Adaptive Sports

Postural control in football players with vision impairment: Effect of sports adaptation or visual input restriction?

Monica M. Nascimento[1], Pablo R.O. Silva[1], Lilian R. Felício[2], Míriam R.M. Mainenti[3], Humberto L. Miranda[4], Gabriel A. Paz[4], Thiago Lemos[1], Arthur de Sá Ferreira[1], Patrícia S. Vigário[1]

[1]*Centro Universitário Augusto Motta, Programa de Pós-Graduação em Ciências da Reabilitação, Rio de Janeiro, RJ, Brazil* [2]*Universidade Federal de Uberlândia, Faculdade de Educação Física e Fisioterapia, Uberlândia, MG, Brazil* [3]*Escola de Educação Física do Exército, Rio de Janeiro, RJ, Brazil* [4]*Universidade Federal do Rio de Janeiro, Laboratório de Desempenho, Treinamento e Exercício Físico, Rio de Janeiro, RJ, Brazil.*

Associate Editor: Giordano Marcio Gatinho Bonuzzi. [1]Universidade Estadual do Piaui, Picos, PI, Brazil. [2]Graduate Program in Kinesiology, Universidade Federal do Vale do São Francisco, Petrolina, PE. Brazil. E-mail: giordanomgb@gmail.com.

Abstract - Aim: To assess the postural control performance of football 5-a-side (FFS) players, comparing them with sighted players. **Methods:** Eight FFS players and 7 sighted futsal players were included. Postural control tests included feet together stance (FTS) and single-leg stance (SLS) tasks, performed on rigid and foam surfaces. Sighted players performed the tests with open (EO) and closed (EC) eyes. Area of displacement (*Area*) and average velocity (*Vavg*) were calculated from the center of pressure time-series coordinates. **Results:** On both surfaces conditions, a significant difference between visually impaired football 5-a-side players and sighted EO players was observed during FTS (higher *Vavg* for visually impaired football 5-a-side players; $p < 0.04$) and SLS (higher *Area* and *Vavg* for visually impaired football 5-a-side players; $p < 0.01$). No differences between visually impaired football 5-a-side players and sighted EC players were found. Differences between sighted EO vs. sighted EC were observed during FTS on the foam surface, and in SLS on both surface conditions ($p < 0.03$). **Conclusion:** FFS players' postural control performance is similar to sighted players with EC but worse than sighted players with EO, suggesting their postural control performance can be simply explained in terms of visual restriction.

Keywords: postural control, visually impaired persons, sports for persons with disabilities.

Introduction

Football is both one of the most played sports worldwide as well as a sport with a high incidence of musculoskeletal injuries[1] mainly affecting the lower limb joints and muscles[2]. Football 5-a-side is one of the most popular sports for visually impaired people; the team is composed of totally blind participants, except for the goalkeeper who may have normal vision[3]. In particular, visually impaired athletes participating in this sport are also among those with a higher incidence of sports-related injury[4] mainly in the lower limb[5,6]. In highly dynamic situations commonly observed in sports such as football - which provide rapid changes of direction, vertical and horizontal jumps -, the ability to align the center of pressure (CoP) concerning the support base is important for physical performance[7,8]. By training this ability, one can minimize the occurrence of injuries as described in recent systematic reviews, that showed that postural control interventions are effective in preventing anterior cruciate ligament injury, hamstring strains, ankle sprains, and groin problems, commonly observed in football athletes[9,10]. For that reason, preseason screening, including postural control assessment, is largely employed to evaluate physiological and biomechanical conditions associated with sports performance, lower limb function, and risk of injury[11,12].

Despite the evidence highlighting the importance of postural control assessment in sports practice, few investigations have addressed this issue in visually impaired athletes, including shooters, judo, goalball, football 5-a-side, and baseball players[13−19]. Santos et al.[16] evaluated football 5-a-side players and Bednarczuk et al.[19] evaluated shooters in comparison to other sports modalities for people with visual impairment, and both found that visual level impairment and sports specificities influence postural control performance. Differently, Jeronymo et al.[18] did not observe differences in postural control levels related to the level of visual impairment in judokas. Besides, Santos et al.[16], observed that football 5-a-side players presented better postural control compared to goalball and judo athletes. Given that upright postural control relies on multisensory integration-from visual, vestibular, and proprioceptive sensors[20] - along with impulsive torque generation from the neuromuscular system[21] some differences in postural control performance between sighted and visually impaired athletes are expected. Visually impaired athletes have better postural control test scores than non-athlete visually impaired subjects[14,15] but not sighted subjects[14,22]. One exception is from the work of Almansba et al.[13] which showed that performance in single-leg stance tasks was similar between visually impaired and sighted judokas and better than that of sighted non-athletes with their eyes closed.

