Pol. J. Sport Tourism **2020**, *27(4), 3-6*
DOI: 10.2478/pjst-2020-0019

Original research papers

EFFECTS OF SURFACE TYPE ON BALANCE CONTROL STRATEGIES IN HANDSTAND

PAWEŁ ARNISTA[1], MICHAŁ BIEGAJŁO[2], ANDRZEJ MASTALERZ[3], TOMASZ NIŹNIKOWSKI[4]

[1]Lomza State University of Applied Sciences, Faculty of Health Sciences, Department of Physical Education
Józef Piłsudski University of Physical Education in Warsaw, Faculty of Physical Education and Health, Department of Physical Education and Sport[2], Department of Sport for All[4], Biała Podlaska, Poland
[3]Józef Piłsudski University of Physical Education in Warsaw, Faculty of Physical Education, Department of Biomedical Sciences

Mailing address: Paweł Arnista, Lomza State University of Applied Sciences, Faculty of Health Sciences, 14 Akademicka Street, 18-400 Łomża, tel.: +48 86 2156607, e-mail: parnista@pwsip.edu.pl

Abstract
Introduction. A proper manner of maintaining body balance in handstand requires high levels of motor and coordination skills and, first and foremost, specialist training. Therefore, this study sought to determine the effects of surface type on body balance strategies in handstand. ***Material and Methods.*** The study included twelve Polish National Team artistic gymnasts with training experience of 16.5 ± 2.12 years. Pedagogical experiment was used as the research method. Body balance assessment of gymnasts was carried out using three tests on different types of the surface. In the first test, the study participants performed handstand on the hard surface. The second one involved executing handstand on canes, whereas the third test consisted in performing handstand on the soft surface. ***Results.*** An increase in ground reaction forces (Fx, Fy) was noted in the handstand tests performed on canes (SNS) and on the soft surface (SNA). ***Conclusions.*** The analysis revealed that the surface type exerts an influence on the effectiveness of balance control. The findings may constitute the source of knowledge for athletes and coaches about changing conditions of maintaining a stable position when performing handstand during gymnastic training.

Key words: gymnastics, balance, handstand

Introduction

Handstand is one of the basic elements in both men's and women's artistic gymnastics. In its static form, it is the initial and final position of many movement structures, while in its dynamic form, it is either the basis of motion or its component [1]. Handstand is one of the basic static balance positions in gymnastics. Proper balance is necessary, since it contributes to the effective performance of motor skills in sport [2]. The level of difficulty of body balance control in handstand increases with subsequent training stages [3].

The issue of balance control in an upright stance has been the subject of numerous investigations [4, 5, 6, 7, 8, 9]. The studies showed the main postural task is to keep the centre of mass (COM) above the base of support, which is usually referred to as quiet standing. However, in non-laboratory settings, quiet standing is hardly ever maintained [10]. It has been established that maintaining a stable standing position is determined by a combination of intrinsic information, COM displacement, body sway and ground reaction forces. Body balance is also influenced by extrinsic information, i.e. touch, light effects or mechanical disturbance of balance. The subject of balance control in handstand is still valid. Researchers mainly focus on strategies of maintaining a balanced position when performing handstand on the hard surface [1, 11, 12]. The study of correlations of body balance in handstand with the level of sports preparation has shown that the level of this skill (specific to artistic gymnastics) plays a significant role in improving performance both in young gymnasts with a few years' experience and in accomplished international-level athletes. Keeping the upright body position in handstand seems to be similar to the two-legged upright stance; however, the former skill is extremely difficult to master. Young gymnasts acquire the ability to freely maintain static body balance in handstand usually after 3-4 years of sports training [13]. Better mastery of complex gymnastic routines depends on properly selected exercises, similar in structure, which help to develop skills needed for a specific motor habit [14]. Keeping handstand balance on the unstable surface requires many years of training as well as performing exercises that stimulate vestibular and visual systems. The level of sports mastery differentiates body stability in handstand [15, 16]. Balance control in handstand occurs in a manner similar to upright stance control, i.e. by swaying COM towards fingers or wrists in the sagittal plane, or to the left or right in the frontal plane. Balance control in this unnatural position mainly involves increasing ground reaction forces as a result of COM displacement towards fingers or an increase in pressure under the wrists during COM displacement towards them [17].

