, García-Unanue et al. (2018) analysed RP of Spanish players according to the opponent's level, and did not indicate significant differences in RP between matches played against low-, medium- and high-level opponents.

Evidently, there is no clear relationship between RP and CV (e.g., match outcome, opponents' level and match location). Since previous cited studies included players from German 1st division, Portuguese and Spanish 2nd division and Brazilian 3rd division, such findings are not surprising. Most likely, these differences in RP are influenced with "cultural" factors of each league and competitions (García-Unanue et al., 2018). For example, English League is characterized by a direct style of play; Italian league is to be characterized by the defensive tactical rigor; and Spanish league favours the aesthetic side of the game and having greater control over the game (García-Unanue et al., 2018). Therefore, associations between RP and CV cannot be generalized and should be evaluated for each competition/league separately. Given to fact that there is no study which examined relationship between RP and CV in Croatian first division, the main objective of this study was to investigate the associations between RP and match outcome, opponents' level and match location. The findings from this study will provide new insights for understanding RP in Croatian soccer players.

Methods

Participants and design

RPs (n=193) of the players from the one team were analysed and used as cases in this study. All data were obtained with a global positioning system technique (see later for details) during the 14 matches in the season 2018/19 and 15 matches in the season 2019/2020 of the Croatian highest national soccer competition. RP was evaluated according to the match location (home: n=107, away: n=86), match outcome (win: n=82, draw: n=71, loss: n=40) and opponents' level (higher ranked: n=92, lower ranked: n=101, for details on division of teams on "higher ranked" and "lower ranked" please see details on Measurements). For the purpose of this study only RP of those players who participated in the whole match were analysed. In the observed period, team played 16 home and 13 guest matches, against 14 higher ranked teams and 15 lower ranked teams, and achieved 12 wins, 11 draws, and 6 losses. Matches that included red card or specific outputs (e.g., bad weather, bad pitch, matches against teams that mathematically assured title or relegation) were not analysed. At the end of the season 2018/19, team finished at 4th position at the table, while in season 2019/20 team finished at 5th position. The investigation was approved by Ethical Board of the Faculty of Kinesiology, University of Split.

Measurements

The variables in this study were divided in two sets: RP variables, and CV (match outcome, opponents' level and match location).

RP of the players was collected by GPS technology (Catapult S5 and X4 devices, Melbourne, Australia) with a sampling frequency of 10 Hz. Reliability and validity of the such devices were demonstrated previously (Johnston, Watsford, Kelly, Pine, & Spurrs, 2014). The RP included: the total distance covered (m), low-intensity (<14.3 km/h), running (14.4–19.7 km/h), high-intensity running (>19.8 km/h), high-speed running (19.8–25.1 km/h) and sprinting (>25.2 km/h). All RP variables were observed according to the CV.

CV included: (i) match outcome, (ii) opponents' level, and (iii) match location. Match outcome was assessed by win, draw or loss. Opponents' level included division of the teams into the higher ranked teams vs. lower ranked teams. Opponents were considered as "higher ranked" when observed team played against teams that were positioned from the 1st to 5th place on the table at the moment of the match. On the other hand, opponents were considered as "lower ranked" when observed team played against teams that were positioned from the 6th to 10th place on the table at the moment of the match (note that Croatian first division consists of 10 teams in total). Match location was coded as "home" when team played at home and "away" when team played away from home.

Statistics

The normality of the distributions was confirmed by the Kolmogorov–Smirnov test, and the data are presented as the means ± standard deviations. Homogeneity was checked by Levene's test.

Differences in RPs according to the match location and opponents' level were analysed by one-way analysis of variance. Effect sizes (ES) for differences in RP were evaluated by partial eta-squared values (>0.02 is small; >0.13 is medium; >0.26 is large) (Ferguson, 2016).

Multinomial logistic regression was used to identify the association between RP (predictors) and match outcome. For such purpose match outcome was considered as criterion variable (won matches were coded as "3", drawn matches as "2", and lost matches as "1"). The Odds Ratio (OR), and 95% Confidence Interval (95%CI) were reported for each predictor variable.

For all analyses, Statistica 13.0 (TIBCO Software Inc., Greenwood Village, CO, USA) and SPSS 16.0 (IBM, Armonk, New York, USA) were used, and p<0.05 was applied.

Results

Descriptive parameters for RP according to the different match outcomes are presented in Table 1. Total distance covered was lowest in won matches (9893±896 m), followed by drawn matches (10298±913 m) and lost matches (10355±1052 m). Also, lowest distances in low-, running- and high- intensity zones were found in won matches (8035±614 m, 1241±312 m and 617±224 m, respectively), followed by drawn matches (8287±638 m, 1363±320 m and 646±251 m, respectively) and lost matches (8279±742 m, 1406±343 m and 661±194 m, respectively). Sprinting distance was slightly greatest in lost matches (162±79 m) in compared to won and drawn matches (156±103 m and 157±99 m, respectively).

Table 1. Descriptive statistics for running performance according to the match outcome (data are given as Mean±SD)

	Match outcome		
	Win (n = 40)	Draw (n = 71)	Loss (n = 82)
Total distance covered	9893±896	10298±913	10355±1052
Low intensity running	8035±614	8287±638	8279±742
Running	1241±312	1363±320	1406±343
High speed running	460±152	490±175	499±144
Sprinting	157±99	156±103	162±79
High intensity running	617±224	646±251	661±194

Table 2 presents the results of multinomial logistic regression for the match outcome. Total distance covered was positively related to the losses (OR: 1.0005; 95%CI:1.0001–1.0009) and draws (OR: 1.0004; 95%CI:1.0001–1.0008). Low intensity running was positively associated only with draws (OR: 1.0006; 95%CI: 1.0001–1.0011), while running zone distance was positively associated with both losses (OR: 1.0016; 95%CI: 1.0004–1.0028) and draws (OR: 1.0012; 95%CI: 1.0001–1.0022). High speed running, sprinting and high

Table 2. Differences in running performance according to the match outcome analysed by multinomial logistic regression (reference category is winning outcome)

Running performance	Match outcome	p	OR	95%CI	
Total distance	Lost	0.013	1.0005	1.0001	1.0009
	Draw	0.009	1.0004	1.0001	1.0008
Low intensity running	Lost	0.051	1.0005	0.9999	1.0011
	Draw	0.019	1.0006	1.0001	1.0011
Running	Lost	0.009	1.0016	1.0004	1.0028
	Draw	0.020	1.0012	1.0001	1.0022
High speed running	Lost	0.203	1.0015	0.9991	1.0039
	Draw	0.243	1.0012	0.9991	1.0032
Sprinting	Lost	0.792	1.0005	0.9966	1.0044
	Draw	0.927	0.9998	0.9965	1.0031
High intensity running	Lost	0.318	1.0008	0.9991	1.0025
	Draw	0.438	1.0005	0.9991	1.0019

OR – Odds Ratio; 95%CI – 95% Confidence Interval

Table 3. Descriptive statistics and differences for running performance according to the match location determined by ANOVA (data are given as Mean±SD)

	Match location		ANOVA		
	Home (n = 107)	Away (n = 86)	F-test	p	Effect size η^2
Total distance covered	10032±921	10269±986	2.98	0.09	0.02
Low intensity running	8142±689	8222±621	0.69	0.41	0.00
Running	1262±294	1392±353	7.83	0.01	0.04
High speed running	468±149	493±170	1.14	0.29	0.00
Sprinting	159±97	157±97	0.02	0.88	0.00
High intensity running	627±222	649±236	0.46	0.50	0.00

intensity running were not associated with match outcomes (p=0.203 to 0.927).

