IMPORTANCE OF BODY SYMMETRY TO ESTABLISH STAND BALANCE AFTER DROP JUMP

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Abstract
The aim of the study was to determine if body symmetry influences the establishment of stand balance after a drop jump. Thirty-two healthy sports students with experience in artistic gymnastics participated in this study. The participants had an average age of 19.8 ± 1.4 years, height of 182.9 ± 6.8 cm and weight of 79.1 ± 8.1 kg. Morphological characteristics were assessed by measuring differences between the left and right sides in forearm girth, upper arm girth, calf girth, thigh girth, long shoulder height, lean mass of legs and lean mass of arms. The standing balance result was calculated based on factor scores obtained from nine measurements taken over 30 seconds after jumping from a 25 cm height platform. These measurements included three for normal stand, three for blind stand, and three for deaf stand. The data was collected using a pressure insoles system and by measuring the difference in ground reaction force between the left and right legs. Stepwise regression analysis revealed that 27% of the differences in leg load could be explained by differences in morphological characteristics between the left and right sides with two significant predictors: the difference in long shoulder height explaining 16% of the variance and the differences in arm lean mass explaining 11% of the variance. Both variables showed a negative relationship with the factor jump standing. It was observed that imbalances in body symmetry could increase the long-term risk of acute or chronic injuries.

Keywords: *3D scan, balance, body symmetry, In Body, jump, pressure insole.*

INTRODUCTION

Artistic gymnastics is classified as a multi-structured sport discipline, as it involves a wide variety of complex motor skills. The possible combinations of these skills further enhance the complexity of motor tasks and expand the range of possibilities (Pegan, 2015).

In all gymnastic disciplines, jumps are a fundamental component. A jump is a motor task consisting of three parts: the take-off, the flight, and the landing (Bolkovič et al., 2002). Landings are crucial in artistic gymnastics as they represent the final element performed after all acrobatic elements. Landings are also executed after each jump on the trampoline. Similarly, in rhythmic gymnastics, landings follow various jumps.

Marinšek (2007) states that success in elite gymnastics is determined by the landing. Sometimes, the difference between the winner and other competitors is determined by nuances that an inexperienced observer may not even notice. These nuances are crucial for distinguishing the best from the good. An athlete must perform three tasks in a successful landing (Antonov, 1975): a) absorb the impact on the surface, b) maintain a balanced body position upon landing, and c) meet traditional aesthetic requirements. The most challenging task of a landing is maintaining a balanced position upon landing. A balanced landing occurs when the kinetic energy is equal to zero, and the body is at rest (Marinšek, 2007).

In a meta-analysis of studies on the impact of ankle injuries on balance after acute ankle sprain and chronic instability, Wikstrom, Naik, Lodha, and Cauraugh (2010) found that balance impairment is significantly weakened following an acute lateral ankle sprain, which negatively affects balance. Ankle sprains can be assessed as asymmetries in the body, and it can be inferred that postural control is compromised when there are weaknesses on one side of the body.

In a study investigating the differences between the dominant and non-dominant limbs during double-leg landings, it was concluded that the non-dominant ankle exhibits a more effective protective mechanism against excessive joint motion, while the dominant ankle is at greater risk of injury during drop landings (Niu, Wang, He, Fan, and Zhao, 2011).

In another study (Čuk & Marinšek, 2013), researchers explored how temporal, kinematic, and dynamic characteristics of landings relate to landing quality in gymnastics. They found that all predictors defined asymmetries between the legs during landing. Landing and maintaining an upright stable position in sports activities (e.g., artistic gymnastics) or everyday activities (such as landing after jumping on stairs) are important for minimizing the risk of injury.

Pajek, Hedbávný, Kalichová, and Čuk (2016) also analyzed take-offs and landings to determine the actions performed by the left leg, both legs simultaneously, or the right leg of professional female gymnasts in balance beam routines. They concluded that asymmetric lower limb loading is present in the routines of elite gymnasts. However, repeated unilateral stress on a healthy locomotor system may lead to functional abnormalities in human posture.

It's worth noting that the most significant dynamic loads on the lower extremities occur during asymmetrical landings, rather than in unsuccessful landings as typically assumed. Asymmetrical yet reasonably successful landings seem to present the greatest injury potential for the Achilles tendon, knee joint, and spine (Panzer, 1987). The deviation from perfect body symmetry is caused by lack of development accuracy. Systematic sport training creates differences in body posture due to the disparity in the muscular-ligament apparatus on the left and right sides of the torso, which is the result of asymmetric body muscle development (Šarabon et al., 2005).

