DOI 10.26773/smj.240206

ORIGINAL SCIENTIFIC PAPER

Differences in Trunk Muscle Strength (Lateral Flexor Group) between Male and Female Athletes

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Abstract

The strength of the lateral flexor muscles in the trunk is necessary for maintaining stability in the rib cage, spinal column, and preventing a higher number of injuries, while also enhancing overall trunk muscle strength. This study, conducted in a transversal manner, aimed to identify gender-based differences in the strength of trunk lateral flexor muscles among university athletes in the younger senior age group. The study involved 46 athletes from the University of Novi Sad, comprising 25 male participants (height =181.27±6.28 cm; weight =78.31±12.14 kg; BMI =23.78±3.13 kg/m2; mean age =23.75±0.30) and 21 female participants (height =168.19±5.48 cm; weight = 3.72±5.94 kg; BMI =22.53±7.78 kg/m2; mean age =23.68±0.22). The results of the independent t-test revealed no statistically significant differences between the two gender groups based on dimorphic characteristics (p>0.05) in the assessment of trunk lateral flexor muscle strength. It is essential to consider other aspects of the locomotor system specific to each sport and discipline to effectively prevent injuries during training and decrease the overall injury rate.

Keywords: *trunk stabilizers, university athletes, strength*

Introduction

Impaired body posture during the execution of specific movements can stem from muscle imbalances (Kopecky, 2004). These imbalances typically manifest in two primary groups of skeletal muscles situated at the front and back of the body. The first group consists of tonic muscles—also referred to as monoarticular, local, postural, or antigravitational muscles—primarily responsible for maintaining static body positions through isometric contractions. In contrast, the second group consists of phasic, multiarticular muscles. These muscles, depending on their subgroup (stabilizers/actuators), regulate the stabilizing and dynamic functions of the locomotor apparatus through isotonic contractions (Richardson et al., 2004; Kendall et al., 2005; Abernethy et al., 2013). This category includes the trunk's lateroflexor muscles. The synchronized collaboration of these two muscle groups ensures a secure transfer of load from the chest to the pelvis. This, in turn, stabilizes the spinal column segments and alleviates forces acting on the lumbar spine during various functional activities (Richardson et al., 2004; McGill, 2015).

The lateroflexors play a crucial role in maintaining trunk stability (Kibler et al., 2006). This involves the ability to control the position and movement of the trunk, facilitating optimal production, transfer, and control of force and movement throughout the integrated kinetic chain activities. According to Reed, Ford, Myer, and Hewett (2012), trunk stability can be observed in maintaining control during the application of trunk strength, indicating the interplay between stability and strength. These authors argue that the strength of the trunk muscles is defined by their capacity to generate and endure force. Due to their central location in nearly all functional kinetic chains, the trunk muscles, particularly the lateroflexors, bear the responsibility of ensuring stability for the spinal column and pelvis. They also contribute significantly to the generation and transfer of force from larger body parts to smaller ones, providing proximal stability for distal mobility (McGill, 2002; McGill, 2004; Kibler et al., 2006; Kato et al., 2018).

Tonic muscles include deep abdominal and dorsal muscles, including m. multifidus, m. transversus abdominis, mm. inter-

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spinalis, mm. intertransversarii, m. semispinalis, the posterior part of m. obliquus internus abdominis, the middle fibers of m. quadratus lumborum, the central part of m. erector spinae, the diaphragm, and the muscles located at the bottom of the pelvis. This group of muscles plays a crucial role in stabilizing and controlling the position of joints or segments in the spinal column. Through their active engagement, they prevent local movements of specific spinal segments and ensure stability in all three planes of the entire spinal column (Richardson et al. 2004; Reeve & Dilley, 2009; McGill, 2015). On the other hand, phasic, multi-articular actuators comprise muscles responsible for actively moving joints, unrelated to anti-gravitational postural activity. This muscle group includes the thoracic part of m. erector spinae, m. rectus abdominis, the anterior part of m. obliquus internus abdominis, m. obliquus externus abdominis, the outer part of m. quadratus lumborum, m. psoas major, m. tensor fasciae latae, m. rectus femoris, and m. adductor longus (Bullock-Saxton et al., 2000; McGill 2015).