Balance control during handstand, which involves movement in the anteroposterior plane, differs from single-leg toe stance, where the frontal displacement of COM is more important for body stability. Postural control is no longer considered simply a summation of static reflexes but, rather, a complex skill based on the interaction of dynamic sensorimotor processes. During perturbed and unperturbed balance in standing, the most common control strategy was the ankle strategy, which was employed for more than 90% of the time in balance. As for perturbed and unperturbed balance in handstand, the most prevalent strategy was the wrist strategy, which accounted for more than 75% of the time in balance [18].

Copyright © 2020 by the Józef Piłsudski University of Physical Education in Warsaw, Faculty of Physical Education and Health in Biała Podlaska

it seems justifiable to gain knowledge of the effects that surfaces have on balance control strategies in handstand.

Therefore, this study sought to determine the effects of surface type on body balance strategies in handstand in elite gymnasts.

Material and Methods

The study included twelve Polish National Team artistic gymnasts (training experience 16.5 ± 2.12 years, body height 169.0 ± 2.83 cm, body mass 66.53 ± 1.18 kg, age 23.0 ± 1.4 years, 25 hours of training per week). Pedagogical experiment was used as the research method. Body balance assessment of gymnasts was carried out using three tests on different types of the surface:

- hard surface (SNRR) – the plate of Kistler's platform,
- two-piece surface (SNS) – pair parallettes gymnastics calisthenics handstand bar wooden fitness exercise tools training gear push-ups double rod stand,
- soft surface (SNA) – balance pad airex 50 x 41 x 6cm.

Prior to performing each task, the participants could make one warm-up attempt. The participants were randomly assigned to begin test. There was a 2-minute interval between the tests. The measurements were made using the Kistler force plate (Type 2812A1-3). Ground reaction forces were collected with 100 Hz and band pass filtered. Data from the force plate were processed and calculated by BioWare® Software (Kistler). Two components of ground reaction force (GRF) were included to the analysis:

- Fx – peak of horizontal component of GRF in anteroposterior axis,
- Fy – peak of horizontal component of GRF in mediolateral axis.

Normality and homogeneity of variances were confirmed with the Shapiro-Wilk and Levenes tests, respectively. One-way analysis of variance (ANOVA) was applied to assess differences between the types of the surface. Post-hoc Fisher's test was employed to analyse significant differences. Cohen's d effect size (d) was calculated [22]. An alpha of 0.05 was used to determine statistical significance. The statistical analysis of the results was carried out using STATISTICA v. 13 (StatSoft Inc., Tulsa, OK, USA, 2017).

Results

The values of the effects of the surface type on mean values of GRF Fx component during handstand are shown in Figure 1.

ANOVA revealed that mean values of GRF Fx component differed significantly $F(4,22) = 49.471$, $p < 0.001$ (Tab. 1).

Based on post-hoc test statistically significant differences ($p < 0.001$) were noted between mean values of GRF Fx component in tests SNRR-SNS ($d = 25.67$), SNRR-SNA ($d = 4.13$), SNS-SNA ($d = 19.89$).

The values of GRF Fy component in handstand performed on different surface types are illustrated in Figure 2.

It was revealed that the differences in mean values of GRF Fy component were statistically insignificant $F(4,22) = 2.7212$, $p = 0.05576$.