As far as we know, there is no investigation about postural control performance in visually impaired football 5-a-side players compared with sighted football players. Considering that changes in postural control are related to increased risk of injuries in football players[9,10] and that the visual system has an important input for the control of CoP in the support base, visually impaired football 5-a-side players could compose a group even more vulnerable to injury. Determining to what extent postural control performance in visually impaired football 5-a-side players compared to sighted football players seems to be important to (a) determine whether the interpretation of postural control test performance-in terms of lower limb function and musculoskeletal injury risk-also applies for visually impaired athletes and (b) development of primary, secondary and tertiary injury rehabilitation programs.

Therefore, this study aimed to investigate postural control performance in visually impaired football 5-a-side players compared with that presented by sighted football players. Different visual contexts (for the sighted players only), as well as biomechanical (stance tasks) and sensorimotor (differing surface) manipulations, were used for further investigations of possible differences in postural control between players. We hypothesized that visually impaired football 5-a-side players have worse postural control performance (in terms of high/large size or velocity of body sway during postural tasks) mainly due to the visual deprivation itself, with challenging conditions (such as single leg stance and foam surface support) inducing larger differences between them and the sighted players, suggesting no specific sports adaptation in the postural control system in those with visual impairment.

Methods

Study design and ethics

This is an observational cross-sectional study. All subjects provided written (read aloud in the case of blind athletes) informed consent before participation. Experiments were approved by the ethical committee of Augusto Motta University Centre (process number 31778614.0.0000.5235) and conformed to the Declaration of Helsinki and its latest amendments.

Participants

A total of 15 players participated in the study (Table 1) and were divided into two groups: visually impaired football 5-a-side players (n = 8) and sighted futsal or football society players (n = 7). The groups were similar concerning age and anthropometric variables. The selection of futsal or equivalent football sighted players was deliberated because futsal is strongly related to visually impaired-adapted football 5-a-side games. Football players were included based on the following criteria: male; age ≥ 18 years; time of football practice ≥ 1 year; training frequency ≥ 3 days/week; and absence of injuries, pain, or movement restriction that could affect postural control performance. Goalkeepers of both groups were not included in the study. There was no difference in the total years of football practice or the training volume (Table 1). A minority of visually impaired (n = 1) and sighted (n = 2) players exhibited left lower limb dominance based on their kicking leg. All football 5-a-side players exhibited congenital total blindness (n = 4) or due to glaucoma in childhood (n = 3) or a car accident (n = 1).

Postural control performance assessment

Postural control was assessed based on current standards[23]. Participants were asked to stand still on a force platform with arms relaxed alongside the body. They were instructed to perform the following tasks: (i) stand upright with the feet together; (ii) stand upright in a single-

Table 1 - Demographic, anthropometric and training data of visually impaired football 5-a-side players (n = 8) and sighted (n = 7) football players. Data are presented as mean ± standard deviation (minimum-maximum). Independent sample *t*- Student test was run for group comparisons, and the corresponding p-value is showed.

	Visually impaired football 5-a-side players	Sighted players	p-value
Age (years)	25.0 ± 5.3 (17.0-30.0)	23.7 ± 2.9 (20.0-28.0)	0.58
Body mass (kg)	72.5 ± 14.4 (50.0-94.8)	69.3 ± 8.2 (59.7-83.0)	0.61
Height (cm)	170.7 ± 3.8 (164.0-175.5)	172.0 ± 4.5 (164.0-178.0)	0.55
Time of practice (years)	7.4 ± 2.2 (5.0-12.0)	7.9 ± 2.9 (4.0-12.0)	0.76
Training volume (days per week)	5.0 ± 0.0 (5.0-5.0)	4.4 ± 1.0 (3.0-5.0)	0.12