Running zone distance covered was significantly greater for away matches (F-test: 7.83, p<0.01, small effect size; 1392±353 m and 1262±294 m, for home and away matches, respectively). Values of total distance covered, low intensity running, high speed running, sprinting and high intensity running were similar irrespective of match location (F-tests: 0.02 to 2.98; p>0.05) (Table 3)

Results indicated similar values of all RP variables (total distance covered, low intensity running, running, high speed running, sprinting and high intensity running) whether the team played against higher or lower ranked opponent (F-tests: 0.52 to 1.53; p>0.05) (Table 4).

Table 4. Descriptive statistics and differences for running performance according to the opponents' level determined by ANOVA (data are given as Mean±SD)

	Opponents' level		ANOVA		
	Higher ranked (n = 92)	Lower ranked (n = 101)	F-test	p	Effect size η²
Total distance covered	10160±1025	10118±892	0.09	0.76	0.00
Low intensity running	8160±699	8194±624	0.13	0.72	0.00
Running	1351±351	1292±303	1.53	0.22	0.00
High speed running	486±158	472±160	0.35	0.56	0.00
Sprinting	160±92	156±101	0.05	0.83	0.00
High intensity running	646±224	629±233	0.25	0.62	0.00

Discussion

This study investigated the associations between RP in CV (match outcome, match location and opponents' level) in Croatian professional soccer players. Results indicated three most important findings: (i) won matches were characterised by lower RP, (ii) association between RP and match location was limited, (iii) RP were not related to the opponent's level.

Match outcome

Our results evidenced significant associations between total distance covered, low intensity running and running zone distance covered with match outcome. Specifically, greater total- and running- zone distance covered were associated with losses and draws, while low intensity running was associated only with draws. In other words, won matches were characterized with lowest overall distance (9893±896 m) and lowest distance covered at low (<14.3 km/h) and moderate (14.4–19.7 km/h) speeds (8035±614 m and 1241±312 m, respectively). In detail, total-, low- and moderate- distance covered in won matches were lower than in lost matches for approximately 5%, 3% and 13%, respectively. Although association between high intensity distance covered and match outcome were not significant, descriptive statistics indicated that high intensity distance covered in won matches was lower for approximately 7% and 5% then in lost and drawn matches, respectively. Putting it altogether, it is evident that won matches in Croatian first division were generally characterised by lower RP.

This altogether indicates that players do not always elicit their maximal physical capacities to win the matches as already noted (Lago et al., 2010). Consequently, it suggests that the results of the matches in Croatian first division are most likely determined by technical and tactical qualities of the players. Indeed, previous studies demonstrated that overall technical and tactical effectiveness probably has a greater impact on the results then RP (Carling, 2013; Asian Clemente et al., 2019). Since examined associations between RP and match outcome in this study were quite weak (please see Table 2), this can be directly supported with findings from our study which indicated that match outcome in general was not strongly influenced by RP.

Match location

Although home advantage in soccer has been extensively discussed (Lago et al., 2010; García-Unanue et al., 2018; Konefał et al., 2020; Barrera et al., 2021; Chmura et al., 2021), studies did not provide consistent evidence about association between RP and match location. For example, previous studies evidenced greater total-, low- and moderate distance covered in home matches, but did not observe differences at submaximal or maximal intensities (Lago et al., 2010; Aquino et al., 2020; Barrera et al., 2021). Similarly, our results also did not evidence differences for submaximal or maximal intensities (i.e., high speed running and sprinting) between home and away matches.

On the other hand, our study indicated some contrast findings when compared to the previously cited studies. Specifically, we evidenced significantly greater running zone distance covered in away matches. In detail, 10% higher running zone distance was evidenced in away matches in compared to the home matches (1392±353 m and 1262±294 m). Here it must be noted that small effect size (ES=0.04) was found for differences in running zone distance between home and away matches, what points to poor association with match location. Also, since all other RP's values were similar irrespective of match location (i.e. no significant differences were evidenced in RP when home- and away-matches were compared), findings from our study collectively demonstrate trivial overall association between RP and match location in Croatian first division. This basically supports previous consideration that influence of home advantage mainly occurs in technical activities rather than physical ones (Zhou, Hopkins, Mao, Calvo, & Liu, 2019; Chmura et al., 2021). Ultimately, it seems that association between RP and match location is strongly influenced by cultural factors of specific competition (Sarmento et al., 2013; García-Unanue et al., 2018).

Opponents' level

Our results do not provide evidence on significant associations between RP and opponents' level. Specifically, no differences were found for any of the RP variables weather the team played against lower- or higher- ranked opponents. Although these findings are in the line with recent study that reported very limited associations between RP and of opponents' level (García-Unanue et al., 2018), most of the previous studies actually indicated that total-, low-, and high- intensity distance covered were higher against "better" than against "weaker" opponents (Bloomfield et al., 2005; Rampinini et al., 2007; Lago et al., 2010). Oppositely, we have found similar values for all RP irrespective to the opponents' level, and from this perspective our results may seem little surprising.

However, the main differences between previously cited studies (Bloomfield et al., 2005; Rampinini et al., 2007; Lago et al., 2010) and our study is the fact that our study analysed only one team. In particular, here observed team played all matches in the same (or similar) tactical formation and preferred the same style of the play. Since RP is highly influenced by tactical formations (Modric et al., 2020b), it is reasonable to expect that the (same) tactical formation and style of play applied in all matches (i.e., against both higher and lower ranked) actually decreased possibility for identifying association between RP and opponents' level. Therefore, to confirm findings from this study RP of different teams should be quantified.

Strengths and limitations

The main limitation of this study comes from the fact that the sample was composed from soccer players that belonged to the same team. Also, due to the methodological reasons, we did not analyse all matches during the observed season, and included only those players who participated in whole matches. All this may influence reported results. On the other hand, this is the first study which analysed associations between RP and CV in Croatian soccer players. Additionally, the data were collected during official games, among professional players, and at the highest national competitive level. Despite the evident limitations, the authors believe that this study may contribute for understanding RP in Croatian soccer players and initiate further research.

