THE RELATIONSHIPS AMONG GYMNASTS' TRAINING AGE, BODY MASS INDEX, BALANCE CONTROL, AND GYMNASTICS PERFORMANCE

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Abstract

The aim of the study was the examination of the relationships among gymnasts' training age, body mass index (BMI), balance control during the execution of handstand, standing scale forward, and stork standing in relevé position, and their performance in competition settings. Forty young competitive gymnasts (20 males; age: 12.20 ± 1.98 years, and 20 females; age: 12.33 ± 2.07 years, mean ± SD) participated in this study. A portable digital platform for posturography was used to measure maximal pressure, center of pressure (CoP) sway area, CoP linear distance displacement and CoP velocity. The resulting data were analyzed using an integrated software module (Foot Checker, version 4.0). The results confirm the reliability of the measurements. Strong positive correlations were found between gymnasts' performance in the gymnastics competition, and their training age and BMI, with relationships also identified between performance and variables related to balance control. Regression analysis revealed that gymnasts' training age, BMI, and balance control in performing the assessed gymnastics skills had predictive significance in determining their performance in the competition, taking into account differences between age groups. Despite the limitations of the study, the results represent a valuable contribution to the literature by expanding knowledge about predicting gymnastics performance in competition. Furthermore, the results provide evidence for the identification of talent in gymnasts, offer coaches insights to improve training efficiency, and provide recommendations for future research in this area.

Keywords: *gymnastics competition, prediction, gymnasts, balancing ability, posturography.*

INTRODUCTION

High-level gymnastic skills are characterized by increased stability, precise posture control during the execution of different movements, and reduced variability in their acceleration time-series. Even minor disruptions to stability can significantly impact gymnastics performance (Asseman, Caron, & Crémieux, 2008; Lamoth, van Lummel, & Beek 2009). Fundamental gymnastics balance skills such as (a) the handstand, (b) the standing scale, scale forward, or front scale, and (c) the standing scale on one leg extended on the ball of the foot (relevé) with the other leg in passé (stork standing in relevé position) – are crucial for ensuring the quality and safety of gymnastics execution and determine the potential for high-level development and performance (Asseman et al., 2008; FIG, 2020a; FIG, 2020b; Fink, Hofmann et al., 2021; Fink, Lopez et al., 2021; Hedbávný, Sklenaříková, Hupka, & Kalichová, 2013; Hrysomallis, 2011; Uzunov, 2008; Živčić-Marković, Krističević, & Aleksić-Veljković, 2015).

Given the essential role these skills play in attaining proficiency in gymnastics, targeted training to develop and perfect these skills is recommended from a young age, typically around 7 years old (Fink, Hofmann et al., 2021; Fink, Lopez et al., 2021). Gymnasts' experience, competition level, number of training hours, and body mass index (BMI) percentiles are associated with their balance control (Liaw, Chen, Pei, Leong, & Lau, 2009; Olchowik et al., 2015; Opala-Berdzik, Głowacka, & Juras, 2021) and have been considered among the most important factors in predicting success in gymnastics (Asseman et al., 2008; Hrysomallis, 2011; Kaur & Koley, 2019; Opala-Berdzik et al., 2021; Vuillerme, Teasdale, & Nougier, 2001; Zemková & Zapletalová, 2022).

Training programs that include a combination of general and sport-specific exercises, specifically targeting postural and core muscles, have demonstrated positive outcomes in terms of improved body balance, increased strength in the back muscles, and enhanced endurance. Research has indicated that incorporating balance training into activities of recreational active individuals or physical education students led to enhancements in vertical jump performance (Kean, Behm, & Young, 2006; Šimek, Milanović, & Jukić, 2007), agility (Šimek et al., 2007), and shuttle run (Yaggie & Campbell, 2006). However, it is not well established whether these improvements effectively translate into enhanced athletic performance (Zemková & Zapletalová, 2022) or how balance training influences the motor skills of elite athletes (Hrysomallis, 2011). Demonstrating a positive impact on athletic performance could further justify incorporating balance training into a comprehensive conditioning regimen (Hrysomallis, 2011).