Discussion

Success in gymnastics depends on the athlete's level of motor abilities, particularly special power in its three forms, i.e. explosive, static and dynamic power. Gymnastics requires a great diversity of movements such as transitions from dynamic to static elements and vice versa, frequent changes of the body position in space, etc. [23]. Successful performance of each element requires accurate muscular activity of specific intensity. Gymnastic elements are classified as combined non-cyclic movements and as such they develop the ability of movement in space and body control in the unsupported phase.

Gymnastic training stimulates balance development and ensures excellent stability even in extreme conditions [24]. It is necessary to monitor the development of balance in young gymnasts [25]. To achieve top results in artistic gymnastics, one has to score high in balance beam tests.

A constant increase in the difficulty of routines performed using gymnastic equipment contributes to an increase in the importance of handstand execution and stable balance on different types of the surface. Research into postural control and changes occurring in different settings has been carried out for a number of years [4, 6, 7, 26, 27, 28, 29, 30, 31].

Horak and MacPherson [32] noted that the mechanism of maintaining body balance is unstable and COM displacement ought to be monitored incessantly. Body balance involves the coordination of movement strategies to stabilise COM during both self-initiated and externally triggered disturbances of stability. The specific response strategy selected depends not only

Table 1. Level of significance of differences for Fisher's test between mean values of GRF Fx component in handstand performed on different types of the surface

	SNRR	SNS	SNA
SNRR		0.001	0.001
SNS	0.001		0.001
SNA	0.001	0.001	

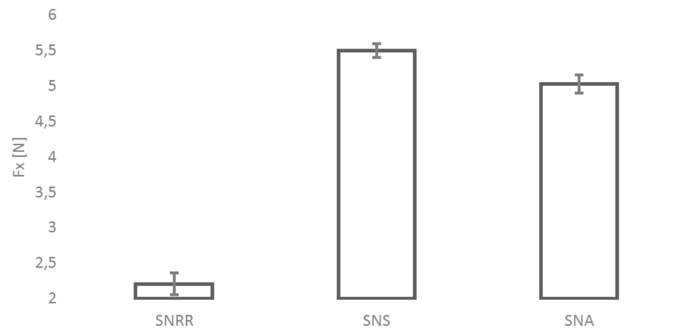

Figure 1. Mean (±SD) values of GRF Fx component on SNRR, SNS and SNA surface

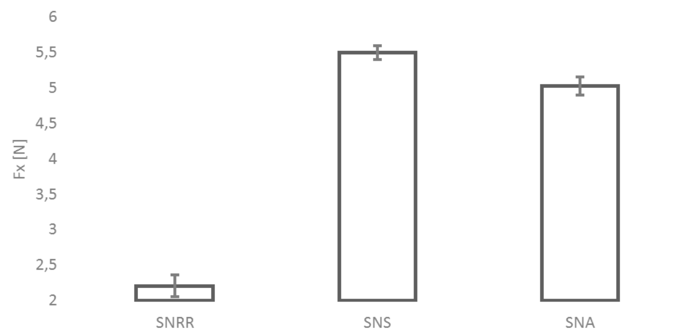

Figure 2. Mean (±SD) values of GRF Fy component on SNRR, SNS and SNA surface

on the characteristics of the external postural displacement but also on the individual's expectations, goals and prior experience.

Horstmann and Dietz [33] found that COM needs to remain above the support surface in order to prevent falls. It is achieved through initiating a number of muscular activities which generate torque in those joints which control COM displacement. Maintaining COM in a steady manner represents the crucial variable for the stabilisation of posture in an upright stance. The visual, vestibular and muscle proprioceptive systems have all been shown to contribute to sway stabilisation. Nevertheless, earlier work has suggested that an additional receptor system is needed to signal the position of COM relative to the support surface, i.e., the feet.

The ease with which people maintain balance in an upright stance means we take balance and postural stability for granted. However, it changes when we assume the position of handstand. Performing handstand seems to be more complicated since it requires the involvement of four (not three) joints, i.e. wrists, shoulders, hips and knees [34]. Blenkinsop et al. [19] describe handstand performance as a single-segment inverted pendulum control strategy, where the multi-segment system is controlled by torque in the most inferior joint with compensatory torques in all superior joints.