Conclusion

This study emphasised that won matches were characterised by lower RP. It seems that Croatian first division soccer players regulate their physical efforts and do not always use their maximal physical capacities when winning. This may suggest that winning is more determined by technical-tactical qualities of the players than by RP. In addition, results from this study demonstrated limited association between RP and match location in Croatian first division, while RP and opponent's level were not inter-related at all. These findings enabled insight into the relationship between RP and contextual variables in Croatian first division players, what allows soccer coaches and analysts better understanding of RP in different circumstances. However, future studies should evaluate RP of other teams from Croatian first division to confirm presented findings.

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Conflict of Interest
The author declares that there is no conflict of interest.

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REVIEW

The Influence of Physical Exercise, Stress and Body Composition on Autonomic Nervous System: A Narrative Review

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Abstract

The heart rate variability (HRV) changes under different situations such as physical exercise, stress and in obese/overweight subjects. It is considered a noninvasive marker of autonomic nervous system function. The aim of this narrative review was to discuss the relationship between HRV and physical exercise. Moreover, we will make an overview about HRV and stress, and HRV and body composition. There are a large number of studies dealing with HRV, however, few of them explain relationship between HRV and physical exercise, stress and body composition. HRV has proved to be a valuable tool to investigate the sympathetic and parasympathetic function of the ANS. Nonlinear parameters can be used to analyze the health of the subjects and is also used to investigate the stress and the physical exercise level. Despite the underlying mechanisms remain to be elucidated, these finding can be used as a starting point to determine a non-invasive index of cardiac wellness for clinical and nutritional application. Thus, physiological feedback via monitoring HRV would prove useful for addressing the individual's present capability, be it during selection processes or returning to duty following injury or illness but should not be used to diagnose any pathological conditions.

Keywords: *autonomic nervous system (ANS), herat rate variability (HRV), cardiovascular disease (CVD), physical activity, stress, overweight*

Introduction

The cardiovascular system, the heart and the circulation, are mostly controlled by higher brain centers and cardiovascular control areas in the brain stem through the activity of sympathetic and parasympathetic nerves (Aubert, Seps, & Beckers, 2003). Control is also affected by baroreceptors, chemoreceptors, muscle afferent, local tissue metabolism and circulating hormones (White & Raven, 2014). Study of cardiovascular variability allows mainly access to the activity of the nerves and the baroreceptors. Analysis of cardiovascular variability permitted insight into the neural control mechanism of the heart, leading to a new discipline: "Neurocardiology" (Aubert & Ramaekers, 1999). This area combines the disciplines of neurosciences and cardiovascular physiology on the research side and of neurology and cardiology on the clinical side. The normal heartbeat and blood pressure vary secondary to respiration, in response to physical, environmental, mental and multiple other factors and is characterized by a circadian variation.

Heart rate variability (HRV) is an easy and non-invasive

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tool for the assessment of variations in beat-to-beat intervals and autonomic nervous system activity with HRV obtained by linear methods within the domains of time and frequency analyses, and nonlinear methods (Task Force of the European Society of Cardiology and the North American Society of Pacing Electrophysiology, 1996). HRV has been studied extensively in regards to cardiovascular disease (Thayer, Yamamoto, & Brosschot, 2010; Frodl & O'Keane, 2013), exercise (Buchheit et al., 2010; Boullosa et al., 2012; Valenzano et al., 2016), stress, such as any type of change that causes physical, emotional, or psychological strain (von Borell et al., 2007; Kim et al., 2018), and body composition (Triggiani et al., 2015, 2019; Messina et al., 2017; Ciliberti et al., 2018). The way in which the cardiovascular system responds to different condition has captured the imagination of sport scientists over the past century (Vitale et al., 2019). For example, during physical activity, critical adjustments are continually made by the cardiovascular system to meet the diver's demands with respect to the musculature and the heart (Fagard, 1997). Rapid changes in heart rate (HR), and blood pressure, cause dynamic adjustments in cardiac and peripheral vascular control, including their regulation by the autonomic nervous system (ANS) (Monda et al., 2016; Messina et al., 2017). These variations also include circadian variations during the course of the day, which could have either a positive or negative effect on sport performance (Vitale & Weydahl, 2017). For this reason, understanding the interactions between cardiovascular function, activity of the ANS, chronobiology, biological rhythms, and chronotype allows to us understand the effects of exercise on human performance. The aim of this narrative review was to discuss the relationship between HRV and physical exercise. Moreover, considering that stress may be defined as a state of threatened homeostasis, which is counteracted by adaptive processes involving affective, physiological, biochemical, and cognitive–behavioral responses in an attempt to regain homeostasis, we will make an overview about HRV and stress, and the relationship between HRV and body composition.

HRV and physical exercise

During physical activity the vagal tone is withdrawn and HR is regulated principally by adrenergic system (Borresen & Lambert, 2008). The mechanism that physical activity induced increase in HR involves parasympathetic and sympathetic circuits. Thus, both the sympathetic and parasympathetic arms of the ANS play a crucial role during physical activity. Modification in HRV in response to physical exercise can vary in accordance to the degree, duration and load of physical activity and/or the kind of it (Plews, 2013; Chieffi et al., 2017). The HR increase during physical activity is due both a parasympathetic withdrawal and an increased sympathetic activity, and the role of the two drivers depends on exercise intensity. In particular, modifications in HRV, including variations in low frequencies (LF), high frequencies (HF), and total power (TP) (frequency domain), were observed in relation to different intensities of aerobic exercise. The HF peak is recognized in the power spectrum in the full range of relative intensity, being responsible for the most part of HRV at maximal load, while LF power does not change during low intensity exercise (below anaerobic threshold) and usually decreases to negligible values at medium–high intensity (above anaerobic threshold), where sympathetic activity is enhanced (Hottenrott, Hoos and Esperer, 2006). Accordingly, it has been showed that HR increase during physical activity is linked with the decrease in HRV in both HF and LF during a graded-work load exercise on a cycle ergometer (Lahiri, Kannankeril, & Goldberger, 2008), and the highest decrease in TP has been reported to occur during steady state exercises (Gronwald, Hoos, & Hottenrott, 2019). It seems that the modification in HF and LF showed during exercise do not reflect the decrease in vagal activity and the activation of sympathetic system occurring at increasing loads (Makivić, Nikić, & Willis, 2013). Moreover, during physical activity, technical problems arise from HR measurements because the steady state, which is mandatory for spectral analysis, is not always obtained (NASPE, 1996). The HRV measurement immediately after the end of physical activity reflects the subjects' responses to exercise, which primarily related to physical fitness. In fact, authors showed that the parasympathetic tone decrease after prolonged exercise and the recovery time was inversely correlated with subjects' maximal aerobic power (Hautala et al., 2001). Others authors have studied the effects of exercise intensity and duration on nocturnal heart rate variability and sleep quality (Myllymäki et al., 2012). In this study was showed that the increasing exercise intensity and/or duration caused a delayed recovery of nocturnal cardiac autonomic modulation (Myllymäki et al., 2012). Regarding the effects of supramaximal intermittent exercise, it was showed that there is relationship between exercise intensity and short- and long-term HRV recovery, because this kind of physical exercise improves post-exercise parasympathetic activity (Bonato et al., 2018). In general, it has been showed that athletes have lower HR values than sedentary controls (Fagard, 2003). Accordingly to this, authors showed that HR recovery after 30 and 120 seconds after exercise performed at different intensities was accelerated in well-trained athletes, highlighting a physiologic adaptation allowing for rapid HR recovery after intense exercise (Imai et al., 1994). According to this reasons, others authors showed that HRV has been widely researched in elite and well-trained athletes in order to understand the body's response via the ANS to intensified training loads (Vitale et al., 2019).