While stability in the strength of both front and back trunk muscles, as well as lateroflexor muscles on the left and right sides of the body, is expected, age-related changes in life modules suggest probable indications of maturation, adaptation, or morphological alterations throughout one's lifetime. Gender differences, evident across all levels, including the top two superfactors of physical activity and gender, have been noted (Masahiro et al., 2022). During the growth process, muscles and ligaments may struggle to keep pace with bone growth, resulting in muscle imbalances and gender disparities (Purcell, 2009). Additionally, gender differences extend to spinal kinematics and core stability (Masahiro, Yoshitaka & Nobuhiro, 2022; Masahiro et al., 2022).

There are several procedures available for testing the strength of the trunk's lateroflexor muscles. The most commonly used diagnostic method is the "side and prone bridge" (McGill, 2002; McGill, 2004; Andrade et al., 2012; Pareira et al., 2014; Shamsi et al., 2016; Freidrich et al., 2017). Given the absence of studies addressing gender differences in the strength of the trunk lateroflexors, this study aims to assess the status of the lateroflexors, with a primary focus on strength, among university athletes.

Method

The conducted study falls under the category of cross-sectional empirical research and is classified as applied, confirmatory research. The field method was employed, emphasizing a moderate degree of control. Data collection involved anthropometric methods and muscle endurance testing methods. The obtained results were then interpreted in the context of previous studies through theoretical analysis. The data underwent processing using suitable statistical procedures, enabling valid conclusions to be drawn about the examined phenomena.

Participants

The study involved a sample of 46 younger senior athletes from the University of Novi Sad, consisting of 25 male participants (height =181.27±6.28 cm; weight =78.31±12.14 kg; BMI =23.78±3.13 kg/m2; age =23.75±0.30) and 21 female participants (height =168.19±5.48 cm; weight =63.72±5.94 kg; BMI =22.53±1.78 kg/m2; age =23.68±0.22). During the assessment of trunk lateroflexor muscle strength, all participants were in good health and were capable of engaging in training and competition, free from injuries.

Procedures

In assessing morphological characteristics, variables were selected following the recommendations of the International Biological Program - IBP (Weiner & Lourie, 1969). The research incorporated the measurement of anthropometric characteristics, including: Body height (cm), and Body weight (kg). From these measurements, the Body Mass Index (BMI) was calculated (kg/m2).

The Martin anthropometer was utilized for measuring body height, and a digital decimal scale was used for measuring body weight.

Measurements

The study incorporated the utilization of standardized motor tests to assess trunk lateral flexor strength: Cylinder left (s), Cylinder right (s) (Hennes, 2018), test of isometric endurance of the lateral flexor muscles of the left trunk - left side bridge measured in seconds, and test of isometric endurance of the lateral flexor muscles of the right side of the body - right side bridge (McGill, Childs, & Liebenson, 1999) measured in seconds.

All measurements took place at the "Scolio Centar" in Novi Sad during 2021. The measurement conditions ensured a well-lit and ventilated room, featuring a secure, flat surface and sufficient space for efficient work with all required equipment. Trained evaluators conducted the measurements, adhering consistently to standard protocols. To minimize the impact of daily variation in measured indicators, anthropometric measurements and muscle endurance measurements were carried out on the same day for each participant. The measurement process spanned several days to encompass all participants.