Gymnasts exhibit excellent neuromuscular control in maintaining posture and core stability. Additionally, they possess a heightened ability to perceive their body's orientation in space, particularly during tasks that require precise postural adjustments. These attributes significantly enhance their efficiency in executing gymnastics-specific movements and overall functional performance (Vuillerme et al., 2001).

Researchers have employed multiple tests to evaluate balance when exploring the relationship between balance ability and athletic performance. The center of pressure (CoP) measurement, obtained through a pressure or force assessment system, is currently the most reliable method for accurately quantifying standing balance (Asseman et al., 2008; Milosis & Siatras, 2012; Milosis & Siatras, 2023). Reduced ranges of CoP displacement indicate improved postural control during the performance of a specific balance position (Asseman et al., 2008; Asseman, Caron, & Crémieux, 2005). In contrast, displacement velocity reflects the effectiveness of the nervous system in regulating the musculoskeletal system's response to momentary imbalances, where a lower average velocity of CoP displacement suggests superior postural control (Asseman, Caron, & Crémieux, 2004).

Within this context, there is a lack of scientific data on the interrelationship between gymnasts' balance ability and gymnastics performance. Therefore, the aim of this study was to determine the correlations between the training age, BMI, and balance control of gymnasts and their performance in gymnastics age-group competitions. It was expected that the results of this study would provide coaches with valuable insights to optimize their gymnasts' training programs more effectively.

METHODS

Forty young competitive gymnasts (20 males; age: 12.20 ± 1.98 years, body mass: 35.55 ± 10.09 kg, height: 142.05 ± 12.90 cm, and 20 females; age: 12.33 ± 2.07 years, body mass: 36.15 ± 6.29 kg, height: 145.50 ± 8.20 cm; mean ± SD) participated in this study. The study included only those gymnasts who were able to maintain a stable base of support and good posture while performing the required skills for at least 10 seconds. The participants had undergone structured training and competitive gymnastics at the national level for a period ranging from 4 to 11 years. Typically, young gymnasts can achieve the skill of maintaining a static handstand on a flat surface, such as the floor, after undergoing specific gymnastics training for 3 to 4 years (Kochanowicz et al, 2015). The gymnasts trained six days per week, with each training session lasting around three hours, and they practiced on every gymnastics apparatus. Training took place in a well-equipped gym, also utilized by the Hellenic national gymnastics team. The older gymnasts, male and female, aged 14 and 15 years, were deemed elite by the Hellenic Gymnastics Federation. The study adhered to the guidelines set by the Ethical Committee of Aristotle University of Thessaloniki. Before any measurements were taken, the parents provided written informed consent for their children's participation in the study.

The distribution of weight and stability during a handstand was measured and analyzed using a vertical posturographic digital platform (Foot Checker, Comex S.A./LorAn Engineering Srl; Castel Maggiore, Bologna, Italy). The platform measured 700 x 500 mm and was positioned on the floor. It comprised 2304 resistive elements with a measurement accuracy of 0.001 kPa, sampled at a frequency of 60 Hz. Maximal pressure (the amount of force acting vertically on the support surface; kPa), CoP mean velocity (the sum of the cumulative CoP displacement divided by the total time; mm/s), and center of pressure (CoP) sway area (defined as an ellipse containing 90% of all displacement points; mm^2) were analyzed using integrated software (Foot Checker, version 4.0).

All measurements were conducted under identical experimental conditions for all participants. The tests were carried out by a single researcher in a dedicated room that minimized distractions for the gymnasts. The portable platform used for the measurements was placed in a marked area. To prevent the effects of training fatigue on the results, the tests were conducted in the afternoon, before the start of the training session. Following a brief warm-up, the participants stood still on the platform with their eyes open for 10 seconds during each test. A two-minute rest period between trials was applied, and all tests were conducted without shoes. A failed attempt was considered when, during the 10-second standing period, there was any variation in the support position, such as shuffling, stepping, or falling. In such cases, the effort was interrupted and repeated after a two-minute rest.