Others authors describe the link between Musculoskeletal overuse injuries and heart rate variability (Gisselman et al., 2016; Cotoia et al., 2018). Those authors hypothesized that athletes with accumulating somatic tissue damage would demonstrate changes in HRV at rest condition, reflecting decreased parasympathetic activity and increased autonomic nervous system (ANS) response. Relative to each athlete's baseline HRV measurements, imbalances in parasympathetic nervous system and sympathetic nervous system activity may indicate that an athlete is in a state of ongoing repair and recovery, as compared to an athlete who is adapting positively to training load (Gisselman et al., 2016; Valenzano et al., 2019).

HRV and stress

The Stress was defined as a maladaptive state in which the sympathetic nervous system is over activated, causing acute or chronic physical, psychological, and behavioral impairment (Kim et al., 2018). The search for stress biomarkers remains a challenging task for researchers and clinicians as there are several obstacles. One obstacle is a lack of consensus on the definition of stress. Furthermore, we lack a comprehensive framework for studying how organisms function in and adapt to constantly changing environments (Thayer et al., 2012;

Buonocore et al., 2020). At present, there is no universally recognized standard for stress evaluation. Different studies using existing stress measurement methods and examining biological markers have been conducted, and recently, studies on HRV and stress are increasing in frequency. An important study showed that increases in stress were associated with decreases in the RR interval (Sloan et al., 1994; Moscatelli et al., 2020). Moreover, psychological stress was significantly associated with an increase in the LF/HF ratio, suggesting increased SNS activity during stressful periods (Sloan et al., 1994; Valenzano et al., 2018). In another study authors investigated the relationship between the number of job stressors, self-reported sleep quality, and daytime autonomic activities (Kageyama et al., 1998; Messina et al., 2018). Those authors found no correlation between the HRV parameters and five job stressor scores Messina et al., 2015a; 2015b). However, subsequent studies have showed that some HRV indicators reflect psychological stress.

HRV is sensitive to changes in ANS activity related to stress. In different studies (Kim et al., 2018; Viggiano et al. ,2008; 2010; 2016), HRV variables changed in response to stress. The most frequently reported factor associated with changes in HRV variables was low parasympathetic activity, which is characterized by a decrease in the HF and an increase in the LF. HRV may be correlated to the activity of a flexible network of neural structures, which are dynamically organized in response to environmental modifications. In fact, neuroimaging investigations show that HRV may be linked to reduced threat perception, mediated by cortical regions involved in the appraisal of stressful situations. In clinical situations, HRV can be considered a tool that reflects heart activity and overall autonomic health, rather than specific mental illnesses or disease states (Kim et al., 2018). Thus, when evaluating the relationship between stress and HRV, it is crucial to consider the overall autonomic context as well as the patient's medical and psychological history.

HRV and body composition

The correlation between the overweight/obese and modifications in the activity of the ANS is widely accepted (Triggiani et al., 2015, 2019). In particular, it is known that the ANS influences physiological time variation between heartbeats. Hence, the HRV is considered an appropriate measure of the cardiac autonomic function (Shaffer & Ginsberg, 2017).

In the last two decades, different authors investigated the relationship between HRV, body mass index (BMI) and other indices of body composition (Skrapari et al., 2007). In particular, a decrease in HRV has been proposed to be related to body fat content (Berthoud, 2008). Moreover, in another important investigation conducted with healthy women, was found a statistically significant inverted U-shaped curve fitting the distribution of some HRV parameters along with the percentage of body fat extent (Triggiani et al., 2015). In particular, this data showed a reduction in HRV either in overweight or underweight subjects compared with normal weight subjects, and this appeared to be a result of the abnormal control of homeostatic mechanisms related to an altered distribution of body fat. One of the emergent explanations for those controversies might arise from the enhancing conviction that visceral adipose tissue (VAT), more than the general body fat mass, might be responsible, or, at least, related to the impairment of ANS activity (Hillebrand et al., 2014). In another important study was investigated visceral fat and HRV (Triggiani et al., 2019). The results of this investigation suggest a general decreased of HRV variables associated with increased body fat content although only HF resulted statistically significant. Moreover, the authors found a significant association between HRV indices and VAT (Messina et al., 2018). This authors conclude that in young adult healthy normotensive women, the association between ANS control and body fat is mostly due to VAT. Despite the underlying mechanisms remain to be elucidated, these finding can be used as a starting point to determine a non-invasive index of cardiac wellness for clinical and nutritional application (Triggiani et al., 2019).

Conclusion

Heart rate variability analysis has become an important tool in cardiology, because its measurements are noninvasive and easy to perform, have relatively good reproducibility and provide prognostic information on patients with heart disease. HRV has proved to be a valuable tool to investigate the sympathetic and parasympathetic function of the ANS. Spectral analysis of HR has clarified the nature of diabetic autonomic neuropathy and of other neurologic disorders that encounter the ANS. Nonlinear parameters can be used to analyze the health of the subjects and is also used to investigate the stress and the physical exercise level. The feasibility and possibilities of HRV within this particular field of application are well documented within the existing literature. Future studies, focusing on translational approaches that transfer current evidence in general practice (i.e. training of athletes) are needed. Thus, physiological feedback via monitoring HRV would prove useful for addressing the individual's present capability, be it during selection processes or returning to duty following injury or illness but should not be used to diagnose any pathological conditions.

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Conflict of Interest
The author declares that there is no conflict of interest.

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- A signed form that states the study was not previously published, nor has been submitted simultaneously for consideration of publication elsewhere, that states that all of the authors are in agreement with submission of the manuscript to SM, and that, for studies that use animal or human individuals, authors must include information regarding their institution's ethics committee, and which identifies the official approval number;
- A signed form that there is no conflict of interest.