Čuk et al. (2012) found significant differences in the morphologic characteristics of top-level gymnasts between the left and right arm in elbow diameter, circumference of the forearm, and skinfold thickness of the triceps brachii. However, they did not find any significant morphological adaptations to asymmetric loads in the legs.

For these reasons, it is reasonable to ask what the relationship is between anthropometric characteristics and landing. Do morphological asymmetries in the body affect the balance position after landing?

Based on the structural complexity of movements in individual sport disciplines, gymnastics is ranked among conventional sports, which are characterized by aesthetic and physically determined cyclical sets of structures to be carried out either in standard or variable external conditions (Matveev, 1977; in Kolar, Samardžija P. & Veličkovič, 2015).

A trainee must constantly adapt to the environment to successfully perform motor tasks (Marinšek, 2007). Three processes characterize every motor task (Schmidt, 1999): a) perception of stimuli (information from the environment), b) response selection (determining what, where, and when to do something), and c) program execution based on response selection.

Information for motor tasks comes from various sources, distinguishing between information coming from the environment and information coming from the body. In sports, vision and hearing provide the most useful environmental information. Among the most important receptors within the body are proprioceptors (Rajtmajer, 1990).

Therefore, in this study, we used different conditions for landing, specifically normal stand, blind stand, and deaf stand.

However, to the best of our knowledge, no studies have been conducted in which dynamic balance abilities after a jump are related to body morphological symmetries. Therefore, the objective of this study was to investigate whether morphological characteristics, especially bilateral asymmetry, influence dynamic human balance. The hypothesis to be tested is (H1) that morphological bilateral asymmetries impact differences in the proportion of ground reaction force (GRF) between the left and right legs in standing balance after jumping from a 25 cm box.

METHODS

Thirty-two sports students registered in the 2015/2016 academic year, who have experience with artistic gymnastics, participated in this study. Their average age was 19.8 ± 1.4 years, their weight was 79.1 ± 8.1 kg, and their height was 182.9 ± 6.8 cm. The subjects' sports orientations were random, and none of them were high-performance athletes. They had no medical conditions. The study was performed in accordance with the Declaration of Helsinki and was approved by the institutional ethics committee. Informed consent for study participation was obtained from all participants.

Our measurements were collected in two stages. In the first part, morphological measurements were taken using a 3D body scanner and the InBody 720 system. The 3D body scanner (NX-16 [TC]2, Cary, North Carolina) scans the whole body and produces a true-to-scale 3D body model. A multi-scan option with 3 consecutive scans was used to obtain the data. Each set of 3 consecutive scans lasted for 24 seconds, and subjects were instructed to remain as still as possible. Previous research (Zancanaro, 2015) has shown the reliability of anthropometry performed by different skilled anthropometrists using a 3D scanner (ICC = 0.996-1.0 for repeated digital measurement). The InBody 720 bioimpedance device measures each individual with high repeatability (Biospace, 2008), and its measurement methods are reliable and valid. The validity of the device InBody 720 device was confirmed by So *et al*. (2012) in a study that showed significant correlations between body composition measurements taken using the body composition measurements taken with air displacement plethysmography and eight-polar bioelectrical impedance analysis, specifically for fat-free mass (M: r=0.911) and body-fat mass (M: r=0.938).

From 3D body scanner (according to ISO 20685:2010 norms) the following measurements were taken: forearm girths (the largest circumference between the wrist and the elbow), upper arm girth (biceps measured 5.08 cm below the armpit), calf girth (largest circumference between the knee and the smallest part of the leg above the ankle), thigh girth (largest circumference between crotch level (-2.54 cm) down to the knee), and long shoulder height (vertical line from the shoulder point to the floor, indicating the height of the shoulder point above the floor). Measurements of lean mass in the legs and arms were obtained from the InBody 720.

The second part of the measurements involved body balance maintenance tests. All participants used two in-shoes insoles with pressure sensors (PedarX, Novel GmbH, Munich, Germany), adjusted to their feet size. To prevent shoes from affecting ankle balance, participants did not wear shoes but had insoles placed between two pairs of socks. The PedarX system was secured with an elastic belt around the subject's waist in the middle of the back, allowing for unrestricted movement without imposing asymmetric loads on their feet. The total weight of the PedarX system is 0.400 kg. Data were wirelessly transferred from the system to the computer using a built-in Bluetooth module. The PedarX measurement system has been proven to be accurate, reliable, and valid (Boyd et al., 1997).

