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Elite and Sub-elite Youth Soccer Players Show no Difference in Vertical Jump Performance

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Abstract

This study aimed to determine whether vertical jump performance differs among youth players with different performance levels. A total of 84 youth male soccer players from the U19 category were recruited. The players were divided into the elite (EG) and sub-elite (SEG) groups based on their performance level. The vertical jump (VJ) performance during countermovement jump with free arms (CMJFA) and drop jump (DJ) were measured using two force platforms Kistler B8611A at a sampling rate of 1000 Hz (KISTLER Instrumente AG, Switzerland). The following outcome variables were calculated in all participants: vertical jump height (VJH), vertical ground reaction force (VGRF), and force impulse (FI) in absolute and relative values. Data analysis showed no significant differences ($p>0.05$) with trivial to small effects in VJH for both jump types (CMJFA and DJ) between EG and SEG. $FI_{relative}$ provides a good indication of VJH in comparison with the other kinematic variables selected in this study. The leg muscle mass (LMM) ratio normalised to body mass provides a better association with VJH than the other selected morphological variables in this study, although a small effect size was observed. VJH does not appear to be a distinguishing feature among soccer players in the first two performance levels in the U19 category. Therefore, the results may not be sensitive enough to differentiate the performance levels, especially when the difference is only in one performance level. Future research should consider using other parameters, such as the eccentric rate of force development or reactive strength index, as recommended in a previous study.

Keywords: *lower limb strength, morphological variables, performance level, vertical jump performance, youth soccer*

Introduction

Defining elite performance levels remains elusive because of the wide range of descriptors used to distinguish elite from non-elite athletes, especially among youth (Lorenz et al., 2013). Elite athletes traditionally play in the higher divisions (Trecroci et al., 2018), sign for a professional club, or play as international youth athletes (Reilly et al., 2000). The assessment of performance in youth can be misleading because the process of growth and development is incomplete. This process is often burdened by the subjective assessment of the coach or scouts who select these players for the club or national team. The key characteristics that would predetermine success in soccer have been the subject of many scientific studies, although the conclusions are inconsistent. Elite youth soccer players have been found to have a greater physical ability than their lower-performing peers, giving them a higher chance of winning tackles, avoiding an opponent, or scoring a goal (Waldron & Murphy, 2013). Soccer requires players to have both great technical skills and optimal physical abilities, such as sprinting, acceleration, deceleration, jumping, and changing direction in a multidirectional manner (Loturco et al., 2020). The close relationship between vertical jumping (VJ) performance and sprinting abilities in soccer players has been previously reported, and it is hypothesized that players able to jump higher will also be more efficient at accelerating their bodies forward and therefore be able to achieve higher velocities over shorter distances (Loturco et al., 2015). The evaluation of VJ performance using a force platform is a professional method for investigating the activity of a closed kinetic chain (Castagna et al., 2013). The authors demonstrated that vertical jump height (VJH) could be a distinguishing criterion between youth soccer players at different levels of competition (Reilly et al., 2000; Gissis et al., 2006; Coelho

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et al., 2010; Trecroci et al., 2018; Trecrori et al., 2019). These differences in VJH performance may be due to differences in muscle strength, coordination patterns, or training experience (Zatsiorsky et al., 2020). In contrast, Cometi et al. (2001) found differences between elite and sub-elite adult players, although there were no differences between elite and amateur players. It should further be mentioned that VJH does not consider the high time requirement for the performance of competing scenarios. Because the ability to jump seems to be an integral part of successful participation in many soccer activities, identifying the independent variables that influence this ability could be useful for individualising training. Morphological factors that positively influence VJ performance include relative body fat, which stems from the fact that body fat is not a contractile tissue and therefore acts as an additional load to be carried against gravity. It should be noted that some morphological variables are relatively difficult to influence, although they can be useful in identifying talent.

Castagna et al. (2013) recommended the evaluation of VJ performance for the prediction of success in elite soccer from a chronological age of 17 years, given that physical fitness has been a covariate with maturation (Carvalho et al., 2011). With the above considerations in mind, it is important to assess whether VJ performance can differentiate between soccer players in late adolescence (under 19 years) at different performance levels. Therefore, this study aimed to determine whether VJH differs between youth athletes of different performance levels. Furthermore, we examined the relationship between individual kinematics, morphological and anthropometric parameters, and JH using the two types of VJ (countermovement jump with free arms (CMJFA) and drop jump (DJ)). We selected players from the 1st and 2nd highest youth leagues as the research object. We hypothesized a significantly higher VJH ($p<0.05$) in elite players compared to sub-elite players.