Name the files according to the family name of the first author. Authors submitting revised versions of the manuscript can use the identification number of their manuscript as provided by the Journal Office. *See* example:

- ✓ FAMILY NAME-manuscript.doc – (main manuscript file)
- ✓ FAMILY NAME-statement.PDF – (authorship statement)
- ✓ FAMILY NAME-declaration.PDF – (declaration of potential conflict of interest)
- ✓ FAMILY NAME-fig1.tiff – (Figure 1)

1.4. Peer Review Process

A manuscript submitted for publication will be submitted to the review process as long as it fits the following criteria:

- The study was not previously published, nor has been submitted simultaneously for consideration of publication elsewhere;
- All persons listed as authors approved its submission to SM;
- Any person cited as a source of personal communication has approved the quote;
- The opinions expressed by the authors are their exclusive responsibility;
- The author signs a formal statement that the submitted manuscript complies with the directions and guidelines of SM.

The editors-in-chief and associate editors will make a preliminary analysis regarding the appropriateness, quality, originality and written style/grammar of the submitted manuscript. The editors reserve the right to request additional information, corrections, and guideline compliance before they submit the manuscript to the ad-hoc review process.

SM uses ad-hoc reviewers, who volunteer to analyze the merit of the study. Typically, one or two expert reviewers are consulted in a double-blind process. Authors are notified by e-mail when their submission has been accepted (or rejected). Minor changes in the text may be made at the discretion of the editors-in-chief and/or associate editors. Changes can include spelling and grammar in the chosen language, written style, journal citations, and reference guidelines. The author is notified of changes via email. The final version is available to the author for his or her approval before it is published.

1.5. Open Access License and Publisher Copyright Policies

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SM only publishes studies that have been approved by an institutional ethics committee (when a study involves humans or animals). Fail to provide such information prevent its publication. To ensure these requirements, it is essential that submission documentation is complete. If you have not completed this step yet, go to SM website and fill out the two required documents: Declaration of Potential Conflict of Interest and Authorship Statement. Whether or not your study uses humans or animals, these documents must be completed and signed by all authors and attached as supplementary files in the originally submitted manuscript.

1.6. After Acceptance

After the manuscript has been accepted, authors will receive a PDF version of the manuscripts for authorization, as it should look in printed version of SM. Authors should carefully check for omissions. Reporting errors after this point will not be possible and the Editorial Board will not be eligible for them.

Should there be any errors, authors should report them to the Office e-mail address **sportmont@ucg.ac.me**. If there are not any errors authors should also write a short e-mail stating that they agree with the received version.

1.7. Code of Conduct Ethics Committee of Publications

C O P E COMMITTEE ON PUBLICATION ETHICS

SM is hosting the Code of Conduct Ethics Committee of Publications of the **COPE** (the Committee on Publication Ethics), which provides a forum for publishers and Editors of scientific journals to discuss issues relating to the integrity of the work submitted to or published in their journals.

2. MANUSCRIPT STRUCTURE

2.1. Title Page

The first page of the manuscripts should be the title page, containing: title, type of publication, running head, authors, affiliations, corresponding author, and manuscript information. *See* example:

Body Composition of Elite Soccer Players from Montenegro

Original Scientific Paper

Elite Soccer Players from Montenegro

Dusko Bjelica[1]

[1]Univeristy of Montenegro, Faculty for Sport an Physical Education, Niksic, Montenegro

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Dusko Bjelica

University of Montenegro

Faculty for Sport and Physical Education

Narodne omladine bb, 81400 Niksic, Montenegro

E-mail: sportmont@t-com.me

Word count: 2,946

Abstract word count: 236

Number of Tables: 3

Number of Figures: 0

2.1.1. Title

Title should be short and informative and the recommended length is no more than 20 words. The title should be in Title Case, written in uppercase and lowercase letters (initial uppercase for all words except articles, conjunctions, short prepositions no longer than four letters etc.) so that first letters of the words in the title are capitalized. Exceptions are words like: “and”, “or”, “between” etc. The word following a colon (:) or a hyphen (-) in the title is always capitalized.

2.1.2. Type of publication

Authors should suggest the type of their submission.

2.1.3. Running head

Short running title should not exceed 50 characters including spaces.

2.1.4. Authors

The form of an author’s name is first name, middle initial(s), and last name. In one line list all authors with full names separated by a comma (and space). Avoid any abbreviations of academic or professional titles. If authors belong to different institutions, following a family name of the author there should be a number in superscript designating affiliation.

2.1.5. Affiliations

Affiliation consists of the name of an institution, department, city, country/territory (in this order) to which the author(s) belong and to which the presented / submitted work should be attributed. List all affiliations (each in a separate line) in the order corresponding to the list of authors. Affiliations must be written in English, so carefully check the official English translation of the names of institutions and departments.

Only if there is more than one affiliation, should a number be given to each affiliation in order of appearance. This number should be written in superscript at the beginning of the line, separated from corresponding affiliation with a space. This number should also be put after corresponding name of the author, in superscript with no space in between.

If an author belongs to more than one institution, all corresponding superscript digits, separated with a comma with no space in between, should be present behind the family name of this author.

In case all authors belong to the same institution affiliation numbering is not needed.

Whenever possible expand your authors' affiliations with departments, or some other, specific and lower levels of organization.

2.1.6. Corresponding author

Corresponding author's name with full postal address in English and e-mail address should appear, after the affiliations. It is preferred that submitted address is institutional and not private. Corresponding author's name should include only initials of the first and middle names separated by a full stop (and a space) and the last name. Postal address should be written in the following line in sentence case. Parts of the address should be separated by a comma instead of a line break. E-mail (if possible) should be placed in the line following the postal address. Author should clearly state whether or not the e-mail should be published.

2.1.7. Manuscript information

All authors are required to provide word count (excluding title page, abstract, tables/figures, figure legends, Acknowledgements, Conflict of Interest, and References), the Abstract word count, the number of Tables, and the number of Figures.

2.2. Abstract

The second page of the manuscripts should be the abstract and key words. It should be placed on second page of the manuscripts after the standard title written in upper and lower case letters, bold.

Since abstract is independent part of your paper, all abbreviations used in the abstract should also be explained in it. If an abbreviation is used, the term should always be first written in full with the abbreviation in parentheses immediately after it. Abstract should not have any special headings (e.g., Aim, Results…).

Authors should provide up to six key words that capture the main topics of the article. Terms from the Medical Subject Headings (MeSH) list of Index Medicus are recommended to be used.

Key words should be placed on the second page of the manuscript right below the abstract, written in italic. Separate each key word by a comma (and a space). Do not put a full stop after the last key word. *See* example:

Abstract

Results of the analysis of

Key words: *spatial memory, blind, transfer of learning, feedback*

2.3. Main Chapters

Starting from the third page of the manuscripts, it should be the main chapters. Depending on the type of publication main manuscript chapters may vary. The general outline is: Introduction, Methods, Results, Discussion, Acknowledgements (optional), Conflict of Interest (optional). However, this scheme may not be suitable for reviews or publications from some areas and authors should then adjust their chapters accordingly but use the general outline as much as possible.