During the standing scale forward, participants were instructed to place their dominant foot in the middle of a rectangular taped area on the platform and slightly lower their upper body. They were then asked to raise their non-dominant leg backward to the horizontal level.

For the stork standing in relevé position, participants stood in the same place with their dominant foot positioned in the center of the platform within the rectangular taped area. They were then asked to place their hands on their hips and position their non-supporting foot against the inside of their supporting leg's knee. Following this, participants were instructed to raise the heel of their supporting foot to balance on the toe. The evaluation began as the heel was lifted from the platform. After completing the test, participants performed the same standing scale on their other leg. All participants were instructed to maintain balance in the same way (by looking straight ahead, with eyes open, and keeping their bodies as still as possible).

To assess handstand balance, the “press to handstand hold” technique was utilized, starting from a standing position with feet apart and hands positioned shoulder-width apart on the platform. Under the guidance of the researcher, the gymnast was assisted in attaining a stable handstand with correct body alignment, with the experimenter lightly touching the sides of their upper legs. The gymnast’s legs were then “released,” and the assessment was conducted and recorded for 10 seconds. The duration of 10 seconds for the handstand test was considered adequate for the goals of the present study, achievable by the participating gymnasts, and has also been applied in previous studies (Kochanowicz et al., 2015). During the test, gymnasts attempted to maintain a stable base by holding still with their wrists and fingers, fixing their gaze within the hand support and in front of the wrists, while keeping their head in a neutral position (Asseman et al., 2005), ensuring that their arms remained straight and their bodies tight, strong, and stable.

The SPSS software (SPSS v. 28, SPSS Statistics, IBM Corp., NY) was used to perform all statistical analyses. To verify the reliability of the measurements, all tests were repeated twice (test-retest) under the same conditions by the same experienced examiner within a one-week period. Test-retest reliability was examined using the intra-class correlation coefficient (ICC). The means and standard deviations of the values for the left and right extremities from the two tests were used to analyze the examined variables related to balance control: (a) Maximal Pressure (kPa) of the hands during handstand (MP_H), Center of Pressure (CoP) mean velocity (mm/s) during handstand (CoP_V_H), and CoP sway area (mm^2) during handstand (CoP_SA_H); (b) Maximal Pressure of the foot during stork standing in relevé (MP_SSR), CoP mean velocity during stork standing in relevé (CoP_V_SSR), and CoP sway area during stork standing in relevé (CoP_SA_SSR); and (c) Maximal Pressure of the foot during standing scale forward (MP_SSF), CoP mean velocity during standing scale forward (CoP_V_SSF), and CoP sway area during standing scale forward (CoP_SA_SSF). Figure 1 displays examples of the measurements of the variables during the execution of the studied skills. The results of the national age group competition were recorded approximately six months after the introduction of the measurements. To facilitate the statistical analyses, the mean values were calculated for the six male apparatuses and the four female apparatuses.

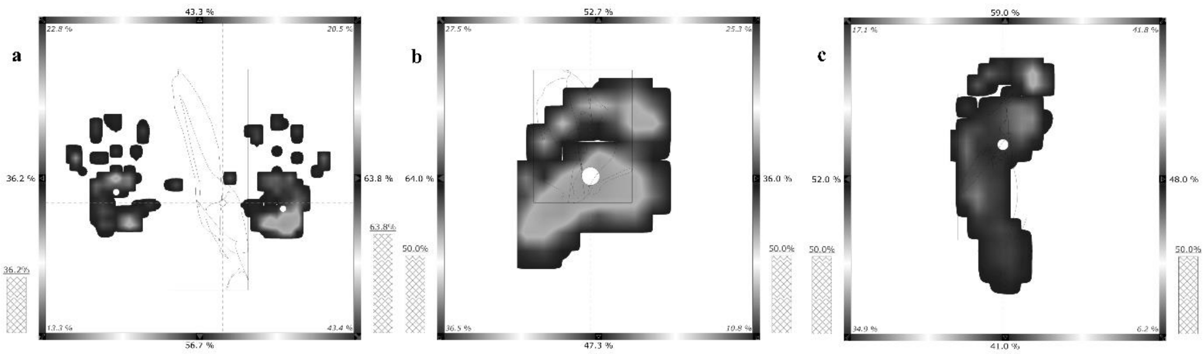

Figure 1: Examples of the measurements of the variables during the execution of the studied skills on the digital platform (a) handstand, (b) stork standing in Relevé, and (c) standing scale forward.

