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Original article

THE RELATIONSHIP BETWEEN THE LEVEL OF PROPRIOCEPTIVE CAPACITY AND THE PERFORMANCE IN COMPETITION IN ROMANIAN TRIPLE JUMPERS

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Abstract

Aim. The aim of the study is to examine the relationship between the level of proprioceptive ability (agility, static and dynamic balance) in triple jumpers. The triple jump is a very complex event that requires, in order to be succesful, the continuous improvement of the specific technique, in accordance with the level of development of the main important motor qualities, and olso an optimal capacity for regulation and self-regulation. It was considered that the development of some perceptual-cognitive components, something too little explored in the specialized studies, can facilitate the development of this capacity, because proprioceptive information plays an important role on cognitive actions, the body image, the control of body movements, balance and coordination, contributing into increasing performance.

*Methods***.** Measurements were performed on 14 high performance triple jumpers, 7 girls (the mean age was 22,4 ±6.5 years; mean body mass 59.1 ±3.6 kg; height mean 171.9 ±3.2cm) and 7 boys (the mean age was 19.6 ±2.8 years; mean body mass 73.4 ±4.4 kg; height mean 184.7 ±4.06 cm), using the vertical static and dynamic balance test with the SensaMove balance platform and the agility test with the WittySem smart indicator. The results recorded in the competition are from May-June 2022.

Results. The results of the Pearson Correlation Coefficient indicates a strong and very strong positive relationship between the results recorded on the static balance test in the female group (on the right leg r= 0.639, p>0.05, and on the left leg r= 0.872, p>0.05), the male group correlations are also direct and positive, but weaker than the female group (r= 0.329 on the right leg and r= 0.353 on the left leg). Strong correlations were found also between agility and performance on levels 1-2 (r=- 0.834, p>0.05 and r=- 0.896, p>0.05) and for level 3 and 4 we have encountered weaker correlations (r=- 0.386, p>0.05 and r=- 0.433, p>0.05). For the male group on level 1 we find a very high correlation (r= -0.784, p>0.05) and for the other 3 levels the correlations are weaker. This proves the fact that there is a strong relationship between the two, and the need to develop some components of the proprioceptive ability in the athletes training.

*Conclusions.*The conclusion cand be useful also in other athletics events in wich balance and agility can play an important role in the performance results.

Key words: triplejump, agility, balance, proprioception, correlation

Introduction

The triple jump is one of the two events in which athletes aim to maximize the horizontal distance, consisting of three consecutive take-off phases, each one having an important role due to the fact that they subject the athlete to extraordinary impact forces and requires maintaining a high level of horizontal speed and a certain balance, a combination of speed and strength (Abeer, 2014; Rogers, 2004). The triple jump event, along with the long jump, is part of the horizontal jump category, in which the goal is to cover as much distance as possible during the flight, where the athlete performs a running phase and a jumping phase. "Although the training for the two events is similar, the technique is different" (Newman 2012). Sports performance can be measured from a paraphysiological point of view by: measuring physical condition – cardiorespiratory measurements, measuring strength and endurance, measuring flexibility, body measurements and by measuring psychomotor parameters – measuring strength, speed, agility, balance, kinesthesia and coordination (Epuran, 2005). Agility does not manifest by itself independently but is closely related to other qualities such as reaction speed in which strength plays a determining role (Bompa & Carrera, 2015). This can be viewed/analyzed from two perspectives, the first one is related to the ability to change direction and the second one is in combination with perceptual-cognitive aspects. In the triple jump, the development of agility requires the improvement of perceptual-cognitive skills (Haff & Triplett, 2016). The way in which proprioception creates an image of the position of the body and its segments in moments of dynamic and static stress represents a basic level of psychomotor coordination (Olteanu & Lupu, 2000). Proprioception allows us to perceive movement, position in space, and actions of our own body (Taylor, 2009).

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This is defined as the conscious or unconscious ability of an individual to perceive the position of his body and its segments in space, performed as a response of the neuromuscular system to sensory information, or as the ability of the body wich helps us to react consciously or unconsciously to stimuli through movement, to place ourselves in space, to feel body posture, an ability that develops over time (Andrews J.R., Harrelson G.L., Wilk, 2012; Gidu & Oltean, 2016). Proprioception encompasses a "complex of sensations that includes the perception of movement, joint position, muscle force, and effort, which are received through the skin, muscles, and joints. (Taylor, 2009).

In combination with other "senses" it allows the individual to position objects in relation to their own body and contributes to the creation of the body image playing an important role in the control of movement in sports that require a good coordination and where "vision plays an integral role in the successful execution of interceptive actions by providing both exteroceptive and proprioceptive information for movement control" (Davids et al., 2002; Taylor, 2009).