Participants performed three types of measurements, each with three repetitions. Each repetition lasted for 30 seconds, starting with the first contact of the feet with the floor after flight. The first measurement was a still-standing position after jumping from a 25 cm high box (Figure 1). Measurements of post-landing balance establishment are valid and reliable for assessing balance during the transition from dynamic to static states (Colby, Hintermeister, Torry, Steadman, 1999; Goldie, Bach, Evans, 1989; Kinzey and Armstrong, 1998 as cited in Wikstrom, 2003) and have been utilized in various studies (Viber and Wojtys, 2001; Onate, Cortes, Welch, and Van Lunen, 2010; Mohammadi, Salavati, Akhbari, Mazaheri, Khorrami, and Negahban, 2012).

All subjects stood with their feet together, hands close to their bodies, and facing forward. The second measurement was a blind still-standing position after jumping from a 25 cm high box, where participants wore glasses with dimmed lenses that prevented them from seeing through them (Figure 2). The third measurement was a deaf still-standing position after jumping from a 25 cm high box, where participants wore protective earmuffs (3M™ PELTOR™ Optime™ II) with an attenuation rating of 31 decibels (Figure 2). All measurements were conducted randomly, and participants had 15 seconds of rest between each measurement.

Figure 1. Subject before jump from a 25 cm high box.

Figure 2. Dimmed glasses and ear muff.

The PedarX system collected results separately for the left and right foot regarding ground reaction force (GRF). The scanning rate was 50 Hz, with a time per frame of 0.02 seconds. GRF results for the left and right foot were recorded every 0.02 seconds. The absolute difference in force load between the legs was calculated every 0.02 seconds, as well as the average difference throughout the entire measurement. The calculation was performed by subtracting the GRF on the right leg from the GRF on the left leg. Perfect balance was indicated when the forces on both legs were equal. The variables included the difference between left GRF and right GRF while still-standing position after jumping (Diff. Jump Standing), the difference between left GRF and right GRF while in a blind still-standing position after jumping (Diff. Jump Blind Standing), and the difference between left GRF and right GRF while in a deaf still-standing position after jumping (Diff. Jump Deaf Standing).

For the analysis, we used the absolute difference between specific morphological characteristics on the left and right sides. The anthropometric variables included the difference between left and right calf girth (Diff. Calf Girth), the difference between left and right upper arm girth (Diff. Upper Arm Girth), the difference between left and right forearm girth (Diff. Forearm Girth), the difference between left and right thigh girth (Diff. Thigh Girth), the difference between left and right long shoulder height (Diff. Long Shoulder Height), the difference between left and right arm lean mass (Diff. Arm Lean Mass), and the difference between left and right leg lean mass (Diff. Leg Lean Mass).

All data were analyzed using Microsoft Excel 2010 and the statistical package SPSS 22.0. First, a Kolmogorov-Smirnov test was conducted to assess the normal distribution of variables. Pairwise t-tests were then performed to compare the results between the left and right sides. Additionally, reliability tests, such as factor analysis and Cronbach's alpha, were conducted.

The evaluation of balance was conducted in two steps. In the first step, factor analysis (principal components) was performed for each type of standing position. From three items of each type of landing, we calculated Factor Diff. Jump Stand, Factor Diff. Jump Blind, and Factor Diff. Jump Deaf, and factor scores were calculated for the first factor using a regression model. In the second step, the factor scores Factor Diff. Jump Stand, Factor Diff. Jump Deaf, and Factor Diff. Jump Blind extracted jointly the first factor, which we named Factor Jump Standing, and calculated factor scores by a regression model. Factor scores from Factor Jump Standing served as the dependent variable in the regression analysis.

Regression analysis (Stepwise method) was performed to assess the relationship between the dependent variable, the difference in GRF between the legs (left/right leg), and the independent variables representing the differences in morphological characteristics (left/right side of the body). All statistical analyses were tested at $p < 0.05$.

RESULTS

All variables followed a normal distribution, except for the difference between left and right calf girth and the difference between left and right forearm girth, as indicated by the Kolmogorov-Smirnov test. Despite this deviation from normality, multivariable analysis was still conducted, as the dependent variable was normally distributed. The overall reliability (Cronbach's alpha) for the difference in GRF between the legs during jump still-standing, jump blind still-standing, and jump deaf still-standing was 0.888. This reliability level aligns with the findings of Lindmark et al. (2012) and Newton (2001) (cited in Sibley et al., 2015).