leg stance on the dominant leg; (iii) stand in a single-leg stance on the non-dominant leg. During a single-leg stance task, the suspended leg had the knee flexed at 90°. These tasks were performed under two surface conditions: (i) on a rigid surface (i.e., directly on the force platform) and (ii) on foam (10 cm height, 30 g/dm^3 density, and 50 x 50 cm dimension- in order to minimize proprioceptive input)[24]. These tasks and conditions were elected to challenge the postural control system in different ways: reducing the support base and disturbing somatosensory information. When enhancing the difficulty of the tests, modifications are easier to be observed, and maybe other conditions would ensure the modifications. Visually impaired football 5-a-side players were asked to keep their heads in a natural position. Sighted athletes were asked to perform all tasks with their eyes closed (EC) and open (EO, fixed on a visual target 1 meter in front of them). All tasks, surfaces, and visual conditions (for sighted participants) were randomly assigned in blocks (to keep the support base), and a 1 min interval was given between tasks to avoid fatigue and the effect of learning the task. Three trials lasting 35 s were performed for each task.

Center of pressure (CoP) coordinates were calculated from the ground reaction forces acquired from a force platform (AccuSway$_{PLUS}$, AMTI, USA). Signal acquisition and processing were performed using custom software written in LabVIEW (National Instruments, USA), namely, SuiteEBG version 1.0.0.1. Data were sampled at 100 Hz and stored for further processing. The first 5 s of the data were discarded, and after low-pass filtering (2.5 Hz, 2nd order Butterworth filter), the 95% confidence interval of the elliptical area of the CoP displacement (*Area*) and the average velocity (*Vavg*) were calculated as surrogate information about postural stability[25]. The average results of the three trials were computed for further analyses to achieve excellent reliability of the measurements[26].

Statistical analysis

Group data are summarized as the mean ± standard deviation (SD). A multivariate analysis of variance (MANOVA) was applied to check for the main effects of group (visually impaired, sighted EO, sighted EC), task (feet together vs. dominant single-leg vs. non-dominant single-leg stance), and surface (rigid vs. foam surface). For proper comparison between visually impaired and sighted players in different visual contexts, the eyes open (EO) and eyes closed (EC) conditions were applied in MANOVA as between-factors, as in previous investigations[27]. Tukey's test was used for post hoc paired comparisons. The observed interaction and main effects were further explored with a single-factor ANOVA to check for differences between groups in each condition. The partial eta squared (η^2) was reported as an effect size measure and it was interpreted as small (0.01), medium (0.06), or large (0.14)[28]. The level of statistical significance was set at 5%. Statistical analysis was run in SPSS 20.0 for Windows (IBM, USA).

Results

No significant three-way interaction was found (Wilk's $\lambda = 0.79$, $p = 0.11$); however, significant two-way interactions were observed for group vs. task (Wilk's $\lambda = 0.64$, $p < 0.01$) and group vs. surface (Wilk's $\lambda = 0.69$, $p < 0.001$) but not for task vs. surface (Wilk's $\lambda = 0.92$, $p = 0.31$). MANOVA revealed main effects for group (Wilk's $\lambda = 0.31$, $p < 0.01$), task (Wilk's $\lambda = 0.22$, $p < 0.01$), and surface (Wilk's $\lambda = 0.42$, $p < 0.01$).

Concerning the groups, significant differences were found in the CoP values for both tasks and surfaces, with higher values for visually impaired football 5-a-side players vs. sighted EO players (all post hoc tests $p < 0.04$). No significant differences were found between visually impaired football 5-a-side players vs. sighted EC players.

MANOVA's main effect for tasks refers to a significant difference between quiet stance and both single leg stances (all post hoc tests $p < 0.001$), with no differences between single leg stance with a dominant and nondominant limb (all post hoc tests $p > 0.83$). Finally, significant differences for surface were associated with high CoP values in the presence of a foam surface.

For the quiet stance task, significant differences among groups were found for *Vavg* in both the rigid (ANOVA $p = 0.05$, $\eta^2 = 0.29$, effect size = large) and foam surface conditions (ANOVA $p < 0.01$, $\eta^2 = 0.47$, effect size = large) but not for *Area* (ANOVA $p > 0.05$ for both surface conditions; Figure 1A). Post hoc tests revealed higher values of *Vavg* in visually impaired football 5-a-side players vs. sighted EO players (Figure 1B), while a significantly higher value was observed in sighted EC vs. EO players only during the foam surface condition (Figure 1B).