The aim of the study was to determine the effects of surface type on COM displacement during handstand. Research carried out so far mainly concerned maintaining body balance in handstand on the stable surface and without changing conditions.

The findings revealed that the surface type exerts a significant influence on COM displacement both in the sagittal plane (Fx) and in the frontal plane (Fy). In her study, Sobera [35] proved that in handstand after a single-leg take-off, there occurs lateral COM displacement. When performing handstand, a gymnast tries to maintain body balance mainly in the anteroposterior plane, in accordance with mobility of the majority of joints. It is easier in the frontal plane, as mobility of body segments is limited. It was established that during handstand on the hard surface (SNRR), micro-movements in the wrist and elbow joints were noted. In turn, when this skill was performed on the soft surface (SNA), movements were observed in shoulder and hip joints. Handstand performance on canes (SNS) resulted in an increase in body sways in the sagittal plane. Moreover, micro-movements in shoulder joints were registered. Support area and body position were the determinants of motor test performance quality.

Different gymnastic apparatuses led to specific muscle activation. This activation predominantly depended on hand support conditions, which alternated the primary wrist strategy of handstand balance control, and, as a consequence, the activation of other muscles that control balance [20].

Taking into account determinants of body balance in handstand, researchers agree that the ability to control this activity in terms of wrist and shoulder joint mobility in the sagittal plane translates into the speed of COM displacement, i.e. balance control [16, 36]. In a number of trials, wrist torque played a dominant role in accounting for COM variance. Ostensibly, superior handstand balances are characterised by important contributions from wrist and shoulder torques with little influence from hip torques. In contrast, hip torques were found to be increasingly influential in less successful balances. Because of different measures and training procedures, it is necessary to monitor progress. This is especially true for intensive monitoring in the younger categories. Since handstand is a key skill in artistic gymnastics, we can improve the training safety and the gymnast's performance with the help of regular control [37]. It will reduce the number of errors made in the initial phase of handstand learning considerably and will allow coaches and gymnasts to identify and eliminate errors that occur while performing key gymnastic elements.

Therefore, further research is needed to analyse strategies of controlling balance in handstand with the help of micro-movements in the wrist joints and to examine the issue of muscle activation in respective limbs. Such research will help us understand the process of motor learning while acquiring the handstand skill [18].

Conclusions

1. The surface type exerts an influence on the effectiveness of balance control in elite gymnasts. In the sagittal plane, greater ground reaction forces were noted in handstand tests performed on canes (SNS) and on the soft surface (SNA) compared to the handstand test on the hard surface (SNRR).
2. Slight body sways both in the sagittal and frontal plane and on three types of the surface can be explained by the fact that the study included elite gymnasts who manifested high levels of stability and balance in handstand.

Practical implications

The findings of the current study contribute to the literature on balance control strategies in handstand with regard to the surface type. They provide athletes and coaches with knowledge about changing strategies of balance control while performing gymnastic exercises on apparatuses, when the grip, hand position and support surface change.