In Figure 3. there is an example of the subject's left and right GRF and the difference between them is depicted. In this example, the difference in GRF between left and right leg is 41.82 N ± 64.24. This value varies among tested subjects and is individually determined. The figure illustrates distinct differences in leg use among participants.

The results of the regression analysis, examining the relationship between the dependent variable (Factor Jump Standing) and the independent anthropometric variables, were found to be significant at $p < 0.05$

Table 1
Descriptive statistic.

	Mean	Std. Deviation	K - S	Maximum	Minimum
Diff. Calf Girth [cm]	0.05	0.51	not	0.90	-1.60
Diff. Upper arm Girth [cm]	-0.33	1.12	n	2.10	-2.70
Diff. Forearm Girth [cm]	-0.48	0.81	not	2.50	-1.60
Diff. Thigh Girth [cm]	0.34	2.34	n	5.60	-4.90
Diff. Long Shoulder Height [cm]	-1.17	1.74	n	3.50	-3.70
Diff. Arms Lean Mass [kg]	-0.04	0.12	n	0.17	-0.39
Diff. Legs Lean Mass [kg]	-0.04	0.13	n	0.39	-0.22
Diff. Jump Standing1 [N]	12.49	71.77	n	126.58	-157.83
Diff. Jump Standing2 [N]	15.91	64.29	n	147.28	-109.02
Diff. Jump Standing3 [N]	19.36	60.91	n	151.08	-96.59
Diff. Jump Deaf Standing1 [N]	3.08	74.70	n	108.54	-241.92
Diff. Jump Deaf Standing2 [N]	12.11	68.84	n	154.74	-138.70
Diff. Jump Deaf Standing3 [N]	7.24	55.85	n	129.91	-127.75
Diff. Jump Blind Standing1 [N]	33.11	85.15	n	164.68	-139.82
Diff. Jump Blind Standing2 [N]	13.24	75.91	n	173.76	-184.64
Diff. Jump Blind Standing3 [N]	5.71	60.97	n	147.57	-145.82
Factor Jump Standing	0.00	1.00	n	1.86	-2.89

Legend: n – normal distribution, not – not normal distribution

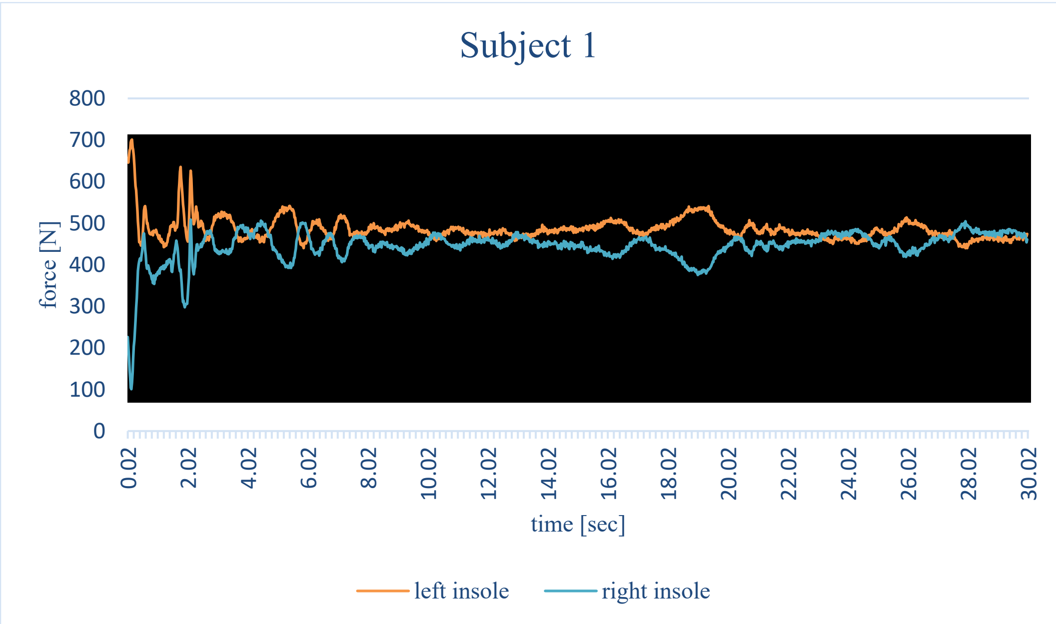

Figure 3. Example of ground reaction force for right and left leg while still standing after jump from 25 cm high box.