For single-leg stance tasks (both legs averaged), significant differences between visually impaired football 5-a-side players and sighted EO players were obtained for *Area* and *Vavg* in the two surface conditions (ANOVA: *Area* rigid, $p < 0.01$, $\eta^2 = 0.64$, effect size = large; *Area* foam, $p < 0.01$, $\eta^2 = 0.36$, effect size = large; *Vavg* rigid, $p < 0.01$, $\eta^2 = 0.73$, effect size = large; *Vavg* foam, $p < 0.01$, $\eta^2 = 0.67$, effect size = large). Specifically, visually impaired football 5-a-side players exhibited higher *Area* and *Vavg* than sighted EO players irrespective of surface conditions (Figure 2A and Figure 2B, respectively). The same occurred for *Vavg* in the sighted EC vs. EO comparison (Figure 2B). On the other hand, the effect of eyes closed in the sighted players' *Area* was only observed in the single-leg stance during the rigid surface condition (Figure 2A).

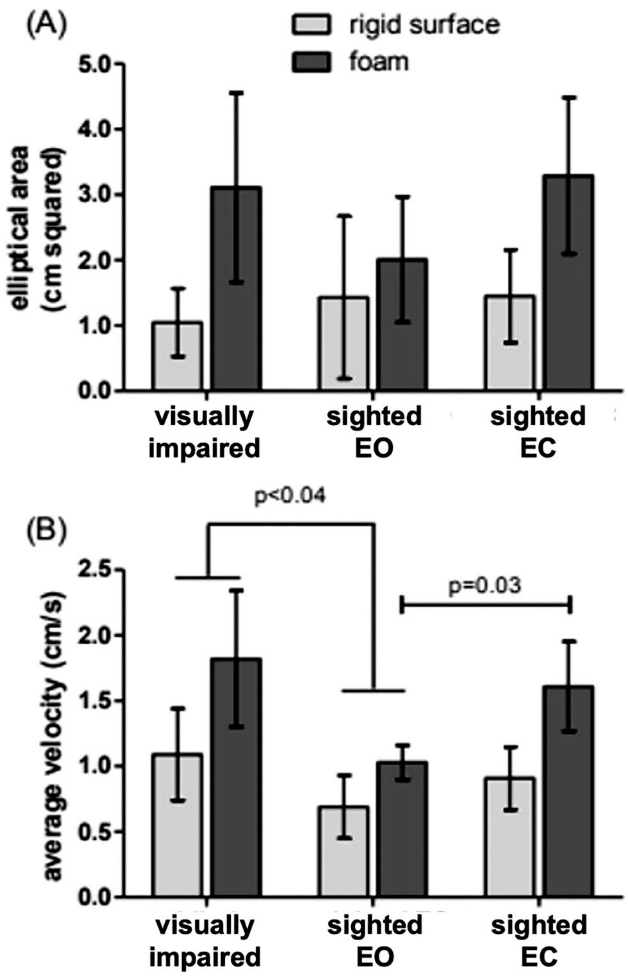

Figure 1 - Postural control performance during a feet together stance task in rigid (light gray) and foam (dark gray) surface. There were significant differences between surfaces for all groups and variables ($p < 0.001$). The 95% confidence interval elliptical area (A) and the average velocity of COP displacement (B) are presented. Connecting lines indicate differences between groups and the corresponding post hoc tests p-values are showed as inset.