2.3.1. Headings

Main chapter headings: written in bold and in Title Case. *See* example:
- ✓ **Methods**

Sub-headings: written in italic and in normal sentence case. Do not put a full stop or any other sign at the end of the title. Do not create more than one level of sub-heading. *See* example:
- ✓ *Table position of the research football team*

2.3.2 Ethics

When reporting experiments on human subjects, there must be a declaration of Ethics compliance. Inclusion of a statement such as follow in Methods section will be understood by the Editor as authors' affirmation of compliance: "This study was approved in advance by [name of committee and/or its institutional sponsor]. Each participant voluntarily provided written informed consent before participating." Authors that fail to submit an Ethics statement will be asked to resubmit the manuscripts, which may delay publication.

2.3.3 Statistics reporting

SM encourages authors to report precise p-values. When possible, quantify findings and present them with appropriate indicators of measurement error or uncertainty (such as confidence intervals). Use normal text (i.e., non-capitalized, non-italic) for statistical term "p".

2.3.4. 'Acknowledgements' and 'Conflict of Interest' (optional)

All contributors who do not meet the criteria for authorship should be listed in the 'Acknowledgements' section. If applicable, in 'Conflict of Interest' section, authors must clearly disclose any grants, financial or material supports, or any sort of technical assistances from an institution, organization, group or an individual that might be perceived as leading to a conflict of interest.

2.4. References

References should be placed on a new page after the standard title written in upper and lower case letters, bold.

All information needed for each type of must be present as specified in guidelines. Authors are solely responsible for accuracy of each reference. Use authoritative source for information such as Web of Science, Medline, or PubMed to check the validity of citations.

2.4.1. References style

SM adheres to the American Psychological Association 6th Edition reference style. Check "American Psychological Association. (2009). Concise rules of APA style. American Psychological Association." to ensure the manuscripts conform to this reference style. Authors using EndNote® to organize the references must convert the citations and bibliography to plain text before submission.

2.4.2. Examples for Reference citations

One work by one author
- ✓ In one study (Reilly, 1997), soccer players
- ✓ In the study by Reilly (1997), soccer players
- ✓ In 1997, Reilly's study of soccer players

Works by two authors
- ✓ Duffield and Marino (2007) studied
- ✓ In one study (Duffield & Marino, 2007), soccer players
- ✓ In 2007, Duffield and Marino's study of soccer players

Works by three to five authors: cite all the author names the first time the reference occurs and then subsequently include only the first author followed by et al.

- ✓ First citation: Bangsbo, Iaia, and Krustrup (2008) stated that
- ✓ Subséquent citation: Bangsbo et al. (2008) stated that

Works by six or more authors: cite only the name of the first author followed by et al. and the year

- ✓ Krustrup et al. (2003) studied
- ✓ In one study (Krustrup et al., 2003), soccer players

Two or more works in the same parenthetical citation: Citation of two or more works in the same parentheses should be listed in the order they appear in the reference list (i.e., alphabetically, then chronologically)

- ✓ Several studies (Bangsbo et al., 2008; Duffield & Marino, 2007; Reilly, 1997) suggest that

2.4.3. Examples for Reference list

Journal article (print):

Nepocatych, S., Balilionis, G., & O'Neal, E. K. (2017). Analysis of dietary intake and body composition of female athletes over a competitive season. *Montenegrin Journal of Sports Science and Medicine, 6*(2), 57-65. doi: 10.26773/mjssm.2017.09.008

Duffield, R., & Marino, F. E. (2007). Effects of pre-cooling procedures on intermittent-sprint exercise performance in warm conditions. *European Journal of Applied Physiology, 100*(6), 727-735. doi: 10.1007/s00421-007-0468-x

Krustrup, P., Mohr, M., Amstrup, T., Rysgaard, T., Johansen, J., Steensberg, A., Bangsbo, J. (2003). The yo-yo intermittent recovery test: physiological response, reliability, and validity. *Medicine and Science in Sports and Exercise, 35*(4), 697-705. doi: 10.1249/01.MSS.0000058441.94520.32

Journal article (online; electronic version of print source):

Williams, R. (2016). Krishna's Neglected Responsibilities: Religious devotion and social critique in eighteenth-century North India [Electronic version]. *Modern Asian Studies, 50*(5), 1403-1440. doi:10.1017/S0026749X14000444

Journal article (online; electronic only):

Chantavanich, S. (2003, October). Recent research on human trafficking. *Kyoto Review of Southeast Asia, 4*. Retrieved November 15, 2005, from http://kyotoreview.cseas.kyoto-u.ac.jp/issue/issue3/index.html

Conference paper:

Pasadilla, G. O., & Milo, M. (2005, June 27). *Effect of liberalization on banking competition*. Paper presented at the conference on Policies to Strengthen Productivity in the Philippines, Manila, Philippines. Retrieved August 23, 2006, from http://siteresources.worldbank.org/INTPHILIPPINES/Resources/Pasadilla.pdf

Encyclopedia entry (print, with author):

Pittau, J. (1983). Meiji constitution. In *Kodansha encyclopedia of Japan* (Vol. 2, pp. 1-3). Tokyo: Kodansha.

Encyclopedia entry (online, no author):

Ethnology. (2005, July). In *The Columbia encyclopedia* (6th ed.). New York: Columbia University Press. Retrieved November 21, 2005, from http://www.bartleby.com/65/et/ethnolog.html

Thesis and dissertation:

Pyun, D. Y. (2006). *The proposed model of attitude toward advertising through sport.* Unpublished Doctoral Dissertation. Tallahassee, FL: The Florida State University.

Book:

Borg, G. (1998). *Borg's perceived exertion and pain scales*: Human kinetics.

Chapter of a book:

Kellmann, M. (2012). Chapter 31-Overtraining and recovery: Chapter taken from Routledge Handbook of Applied Sport Psychology ISBN: 978-0-203-85104-3 *Routledge Online Studies on the Olympic and Paralympic Games* (Vol. 1, pp. 292-302).

Reference to an internet source:

Agency. (2007). Water for Health: Hydration Best Practice Toolkit for Hospitals and Healthcare. Retrieved 10/29, 2013, from www.rcn.org.uk/newsevents/hydration

2.5. Tables

All tables should be included in the main manuscript file, each on a separate page right after the Reference section.

Tables should be presented as standard MS Word tables.

Number (Arabic) tables consecutively in the order of their first citation in the text.

Tables and table headings should be completely intelligible without reference to the text. Give each column a short or abbreviated heading. Authors should place explanatory matter in footnotes, not in the heading. All abbreviations appearing in a table and not considered standard must be explained in a footnote of that table. Avoid any shading or coloring in your tables and be sure that each table is cited in the text.

If you use data from another published or unpublished source, it is the authors' responsibility to obtain permission and acknowledge them fully.