Table 2
Results of Factor analyses.

	Communalities	Total Variance Explained Initial Eigenvalues		Component matrix	Cronbach's alpha
	Extraction	Total	Cumulative %		
1. Diff. Jump Standing1	0.56	1.85	61.45	0.75	0.681
2. Diff. Jump Standing2	0.89	0.66	83.42	0.83	
3. Diff. Jump Standing3	0.60	0.50	100.00	0.78	
1. Diff. Jump Deaf Stand. 1	0.67	1.91	63.65	0.82	0.711
2. Diff. Jump Deaf Stand. 2	0.80	0.76	89.01	0.89	
3. Diff. Jump Deaf Stand. 3	0.44	0.33	100.00	0.67	
1. Diff. Jump Blind Stand. 1	0.72	2.20	73.23	0.85	0.810
2. Diff. Jump Blind Stand. 2	0.82	0.52	90.63	0.91	
3. Diff. Jump Blind Stand. 3	0.66	0.28	100.00	0.81	
1. Factor Diff. Jump Stand.	0.76	2.40	79.82	0.87	0.873
2. Factor Diff. Jump Deaf Stand.	0.86	0.38	92.51	0.93	
3. Factor Diff. Jump Blind Stand.	0.78	0.23	100.00	0.88	

Table 3
Pearson's correlation coefficients between variables.

	Diff. Calf Girth	Diff. Upper arm Girth	Diff. Forearm Girth	Diff. Thigh Girth	Diff. Long Shoulder Height	Diff. Arms Lean Mass	Diff. Legs Lean Mass
Diff. Calf Girth	1						
Diff. Upper arm Girth	0.02	1					
Diff. Forearm Girth	0.25	0.32	1				
Diff. Thigh Girth	-0.24	-0.01	-0.29	1			
Diff. Long Shoulder Height	0.07	-0.34	0.07	0.23	1		
Diff. Arms Lean Mass	0.05	0.21	0.38*	-0.18	0.09	1	
Diff. Legs Lean Mass	0.36*	0.05	-0.05	0.04	-0.03	0.00	1
Factor Jump Standing	-0.23	0.16	-0.27	-0.06	-0.41*	-0.37*	-0.18

*Notes: Pearson correlation coefficient, $p < 0.05$, * significant*

Table 4
Results of Stepwise regression analysis; dependent variable Factor Jump Standing.

Step	R (Uncorr.)	R Square	F Change	df1	df2	Sig. F Change
1	0.41	0.16	5.9	1	30	0.022*
2	0.52	0.27	5.4	2	29	0.010*

	Unstd. Coefficients		Std. Coefficients	t	Sig
	B	Std. Error	Beta		
Constant	-0.36	0.19	-0.41	-1,88	0.069
diff Long Shoulder High	-0.22	0.09	-0.38	-2.36	0.025*
diff Arms Lean Mass	-2.88	1.38	-0.33	-2.09	0.046*

*Notes: $p < 0.05$, * significant*

DISCUSSION

The primary finding of this research is that morphological bilateral asymmetries have an impact on differences in leg GRF during stand balance after a jump from a 25 cm high box. Significant differences were identified in forearm girth and long shoulder height, indicating an asymmetric body posture among the participants. Specifically, the left arm height and forearm girth were lower compared to the right side, which may be attributed to differences in fat mass rather than lean mass.

Although these asymmetries in body posture may seem small and potentially insignificant in normal life, they play a crucial role in determining leg load. For instance, the lower left shoulder height indicates a higher load on the right leg (Table 3). These findings expand upon the observations of Šarabon et al. (2005), who previously identified significant bilateral asymmetries only among individuals involved in unilateral sports. This study demonstrates that even recreational-level sports activities can lead to bilateral asymmetries in body posture.

Reliability analysis (Table 2) via factor analysis showed that cumulative explained variance with the first factor is from 61.5% for normal standing, through 63.7% for deaf standing, to 73.2% for blind standing can be defined as reliable tests. Cronbach's alpha had even higher values (respectively 0.681 for normal stand after jump, 0.711 for deaf stand after jump and 0.810 for blind stand after jump). Furthermore, factor analysis of factor scores for each type of stand balance after jump measurements extracted the first factor with 79.8% of variance and Cronbach's alpha of 0.873. This analysis revealed that the somatosensory system, as described by Shumway-Cook and Horak (1986), played a significant role in postural balance.