RESULTS

Assumptions and reliability of the measurements

The criteria for a normal distribution were met by the independent variables, as evidenced by their skewness and kurtosis falling within the acceptable range (-1.0 to +1.0), and the Shapiro-Wilk test supported the normal distribution of the examined variables ($p > .05$). The single measures intra-class correlation coefficient values ranged from .66 to .96. The equality of variance-covariance matrices among groups was confirmed by Box's test. Similarly, Bartlett's test of sphericity revealed that the variances were equivalent across groups, and Levene's test demonstrated that there was no significant difference in error variance among groups ($p > .05$).

Relationships between training age, BMI, balance control parameters and gymnastics performance

Pearson's correlation coefficients showed significant correlations between the performance of participants in the gymnastics competition and their training age, BMI, and balance control in the three examined gymnastics skills, ranging from low negative to high positive (-.31 to .91, Table 1).

The normal P-P plot supported the normality of the data, and the scatterplot of the residuals indicated homoscedasticity. Tolerance values between 0.122 and 0.715 and VIF values ranging from 1.399 to 8.193 indicated acceptable collinearity (Vittinghoff, Glidden, Shiboski, & McCulloch, 2005). The Durbin-Watson test result of 2.031 (within the acceptable range of 1.5 to 2.5) confirmed the independence of errors. The results from the regression analysis showed that training age and BMI emerged as significant predictors of gymnasts' performance, accounting for 41.5% of the variance in performance, $F(2,37) = 13.15$, $p < 0.001$. Adding MP_H, CoP_V_H, and CoP_SA_H in the second step accounted for an additional 3.2% of variation in performance, $F(3,34) = 0.65$, $p = 0.587$. Including MP_SSR, CoP_V_SSR, and CoP_SA_SSR in the third step accounted for an additional 16% of variation in performance, $F(3,31) = 4.22$, $p < 0.01$. Finally, adding MP_SSF, CoP_V_SSF, and CoP_SA_SSF in the fourth step accounted for an additional 6.3% of variation in performance, bringing the total proportion of explained variance to 67.1%, $F(3,28) = 1.79$, $p = 0.173$. The results from the analysis of variance (ANOVA) table confirmed that the model significantly predicted the dependent variable in all steps: $F(2,37) = 13.15$, $p < 0.001$; $F(5,34) = 5.50$, $p < 0.001$; $F(8,31) = 6.00$, $p < 0.001$; and $F(11,28) = 5.18$, $p < 0.001$ (Table 2). The equation generated by the regression model to predict gymnastics performance based on balance control in the three examined gymnastics skills was calculated as follows:

Gymnastics performance = -11.192 + (0.217 × training age) – (0.092 × BMI) + (0.004 × MP_H) + (0.039 × CoP_V_H) + (0.001 × CoP_SA_H) + (0.087 × MP_SSR) – (0.125 × CoP_V_SSR) + (0.009 × CoP_SA_SSR) + (0.007 × MP_SSF) + (0.018 × CoP_V_SSF) – (0.002 × CoP_SA_SSF).

Table 1
Descriptive statistics and correlations for study variables

Variable	M	*SD*	1	2	3	4	5	6	7	8	9	10	11	12
1. Performance	10.95	1.45	–											
2. Training age	6.38	2.30	.64***	–										
3. BMI	17.10	1.83	.51***	.74***	–									
4. MP_H	392.50	21.74	.30	.31*	.37*	–								
5. CoP_V_H	32.89	8.88	-.15	-.05	-.08	.32*	–							
6. CoP_SA_H	919.78	359.29	-.18	-.01	-.02	.43**	.75***	–						
7. MP_SSR	223.39	9.06	.56***	.36*	.37*	.17	-.42**	-.37*	–					
8. CoP_V_SSR	28.72	8.18	-.31*	-.21	-.26	-.07	.51***	.50***	-.58***	–				
9. CoP_SA_SSR	337.90	148.55	-.17	-.14	-.19	.01	.49***	.46**	-.56***	.91***	–			
10. MP_SSF	183.38	23.75	.20	.28	.30	.18	-.19	-.08	.00	-.04	-.02	–		
11. CoP_V_SSF	44.96	13.74	-.39*	-.43**	-.11	-.45**	.54***	-.48**	-.38*	.61***	.53***	-.32*	–	
12. CoP_SA_SSF	896.11	387.60	-.42**	-.44**	.04	-.29	.54***	-.46**	-.34*	.53***	.58***	-.24	.73***	–

