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POSSIBLE CORRELATIONS BETWEEN STRENGTH AND LEG STABILITY IN ADOLESCENTS

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Abstract: *The purpose of this study is to measure the relationships established between the strength and stability of the lower limbs in adolescents from the eastern region of Romania. The study included 29 girls and 18 boys. Handgrip strength and explosive leg strength were measure. Stability was determined using the Y-Balance test. There is a relationship between the left limb index and countermovement jump with arm swing in boys (r = -0.49; p < 0.05). Both groups recorded significant correlations only between the Y coefficients of the lower limbs (r = 0.60; p < 0.001), and the Y coefficient of the left limb and the Y score (r = 0.62; p < 0.001). In the adolescents evaluated by us, strength and stability have non-significant relationships.*

Key words: *vertical jump, performance assessment, balance.*

1. Introduction

The musculature intervenes in the motor acts that the human body performs. At the adolescents, agility speed and strength of the lower limbs can be influenced by: rapid energy transfer, predominance of fast twitch muscle fibers, increased motoneuron excitability, nerve conduction velocity, concentric strength development and other factors [16].

The importance of understanding strength development in the context of improving motor performance, health benefits and accident prevention in adolescents was emphasized [15].

Chronological age, body dimensions and motor coordination are important longitudinal predictors of explosive power [4].

Practicing a sport can significantly influence the explosive force of the legs, the same being determined by the specifics of the sports training that teenagers might do. Also, high muscle mass and low body fat can be factors in strength and power [18].

Combined plyometric exercises (vertical and horizontal) can lead to optimizations of jump height, endurance and balance [21]. Plyometric training has been identified as an effective method for developing this ability in adolescents, but research is ongoing to determine the

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optimal training combinations for maximum results [9, 20].

The effects of this type of training can be exerted on running speed, agility and long jump [23].

The role of strength was emphasized by exposing men to such training. These resulted in an improvement in speed and dynamic balance [11].

Among teenagers, vertical jump tests are very important to assess lower body strength and leg stability [8].

Balance and motor skills are essential aspects of normal physical development in children. Significant correlations have been shown between balance and performance of fundamental motor skills [10].

In adolescents aged 14, the Y Balance Test (YBT) is a suitable way of measuring the mobility of the leg joints and the working capacity of the knee extensors [24].

Links between balance and lower limb explosive power have been addressed in other studies, with inconclusive results. Erkmen (2010) reported a significant correlation between unilateral balance and vertical release, as well as between jump height and total balance score in soccer players. In contrast, Granacher and Gollhofer (2011) found no correlation between vertical jumps and static/reactive balance among adolescent students [25].

In adolescence, leg stability is poorly developed, which challenges the assessor's ability to get the best results from each individual [8].

Injury prevention is an important topic for younger generations who may face joint trauma during their development. The use of stability testing tools could help prevent unwanted events for young athletes [1].

Based on existing information, the present study aims to analyze the connection that may exist between the strength and stability of the lower body of adolescents. Strength is to be assessed through vertical jump as well as hand grip strength. Regarding stability, evaluation is proposed through the application of YBT. The collected data would be analyzed by determining the strength of the correlations between them.

We assume that there is a significant connection between the lower limb stability and the strength of adolescents from Eastern Romania, considering the involvement of muscles in joint balancing.

2. Material and Methods

Our study is a cross-sectional one, in which we aim to analyze whether there is a connection between the strength and stability of the lower limbs of adolescents.

Data were collected from 47 teenagers from Eastern Romania, aged between 15 and 19 years old. Among these, 29 were girls (16.69 ± 1 years, 163 ± 7.2 cm and 57.86 ± 9.63 kg), and 18 boys (16.39 ± 1.04 years, 175.2 ± 7.04 cm and 67.20 ± 7.49 kg) (Table 1). The measurements were made by trained students of the Sports Selection and Counseling Center within the Physical Education and Sport Faculty of the "Alexandru Ioan Cuza" University of Iasi. Each teenager had written consent from a legal representative to participate in the evaluation. Measurements were made in July 2023.

Participant characteristics Table 1

	Girls (n = 29)		Boys (n = 18)		Overall (n = 47)	
	Mean	SD	Mean	SD	Mean	SD
Age (years)	16.69	1.00	16.39	1.04	16.57	1.02
Height (cm)	163.00	7.20	175.20	7.04	167.70	9.27
Weight (kg)	57.86	9.63	67.20	7.49	61.44	9.91
BMI (kg/m2)	21.76	3.12	21.96	2.58	21.84	2.90

The anthropometric measurements included height, body mass, and body mass index (BMI). The height was measured with a Handy electronic level placed with a Bosch GLM80 Professional rangefinder. The subject positioned themselves standing on a horizontal surface, maintaining a straight posture. The level was placed on their crown, following the rangefinder screen to indicate the height value. Results were recorded in centimetres. For body mass, a Tanita BC-601 CG body analyzer was used. The body mass index (BMI) was calculated by dividing body mass by the square of the height.