Coordination is fundamental in sports, as it is based on the processes of control and regulation of movement, allowing athletes to control their own actions with greater ease and to learn much faster new and complex movements. An important component of coordination is postural control, or balance, which can be static or dynamic - assuming the maintenance of a stable position of the body during the performance of a task (Ricotti, 2011). By developing balance, which derives from sensory nerve endings, called proprioceptors, the body becomes more agile in movements and at the same time decreases the risk of injuries (Mihăilescu et al., 2018).

Balance is considered an important factor in many athletic skills, but the relationship between competitive performance and balance is not yet fully understood. A low level of balance is associated with various injuries (Brachman et al., 2017).

For triple jumpers, following repeated take-offs and landings can frequently lead to joint injurys due to strength deficiencies or balance differences between the right and left leg (Wikstrom et al., 2004).

Balter et al (2004) suggest that a more developed balance in the case of experienced athletes is the result of a systematic training aimed to influence motor responses, thus changes in both the sensory and motor systems influence the level of balance (Balter et al., 2004).

The central nervous system has the role of constantly regulating the messages transmitted by the analyzers and of developing its own motor programs that implement a well-determined project of acts, actions, or motor activities (Simion et al., 2011). The central nervous system along with the muscular system are responsible of performing the motor acts of strength, speed and skills, which are essential in training for the triple jump event.

Schinke (2012) states that regulation and self-regulation, along with adaptation in sports are in an interdependent relationship in the sphere of sports competitions and are essential psychological characteristics in the adaptation process so necessary for the performance athletes (Schinke et al., 2012).

Because training and performance are closely related, based on a multitude of factors that uniquely influence each individual, there has been an increase in the use of monitoring systems and in the financial resources invested in this process to verify the level regulation of athletes (Joyce 2014).

Self-regulation is seen as a control system that provides feedback in intervention and control activities such as activation, balancing and correction (Epuran M. et al, 2008).

The aim of the study is to examine the relationship between the level of proprioceptive ability (agility, static and dynamic balance) in triple jumpers.

Methods

Participans

Fourteen top national triple jumpers, 7 girls (the mean age was 22,4 ±6.5 years; mean body mass 59.1 ±3.6 kg; height mean 171.9 ±3.2cm; training experience 9.6 ± 6.7 years) and 7 boys (the mean age was 19.6 ±2.8 years; mean body mass 73.4 ±4.4 kg; height mean 184.7 ±4.06 cm; training experience 7.5 ±4.5 years) participated in the study between April and June 2022. The athletes chosen are top 3 in their category at the National Championship.

Every athlete over 18 years old signed a participation agreement and the parents of the underage athletes signed a consent for their children to participate in the research experiment. The study was aproved and supported by the Research Center for Human Performance of the Physical Education and Sports University of Pitesti.

Design and Procedures

The study was performed between April and June 2022, after studying the existing literature in order to identify the aspects regarding the optimization and adaptation of the motor behavior of triple jumpers and after identifying the methods on how to determine the specific parameters to the theme in question.

We created a complementary training program designed to develop the proprioceptive capacity, balance and agility, integrated into the athletes training plan for the outdoor season, over a period of 10 weeks. Complementary exercises were performed 2 times a week in the preparatory stage and 3 times a week in the pre-competitive and competitive stage, after the specific warm-up.

We used a series of tests and measurements before and after the training program was applied, designed to determine the level of agility and balance.

The structure and content of the trainings were presented and discussed with the coaches and athletes before they were applied, and were made in accordance with their training plan and the competition calendar, avoiding as much as possible the disruption of their training program. Before the agility and balance measurements, the athletes underwent basic anthropometric measurements.

Agility measurements

We determined the level of agility using the Witty Sem device (Microgate, Italy), consisting of 4 individual photocells with a 6 x 5 LED array capable of projecting any number, letter or directional arrow in a range of colors allowing the user to select or pre-define test and training protocols for reaction, agility and cognitive strategy. The data acquired is transmitted to the timer with the maximum precision (±0.4 thousandths of a second) (https://performbetter.co.uk/product/witty-sem-cognitive-training-system/). This system can be used both in performing tests and measurements, as well as performing training protocols.

From standing position, the athletes had to react with their left and right hand to a specific symbol on 4 cells in the shortest possible time, to 20 visual stimuli, these being triggered after each response, on 4 different difficult levels.