2.5.1. Table heading

Table heading should be written above the table, in Title Case, and without a full stop at the end of the heading. Do not use suffix letters (e.g., Table 1a, 1b, 1c); instead, combine the related tables. *See* example:

- ✓ **Table 1.** Repeated Sprint Time Following Ingestion of Carbohydrate-Electrolyte Beverage

2.5.2. Table sub-heading

All text appearing in tables should be written beginning only with first letter of the first word in all capitals, i.e., all words for variable names, column headings etc. in tables should start with the first letter in all capitals. Avoid any formatting (e.g., bold, italic, underline) in tables.

2.5.3. Table footnotes

Table footnotes should be written below the table.

General notes explain, qualify or provide information about the table as a whole. Put explanations of abbreviations, symbols, etc. here. General notes are designated by the word *Note* (italicized) followed by a period.

- ✓ *Note.* CI: confidence interval; Con: control group; CE: carbohydrate-electrolyte group.

Specific notes explain, qualify or provide information about a particular column, row, or individual entry. To indicate specific notes, use superscript lowercase letters (e.g. [a, b, c]), and order the superscripts from left to right, top to bottom. Each table's first footnote must be the superscript [a].

- ✓ [a]One participant was diagnosed with heat illness and n = 19.[b]n =20.

Probability notes provide the reader with the results of the texts for statistical significance. Probability notes must be indicated with consecutive use of the following symbols: * † ‡ § ¶ || etc.

- ✓ *P<0.05,†p<0.01.

2.5.4. Table citation

In the text, tables should be cited as full words. *See* example:

- ✓ Table 1 (first letter in all capitals and no full stop)
- ✓ ...as shown in Tables 1 and 3. (citing more tables at once)
- ✓ ...result has shown (Tables 1-3) that... (citing more tables at once)
- ✓ ....in our results (Tables 1, 2 and 5)... (citing more tables at once)

2.6. Figures

On the last separate page of the main manuscript file, authors should place the legends of all the figures submitted separately.

All graphic materials should be of sufficient quality for print with a minimum resolution of 600 dpi. SM prefers TIFF, EPS and PNG formats.

If a figure has been published previously, acknowledge the original source and submit a written permission from the copyright holder to reproduce the material. Permission is required irrespective of authorship or publisher except for documents in the public domain. If photographs of people are used, either the subjects must not be identifiable or their pictures must be accompanied by written permission to use the photograph whenever possible permission for publication should be obtained.

Figures and figure legends should be completely intelligible without reference to the text.

The price of printing in color is 50 EUR per page as printed in an issue of SM.

2.6.1. Figure legends

Figures should not contain footnotes. All information, including explanations of abbreviations must be present in figure legends. Figure legends should be written bellow the figure, in sentence case. *See* example:

- ✓ **Figure 1.** Changes in accuracy of instep football kick measured before and after fatigued. SR – resting state, SF – state of fatigue, *p>0.01, †p>0.05.

2.6.2. Figure citation

All graphic materials should be referred to as Figures in the text. Figures are cited in the text as full words. *See* example:

- ✓ Figure 1
    - × figure 1
    - × Figure 1.
    - ✓ ….exhibit greater variance than the year before (Figure 2). Therefore…
    - ✓ ….as shown in Figures 1 and 3. (citing more figures at once)
    - ✓ ….result has shown (Figures 1-3) that... (citing more figures at once)
    - ✓ ….in our results (Figures 1, 2 and 5)... (citing more figures at once)

2.6.3. Sub-figures

If there is a figure divided in several sub-figures, each sub-figure should be marked with a small letter, starting with a, b, c etc. The letter should be marked for each subfigure in a logical and consistent way. *See* example:

- ✓ Figure 1a
- ✓ …in Figures 1a and b we can…
- ✓ …data represent (Figures 1a-d)…

2.7. Scientific Terminology

All units of measures should conform to the International System of Units (SI).

Measurements of length, height, weight, and volume should be reported in metric units (meter, kilogram, or liter) or their decimal multiples.

Decimal places in English language are separated with a full stop and not with a comma. Thousands are separated with a comma.

Percentage	Degrees	All other units of measure	Ratios	Decimal numbers
✓ 10%	✓ 10º	✓ 10 kg	✓ 12:2	✓ 0.056
× 10 %	× 10 º	× 10kg	× 12 : 2	× .056

Signs should be placed immediately preceding the relevant number.		
✓ 45±3.4	✓ p<0.01	✓ males >30 years of age
× 45 ± 3.4	× p < 0.01	× males > 30 years of age

2.8. Latin Names

Latin names of species, families etc. should be written in italics (even in titles). If you mention Latin names in your abstract they should be written in non-italic since the rest of the text in abstract is in italic. The first time the name of a species appears in the text both genus and species must be present; later on in the text it is possible to use genus abbreviations. *See* example:

- ✓ First time appearing: *musculus biceps brachii*

Abbreviated: *m. biceps brachii*

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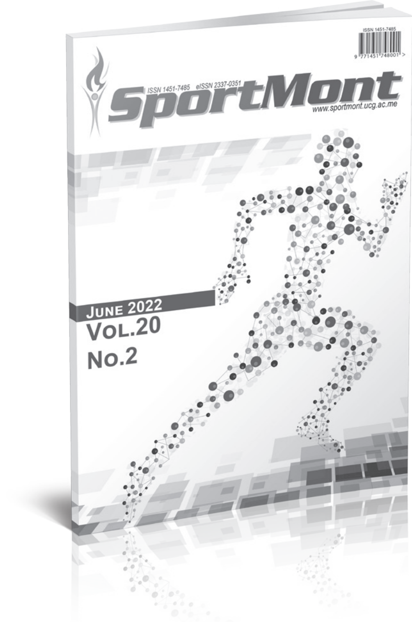

ISSN 1451-7485

Sport Mont (SM) is a print (ISSN 1451-7485) and electronic scientific journal (eISSN 2337-0351) aims to present easy access to the scientific knowledge for sport-conscious individuals using contemporary methods. The purpose is to minimize the problems like the delays in publishing process of the articles or to acquire previous issues by drawing advantage from electronic medium. Hence, it provides:

- Open-access and freely accessible online;
- Fast publication time;
- Peer review by expert, practicing researchers;
- Post-publication tools to indicate quality and impact;
- Community-based dialogue on articles;
- Worldwide media coverage.

SM is published three times a year, in February, June and October of each year. SM publishes original scientific papers, review papers, editorials, short reports, peer review - fair review, as well as invited papers and award papers in the fields of Sports Science and Medicine, as well as it can function as an open discussion forum on significant issues of current interest.

SM covers all aspects of sports science and medicine; all clinical aspects of exercise, health, and sport; exercise physiology and biophysical investigation of sports performance; sport biomechanics; sports nutrition; rehabilitation, physiotherapy; sports psychology; sport pedagogy, sport history, sport philosophy, sport sociology, sport management; and all aspects of scientific support of the sports coaches from the natural, social and humanistic side.