Handgrip strength (HS) was measured standing with the arms extended in an oblique-lateral position and the palms facing forward. At the same time, 2 dynamometers were grasped (Constant 14192-760E). Each teenager had 2 attempts, from which the best value was chosen. The presented results were expressed in kilograms, representing the average obtained for both parts.

Power of the lower limbs was measured following the protocols of squat jump (SJ), countermovement jump (CMJ), and countermovement jump with arm swing (CMJ-AS). The Just Jump system (Probotics, Huntsville, Alabama, USA) determined the flight time and height of each jump, as this is a validated system for explosive strength evaluation [5]. The subjects first performed SJ by stepping up on the mat, taking the starting position, and then performing a separation from the ground vertically. In the starting position, the knees were bent at 90°, and the hands-on hips. This position was maintained for two to three seconds, and then the rapid extension of the knees was initiated. During the flight, the hand's position was maintained, and the knees were extended. The aim was to land in the same spot. A common method of evaluating explosive power in the lower limbs is Counter Movement Jump (CMJ) [25]. CMJ was performed similar to SJ, the difference being in the dynamic of the execution. The starting position became an intermediary position, the teenagers started by standing with the hands-on hips. They rapidly descended until the thighs were perpendicular to the lower legs, followed by an opposite action of extension through which a maximum vertical jump was performed. Likewise, the hands were locked on the hips. The last jump, CMJ-AS derived from CMJ, with the difference that the arms were allowed to swing to aid the jump. Each jump was performed twice, the best result being recorded.

Lower limb stability was determined using YBT. It has been shown that YBT is a reliable and valid tool for dynamic balance performance assessment, applicable in identifying chronic ankle instability and increased risk of lower limb injuries [19]. The reliability of this method has been verified and confirmed for adolescent athletes [14]. There are alternative methods that involve the subject's interactivity with a monitor, these are more costly and imply reduced accessibility to the general public. In contrast, their complexity and accuracy may be higher [17].

During the measurement, the subjects were barefoot, to avoid the influence of shoes. The first determination was the length of the lower limbs, equivalent to the distance between the anterior superior iliac spine and the inner ankle bone. Before stepping on the central piece of the test kit, the teenagers performed the movements 3-4 times to get used to them when it was their turn. After preparing the specific moves, the teenagers stepped on the Y plate with the right foot and pushed the mark indicator as far as they could forward. After a 2-3 second break, they switched sides and followed the same direction. The legs were alternated, moving to the arm on the left and then the one on the right side of the kit. For each of the 6 attempts, the subjects were asked to push as far as possible into the indicator without losing balance. A repetition was considered successful in one direction when the pushing foot was brought back to the initial position by air. Contact between the foot and the ground was followed by a repetition, as in the case when the indicator was suddenly pushed. A Bosch GLM80 Professional rangefinder was mounted on the test's indicator, with values expressed in cm. For each part, a Y index was calculated, representing the ratio between the sum of the three distances obtained for each direction and the triple length of the lower limb, multiplied by 100. Afterward, the YBT score was calculated as a percentage difference between the two indices obtained [2].

The results are presented in tables based on average and standard deviation (SD). These were calculated with GraphPad Prism 9.3.0 (GraphPad Software Inc.). Before processing descriptive statistics outliers were searched and the ROUT method (Q = 1) was applied. The connections between the analyzed parameters were expressed using the Pearson r coefficient, their power being given by the absolute value (non-significant - <0.29; moderate - 0.30-0.49; strong - 0.50-0.69; very strong - 0.70-0.89; almost perfect - >0.90) [12]. The threshold for significance was set at 0.05.

3. Results

The data of the study were needed to find the correspondence between the strength and stability of the lower train of adolescents. Analysis parameters were determined to identify the extent to which force might be related to balance.

Table 2 presented descriptive statistics of the subjects by gender as well as at the group level. Data are expressed as mean and standard deviation for hand grip, SJ, CMJ, CMJ-AS, indices and YBT score. Between girls and boys there are differences for all strength tests, the male category values being higher ($p < 0.0001$). In contrast, inner train stability shows non-significant gender differences.