Balance mesurements

To determine the level of static and dynamic balance we used the Sensabalance Mini Board platform (Sensamove, Netherlands) that combines the interactive training software and exercise games with the well-known benefits of a conventional wobble board. This results in an innovative and very effective new product in the range of interactive balance products of Sensamove. With easy exchangeable accessories the tilting angle and exercise difficulty can be customized. This makes the Miniboard a widely applicable training and therapy tool.

The athletes stood in one leg support on the platform (on the left and then on the right leg), the supporting leg with the knee slightly bent, the knees at the same level, the arms crossed with the hands on the shoulders, holding the position for 20 seconds, following a fixed landmark on the computer`s monitor.

For the dynamic vertical balance the athletes had to maintain the initial position described in the static balance test and performed a back-and-forth movement of the leg on the platform, staying within a delimited space displayed on the computer screen.

For the competition results, we selected the best results of the season for each athlete, established between May and June 2022, recorded on the Romanian Athletics Federation website.

Training program

The trainig program was performed for a period of 10 weeks, as it shows in table 1, and involved a group of 7 male triple jumpers and 7 female triple jumpers. The exercises were carried out both during the preparatory period and during the competitive period, their placement in the weekly training cycle was in different days for each athlete, depending on the objective of the daily training. The athletes did not perform other exercises to develop static and dynamic balance or agility apart from those implemented by us.

Statistical analyses

Descriptive statistics (mean, SD) were calculated for all dependent variables. To test the diferences between the initial and the final testing we applied the t-test, analyseing the p-value.

To determine the degree of statistical connection between the components of the proprioceptive capacity measured by us and the performance obtained in the competition, we determined the linear correlations for each of its components (static balance, vertical dynamic balance and agility) by calculating the Pearson correlation index.

Results

After analysing the data collected from the initial and final testing, presented in table 2 and 3, we calculated the Pearson correlation index for each component of the proprioceptive capacity, static balance, dynamical balance and agility. The results are expressed in percentages. The correlation results between balance, agility and the competition performance are presented synoptically in table 4 and 5 (M+F) and suggestively represented by Scatter graphics.

Table 1. The content and intensity of the training program

Training no. 1	Intensity	Training sessions	Weeks	Break	No. of rep	Series
Excercise 1. Reacting with both hands to a certain symbol displayed on the 4 Witty Sem cells standing on a Bosu ball.	medium	10	5	2-3 min	20	3

Excercise 2. Reacting with the left and right hand to a certain symbol displayed on the 4 Witty Sem cells from standing in one leg on a balance platform.	high	10	5	2-3 min	20	4
Training no. 2						
Excercise 1. Excercise 1. From standing on one leg, in front of a Witty Sem cell, jumps in the direction indicated by the green arrows (forward, left, right, back).	medium	10	5	2-3 min	20 on each leg	4
Excercise 2. Jumping on one leg in the direction indicated by the green arrows (forward, left, right, back) and in the opposite direction indicated by the red arrows.	high	10	5	2-3 min	20 on each leg	4
Training no. 3						
Excercise 1. From standing on one leg on the Sensabalance mini board, performing a maze quest on the computer, tilting the platform.	high	10	5	2-3 min	15 levels on each leg	1

Table 2. Balance results

Male					
		Static balance R	Static balance L	Dynamic vertical balance R	Dynamic vertical balance L
T1	Mean (%)	84.9	80.9	95.0	91.1
	st dev (±%)	4.5	8.6	1.83	9.8
T2	Mean (%)	83.3	82.4	86.7	89.1
	st dev (±%)	4.0	6.0	11.67	10.6
T test		0.43	0.18	0.63	0.25
		p>0.05	p>0.05	p>0.05	p>0.05
Female					
		Static balance R	Static balance L	Dynamic vertical balance R	Dynamic vertical balance L
T1	Mean (%)	83.0	78.9	84.9	85.6

	st dev (±%)	3.9	5.8	7.5	9.7
T2	Mean (%)	81.57	82.43	87.3	90.7
	st dev (±%)	2.4	2.8	10.3	5.1
		0.50	0.70	0.34	0.69
		p>0.05	p>0.05	p>0.05	p>0.05

Table 3. Agility Test results

Male					
Test		**Level 1**	**Level 2**	**Level 3**	**Level 4**
T1	Mean (sec)	0.686	0.755	1.029	1.284
	St dev (±sec)	0.057	0.061	0.104	0.133
T2	Mean (sec)	0.649	0.800	0.920	1.041
	St dev (±sec)	0.098	0.109	0.172	0.192
T Test		0.41	0.37	0.18	0.02
		p>0.05	p>0.05	p>0.05	p<0.05
Female					
Test		Level 1	Level 2	Level 3	Level 4
T1	Mean (sec)	0.831	0.903	1.259	1.460
	st dev (±sec)	0.109	0.173	0.179	0.237
T2	Mean (sec)	0.805	0.840	1.109	1.327
	st dev (±sec)	0.126	0.097	0.101	0.217
T Test		0.69	0.42	0.08	0.29
		p>0.05	p>0.05	p>0.05	p>0.05

