DOI 10.26773/jaspe.220702

Journal of Anthropology of Sport and Physical Education

ORIGINAL SCIENTIFIC PAPER

Differences in Balance with Eyes Closed, Eyes Opened and Virtual Reality Environment: A pilot-study

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Abstract

Many studies have examined differences between maintaining balance with open and closed eyes. In this research Virtual Reality (VR) technology is included as a special type of visual input for creating static and dynamic virtual environments. PURPOSE: The purpose of this paper was to determine whether there is a difference between results in balance tests on Biodex Balance System (BBS) with different visual input. METHODS: Participants (n=12) in the study were young, healthy and active males with an average age of 21.25±1.14 years, body mass 82.57±8.37 kg and average body height 185.42±5.18 cm. Six balance tests were applied on BBS, four in the real world and two in the virtual environment. Duration and instability level of the BBS platform were the same for all tests. RESULTS: None of the participants finished the test in a dynamic virtual environment so that test was excluded from further statistical analysis. Factor analysis revealed two main factors (latent dimensions). The first factor is characterized by open eyes tests while extremely high projection on the second factor can only be seen in a case of a test done with the eyes closed.

Keywords: *Visual input, Biodex Balance System, Virtual reality, Balance testing, Virtual environment*

Introduction

Studies suggest that the Biodex Balance System is a reliable tool for determining dynamic postural balance ability (Kararti et al., 2021; Karimi, Ebrahimi, Kahrizi & Torkaman, 2008; Sherafat et al., 2013). Postural control is defined as the act of maintaining, achieving, or restoring a state of balance during any posture or activity (Pollock, Durward, Rowe, & Paul, 2000). Studies which tested balance were done on various testing instruments such as force plates (Kuczynski, Rektor & Borzucka, 2009; Ricotti, & Ravaschio, 2011), Kistler force platforms (Zając, Kuczyński, & Bieć, 2017), Balance Master force platform (Srivastava, Taly, Gupta, Kumar, & Murali, 2009), Wii Balance Board (Bower, McGinley, Miller, & Clark, 2014), AccuGait AMTI platform (Wilczyński, 2018). In this study the BBS was used for measuring balance because of its dynamic nature (a movable platform) and high reliability of balance testing (Cachupe, Shifflett, Kahanov, & Wughalter, 2009) as well as to add dynamic component to standing platform that we thought was lacking in a previous, similar study (Fransson, Patel, Jensen, Lundberg, Tjernström, Magnusson, & Hansson, 2019). Studies suggest that visual input is of significance when assessing balance and when assessing balance capabilities with eyes closed and eyes open (Perrin, Jeandel, Perrin, & Béné, 1997; Hammami, Behm, Chtara, Ben Othman, & Chaouachi, 2014). One study analyzed the effects of low-dose alcohol consumption on postural control with the results providing insight into the complexity of regulation balance, which not only depends on the proprioceptive and vestibular system but also strongly on the visual system and its input (Palm, Waitz, Strobel, Metrikat Hay, & Friemert, 2010). It could be said with high certainty that balance is strongly dependent on visual input. The aim of this paper is to investigate differences in the results of the same balance test using different visual inputs. Additionally, the aim is to explore, in depth, the differences in balance between eyes open, eyes closed and to see if virtual reality (VR) technology is representative enough to replace visual input from the real world.