Regarding the laws between HS and the other parameters of the girls, they are insignificant (p > 0.05). Between the left and the right limb the correlation is medium to strong (r = 0.77, p < 0.0001), adding a moderate correlation that is identified between the left leg index and the Y test score (r = 0.40, p < 0.05).

The caracteristics of the subjects acccording to gender Table 2

	Girls (n = 29)		Boys (n = 18)		Overall (n = 47)	
	Mean	SD	Mean	SD	Mean	SD
HS (kg)	23.51	4.43	36.72****	6.13	28.68	8.28
SJ (cm)	11.48	1.87	17.63****	2.68	13.84	3.73
CMJ (cm)	11.94	1.97	18.51****	2.35	14.46	3.85
CMJ-AS (cm)	13.32	2.03	20.76****	2.73	16.17	4.31
Y-L	88.55	7.28	90.21	8.29	89.19	7.64
Y-R	89.23	7.04	89.85	5.07	89.47	6.31
Y%	-0.95	5.71	-0.24	8.93	-0.68	7.03

HS - Handgrip strength; SJ - squat jump; CMJ - countermovement jump; CMJ-AS - countermovement jump with arm swing; **** – p < 0.0001

Correlations between girls' leg strength and stability Table 3

	Y-L_G	Y-R_G	Y_G%	HS_G (kg)	SJ_G (cm)	CMJ_G (cm)
Y-R_G	0.77****					
Y_G%	0.40*	-0.27				
HS_G (kg)	0.12	0.37	-0.34			
SJ_G (cm)	0.17	0.34	-0.24	0.36		
CMJ_G (cm)	0.08	0.25	-0.26	0.30	0.91****	
CMJ-AS _G (cm)	0.14	0.32	-0.27	0.24	0.87****	0.89****

Y-L_G – girls' YBT index for the left side; Y-R_G – girls' YBT index for the right side; Y_G% - girls' YBTal score; HS_G – Girls' Grip Strength; SJ_G – Girls squat jump; CMJ_G – Girls countermovement jump; CMJ-AS_G – Girls countermovement jump with arm swing; * – p < 0.05; **** – p < 0.0001.

Correlations between boys' leg strength and stability Table 4

	Y-L_B	Y-R_B	Y_B%	HS_B (kg)	SJ_B (cm)	CMJ_B (cm)
Y-R_B	0.29					
Y_B%	0.82****	-0.30				
HS_B (kg)	0.09	-0.44	0.33			
SJ_B (cm)	-0.29	0.08	-0.30	0.07		
CMJ_B (cm)	-0.24	0.04	-0.23	0.15	0.90****	
CMJ-AS _B (cm)	-0.49*	-0.15	-0.38	0.30	0.81****	0.79****

Y-L_B – boys' YBT index for the left side; Y-R_B – boys' YBT index for the right side; Y_B% - YBT score of boys; HS_B – Boys' Grip Strength; SJ_B – Boys squat jump; CMJ_B – Boys counter-movement jump; CMJ-AS_B – Boys' countermovement jump with arm swing; * – p < 0.05; **** – p < 0.0001.

Explosive strength of adolescent girls shows strong positive correlations between all 3 measured values. Thus, the strongest link is established between SJ_G and CMJ_G (r = 0.91, p < 0.0001), followed by CMJ_G and CMJ-AS_G (r = 0.89, p < 0.0001), respectively SJ_G and CMJ-AS_G (r = 0.87, p < 0.0001). The correlations of interest to us are nonexistent among the girls we measured (Table 3). The left leg index and the test score of the boys are strongly positively correlated (r = 0.82, p < 0.0001). At the same time, for the same part we found a moderate negative correlation with CMJ-AS _B (r = -0.49, p < 0.05). This could be the only connection that I could not identify on the way to verifying the hypothesis. Explosive strength, as in girls, showed strong positive correlations in the group of boys, their level being lower: SJ_G – CMJ_G (r = 0.90, p < 0.0001), SJ_G – CMJ-AS_G (r = 0.81, p < 0.0001) and CMJ_G – CMJ-AS_G (r = 0.79, p < 0.0001) (Table 4).

The correlations between the strength and stability of the legs of sample Table 5

	Y-L_B	Y-R_B	Y_B%	HS_B (kg)	SJ_B (cm)	CMJ_B (cm)
Y-R_B	0.29					
Y_B%	0.82****	-0.30				
HS_B (kg)	0.09	-0.44	0.33			
SJ_B (cm)	-0.29	0.08	-0.30	0.07		
CMJ_B (cm)	-0.24	0.04	-0.23	0.15	0.90****	
CMJ-AS _B (cm)	-0.49*	-0.15	-0.38	0.30	0.81****	0.79****

Y-L – YBT index for the left side; Y-R – YBT index for the right side; Y% - YBT score; HS – Handle strength; SJ – Squat jump; CMJ – Countermovement Jump; CMJ-AS_B – Countermovement jump with arm swing; **** – p < 0.0001.