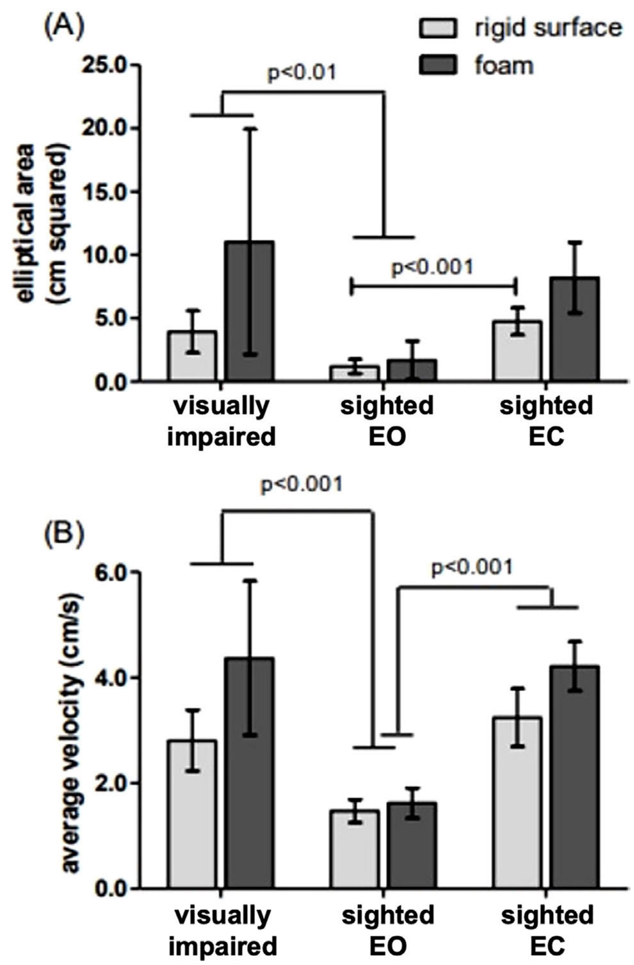

Figure 2 - Balance performance during single-leg stance (both legs averaged) in rigid (light gray) and foam (dark gray) surface. There were significant differences between surfaces for all groups and variables ($p < 0.001$). The 95% confidence interval elliptical area (A) and the average velocity of COP displacement (B) are presented. Connecting lines indicate differences between groups and the corresponding post hoc tests p-values are showed as inset.

Discussion

This study aimed to investigate postural control performance in visually impaired football 5-a-side players and compare it with that in sighted football players. Given that purpose, tasks and conditions with different degrees of postural instability were tested. Our main findings were as follows: (i) the postural control performance of visually impaired football 5-a-side players is similar to that of sighted players in the visually deprived state (eyes closed), irrespective of task or surface condition; and (ii) CoP parameters (both its amplitude and velocity) is greater in visually impaired football 5-a-side players than in their sighted counterparts in the usual visual (eyes open) state, with larger differences appearing during the single-leg stance task. Collectively, they provide evidence in favor of our hypothesis that blind football players have worse postural control performance when compared to their sighted counterparts with opened eyes, mainly in a single-leg stance.

Despite the current evidence about the relationship between visual impairment and postural control, there is still no consensus about the effect of blindness on upright postural control. Studies indicate that people with vision impairment could perform worse[22,27,29,30], similarly[31], or even better[32,33] in postural control assessments than sighted people, especially in positions with vibration[33] or with vision or hearing disturbances[32]. Notably, evaluation of postural control ability in challenging conditions (such as single-leg stance) seems to evoke larger discrepancies between blind and sighted subjects[27]. However, these studies investigated elderly individuals with vision impairment[29] or non-athlete subjects[27,31], who performed less challenging positions.

Based on this controversial background, it can be argued that vision impairment can result in either a deficit (*i.e.*, postural sway of blind subjects is larger than that exhibited by sighted subjects)[18,22,29,30] or compensation (*i. e.*, postural sway equals or is smaller in blind subjects)[31−33] in postural control performance. Different from the results of Giagazoglou et al.[27], that observed increases in amplitude and velocity of postural sway in visually impaired than in sighted persons with eyes closed and reduced base of support conditions (e.g., tandem and single leg stance), here we found that visually impaired football 5-a-side players were able to sustain an upright stance in challenging conditions that is comparable to the sighted players in restricted visual inputs (eyes closed; see Figure 2, visually impaired *vs.* sighted EC).