References

1. Hedbavny P., Sklenarikova J., Hupka D., Kalichova M. (2013). Balancing in handstand on the floor. *Science of Gymnastics Journal* 5(3), 69-79.
2. Metikoš B., Kovač S., Čović N., Mekić A. (2014). Male athlete's body composition and postural balance correlation. *Homo Sporticus* 16(1), 5-9.
3. Gautier G., Thouvarecq R., Vuillerme N. (2008). Postural control and perceptive configuration: Influence of expertise in gymnastics. *Gait and Posture* 28, 46-51. DOI: 10.1016/j.gaitpost.2007.09.007
4. Croft J.L., Zernicke R.F., von Tscharner V. (2008). Control strategies during unipedal stance on solid and compliant surfaces. *Motor Control* 12(4), 283-295. DOI: 10.1123/mcj.12.4.283
5. Grimshaw P., Lees A., Fowler N., Burden A. (2010). *Sports Biomechanics*. Warsaw: PWN. [in Polish]
6. Johannsen L., Wing A.M., Hatzitaki V. (2007). Effects of maintaining touch contact on predictive and reactive balance. *Journal of Neurophysiology* 4, 2686-2695. DOI: 10.1152/jn.00038.2007
7. Kiebele A., Granacher U., Muehlbauer T., Behm D.G. (2015). Stable, unstable and metastable states of equilibrium: Definitions and applications to human movement. *Journal of Sports Science and Medicine* 14, 885-887.
8. Mańko G., Kruczkowski D., Niźnikowski T., Perliński J., Chantsoulis M. et al. (2014). The effect of programmed physical activity measured with levels of body balance maintenance. *Medical Science Monitor* 20, 1841-9.
9. Stodolka J., Golema M., Migasiewicz J. (2016). Balance maintenance in the upright body position: Analysis of au-