Prospective authors should submit manuscripts for consideration in Microsoft Word-compatible format. For more complete descriptions and submission instructions, please access the Guidelines for Authors pages at the SM website: http://www.sportmont.ucg.ac.me/?sekcija=page&p=51. Contributors are urged to read SM's guidelines for the authors carefully before submitting manuscripts. Manuscripts submissions should be sent in electronic format to sportmont@ucg.ac.me or contact following Editors:

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Publication date: Autumn issue – October 2022
Winter issue – February 2023
Summer issue – June 2023

MONTENEGRIN SPORTS ACADEMY

Founded in 2003 in Podgorica (Montenegro), the Montenegrin Sports Academy (MSA) is a sports scientific society dedicated to the collection, generation and dissemination of scientific knowledge at the Montenegrin level and beyond.

The Montenegrin Sports Academy (MSA) is the leading association of sports scientists at the Montenegrin level, which maintains extensive co-operation with the corresponding associations from abroad. The purpose of the MSA is the promotion of science and research, with special attention to sports science across Montenegro and beyond. Its topics include motivation, attitudes, values and responses, adaptation, performance and health aspects of people engaged in physical activity and the relation of physical activity and lifestyle to health, prevention and aging. These topics are investigated on an interdisciplinary basis and they bring together scientists from all areas of sports science, such as adapted physical activity, biochemistry, biomechanics, chronic disease and exercise, coaching and performance, doping, education, engineering and technology, environmental physiology, ethics, exercise and health, exercise, lifestyle and fitness, gender in sports, growth and development, human performance and aging, management and sports law, molecular biology and genetics, motor control and learning, muscle mechanics and neuromuscular control, muscle metabolism and hemodynamics, nutrition and exercise, overtraining, physiology, physiotherapy, rehabilitation, sports history, sports medicine, sports pedagogy, sports philosophy, sports psychology, sports sociology, training and testing.

The MSA is a non-profit organization. It supports Montenegrin institutions, such as the Ministry of Education and Sports, the Ministry of Science and the Montenegrin Olympic Committee, by offering scientific advice and assistance for carrying out coordinated national and European research projects defined by these bodies. In addition, the MSA serves as the most important Montenegrin and regional network of sports scientists from all relevant subdisciplines.

The main scientific event organized by the Montenegrin Sports Academy (MSA) is the annual conference held in the first week of April.

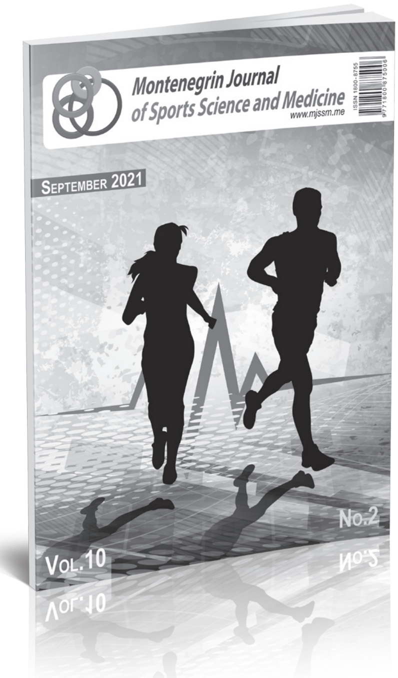
Annual conferences have been organized since the inauguration of the MSA in 2003. Today the MSA conference ranks among the leading sports scientific congresses in the Western Balkans. The conference comprises a range of invited lecturers, oral and poster presentations from multi- and mono-disciplinary areas, as well as various types of workshops. The MSA conference is attended by national, regional and international sports scientists with academic careers. The MSA conference now welcomes up to 200 participants from all over the world.

It is our great pleasure to announce the upcoming 19th Annual Scientific Conference of Montenegrin Sports Academy “Sport, Physical Activity and Health: Contemporary Perspectives” to be held in Dubrovnik, Croatia, from 7 to 10 April, 2022. It is planned to be once again organized by the Montenegrin Sports Academy, in cooperation with the Faculty of Sport and Physical Education, University of Montenegro and other international partner institutions (specified in the partner section).

The conference is focused on very current topics from all areas of sports science and sports medicine including physiology and sports medicine, social sciences and humanities, biomechanics and neuromuscular (see Abstract Submission page for more information).

We do believe that the topics offered to our conference participants will serve as a useful forum for the presentation of the latest research, as well as both for the theoretical and applied insight into the field of sports science and sports medicine disciplines.

Montenegrin Journal of Sports Science and Medicine



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Montenegrin Journal of Sports Science and Medicine (MJSSM) is a print (ISSN 1800-8755) and electronic scientific journal (eISSN 1800-8763) aims to present easy access to the scientific knowledge for sport-conscious individuals using contemporary methods. The purpose is to minimize the problems like the delays in publishing process of the articles or to acquire previous issues by drawing advantage from electronic medium. Hence, it provides:

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- Fast publication time;
- Peer review by expert, practicing researchers;
- Post-publication tools to indicate quality and impact;
- Community-based dialogue on articles;
- Worldwide media coverage.

MJSSM is published biannually, in September and March of each year. MJSSM publishes original scientific papers, review papers, editorials, short reports, peer review - fair review, as well as invited papers and award papers in the fields of Sports Science and Medicine, as well as it can function as an open discussion forum on significant issues of current interest.

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Prospective authors should submit manuscripts for consideration in Microsoft Word-compatible format. For more complete descriptions and submission instructions, please access the Guidelines for Authors pages at the MJSSM website: http://www.mjssm.me/?sekcija=page&p=51. Contributors are urged to read MJSSM's guidelines for the authors carefully before submitting manuscripts. Manuscripts submissions should be sent in electronic format to office@mjssm.me or contact following Editors:

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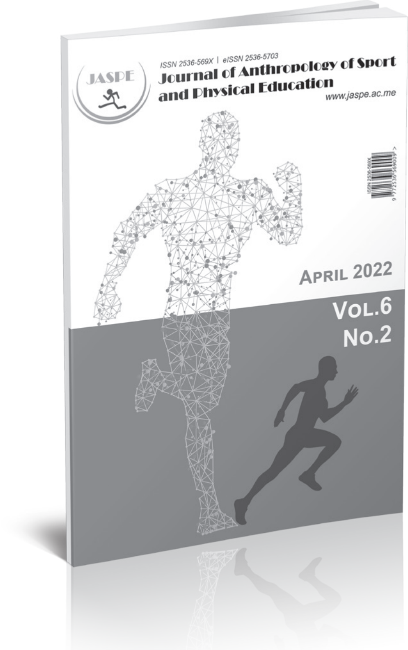
	Spring issue – March 2023

Journal of Anthropology of Sport and Physical Education



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