The regression analysis demonstrated that 27% of the differences in GRF during stand after a jump could be explained by morphological characteristics (Table 4). The significant predictors were the difference in long shoulder height (16%) and the difference in arm lean mass (11%), both exhibiting a negative relationship with leg GRF differences.

Comparing these findings to previous research, Alonso et al. (2015) found that anthropometric variables explained more variance in medial-lateral postural variability (12% eyes open, 18% eyes closed) compared to the anteroposterior direction (6% eyes open, 0% eyes closed). Although the current study did not specifically discuss the reasons for this difference, it observed a higher overall percentage of explained variance.

Greve et al. (2007) researched the correlation between body mass index and general postural balance, including the anteroposterior stability index and lateral stability index on dominant and non-dominant legs. They found no statistically significant differences in balance indexes between the dominant and non-dominant legs, which is consistent with the current study where only one pairwise t-test out of nine showed a significant difference in leg load between the left and right legs (specifically, during the first attempt of a blind jump).

CONCLUSIONS

The study examined the impact of morphological bilateral asymmetries on leg GRF differences in stand balance after a drop jump from a 25 cm height. It can be concluded that morphological bilateral asymmetries exert a notable effect on leg GRF differences during stand balance after a jump. The study highlights the significance of maintaining symmetrical body loads to uphold balanced body posture and minimize the risk of acute or chronic injuries associated with imbalances.

To summarize the main conclusions:

- Bilateral differences in morphological characteristics were observed among active sports students, with significant variations noted in forearm girth and long shoulder height.
- Morphological bilateral differences significantly contribute to variations in leg GRF during stand balance after a jump, explaining 27% of the variance.
- The best predictors of leg GRF differences were the disparities in long shoulder height (explaining 16% of the variance) and arm lean mass (explaining 11% of the variance).
- Both predictors exhibited a negative relationship with leg GRF differences, suggesting higher values on the left leg GRF side, higher values of right long shoulder height, and higher values of right arm lean mass.

Maintaining symmetrical body loads is critical for preserving symmetrical body posture and reducing the risk of injuries associated with imbalance.

REFERENCES

Alonso, A. C., Mochizuki, L., Silva Luna, N. M., Ayama, S., Canonica, A. C., & Greve, J. M. (2015). Relation between the sensory and anthropometric variables in the quiet standing postural control: is the inverted pendulum important for the static balance control?. *BioMed research international*, *2015*.

Antonov, L. (1975). Preskoci za žene. Moskva: Fiskultura i sport.

Biospace. InBody (720), *User's Manual,* 2008.

Bolkovič, T., Čuk, I., Kokole, J., Kovač, M. in Novak, D. (2002). Izrazoslovje v gimnastiki. Ljubljana: Fakulteta za šport, Inštitut za šport, Inštitut za kineziologijo

Boyd, L. A., Bontrager, E. L., Mulroy, S. J., & Perry, J. (1997). The reliability and validity of the novel Pedar system of in-shoe pressure measurement during free ambulation. *Gait & Posture*, *2*(5), 165.

Čuk, I., & Marinšek, M. (2013). Landing quality in artistic gymnastics is related to landing symmetry. *Biology of sport*, *30*(1), 29-33.

Čuk, I., Pajek, M., Jakše, B., Pajek, J., & Peček, M. (2012). Morphologic bilateral differences of top level gymnasts. *International journal of morphology*, *30*(1), 110–114.

Greve, J., Alonso, A., Bordini, A. C. P., & Camanho, G. L. (2007). Correlation between body mass index and postural balance. *Clinics*, *62*, 717-720.

Kolar, E., Pavletič Samardžija, M. & Veličković, S. (2015). Importance of biomechanical modeling for tehnical preparation of gymnast in Samardžija Pavletič, M. & Bučar Pajek. (ed.). 2nd International scientific congress. Portorož: Gimnastična zveza Slovenije.

Niu, W., Wang, Y., He, Y., Fan, Y., & Zhao, Q. (2011). Kinematics, kinetics, and electromyogram of ankle during drop landing: A comparison between dominant and non-dominant limb. *Hum Mov Sci,* 30(3),614–623. doi:10.1016/j.humov.2010.10.010

Marinšek, M. (2007). *Napake pri doskokih pri saltih na parterju: magistrska naloga*

Mohammadi, F., Salavati, M., Akhbari, B., Mazaheri, M., Khorrami, M. in Negahban, H. (2012). Static and dynamic postural control in competitive athletes after anterior cruciate ligament reconstruction and controls. *Knee Surgery, Sports Traumatology, ArthrosSPy, 20*(8), 1603–1610.