Methods

Study design

This study used a cross-sectional design. Data collection was conducted at the beginning of the summer pre-season part of the macrocycle. The measurements were performed under constant conditions during the morning hours. Before testing, the participants were familiarised with the experimental protocol and did not perform any high intensity physical activity lasting a significant duration for 48 h prior to testing.

Participants

A total of 84 young male soccer players from the U19 category (age=17.64±0.49 years) were recruited. Basic anthropometric data are presented in Table 1. The players were divided into two groups based on their performance level: the elite group (EG), comprising elite players of a team ranked 1st and 2nd in the first national youth league; and the sub-elite group (SEG), comprising sub-elite players part of a team ranked 1st and 4th in the second national youth league. Groups were classified as EG and SEG, according to the definition used by Lorenz et al. (2013), who considered elite athletes as those who played at a higher level than their peers within a sport. The exclusion criteria were any health issues that jeopardised participation or performance in the study, such as soft tissue injury, delayed muscle pain, recent illness, or recent recovery from injury. This study was approved by the Ethics Committee of the Faculty of Physical Education and Sport, Charles University (approval number 259/2020; 30.10.2020.), and all participants provided written informed consent. Measurement were carried out in accordance with ethical standards of Declaration of Helsinki and ethical standards in sport and exercise science research (Harriss et al., 2017).

Table 1. Descriptive characteristics of the elite and sub-elite groups.

Characteristic	Elite Group	Sub-elite Group	P
Number	42	42	
Age (years)	17.62 ± 0.67	17.68 ± 0.77	.69
Stature (cm)	181.59 ± 6.44	180.35 ± 5.54	.34
BM (kg)	73.71 ± 6.30	72.46 ± 8.33	.44
FFM (kg)	63.60 ± 6.34	63.05 ± 6.32	.68
LMM (kg)	21,39 ± 2.11	21.35 ± 2.15	.92
Training per week	5–6	4–5	

Legend: FFM: absolute value of fat free mass, BM: body mass, LMM: absolute value of leg muscle mass, p: probability

Stature and body composition

Stature was measured using a digital stadiometer Seca 242 (Seca, Hamburg, Germany) with an accuracy of 0.1 cm, and body mass was measured using a digital scale Seca 769 (Seca, Hamburg, Germany) with an accuracy of 0.1 kg. Body composition was assessed using a multi-frequency bioimpedance analyser MC-980MA (Tanita Corporation, Tokyo, Japan), according to the manufacturer's guidelines. Standardized conditions for bio-impedance measurement were maintained (Kyle et al., 2004). The following body composition indicators were selected: body mass (BM), stature, absolute and relative value of fat free mass (FFM), absolute and relative value of leg muscle mass (LMM).

Vertical jump

Before measurement, all tested participants completed a warm-up procedure (dynamic half squats, 3 sets × 10 repetitions; forward lunges 3 sets × 10 repetitions). All participants performed two types of VJs: CMJFA and DJ. For the CMJFA, the participants began with their arms free of downward movement until they reached a crouching position with a knee angle of approximately 90°, followed by a jump at maximal height. The DJ was started by instructing the participants to stand on a 20 cm high box with both legs stationary. The participant dropped from the platform, landed in front, and immediately jumped vertically (Yokoyama et al., 2019). The JH and kinematic parameters of each lower limb were measured using two force platforms Kistler B8611A at a sampling rate of 1000 Hz (KISTLER Instrumente AG, Switzerland). For JH, a calculation based on the flying phase time during the jump was used. Participants completed three trials for each type of

VJ performance, with instructions to jump as high as possible. The trial with the highest achieved JH value was selected for further result processing using the software BioWare 4.0.0 and MatlabR2013. The following outcome variables were assessed: JH (cm), vertical ground reaction force (VGRF, N), vertical ground reaction force in relative values ($VGRF_{relative}$, $N.kg^{-1}$), force impulse (FI, $N.s^{-1}$), and relative force impulse ($FI_{relative}$, $N.s^{-1}. kg^{-1}$) during the concentric phase of take-off.

Data analysis

Descriptive statistics (mean and standard deviation) were calculated for all dependent variables. The Shapiro–Wilk test was used to evaluate the normality of the data distribution, and Leven's test was used to assess the equality of variance. The statistical significance of the differences in the observed dependent variables between performance levels calculated by an independent sample t-test was used. Effect size was calculated using Cohen's d coefficient and classified as follows: large (d>0.80), medium (0.50<d<0.80), small (0.20<d<0.50), and trivial (d<0.20) effect sizes (Cohen, 1992). Pearson's correlation coefficient was used to determine the associations between the selected variables and JH for both types of vertical jumping. According to Hopkins (2000), the reference values for the effect size were nearly perfect (r>0.90), very large (0.70<r<0.90), large (0.50<r<0.70), moderate (0.30<r<0.50), small (0.10<r<0.30), and trivial (r<0.10). For all analyses, statistical significance was set at either p<0.05 or 0.01. Statistical analysis was performed using IBM SPSS v21 (Statistical Package for Social Science, Inc., Chicago, IL, USA, 2012).