The results of all subjects keep the correlation between the left limb index and the YBT score (r = 0.60, p < 0.0001), as in that case, the strength is greater than in girls and less than in boys. Like the girls, the study sample - links the values of the index of the left limb to the Be of the right limb through a moderate positive correlation (r = 0.60, p < 0.0001). Here too, the correlations between the force parameters are significant. The heights of the 3 jumps performed considering strongly correlate with each other (r >0.95), each of them a moderate positive link with HS. (Table 5)

4. Discussions

Confirmation of our hypothesis involved a correlative analysis on strength and stability indices. This practical approach is based on the fact that muscle strength is an important factor in the balance that the joints can display in various motor postures.

Our data show that strength indices, as most research shows, higher values among boys. They can jump higher by applying the 3 protocols we use and squeeze the dynamometers with strength harder. The higher level of strength does not give them an advantage in terms of lower limb stability. Balance at this level shows no gender differences. At the same time, adolescent girls and boys show a balance of the lower train by approaching the values of the YBT parameters on the right and left sides.

Alnahdi et al.[3] determined the stability of 31 female and 30 male adults with YBT. The study followed the parallel between 2 measurement methods, but for us the gender difference is important and it was established in favour of men. They were able to move the kit pointer anteriorly, posteromedially, and posterolaterally over greater distances. At the same time, the male subjects, who were from Saudi Arabia, scored better in the test than the women.

The effect of age was tested by analyzing 3 groups of men aged around 20, 40 and 70 years. The isometric strength of those in the latter group was 46% lower than that of the 20-year-old subjects. Among the explosive strength, the decline from 20 to 70 years was 64% [13].

In the research of Groselj et al., the link between balance and fundamental motor skills in children was investigated. Balance was tested under static and dynamic conditions. Boys were found to associate static balance with explosive muscle power, but also with abdominal strength, speed, coordination and aerobic endurance [10]. Sember et al.'s study revealed better performance of 11-year-old girls on balance tests compared to boys, with eyes closed and eyes open measurements [22].

The influence on the one-leg long jump test of explosive strength, anthropometric parameters and balance was measured in 2021 on young female basketball practitioners, whose age was between 13 years and 17. Explosive power was measured by CMJ and balance by YBT. Both parameters were assessed as influencing factors for the one-legged long jump. The relationship between détente and balance was not addressed in this paper [6].

Significant correlations were found between muscle strength and balance test results of a sample of adolescent soccer practice. Using a Biodex dynamometric system, it was found that the knee flexors and extensors contributed significantly to the common variance of the stability index in both dominant and non-dominant segments. These results emphasize the importance of bilateral monitoring to increase performance in tasks involving unilateral movements, such as changes of direction and sprints, and to identify players at increased risk of injury [7].

In order to confirm the hypothesis that balance and motor performance of preadolescents are closely related and indicate the need for interventional studies that include specific exercises to strengthen the associated motor skills, a study was conducted. Significant associations were identified between static balance and coordination ($r = 0.553$; $p < 0.01$), abdominal strength ($r = -0.435$; $p < 0.01$), aerobic endurance ($r = 0.556$; $p < 0.01$), speed ($r = 0.469$; $p < 0.01$), respectively explosive muscle power ($r = -0.482$; $p < 0.01$). Dynamic balance correlated with explosive muscle power ($r = -0.429$; $p < 0.01$) and aerobic endurance ($r = 0.427$; $p < 0.01$) [10].

5. Conclusions

As in other studies, the gender difference indicates greater strength in adolescent boys, but this does not imply better lower limb stability.

Strongly positive relationships are established between SJ, CMJ and CMJ-AS when the analysis is done by gender. When the results are approached for the whole sample, the strength of these correlations increases and the links between the values of the three jumps with handgrip strength become significant. The only correlation between the YBT results and those of strength is found in boys between the index of the left limb and the jump performed with free arms. According to the statistical value, an increase in the stability of the left limb would cause a decrease in the jump height. The same is no longer true for the entire sample, so we can consider this phenomenon as isolated. This study disproves the hypothesis according to which explosive force and handgrip strength would be related through absolute values among adolescents from eastern Romania.

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