Abbreviations: M = mean; SD = standard deviation; BMI = body mass index; MP_H = maximal pressure of the hands during handstand; CoP_V_H = center of pressure mean velocity during handstand; CoP_SA_H = center of pressure sway area during handstand; SSS = stork standing in relevé, SSF = standing scale forward.
****p < .001, **p < .01, *p < .05.*

Table 2
Hierarchical regression results for gymnastics performance in the age group competition

Variable	B	95% CI for B		SE B	β	R^2	AdjR^2	*t*
		LL	UL					
Step 1						.42	.38	
Constant	7.62	3.48	11.75	2.04				3.73***
Training age	0.37	0.13	0.61	0.12	.59			3.16**
BMI	0.06	-0.24	0.36	0.15	.07			0.38
Step 2						.45	.37	
Constant	7.23	-0.85	16.03	4.22				1.81
Training age	0.37	0.13	0.62	0.12	.59			3.12**
BMI	0.47	0.13	0.62	0.16	.06			0.31
MP_H	0.00	-0.02	0.02	0.01	.02			0.14
CoP_V_H	0.01	-0.06	0.07	0.03	.03			0.15
CoP_SA_H	-0.00	-0.00	0.00	0.00	-.19			-0.92
Step 3						.61	.51	
Constant	-6.70	-20.52	7.13	6.78				-0.99
Training age	0.33	0.10	0.56	0.11	.53			2.95**
BMI	-0.09	-0.39	0.21	0.15	-.11			-0.61
MP_H	0.00	-0.02	0.02	0.01	.06			0.38
CoP_V_H	0.02	-0.04	0.08	0.03	.10			-0.58
CoP_SA_H	0.00	-0.00	0.00	0.01	-.10			0.51
MP_SSR	0.07	0.02	0.12	0.02	.45			2.96**
CoP_V_SSR	-0.09	-0.18	0.02	0.05	-.51			-1.74
CoP_SA_SSR	0.01	0.00	0.01	0.00	.61			2.09*
Step 4						.67	.54	
Constant	-11.19	-25.68	3.29	7.07				-1.58
Training age	0.22	-0.04	0.48	0.13	.34			1.70
BMI	-0.09	-0.40	0.22	0.15	-.12			-.60
MP_H	0.00	-0.02	0.03	0.01	.07			.44
CoP_V_H	0.04	-0.02	0.10	0.03	.24			1.30
CoP_SA_H	0.00	-0.00	0.00	0.00	-.07			-.40
MP_SSR	0.09	0.00	0.04	0.03	.55			3.56***
CoP_V_SSR	-0.13	-0.24	-0.01	0.06	-.71			-2.27*
CoP_SA_SSR	0.01	0.01	0.02	0.00	.90			2.91**
MP_SSF	0.01	-0.01	0.02	0.01	.12			.89
CoP_V_SSF	0.02	-0.03	0.06	0.02	.17			.81
CoP_SA_SSF	-0.00	-0.00	0.00	0.00	-.42			-2.13*

Abbreviations: CI = confidence interval; LL = lower limit; UL = upper limit; BMI = body mass index; MP_H = maximal pressure of the hands during handstand; CoP_V_H = center of pressure mean velocity during handstand; CoP_SA_H = center of pressure sway area during handstand; SSS = stork standing in relevé, SSF = standing scale forward.
****p < .001, **p < .01, *p < .05.*

DISCUSSION

This study aimed to determine the relationships between gymnasts' training age, BMI, and balance control, and their performance in age group competitions. Currently, the most reliable approach to accurately quantify balance is through the measurement of the center of pressure (CoP) using a pressure or force assessment system

(Asseman et al., 2008; Milosis & Siatras, 2012; Milosis & Siatras, 2023). The findings of this study supported the reliable and effective use of the portable posturographic digital platform as a tool for measuring CoP in assessing balance skills in gymnastics settings (ICC ranged from .66 to .96).