Results

The descriptive statistics of JH, $VGRF_{relative}$, and $FI_{relative}$ for the elite and sub-elite groups are shown in Table 2. A higher VJH in DJ than in CMJFA for both groups was observed (2.1% for the EG and 2.75% for the SEG). No significant differences (p>0.05) with trivial to small effects in VJH and kinematic parameters relative to body mass between the elite and sub-elite groups were found.

Table 2. Vertical jump height and kinematic parameters of CMJFA and DJ.

Parameters		Elite Mean ± SD	Sub-elite Mean ± SD	P	d
CMJFA	JH (cm)	44.01±4.16	44.67±4.23	0.46	0.15
	VGRFrelative (N/kg)	2.62±0.14	2.63±0.21	0.92	0.05
	FIrelative (N·s·kg-1)	3.24±0.24	3.26±0.31	0.74	0.07
DJ	JH (cm)	44.95±4.49	45.93±4.70	0.33	0.21
	VGRFrelative (N/kg)	4.43±0.80	4.38±0.91	0.76	0.05
	FIrelative (N·s·kg-1)	5.06±0.32	5.04±0.27	0.73	0.06

Legend: CMJFA: countermovement jump with free arms, DJ: drop jump, JH: jump height, VGRF: vertical ground force reaction, FI: force impulse, SD: standard deviation, p: probability of significant differences in compared means, d: Cohen effect size.

The correlation between the JH of the CMJFA and DJ and the selected variables is shown in Table 3. Significant moderate positive associations were found between VJH (CMJFA and DJ) and $FI_{relative}$ (r=0.356 and 0.456, respectively, p<0.01). Positive significant correlations between VJH of CMJFA and $VGRF_{relative}$ (r=0.259, p<0.05) and LMMrel ratio (r=0.248, p<0.05) were found, but with a small effect size.

Table 3. Correlation among the vertical jump heights of CMJFA and DJ and selected variables.

Variables	CMJFA	DJ
Stature (cm)	-0.08	-0.12
Body mass (kg)	0.02	-0.11
FFM (kg)	0.09	-0.03
FFMrel	0.14	0.15
LMM (kg)	0.15	-0.00
LMMrel	0.24*	0.19
BF (%)	-0.13	-0.13
aVGRF (N)	0.16	-0.09
aVGRFrelative (N.kg-1)	0.25*	-0.13
aFI (N.s)	0.20	0.20
aFIrelative (N.s.kg-1)	0.35**	0.45**

Legend: a - data were calculated for each jump type (CMJFA and DJ), CMJFA: countermovement jump with free arms, DJ: drop jump, VGRF: vertical ground force reaction, FI: force impulse, FFM: absolute fat free mass, FFMrel: relative fat free mass, BM: body mass, LMM: absolute leg muscle mass, LMMrel: relative leg muscle mass BF: fat mass, *p<0.05, **p<0.01.

Discussion

This study was conducted to determine whether VJH differs between youth players of different performance levels, and to thereby further delineate variables that are related to VJH. Surprisingly the SEG (CMJFA=44.67±4.23 cm; DJ=45.93±4.70 cm) was found to have a better VJ performance (CMJFA and DJ) than the EG (CMJFA=44.01±4.16 cm; DJ=44.95±4.49 cm), although this difference was not statically significant (p>0.05). We must point out that our players' VJH was higher in CMJFA than of their U19 peers in the study by Maly et al. (2015) (CMJFA=40.82±3.96 cm). According to a study by Torreblanca-Martinez et al. (2020), the U19 category of the highest Spanish league had slightly higher DJ values (46.34±5.94 cm) compared to our players. It should be mentioned that, although it was a DJ, the landing in the first phase took place with an elevated box of 45 cm instead of a height of 20 cm in our study. Greater performance may be related to greater motor unit recruitment (Dimitrova et al., 2002), possibly because of optimal eccentric phase forces (Andrade et al., 2020).