An important factor that could affect the postural control performance of blind subjects is their level of physical fitness. Sports practice for sighted subjects is associated with better postural control ability during both quiet standing[34] and single-leg stance[35,36]. The few studies available indicate that this could be the same for blind athletes as follows, where vision impairment level is related to postural control level[16,19]. For example, it was observed that goalball[14] and baseball[15] athletes had better postural control performance when compared to sedentary subjects. However, when compared to sighted physically active persons[14] and sighted athletes[22], the postural control performance of goalball players was inferior. On the other hand, visually impaired judokas were able to sustain a single-leg stance for as long as sighted athletes and sedentary subjects with their eyes open (42 s)[13] and were even better than sedentary subjects with their eyes closed (16 s for blind and sighted athletes vs. 8 s for sighted sedentary subjects). Our results showing that visually impaired football 5-a-side players perform as well as sighted players with eyes closed corroborate those found for blind judokas[13]. The fact that these athletes did not achieve the same postural control performance as the sighted players with eyes open, and being similar to sighted athletes with closed eyes, suggests that there was no specific sports-induced adaptation in postural control and sensorial systems adaptations (proprioceptive and vestibular information). Likely because of the particular dynamics of the game, compared with other sports practitioners, football players usually exhibit enhanced postural control among sports practitioners, mainly in single-leg conditions[36].

A large effect size (i.e., the difference between blind the single-leg stance task, in which both CoP amplitude and velocity were higher in visually impaired subjects (see Figure 2). Unstable postures such as single-leg stance requires an increased reliance upon sensory integration and neuromuscular coordination, especially from lower limb joints[37], which could exacerbate the differences in balance control from visually impaired to sighted players. It was demonstrated that postural control performance during single-leg stance is not only used to discriminate between those with injured lower limbs and those without any lesions[38] but also has a positive association with ankle sprain incidence[39]. Given the degree of injury observed in blind athletes, mainly in the lower limb[5,6], it could be suggested that functional tests such as single-leg stance must be included in preparticipation exam routines in this population. However, outcomes of such an exam should be interpreted with caution once balance performance in a single-leg position does not reflect only the lower limb function[38], but also possible changes in postural control related to visual impairment.

A limitation of this study is the small sample size, which could have precluded large effect sizes for two- and three-way interactions. Despite the high prevalence of vision impairment in the young population[40], the number of blind subjects practicing in high-level sports is very low; by including all players on a football 5-a-side team (with the obvious exception of the goalkeeper), we expect the external validity of our study to be met. Sighted athletes performed twice as many trials (OE and CO) than visually impaired athletes. Although tasks, surfaces, and visual conditions were randomized and resting intervals were given between trials, we cannot guarantee that the effect of learning the task has influenced the results. Nonetheless, our study design allowed us to observe large effects (*e.g.*, η^2 ranging from 0.4-0.8 for the group effect in single-leg stance) for postural control performance between groups, corroborating the findings of others[17] and extending them for the specific postural behavior of football players.

Conclusions

The postural control performance of visually impaired football 5-a-side players during feet together and single-leg stances was similar to that of sighted players with eyes closed but worse than that of sighted players with their eyes open. These results suggest no significant adaptation in the postural control system in visually impaired athletes, as its performance in the postural control test is simply explained in terms of visual restriction.

Perspectives

Our results highlight the importance of considering differences in the postural control performance of sighted and visually impaired athletes for proper interpretation of postural control assessment, postural control training design, and injury prevention program development. Since it was observed higher CoP oscillation on both elliptical area and average velocity, a single-leg stance task should be considered for inclusion in the preparticipation exam routine of football 5-a-side players, and its association with rate and level of injury should be addressed in future studies. Furthermore, since large differences between sighted and visually impaired athletes were only observed when sighted athletes assumed a single-leg stance with the eyes open (thus, suggesting that postural control performance in visually impaired subjects could be explained in terms of simple visual restriction) further research should be carried out to explore whether adaptations to other sensory or neuromuscular systems also occur in subjects with vision impairment.

Acknowledgments

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001, the Carlos Chagas Filho Foundation for the Research Support in Rio de Janeiro State (FAPERJ) - E-26/203.256/2017 and Brazilian Council for the Technological and Scientific Development (CNPq).