Onate, J., Cortes, N., Welch, C. in Van Lunen, B. (2010). Expert versus novice interrater reliability and criterion validity of the landing scoring system. *Journal of sport rehabilitation*, *19*(1), 41–56.

Pajek, M., Hedbávný, P., Kalichová, M., and Čuk, I. (2016). The asymmetry of lower limb load in balance beam routines. *Science of Gymnastics Journal*, 8(1), 5-13.

Panzer, V. P. (1987). Lower extremity loads in landings of elite gymnasts [doctoral dissertation]. *Eugene(OR): University of Oregon*.

Pegan, A. (2015). *Teoretični biomehanski model prvine „Pegan" na drogu: diplomsko delo*

Rajtmajer, D. (1990). Metodika telesne vzgoje – 1. knjiga. Maribor: Pedagoška fakulteta. Schmidt, R. A. (1991). Motor learning & performance – from principles to practise. Champaign, IL: Human Kinetics Books. 59.

Schmidt, R. A. (1999). Motor control & learning – behavioral emphasis. Champaign, IL: Human Kinetics Books.

Shumway-Cook, A., & Horak, F. B. (1986). Assessing the influence of sensory interaction on balance: suggestion from the field. *Physical therapy*, *66*(10), 1548-1550.

Sibley, K. M., Beauchamp, M. K., Van Ooteghem, K., Straus, S. E., & Jaglal, S. B. (2015). Using the systems framework for

Alonso, A. C., Mochizuki, L., Silva Luna, N. M., Ayama, S., Canonica, A. C., & Greve, J. M. (2015). Relation between the sensory and anthropometric variables in the

postural control to analyze the components of balance evaluated in standardized balance measures: a scoping review. *Archives of physical medicine and rehabilitation*, *96*(1), 122-132.

So, W. Y., Swearingin, B., Crooms, B., Lee, R., Choi, Y., Dail, T. K., ... & Ha, C. H. (2012). Body composition measurements determined by air displacement plethysmography and eight-polar bioelectrical impedance analysis are equivalent in African American college students. *HealthMED*, *6*, 1896-1899.

Šarabon, N., Košak, R., Fajon, M. in Drakslar, J. (2005). Nepravilnosti telesne drže – mehanizmi nastanka in predlogi za korektivno vadbo. *Šport, Revija za teoretična in praktična vprašanja športa, 53*(1), 35–41.

Vibert, B. in Wojtys, E. M. (2001). Gender differences in knee angle when landing from a drop-jump. *The American journal of knee surgery*, *14*(4), 215–220.

Wikstrom, E. A. (2003). *Functional VS Isokinetic Fatigue Protocol: Effects on time to stabilization, peak vertical ground reaction forces, and joint kinematics in jump landing.* Doctoral dissertation, University of Florida.

Wikstrom, E. A., Naik, S., Lodha, N. in Cauraugh, J. H. (2010). Bilateral balance impairments after lateral ankle trauma: a systematic review and meta-analysis. *Gait in posture*, *31*(4), 407–414.

Zancanaro, C., Milanese, C., Lovato, C., Sandri, M., & Giachetti, A. (2015). Reliability of three-dimensional photonic scanner anthropometry performed by skilled and naïve operators. *IJEG*, *5*(1), 1-11.

quiet standing postural control: is the inverted pendulum important for the static balance control?. *BioMed research international*, *2015*.

Antonov, L. (1975). Preskoci za žene. Moskva: Fiskultura i sport.

Biospace. InBody (720), *User's Manual,* 2008.

Bolkovič, T., Čuk, I., Kokole, J., Kovač, M. in Novak, D. (2002). Izrazoslovje v gimnastiki. Ljubljana: Fakulteta za šport, Inštitut za šport, Inštitut za kineziologijo

Boyd, L. A., Bontrager, E. L., Mulroy, S. J., & Perry, J. (1997). The reliability and validity of the novel Pedar system of in-shoe pressure measurement during free ambulation. *Gait & Posture*, *2*(5), 165.

Čuk, I., & Marinšek, M. (2013). Landing quality in artistic gymnastics is related to landing symmetry. *Biology of sport*, *30*(1), 29-33.