Cylinder left and right

The subject was positioned on the left or right knee, with the other leg being abducted to the side (hands on hips) depending on the desired side of the trunk and lateral flexor muscles being tested. The subject then performed a bend to the left side while maintaining a corrected posture. At that point, the center of gravity was shifted to the left side. The leg on the T-side was placed on a stool or Swedish box frame to the side. Beginners place the leg to the side without raising it to a height of 40 cm, but in this study, since the subjects are athletes, the leg was raised on the Swedish box. The arm on the left side of the trunk was placed on the lumbar prominence, and the opposite arm was placed on the prominent hip bone (LHT). The spine was elongated while breathing normally. The subject maintained the position. The tester had to pay attention to the correction of the neck and the basic tension of the muscles.

The purpose of the test is to evaluate the strength of the trunk lateral flexor muscles, with time measured in seconds, and the maximum duration of the test set at 5 minutes (300 s). The test was conducted three times, and the best result from each trial was considered for both the left and right sides of the trunk (Hennes, 2018).

Test of Isometric Endurance of Trunk Lateral Flexor Muscles - Side Bridge, Left and Right

This test involves the examinee assuming a side position, supported on their elbow, with legs extended and the "upper" leg slightly forward. The body must maintain a straight and active position without joint flexion, particularly in the hip joint (considering this in the examinee's procedure). The free hand is placed next to the body. The examinee is allowed a practice attempt before the actual measurement. Upon taking the starting position, the stopwatch is initiated, and the duration the examinee maintains the position is measured. The test concludes when the examinee touches the floor with their hip, disrupting the prescribed body position, prompting the cessation of the test, and stopping the timer. Time is recorded in seconds. This test evaluates the endurance of the trunk lateral flexors (McGill et al., 1999). It is separately performed for both the left and right side of the trunk (McGill et al., 1999).

Statistics

The statistical analysis of the data involved calculating basic descriptive statistics, including mean (M), standard deviation (SD), minimum (MIN), and maximum (MAX) values of the measurement results. Additionally, the coefficient of determination (R2 - %) was calculated to clarify differences between subgroups. The normality of variable distribution was assessed using the Shapiro-Wilk test for small samples. An independent sample t-test was applied to determine differences between groups of subjects. All data processing was conducted using the IBM SPSS 26 software package (Statistical Package for the Social Sciences), with a significance level set at $p<0.05$.

Results

Based on the average values presented in Table 1, a notable heterogeneity of results is observed in all four variables for both groups of subjects. The predominant unevenness is noticeable in the strength of the left and right side muscles of the trunk within both subject groups. The Shapiro-Wilk coefficient values, as indicated in Table 1, suggest normality in the distribution for all four analyzed motor variables (SW $p>0.05$) within both sub-samples.

Table 1. Descriptive statistics of the torso lateral flexor variables based on gender

Variable	Male athletes (N=25)			Female athletes (N=21)		
	AM±S	CV	SWp	AM±S	CV	SWp
Left cylinder (s)	162.67±41.88	25.74	0.66	202.16±89.33	44.19	0.15
Right cylinder (s)	158.50±50.88	32.10	0.06	184.49±89.83	48.69	0.23
Left side bridge (s)	89.03±27.48	30.87	0.33	82.41±21.48	26.06	0.70
Right side bridge (s)	92.05±27.21	29.56	0.47	82.63±22.62	27.38	0.31

Note N - number of participants; M - male athletes; F - female athletes; AM - arithmetic mean; S - standard deviation; CV - coefficient of variation; SWp - level of statistical significance of Shapiro-Wilk coefficient.

The results of the independent samples t-test reveal no statistically significant differences between male and female athletes from the University of Novi Sad concerning the variables measuring the strength of the trunk lateral flexors ($p>0.05$). Although certain differences in means were found, such as in the cylinder left and cylinder right variables favoring female athletes, and in the left side bridge and right side bridge variables favoring male athletes, these differences did not reach statistical significance (Table 2). A more detailed exploration of these differences is illustrated in Graph 1.