In this study, strong positive correlations were found between gymnasts' performance in competitions and both training age (r = 0.64) and BMI (r = 0.51). Additionally, relationships were identified between performance and variables related to balance control. In particular, positive correlations were observed with maximal pressure, which refers to the vertical force exerted on the support surface during the performance of the studied gymnastics skills. These correlations were robust and statistically significant, especially concerning stork standing in relevé position (r = 0.56). Conversely, this study revealed negative relationships between performance and the CoP mean velocity and CoP sway area during the execution of the examined gymnastics skills. These correlations were of moderate strength and statistical significance, particularly regarding stork standing in relevé position (r = -0.31) and standing scale forward (r = -0.39, -0.42). Higher maximal pressure and lower CoP mean velocity and sway area are mentioned as determinants of better-quality balance control (Asseman et al., 2004; Asseman et al., 2005; Asseman et al., 2008; Hrysomallis, 2011; Sobera, Serafin, & Rutkowska-Kucharska, 2019; Yeadon & Trewartha, 2003). Significant correlations have been identified between balance ability and a range of performance measures (Hrysomallis, 2011).

The results of the present study support the hypothesis that effective development of postural control skills is crucial for young gymnasts to attain proficiency in fundamental movement skills (Clark, 2005; Lubans, Morgan, Cliff, Barnett, & Okely, 2012) and enhance their overall athletic performance (Hrysomallis, 2011; Zemková & Zapletalová, 2022). It has been shown that the enhanced postural stability observed in artistic gymnasts is associated with their training experience and BMI percentiles (Liaw et al., 2009; Olchowik et al., 2015; Opala-Berdzik et al., 2021). Several studies have demonstrated the substantial influence of professional gymnastic training on body stability, both in natural and unnatural balance positions (Gautier, Thouvarecq, & Larue, 2008; Hedbávný et al., 2013; Kochanowicz et al., 2018). Furthermore, it has been argued that the strength relative to the body mass of gymnasts plays a decisive role in their performance in gymnastics (Bradshaw & Rossignol, 2004; Kaur & Koley, 2019).

In addition, the results of the regression analysis revealed that gymnasts' training age, BMI, and balance control during the performance of the studied gymnastics skills had predictive significance in determining their performance in age group competitions. The equation generated by the regression model can be used to predict performance in competition based on gymnasts' training age, BMI, and balance control during the execution of the studied gymnastics skills.

Based on the findings, the model demonstrated significant predictive ability for the dependent variable (performance in the competition) across all stages, accounting for a substantial 67.1% of the variance in the final step. An examination of the beta coefficients in the final step concluded that the CoP sway area, CoP mean velocity, and maximal pressure during stork standing in relevé, as well as the CoP sway area during the execution of standing scale forward, made the most substantial contributions to predicting performance in competition. These findings indicate that the skill of stork standing in relevé holds greater significance for performance compared to standing scale forward and handstand skills. The handstand is widely acknowledged as an essential balancing skill for both male and female gymnasts (Hedbávný et al., 2013; FIG, 2020a; FIG, 2020b; Uzunov, 2008; Živčić-Marković et al., 2015). It serves as a versatile position, utilized as both the initial and final posture in various gymnastic exercises. For example, it is a fundamental element within larger motor sequences, such as executing a forward or backward handspring. It is also used in other gymnastic exercises, such as transitioning from a swing with straight arms to a handstand on rings or executing a basket to handstand on parallel bars. However, the findings from the present study indicate that balance control during the execution of a handstand does not significantly predict performance outcomes in competition. The wide age range and inclusion of both genders among the young gymnasts in this study may have influenced the results, thereby downplaying the predictive validity of the handstand on their performance, particularly when considering the effects of the other variables studied.