tocorrelation. *Journal of Human Kinetics* 50(1), 45-53. DOI: 10.1515/hukin-2015-0140
10. Gautier G., Marin L., Leroy D., Thouvarecq R. (2009). Dynamics of expertise level: Coordination in handstand. *Human Movement Science*, 129-140. DOI: 10.1016/j.humov.2008.05.003
11. Hedbavny P., Bago G., Kalichova M. (2013). Influence of strength abilities on quality of handstand. International *Journal of Medical, Health, Biomedical, Bioengineering and Pharmaceutical Engineering* 10, 602-608.
12. Uzunov V. (2008). The handstand: A four stage training model. *Gym Coach* 2, 52-59. DOI: 10.13140/RG.2.1.2985.1363
13. Kochanowicz A., Kochanowicz K., Niespodziński B., Mieszkowski J., Biskup L. (2015) The level of body balance in a handstand and the effectiveness of sports training in gymnastics. *Baltic Journal of Health and Physical Activity* 7(4), 103-116.
14. Sherin B. (2013). Basic technologies in gymnastic preparation and training. *Becmnuk Tomckozo Zocydapcnwehhozoy Hueepcumema* 372, 167-169.
15. Omorczyk J., Bujas P., Puszczałowska-Lizis E., Biskup L. (2018). Balance in handstand and postural stability in standing position in athletes practicing gymnastics. *Acta of Bioengineering & Biomechanics* 20(2), 139-147. DOI: 10.5277/ABB-01110-2018-02
16. Rohleder J., Vogt T. (2019). Efficacy of wrist strategy coaching on handstand performances in novices: Inverting explicit and implicit learning of skill-related motor tasks. *Science of Gymnastics Journal* 11(2), 209-222.
17. Sobera M., Siedlecka B., Piestrak P., Sojka-Krawiec K., Graczykowska B. (2007). Maintaining body balance in extreme positions. *Biology of Sport* 24(1), 81-88.
18. Rohleder J., Vogt T. (2018). Performance control in handstands: challenging entrenched coaching strategies for young gymnasts. *International Journal of Performance Analysis in Sport* 18(1), 17-31. DOI: 10.1080/24748668.2018.1440459
19. Blenkinsop G.M., Pain M.T.G., Hiley M.J. (2017). Balance control strategies during perturbed and unperturbed balance in standing and handstand. *Royal Society Open Science* 4(7). DOI: 10.1098/rsos.161018
20. Kochanowicz A., Niespodzinski B., Marina M., Mieszkowski J., Kochanowicz K., Zasada M. (2017). Changes in the muscle activity of gymnasts during a handstand on various apparatus. *Journal of Strength & Conditioning Research* 33(6), 1609-1618. DOI: 10.1519/JSC.0000000000002124
21. Puszczałowska-Lizis E., Omorczyk J. (2019). The level of body balance in standing position and handstand in seniors athletes practicing artistic gymnastics. *Acta of Bioengineering & Biomechanics* 21(2), 37-44. DOI: 10.5277/ABB-01352-2019-02
22. Cohen J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.
23. Bučar Pajek M., Čuk I., Kovač M., Jakše B. (2010). Implementation of the gymnastics curriculum in the third cycle of basic school in Slovenia. *Science of Gymnastic Journal* 2(3), 15-27.
24. Atilgan A.O.E., Akin M., Alpkaya U., Pinar S. (2012). Investigating of relationship between balance parameters and balance lost of elite gymnastics on balance beam. *International Journal of Human Sciences* 9(2), 1260-1271.
25. Aleksić-Veljković A., Madić D., Veličković S., Herodek K., Popović B. (2014). Balance in young gymnasts: age group differences. *Facta Universitatis: Series Physical Education & Sport* 12(3), 289-196.
26. Dault M.C., Haart M., Geurts A.C.H., Arts I.M.P., Nienhuis B. (2003). Effects of visual center of pressure feedback on postural control in young and elderly healthy adults and in stroke patients. *Human Movement Science* 22(3), 221- 236. DOI: 10.1016/s0167-9457(03)00034-4
27. Horak F.B. (2006). Postural orientation and equilibrium: what do we need to know about neural control of balance to prevent falls? *Mechanistic and Physiological Aspects* 35(2), 7-11. DOI: 10.1093/ageing/afl077
28. Kuczyński M., Wieloch M. (2008). Effects of accelerated breathing on postural stability. *Human Movement* 9(2), 107-110. DOI: 10.2478/v10038-008-0012-9
29. Litvienko Y.V., Sadowski J., Niźnikowski T., Bołoban V.N. (2015). Static- dynamic stability of the body gymnasts qualifications. *Pedagogics Psychology Medical-biological Problems of Physical Training and Sports* 19(1), 46-51. DOI: 10.15561/18189172.2015.0109
30. Morasso P.G., Spada G., Capra R. (1999). Computing the COM from the COP in postural sway movements. *Human Movement Science* 18(6), 759-767. DOI: 10.1016/S0167-9457(99)00039-1
31. Vuillerme N., Teasdale N., Nougier V. (2001). The effect of expertise in gymnastics on proprioceptive sensory integration in human subjects. *Neuroscience Letters* 311(2), 73-76. DOI: 10.1016/s0304-3940(01)02147-4
32. Horak F.B., Macpherson J.M. (1996). Postural orientation and equilibrium. In L.B. Rowell, J.T. Shepard (eds), *Handbook of Physiology*. New York: Oxford University Press.
33. Horstmann G.A., Dietz V. (1990). A basic posture control mechanism: the stabilization of the centre of gravity. *Electroencephalography and Clinical Neurophysiology* 76(2), 165-176. DOI: 10.1016/0013-4694(90)90214-5
34. Asseman F., Caron O., Cremieux J. (2003). Is there a transfer of postural ability from specific to unspecific postures in elite gymnasts? *Neuroscience Letters* 358(2), 83-86. DOI: 10.1016/j.neulet.2003.12.102
35. Sobera M. (2001). Comparison of the process of maintaining balance when performing a standing on the arms with a swing and the so-called "Spikes". *Sport Gimnastyczny i Taniec* 156-160.
36. Kerwin D.G., Trewartha G. (2001). Strategies for maintaining a handstand in the anterior-posterior direction. *Medicine & Science in Sports & Exercise* 33(7), 1182-88. DOI: 10.1097/00005768-200107000-00016
37. Balicic B., Samardžija P.M. (2015). Handstand on force plate in artistic gymnastics. In P.M. Samardžija, M. Bucar Pajek (eds), *2nd International Scientific Congress Slovenian Gymnastics Federation* (pp. 127-136). University of Primorska: Portoroz.

Submitted: November 23, 2020
Accepted: December 17, 2020