Table 2. Differences by gender in variables for strength assessment of trunk lateral flexor muscles

Variable	Male atheletes (N=25)		Female athletes (N=21)		t	p
	AM	S	AM	S		
Left cylinder (s)	162.67	41.88	202.16	89.33	-1.86	0.08
Right cylinder (s)	158.50	50.88	184.49	89.33	-1.18	0.25
Left side bridge (s)	89.03	27.48	82.41	21.48	0.90	0.38
Right side bridge (s)	92.05	27.21	82.63	22.62	1.26	0.21

Note t - value of the independent t-test, p - level of statistical significance of the t-test.

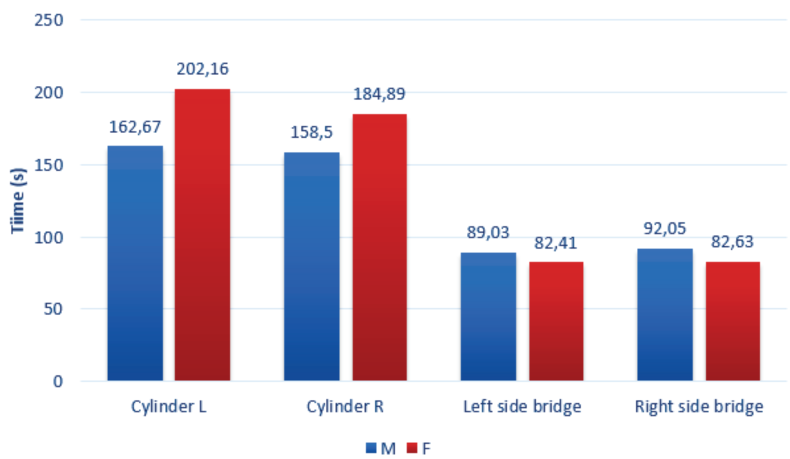

FIGURE 1. Graphic representation of the analysis of the average values of the trunk lateral flexors based on gender

Discussion

The aim of the study was to explore gender-based differences in the strength of trunk lateral flexor muscles among university athletes. The research involved 46 subjects, university athletes, with a mean age of 23.72±0.29. This group comprised 25 male athletes (mean age =23.75±0.30; mean height =181.27±6.28 cm; mean weight =78.31±12.14 kg; mean BMI =23.78±3.13 kg/m2) and 21 female athletes (mean age =23.68±0.22; mean height =168.19±5.48 cm; mean weight =63.72±5.94 kg; mean BMI =22.53±7.78 kg/m2).

The results indicate that there are no statistically significant differences in the strength of the trunk lateral flexor muscles between male and female athletes at the University of Novi Sad, as assessed by standardized tests (Side bridge left and right and Cylinder left and right) with p>0.05. Despite female athletes displaying higher average values in the Cylinder left and Cylinder right tests compared to their male counterparts, these differences did not reach statistical significance. It appears that the strength of the central trunk muscles, as well as all associated soft tissues (including joint and fibrous structures, cartilage, ligaments, tendons, muscles, and fascia) with a proximal extension originating from the axial skeleton, is at a very similar level in both male and female athletes. The active engagement in maintaining stability during the Cylinder left and Right tests suggests a slightly greater strength in the m. multifidus (lumbar), m. erector spinae, m quadratus lumborum, external oblique, m. oblique externus abdominis, internal oblique muscle of the abdomen (m. oblique internus abdominis), rectus abdominis muscle (m. rectus abdominis), transverse abdominal muscle (m. transversus abdominis), m. psoas major, and pelvic floor muscles in female athletes (Corbin et al., 2004; Gonçalves et al., 2018).

It is reasonable to consider that the previous training period (training level) and likely the state of movement functionality may influence subjects of different sexes, even with a similar level of strength in lateral flexors among athletes. The study acknowledges a limitation in not ranking athletes based on the degree (level) of competition, such as international athletes, state-level athletes, or athletes of lower ranks of competition, due to the small-sized but appropriate sample. In future research on this issue, it is essential to give more attention to the ranking of athletes irrespective of gender and subsequently assess the strength of the trunk lateroflexors.