The extent to which improvements in performance can be attributed to the specific balance training stimulus, rather than the overall increase in physical conditioning resulting from integrating balance training, remains uncertain. Some theories suggest that advancements in balance skills might decrease the allocation of muscles for stabilization purposes, enabling them to contribute more effectively to generating motive force (Kean et al., 2006). Significant improvements in motor skill performance have been observed as a result of balance training, indicating notable adaptations (Hrysomallis, 2011). Furthermore, evidence suggests that balance training can enhance maximum voluntary isometric contraction (MVIC) force (Heitkamp et al., 2001), improve the rate of force development (RFD) during MVIC (Gruber & Gollhofer, 2004), and potentially optimize musculotendinous and joint stiffness, thereby reducing the amortization phase in the stretch-shortening cycle (Kean et al., 2006).

Moreover, engaging in balance training can result in specific neural adaptations at both spinal and supraspinal levels. These adaptations include the suppression of spinal reflex excitability (Taube et al., 2008), as well as improved agonist-antagonist muscle co-contraction, leading to increased joint stiffness and enhanced joint stability against disturbances (Lloyd, 2001). Additionally, balance training has been associated with a shift in movement control, transitioning from cortical structures to subcortical and cerebellar regions, as supported by research findings (Taube et al., 2008). Lastly, several sensory adaptations to the balance training stimuli inherent in various sports activities have been proposed (Hrysomallis, 2011; Vuillerme et al., 2001).

Nevertheless, while these task-specific adaptations can account for the enhanced balance ability resulting from balance training, they may not fully elucidate the concurrent improvement in motor skills. The specific contribution of enhanced motor or sensory function to the improvement in motor task performance from balance training remains unclear. Proprioception, a component of the sensory system, provides information about joint position sense and detects joint motion, making it a crucial element of the balance system (Fallas-Campos et al., 2023; Vuillerme et al., 2001). It has been suggested that athletes may develop increased skill in focusing on and attending to relevant sensory cues through training, thereby enhancing their ability to generate precise motor responses. For example, gymnasts who balance on the beam may learn to prioritize their attention to detect even the slightest body segment acceleration, aiming to minimize unnecessary motion and ultimately enhance their performance (Ashton-Miller et al., 2001). Specifically, the ability to reduce CoP displacements through the reinsertion of proprioceptive information is more pronounced in gymnasts compared to non-gymnasts (Vuillerme et al., 2001).

A limitation of this study was the inclusion of a sample consisting of both male and female gymnasts, which was necessary to ensure an adequate size for statistical analyses. However, it is possible that the balance skills studied had different effects on gymnastics performance between genders. For instance, the handstand may have a more prominent impact on the performance of male gymnasts due to its greater utilization in skills performed on male apparatus. Conversely, the standing scale forward and stork standing in relevé position may be more strongly associated with female performance, as these skills are fundamental for executing balances, turns, and jumps on the floor and balance beam.

Furthermore, this study included a wide range of athletes, encompassing individuals aged approximately 10 to 15 years with varying levels of training experience (4 to 9 years). While the gymnasts participated in a gymnastics age group competition, it is important to recognize that differences in age and training experience likely influence the relationships between balance control and performance results. Further research is needed to explore the relationship between balance ability and gymnastics performance in male and female gymnasts separately. Additionally, employing larger and more homogeneous samples regarding age and training experience would enhance the validity of the findings.

CONCLUSIONS

The results of this study revealed that variables such as the gymnasts' training age, BMI, and balance control during the execution of handstands, stork standing in relevé position, and standing scale forward had a positive predictive relationship with their performance in upcoming competitions. Demonstrating a positive impact on athletic performance strengthens the rationale for integrating balance training as a critical component of a comprehensive conditioning program. Based on these findings, incorporating static balance tests of specific skills could also be beneficial in the talent identification process for selecting promising gymnasts during early specialization. Furthermore, these tests may serve as valuable assessment tools for evaluating and identifying high-performance gymnasts.

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