References

1. Walls RJ, Ross KA, Fraser EJ, Hodgkins CW, Smyth NA, Egan CJ, et al. Football injuries of the ankle: a review of injury mechanisms, diagnosis, and management. World J Orthop. 2016;7(1):8-19. doi
2. Eliakim E, Doron O, Meckel Y, Nemet D, Eliakim A. Pre-season fitness level and injury rate in professional soccer - a prospective study. Sports Med Int Open. 2018;2(3):E84-E90. doi
3. International Blind Sports Federation. IBSA blind football rulebook 2017-2021. Available from: https://blindfootball.sport/wp-content/uploads/2021/02/960-Rules-IBSA-Blind-Football-B1-Rulebook-2017-2021.pdf [Accessed 30th December 2021].
4. Derman W, Runciman P, Schwellnus M, Jordaan E, Blauwet C, Webborn N, et al. High precompetition injury rate dominates the injury profile at the Rio 2016 Summer Paralympic Games: a prospective cohort study of 51 198 athlete days. Br J Sports Med. 2018;52(1):24-31. doi
5. Magno e Silva MP, Morato MP, Bilzon JL, Duarte E. Sports injuries in Brazilian blind footballers. Int J Sports Med. 2013;34(3):239-43. doi
6. Webborn N, Cushman D, Blauwet CA, Emery C, Derman W, Schwellnus M, et al. The epidemiology of injuries in football at the London 2012 Paralympic Games. PM R. 2016;8(6):545-52. doi
7. Kibele A, Granacher U, Muehlbauer T, Behm DG. Stable, unstable and metastable states of equilibrium: definitions and applications to human movement. J Sports Sci Med. 2015;14(4):885-7.
8. Behm DG, Drinkwater EJ, Willardson JM, Cowley PM. Canadian Society for Exercise Physiology position stand: the use of instability to train the core in athletic and non-athletic conditioning. Appl Physiol Nutr Metab. 2010;35 (1):109-12. doi
9. Pérez-Gómez J, Adsuar JC, Alcaraz PE, Carlos-Vivas J. Physical exercises for preventing injuries among adult male football players: a systematic review. J Sport Health Sci. 2022;11(1):115-22. doi
10. Olivares-Jabalera J, Fílter-Ruger A, Dos'santos T, Afonso J, Della Villa F, Morente-Sánchez J, et al. Exercise-based training strategies to reduce the incidence or mitigate the risk factors of anterior cruciate ligament injury in adult football (soccer) players: a systematic review. Int J Environ Res Public Health. 2021;18(24):13351. doi
11. de la Motte SJ, Lisman P, Gribbin TC, Murphy K, Deuster PA. Systematic review of the association between physical fitness and musculoskeletal injury risk: part 3-flexibility, power, speed, balance, and agility. J Strength Cond Res. 2019;33(6):1723-35. doi
12. Hrysomallis C. Relationship between balance ability, training, and sports injury risk. Sports Med. 2007;37(6):547-56. doi
13. Almansba R, Sterkowicz-Przybycien K, Sterkowicz S, Mahdad D, Boucher JP, Calmet M, et al. Postural balance control ability of visually impaired and unimpaired judoists. Arch Budo. 2012;8(3):153-8. doi
14. Aydog E, Aydog ST, Cakci A, Doral MN. Dynamic postural stability in blind athletes using the biodex stability system. Int J Sports Med. 2006;27(5):415-8. doi
15. Marini M, Sarchielli E, Portas MF, Ranieri V, Meli A, Piazza M, et al. Can baseball improve balance in blind subjects? J Sports Med Phys Fitness. 2011;51(2):227-32. PMID
16. Santos CN, Carvalho TL, Felício LR, Mainent MRM, Vigário PS. Postural control in athletes with different degrees of visual impairment. J Phys Educ. 2018;29:e2936. doi
17. Kons RL, Sakugawa RL, Rossato M, Diefenthaeler F, Detanico D. Neuromuscular and postural control in visually and nonvisually impaired judo athletes: a case study. J Exerc Rehabil. 2019;15(1):60-6. doi
18. Jeronymo BF, Silva PRO, Mainenti M, Felício LR, Ferreira AS, Carvalho TL, et al. The relationship between postural stability, anthropometry measurements, body composition, and sports experience in judokas with visual impairment. Asian J Sports Med. 2020;11(3):e103030. doi
19. Bednarczuk G, Wiszomirska I, Marszalek J, Rutkowska I, Skowroński W. Static balance of visually impaired athletes in open and closed skill sports. Pol J Sport Tourism. 2017;24(1):10-4. doi
20. Peterka RJ. Sensory integration for human balance control. Handb Clin Neurol. 2018;159:27-42. doi
21. Loram ID, Maganaris CN, Lakie M. Human postural sway results from frequent, ballistic bias impulses by soleus and gastrocnemius. J Physiol. 2005;564(Pt 1):295-311. doi
22. Aras D, Güler Ö, Gülü M, Akça F, Arslan E, Akalan C. Comparison of balance skills of visually impaired and non-impaired judo athletes and goalball/futsal players. Phys Educ Stud. 2018;(6):292-7. doi
23. Ruhe A, Fejer R, Walker B. The test-retest reliability of centre of pressure measures in bipedal static task conditions - a systematic review of the literature. Gait Posture. 2010;32 (4):436-45. doi
24. Prasad T, Ghosh S, Goswami A. Static balance ability of persons with visual impairment on firm and foam surfaces. EUJAPA. 2020;13(2):10. doi