Linear correlation between balance and performance

Table 4. Correlation results between balance and performance

Category	Static balance- right foot	P value	Static balance - left foot	P value	Dynamic vertical balance – right foot	P value	Dynamic vertical balance – left foot	P value
F	r= 0.639	p>0.05	r = 0.872	p>0.05	r=0.869	p>0.05	r=0.514	p>0.05
M	r= 0.329	p>0.05	r= 0.353	p>0.05	r= 0.713	p>0.05	r= 0.390	p>0.05

In the female group the Pearson correlation coefficient for the static balance, on the right leg indicates a strong direct, positive linear correlation (r= 0.639, p>0.05). For the left leg, where the value is r=0.872, p>0.05, the correlation is still direct and positive, showing a difference between the right and the left leg.
In the male group, for the static balance we have positive direct correlations (on the right leg r= 0.329, and on the left leg r= 0.353, p>0.05), but weaker values compared to the female results
For the vertical dynamic balance for the female group (r =0.869, p>0.05 on the right leg), we have a very high, direct and positive correlation, and on the left leg (r= 0.514, p>0.05), also a positive and reasonable linear correlation, resulting, as for the static balance, differences between the right and the left leg.
For the male vertical dynamic balance, on the right leg (r= 0.713, p>0.05), we see a high, direct and positive correlation, and on the left leg (r= 0.390, p>0.05), also a direct and positive correlation, but weaker in value. The p values were considered insignificant.

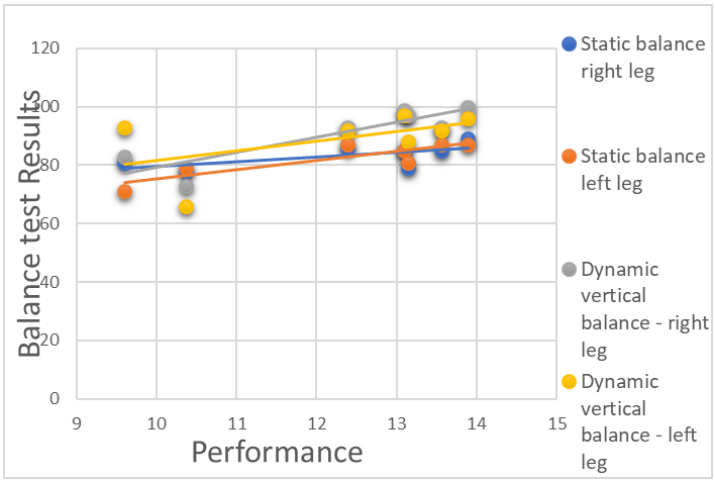

Figure 1. Representation of the linear correlations between the balance test results and the competition results – female

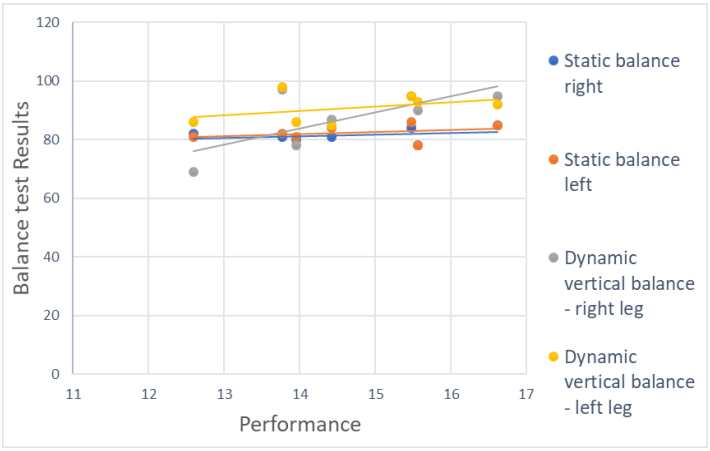

Figure 2. Representation of the linear correlations between the balance test results and the competition results - male

Linear correlation between agility and performance results

To determine the correlation between agility and performance result, we calculated the Pearson correlation coefficient for the competition results and the times obtained at each level of the Agility Test (difficulty levels 1-4), separately for men and women, as shown in table 5.