The comparable muscle strength observed among younger senior athletes in the mentioned body regions, as evidenced by the mentioned tests, could be attributed to the heightened role of fusimotor fibers. Fusimotor fibers, activated during the excitation of cross-striated muscles, are known to concurrently intensify the activity of sensory fibers within the neuromuscular spindle. This phenomenon is believed to arise from the contraction of intrafusal fibers. It is conceivable that fusimotor neurons are maximally engaged throughout the multi-year training processes undergone by both groups of younger athletes. In deliberate, targeted movements with precise definitions, such as the testing examples mentioned involving specific positions, fusimotor neurons likely do not precede but rather follow, building upon alpha motor activity, albeit with a minor, negligible delay (Galeano et al., 2000). It can be hypothesized that innervations (load levels causing overload, stimuli) during training sessions within this group of individuals in the training process prevent intrafusal fiber relaxation during contraction, thereby facilitating better motor control of movements.

If they wouldn't have been activated in time, the neuromuscular spindles as motion sensors would have remained inactive. Similar intramuscular coordination of movement could have been crucial for similar results in analyzed variables among university athletes in the tested sample. It should be particularly emphasized that muscle strength is determined by intramuscular coordination (Zatsiorsky & Kraemer, 2009). The more complex the movement is, the greater the activity of muscle fibers and their mutual cooperation is required, as demonstrated when performing the Side bridge left or right and the Cylinder left and Cylinder right test. Athletes in the training process can better coordinate the activation of fibers in individual muscles (Suchomel et al., 2018), which is the result of good neural adaptation, and therefore, the results are probably similar among the tested groups of athletes.

The average body height could potentially explain the moderately better results of female athletes in the variables Cylinder left and Cylinder right, given their shorter average height. Biomechanical considerations, particularly the length of lower extremities, influencing the lower center of gravity in female athletes, might contribute to the comparatively better average results in favor of this group (Purcell, 2009; Butler et al., 2014). Conversely, in the variable side bridge, male athletes exhibited superior average results. In the side bridge variable, endurance in a static regime played a crucial role, with the center of gravity being a less significant factor in this segment. Studies suggest that isometric strength training in both men and women leads to less fatigue and results in superior strength for specific joint angles compared to dynamic strength training. This type of training has shown to be beneficial for dynamic sports-related performance, such as running and jumping (Lum & Barbosa, 2019). It can be presumed that this form of training was incorporated by some athletes, leading to a discernible difference in the exertion of strength in the trunk lateral flexors. This training method is designed to circumvent excessive fatigue while still promoting positive neuromuscular adaptations. It aims at enhancing strength, particularly in biomechanically challenging joint positions during specific movements. This type of training is beneficial for improving specific movements relevant to sports that primarily involve isometric contractions, especially when athletes are restricted in movement due to injuries.

The importance of core muscles, often referred to as trunk or central core muscles, in stabilizing and generating force across various sports activities is gaining increased recognition (Kibler et al., 2006; Wirth et al., 2016). Muscular strength, in this context, is essentially a static ability that can be best understood as the pre-programmed integration of local, single-joint muscles and multi-joint muscles. This integration aims to provide stability and facilitate movement (Myers, Poletti, & Butler, 2017). The stability of trunk muscles, or their strength, appears to be quite similar among university athletes from Novi Sad. This similarity may contribute to proximal stability, distal mobility, a semblance of distal force creation, and the generation of interactive moments that drive and safeguard distal joints in both groups of subjects.