25. Portela FM, Rodrigues EC, Ferreira AS. A critical review of position-and velocity-based concepts of postural control during upright stance. Hum Mov. 2014;15(4):227-33. doi
26. Ferreira AS, Baracat PJ. Test-retest reliability for the assessment of postural stability using center of pressure spatial patterns of three-dimensional statokinesigrams in young healthy participants. J Biomech. 2014;47(12):2919-24. doi
27. Giagazoglou P, Amiridis IG, Zafeiridis A, Thimara M, Kouvelioti V, Kellis E. Static balance control and lower limb strength in blind and sighted women. Eur J Appl Physiol. 2009;107(5):571-9. doi
28. Cohen J. Statistical power analysis for the behavioral sciences. 2nd ed. New Jersey, Lawrence Erlbaum Associates; 1988.
29. Maeda A, Nakamura K, Otomo A, Higuchi S, Motohashi Y. Body support effect on standing balance in the visually impaired elderly. Arch Phys Med Rehabil. 1998;79(8):994-7. doi
30. Zetterlund C, Lundqvist LO, Richter HO. Visual, musculoskeletal, and balance symptoms in individuals with visual impairment. Clin Exp Optom. 2019;102(1):63-9. doi
31. Schmid M, Nardone A, De Nunzio AM, Schmid M, Schieppati M. Equilibrium during static and dynamic tasks in blind subjects: no evidence of cross-modal plasticity. Brain. 2007;130(Pt 8):2097-107. doi
32. Juodzbaliene V, Muckus K. The influence of the degree of visual impairment on psychomotor reaction and equilibrium maintenance of adolescents. Medicina (Kaunas). 2006;42 (1):49-56.
33. Pyykkö I, Vesikivi M, Ishizaki H, Magnusson M, Juhola M. Postural control in blinds and Usher's syndrome. Acta Otolaryngol Suppl. 1991;481:603-6. doi
34. Herpin G, Gauchard GC, Lion A, Collet P, Keller D, Perrin PP. Sensorimotor specificities in balance control of expert fencers and pistol shooters. J Electromyogr Kinesiol. 2010;20(1):162-9. doi
35. Kiers H, van Dieën J, Dekkers H, Wittink H, Vanhees L. A systematic review of the relationship between physical activities in sports or daily life and postural sway in an upright stance. Sports Med. 2013;43(11):1171-89. doi
36. Matsuda S, Demura S, Uchiyama M. Centre of pressure sway characteristics during static one-legged stance of athletes from different sports. J Sports Sci. 2008;26(7):775-9. doi
37. Doherty C, Bleakley C, Hertel J, Caulfield B, Ryan J, Delahunt E. Postural control strategies during single limb stance following an acute lateral ankle sprain. Clin Biomech. 2014;29(6):643-9. doi
38. Tropp H, Odenrick P. Postural control in single-limb stance. J Orthop Res. 1988;6(6):833-9. doi
39. Trojian TH, McKeag DB. Single leg balance test to identify the risk of ankle sprains. Br J Sports Med. 2006;40(7):610-3. doi
40. Pascolini D, Mariotti SP. Global estimates of visual impairment: 2010. Br J Ophthalmol. 2012;96(5):614-8. doi

Corresponding author

Patrícia dos Santos Vigário. Centro Universitário Augusto Motta, Programa de Pós-Graduação em Ciências da Reabilitação, Rua Dona Isabel, n. 94, Bonsucesso, Rio de Janeiro, RJ, Brazil.
E-mail: patriciavigario@yahoo.com.br.

Manuscript received on September 1, 2021
Manuscript accepted on May 17, 2022