Čuk, I., Pajek, M., Jakše, B., Pajek, J., & Peček, M. (2012). Morphologic bilateral differences of top level gymnasts. *International journal of morphology*, *30*(1), 110–114.

Greve, J., Alonso, A., Bordini, A. C. P., & Camanho, G. L. (2007). Correlation between body mass index and postural balance. *Clinics*, *62*, 717-720.

Kolar, E., Pavletič Samardžija, M. & Veličković, S. (2015). Importance of biomechanical modeling for tehnical preparation of gymnast in Samardžija Pavletič, M. & Bučar Pajek. (ed.). 2nd International scientific congress. Portorož: Gimnastična zveza Slovenije.

Niu, W., Wang, Y., He, Y., Fan, Y., & Zhao, Q. (2011). Kinematics, kinetics, and electromyogram of ankle during drop landing: A comparison between dominant and non-dominant limb. *Hum Mov Sci,* 30(3),614–623. doi:10.1016/j.humov.2010.10.010

Marinšek, M. (2007). *Napake pri doskokih pri saltih na parterju: magistrska naloga*

Mohammadi, F., Salavati, M., Akhbari, B., Mazaheri, M., Khorrami, M. in Negahban, H. (2012). Static and dynamic postural control in competitive athletes after anterior cruciate ligament reconstruction and controls. *Knee Surgery, Sports Traumatology, ArthrosSPy, 20*(8), 1603–1610.

Onate, J., Cortes, N., Welch, C. in Van Lunen, B. (2010). Expert versus novice interrater reliability and criterion validity of the landing scoring system. *Journal of sport rehabilitation*, *19*(1), 41–56.

Pajek, M., Hedbávný, P., Kalichová, M., and Čuk, I. (2016). The asymmetry of lower limb load in balance beam routines. *Science of Gymnastics Journal*, 8(1), 5-13.

Panzer, V. P. (1987). Lower extremity loads in landings of elite gymnasts [doctoral dissertation]. *Eugene(OR): University of Oregon*.

Pegan, A. (2015). *Teoretični biomehanski model prvine „Pegan" na drogu: diplomsko delo*

Rajtmajer, D. (1990). Metodika telesne vzgoje – 1. knjiga. Maribor: Pedagoška fakulteta. Schmidt, R. A. (1991). Motor learning & performance – from principles to practise. Champaign, IL: Human Kinetics Books. 59.

Schmidt, R. A. (1999). Motor control & learning – behavioral emphasis. Champaign, IL: Human Kinetics Books.

Shumway-Cook, A., & Horak, F. B. (1986). Assessing the influence of sensory interaction on balance: suggestion from the field. *Physical therapy*, *66*(10), 1548-1550.

Sibley, K. M., Beauchamp, M. K., Van Ooteghem, K., Straus, S. E., & Jaglal, S. B. (2015). Using the systems framework for postural control to analyze the components of balance evaluated in standardized balance measures: a scoping review. *Archives of* *physical medicine and rehabilitation*, *96*(1), 122-132.

So, W. Y., Swearingin, B., Crooms, B., Lee, R., Choi, Y., Dail, T. K., ... & Ha, C. H. (2012). Body composition measurements determined by air displacement plethysmography and eight-polar bioelectrical impedance analysis are equivalent in African American college students. *HealthMED*, *6*, 1896-1899.

Šarabon, N., Košak, R., Fajon, M. in Drakslar, J. (2005). Nepravilnosti telesne drže – mehanizmi nastanka in predlogi za korektivno vadbo. *Šport, Revija za teoretična in praktična vprašanja športa, 53*(1), 35–41.

Vibert, B. in Wojtys, E. M. (2001). Gender differences in knee angle when landing from a drop-jump. *The American journal of knee surgery*, *14*(4), 215–220.

Wikstrom, E. A. (2003). *Functional VS Isokinetic Fatigue Protocol: Effects on time to stabilization, peak vertical ground reaction forces, and joint kinematics in jump landing.* Doctoral dissertation, University of Florida.

Wikstrom, E. A., Naik, S., Lodha, N. in Cauraugh, J. H. (2010). Bilateral balance impairments after lateral ankle trauma: a systematic review and meta-analysis. *Gait in posture*, *31*(4), 407–414.

Zancanaro, C., Milanese, C., Lovato, C., Sandri, M., & Giachetti, A. (2015). Reliability of three-dimensional photonic scanner anthropometry performed by skilled and naïve operators. *IJEG*, *5*(1), 1-11.

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