Postural control is a sophisticated mechanism that relies on receiving, processing, and responding to afferent signals from the visual, somatosensory, and vestibular systems. These systems register changes in the body's center of gravity based on internal oscillations and the effects of external loads. Each system contributes to effective postural control by providing specific information about body posture to the central nervous system. The somatosensory system, which includes muscle and joint receptors and mechanoceptors, offers proprioceptive information about the body's position in space (Mahdieh et al., 2020). An observed difference in the analyzed variables, specifically Cylinder left and Cylinder right, favored female individuals, while the other two variables, Side bridge left and Side bridge right, on average, demonstrated better results for male subjects. It's important to note that one muscle stabilizer of trunk movement (trunk core) and four core actuator muscles (m. rectus abdominis, m. obliquus externus abdominis, m. erector spinae, and m. quadratus lumborum) participate in the lateral flexion of the trunk. However, six individual muscles and muscle groups are involved in core muscles and are not directly engaged in lateral flexion. Considering the above, it can be observed that the coordinated contraction of all stabilizers and global executors of trunk movements facilitated optimal spinal stabilization in both groups of subjects, with minor observable differences in average values in both applied tests.

The strength of the trunk lateroflexor muscles and the overall balance with core muscles play a crucial role in preventing sports injuries and enhancing sports performance (Rivera, 2016; Kuniki et al., 2022). Robust trunk lateroflexor muscles contribute to efficiency in various sports (Behm et al., 2010; Barbado et al., 2016; Correia et al., 2016). It is widely believed that a correlation exists between the maximum muscular force of the trunk (core) muscles and the muscular endurance of lateroflexors, directly influencing athletic performance at a higher level (Sharma & Yadav, 2020). Conversely, weak core muscles, including the cylinder muscles, can potentially lead to health issues (Davidek, Andel & Kobesova, 2018). It's crucial to highlight that weak core muscles have a negative impact on athletic performance. Additionally, insufficient trunk lateroflexor muscles may contribute to the development of incorrect movement patterns, impaired postural control, and consequently, an increased risk of injury (Davidek et al., 2018).

The results of this study exhibit notable similarities to those of Escamilla et al. (2016), who highlighted a comparable level of strength in the rectus abdominis muscle, as well as both the external and internal oblique muscles of the trunk in male and female subjects. Specifically, the strength of the external oblique abdominal muscles was significantly greater in athletes during the Side bridge test, where the strength of these muscles becomes more evident (Escamilla et al., 2016). This is attributed to maintaining a longer lever arm for work, particularly in the upper body, as the lever extends with lateral flexion in the form of the side bridge position. In comparison to bringing the side position (left or right) in a half-squat position, and the side bridge position (board) on the knees (test of isometric contraction of trunk muscles), greater strength is required for these muscles. In this context, male athletes demonstrated dominance in this area.

Nevertheless, differences in the strength expression of the lateral flexor muscles on the left and right sides of the trunk have been confirmed. Such favoritism toward one or more muscle structures over another can result in muscle imbalances and their interrelated dysfunction, a phenomenon supported by prior research (Cresswell et al., 1994; Wilke et al., 1995; Norris, 2000). Participants of both genders exhibited higher average values in the test for the left cylinder and the right side bridge, with the distinction being more pronounced in male athletes compared to their female counterparts. The study's limitation lies in the small number of respondents, restricted solely to athletes. In future research of this nature, it is recommended to monitor the state of musculature over an extended period, such as during training.

In general, it can be concluded that the level of strength in the trunk lateral flexor muscles is similar among University of Novi Sad athletes, with certain minor differences in muscle strength observed between the left and right sides of the body. The condition of the trunk muscles, crucial for overall postural stability, significantly impacts the maximum functional abilities of athletes. Enhanced strength in the lateroflexors contributes to better injury prevention and more efficient training optimization.

Having information on the level of core muscle strength in young athletes can lead to improved injury prevention, enhanced training optimization, and, consequently, better sports results in the future.

Acknowledgments
There are no acknowledgments.

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

Received: 30 November 2023 | **Accepted:** 14 January 2024 | **Published:** 01 February 2024

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