The results showed that among youth players in the U19 category, VJ performance could not differentiate between performance levels. Our findings are consistent with those of Cometi et al. (2001), who did not identify any differences between first-division players and amateur soccer players. One reason for this may be that the players jump only 15.5 times during the game (Reily et al., 2000), which means that this capacity cannot develop in match situations, and it can, therefore, be assumed that soccer training may be an inadequate training stimulus to develop jumping ability. Castagna et al. (2013) showed that VJs could not differentiate between competition levels in soccer players selected for the national team. The results of this study showed that in elite male players, VJ performance was not dependent on the competition level. Our finding is in contrast with those of other studies, which reported that elite players showed a better VJ performance (10–16%) during the CMJ test in U16 (Trecrori et al., 2019) and U15 (Trecroci, Milanović et al., 2018) and during the SJ test in U14 (Coelho E Silva et al., 2010) and U17 (Gissis et al., 2006) compared to that of sub-elite peers. Higher differences in elite and sub-elite players have been reported for CMJ (16%) than for SJ (10–14%), indicating a better ability of elite players to transition from downward-phase eccentric loading to upward-phase concentric power production (Król & Mynarski, 2012), although this trend was absent in our study.

In addition, in a study of adult players in the Greek League, Kalapotharakos et al. (2006) showed that players from the teams ranked in the first three positions of the table achieved higher performance in the height jump in CMJ than from the teams that were in the middle and at the bottom of the ranking table. One possibility to explain the lack of this trend in our study could be that our players are still undergoing growth and development, and therefore their potential may not be fulfilled yet. On the other hand, some studies do not find a difference between youth teams U17 (Castagna et al., 2013) and U18 (Mujika et al., 2009) as compared to senior players. It is also necessary to mention that the observed VJH is relatively high for both groups (elite and sub-elite), which may indicate an increase in the physical requirements of the players at both levels. Soccer is a developing sport in general, and even smaller clubs have access to quality training conditions with sufficiently educated trainers and a sophisticated training program for the development of individual strength components. Finally, the fluctuation of players in the youth categories was high; some players went through top academies in their youth categories and were transferred to other teams at the sub-elite level, which could have an impact on the overall results. Unfortunately, we did not analyse the players' history.

The current investigation showed slightly lower values than in other studies that identified associations between JH and kinematic parameters, such as VGRF or FI (McBride et al., 2011; Daugherty et al., 2021). Interestingly, only the $FI_{relative}$ associated with JH was observed during DJ. To jump higher, an athlete must quickly apply substantial force against the ground from the beginning of the movement to the point of projection (take-off) (Bosco et al., 1983). As the VGRF increases, the vertical velocity at take-off increases, and hence, the JH increases (Loturco et al., 2015). Percentage of fat mass was not associated with VJ performance and could not be used to explain jumping ability, which is inconsistent with the observations of other studies (Davis et al., 2006; Caia et al., 2016). One explanation for this is that there are higher differences in % body fat among amateur players, while players in our study were more homogeneous with similar training volumes (4–5 vs 5–6 training per week). Among the morphological variables, only the LMMrel ratio (r=0.248, p<0.05) had a positive association with JH during CMJFA, but with a small size effect. This finding indicates that the distribution of muscle mass in the lower extremities relative to the BM appears to be a better indicator of the selection of morphological variables in this study. These findings could aid training and conditioning trainers to estimate jump potential and prescribe individual interventions to maximise the potential. The morphological features linked to specific body regions (upper and lower limb) may be preferred over whole-body measures to interpret male players' physical potential in vertical jump and sprint performance (Bongiovanni et al., 2021). The idea to manage the training process by monitoring the multidimensional performance can work to the advantage of practitioners (Turner et al., 2019), especially if information based on an individual's anthropometric measures (e.g., morphological data of upper and lower limbs) can be associated (Rossi et al., 2022).

One of the limitations of this study was its cross-sectional design, which only allowed us to present the players' current status, but could not reveal the long-term development of youth players. Future research should consider the differentiation of player positions in soccer (Sporis et al., 2009). Furthermore, the results obtained in this research are applicable only to U-19 young soccer players. Recently, the eccentric rate of force development and reactive strength index have been recommended as variables to be evaluated alongside JH (Barker et al., 2018).

Conclusions

This study concludes the following: (1) VJH could not detect differences between players in the first two performance levels in the U19 category. (2) The $FI_{relative}$ normalised to body mass provided a good indication of JH in comparison with the other selected morphological variables in this study. (3) The LMMrel ratio provided a better association with JH than the other selected morphological variables in this study, although a small effect size was observed. When evaluating VJ performance in young soccer players, measurers should consider that the results may not be sufficiently sensitive to differentiate performance levels, especially when the difference is only one performance level. Further studies to delineate elite and sub-elite athletes in youth soccer should be encouraged to control for possible confounding factors.

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Conflicts of Interest
The authors declare no conflict of interest.

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