Table 5. Correlation results between agility and competition performance

Category	Level 1		Level 2		Level 3		Level 4	
F	r= -0.834	p>0.05	r= -0.896	p>0.05	r= -0.386	p>0.05	r= -0.433	p>0.05
M	r= -0.784	p>0.05	r= 0.592	p>0.05	r= -0.222	p>0.05	r= -0.160	p>0.05

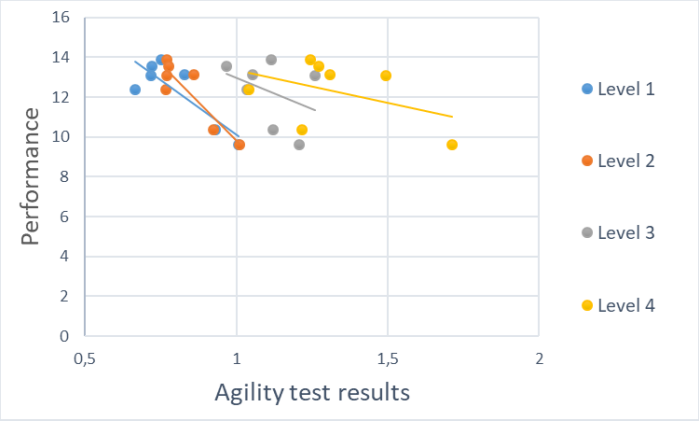

Figure 3. Representation of the linear correlations between the results in the agility test and the competition results - female

Figure 4. Representation of the linear correlations between the results in the agility test and the competition results - male

For the agility tests, the second calculated variable being the time on each level, expressed in seconds, it is normal to have a negative correlation, because the performance in the competition increases and the time decreases.
The results show a very high, direct and negative correlations for levels 1-2 (r=-0.834, p>0.05 and r=-0.896, p>0.05), and a direct negative correlation, but weaker for levels 3-4 (r= -0.386, p>0.05 and r= -0.433, p>0.05), the female athletes registering weaker values on levels 3 and 4 compared to levels 1 and 2.
For the male group, the strongest correlation is found at level 1 where r= -0.784, p>0.05, which indicates a negative, direct and strong correlation, and for level 2, where the value is r= 0.592, p>0.05 we have a direct, positive correlation, due to the fact that the athlete with the best result in competition recorded a weaker result in the agility test. The correlation coefficient for level 3 and level 4 indicate a weak correlation (r= -0.222, p>0.05 and r= -0.160, p>0.05). The p values were considered insignificant.

Discussion

The evaluation of the athletes in competition shows their ability to accumulate the contents of the training process, emphasizing how they can express themselves in the conditions of various environmental and stress factors (Mihai I., 2010). After calculating the Pearson correlation index, we found that there are strong correlations between static balance and performance results in the female group (on the right leg r= 0.639, p>0.05 and on the left leg r= 0.872, p>0.05), which confirms the research hypothesis. For the male group correlations are also direct and positive, but weaker than the female group (r= 0.329, p>0.05 on the right leg and r= 0.353, p>0.05 on the left leg). We believe that these correlations can be improved by introducing some complementary trainings that stimulate the development of the static balance necessary for the efficiency of the take off and landing phases.

In vertical dynamic balance for the female group (r= 0.869, p>0.05 on the right leg) we have a positive, direct and very high correlation, and on the left leg (r= 0.514, p>0.05) a reasonable, direct and positive correlation.

The male group correlation coefficient on the right leg (r= 0.713, p>0.05) shows a direct, positive and strong correlation, and for the left leg (r= 0.390, p>0.05) also a positive correlation, but weaker.

Regarding agility, in the female group we see very strong correlations on levels 1-2 (r=- 0.834 and r=- 0.896) and for level 3 and 4 we have encountered weaker correlations (r=- 0.386 and r=- 0.433). For the male group on level 1 we find a very high correlation (r= -0.784) and for the other 3 levels the correlations are weaker. For level 2 (r=0.592, p>0.05) we have a positive correlation instead of a negative one due to the fact that the athlete with the best competition result obtained a slower time, and for levels 3 and 4 (r=-0.222, p>0.05 and r =-0.160, p>0.05) the correlations are direct, negative, but weaker in value. Both in the case of girls and boys, we find that the values recorded on the first two levels are much better than on levels 3 and 4, where the difficulty is higher, hence the weaker values of the correlations.

Conclusion

The analysis of these data indicates that there is a strong correlation between the level of some components of proprioception and the result in the competition, resulting in the fact that the development of the proprioceptive capacity of triple jumpers is a requirement that should not be neglected in their continuous training to achieve the regulation and self-regulation of motor behavior in training and competition. We belive that the trainig program can be useful to coaches and athletes aiming to improve their balance and agility in order to increase the performance.

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