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Methods

The study took place in Autumn of 2019 at the Faculty of Kinesiology, University of Split. Twelve (n=12) young, healthy and active males participated in this study. All participants live in Split, Croatia and were students in the University of Split from various faculties. Anthropological measurements of the participants were taken upon entering the training facilities, before conducting the balance tests. The participants had an average of 21.25±1.14 years, body mass of 82.57±8.37 kg and average body height of 185.42±5.18 cm. The Biodex Balance System (BBS) was used as the apparatus for testing the balance capabilities of the participants. The testing was done over 4 days because of the lengthy testing procedure which is normal for that kind of testing on the BBS. To match the conditions of testing from day to day, the testing was done in the afternoon so that sunlight can be utilized instead of artificial lightning which put a reflection on the screen of the BBS, causing visual distractions for the participants and therefore a potential study limitation. Before the testing started for the day, the BBS was calibrated each day of testing to minimize mistakes caused from other people handling the BBS between active periods of testing. Six tests were applied on the participants using the BBS and each test was 90 seconds long. The duration of all the tests were tailored to the sixth test because the dynamic environment in this test, which will be explained later, had a duration of 90 seconds and could not be changed. The level of instability of the BBS platform was uniform across all 6 tests and was set to 6. The range of instability on the BBS can be set from 1 to 12. Before the actual tests, the participants stepped on the BBS platform and their center of body mass (COM) was adjusted so that the cursor was in the middle of the screen. In the adjusting phase, the screen was blocked from the vision of the participants to avoid the participant trying to lean to adjust his COM. Instead, stepping and physically moving his location was favored so that the participant was upright, without lean. The positioning of the participants' feet was recorded so there is no difference in stances. The participants were allowed to rest between tests for up to a maximum of 3 minutes. The tests varied only in visual input whilst every other parameter stayed the same. Before embarking on the actual testing, the participants had a moment to familiarize themselves with standing on the platform. When ready, the participants were asked to maintain their balance for 90 seconds for each test, respectively. In the first test, the screen of the BBS was covered so the cursor which visually displays the COM of the participants was not visible to them. In the second test, the participants were able to see the screen and their COM. In the third test, a pre-recorded video on a tablet was put instead of the screen. The video was recorded prior to testing the subjects and it shows a different (false) position of COM rather than the real participants. In the fourth test, the participants had their eyes closed. In the fifth test, VR technology was applied. The participants had a VR headset strapped to their head and it showed the participants a static room which was a part of the software and interface of the technology. In the sixth test, VR technology is also applied. This time the environment was dynamic, and the participants were shown a roller coaster simulation (Desert Ride Coaster developed by iNFINITE Production released December 7th, 2016) which lasted 90 seconds. This type of test design was intended to serve as a method of assessing if the participants could successfully ignore the visual input in such an environment and to maintain balance relying only on the proprioceptive and vestibular system. The sixth test was intentionally put as the last because of the expected high difficulty. The fifth test was the methodological step back to the sixth test, to familiarize the participants with the VR technology environment, the actual weight that is placed on the participants' heads and to see their behavior in the static VR environment with their eyes open. The fourth, closed eyes test, was put last in the VR-free tests because of the expected high difficulty and to act as a kind of safety net in regard to figuring out if the participants closed their eyes in the fifth and sixth test because the version of the used VR technology did not have an eye tracking mechanism. If some participants did try to close their eyes in the VR tests, results could simply be compared to the fourth test which had their eyes closed. The third test tried to challenge the balance with a different visual stimulus. The second test simply showed the visual feedback of their COM (the classic BBS test). HTC VIVE VR technology was used for this study. The participants were instructed to avoid movement of the feet on the platform even if they lose their balance and are falling or have reached the maximum range of motion of the platform. If they did indeed completely lose their balance they were instructed to freely fall and let the people around them catch them. There were always 2 people around the participants to ensure their safety. During the VR tests, one person held the wire from the headset to minimize the weight of the cable pulling up the head of the participants.

Results

The sixth test was not included in the statistical analysis because none of the participants were able to finish the full duration of the test. Descriptive statistics (Table 1) were used to describe the sample of participants, which included age, body height, body mass and the tests, except for the sixth test as mentioned previously. Valid variables for every mentioned parameter were 12 (valid N = 12) except for the fourth test, which had 9 valid variables because 3 of the participants were not able to complete the full 90 seconds of the test. The average age of the participants was 21.25±1.14 years with a body mass of 82.57±8.37 kg and average body height of 185.42±5.18 cm. The average result of the first test was 2.80±1.02, the second 1.31±0.24, the third 2.03±0.62, the fourth 8.59±2.43 and the fifth 5.00±1.23. The normal distribution for all variables included in the analysis was confirmed by the Kolmogorov-Smirnov normality test (p>0.20).

Table 1. Descriptive statistics

V	N	Mean+SD	MIN	MAX	KS	p
Age	12	21.25±1.14	19.00	23.00	0.25	>.20
BH	12	185.42±5.18	177.50	196.00	0.12	>.20
BW	12	82.57±8.37	63.50	95.30	0.19	>.20
TEST 1	12	2.80±1.02	1.80	5.00	0.22	>.20
TEST 2	12	1.31±0.24	0.90	1.90	0.19	>.20
TEST 3	12	2.03±0.62	1.20	2.90	0.16	>.20
TEST 4	9	8.59±2.43	4.20	12.50	0.15	>.20
TEST 5	12	5.00±1.23	3.30	7.40	0.13	>.20

Legend: V – variable; N – number of valid participants; Mean – arithmetic mean; SD – standard deviation; MIN – minimum; MAX – maximum; KS – KolmogorovSmirnov test; p – p-value

The factor analysis (Table 2) revealed two main factors or latent dimensions. The first factor showed statistically significant correlation with the second and third test, while the second factor showed statistically significant correlation with the fourth test.

The correlation matrix (Table 3) showed statistically significant correlation between the second and third test.

Table 2. Factor analysis of the tests

V	F1	F2
TEST 1	0,461093	0,383795
TEST 2	0,979131*	-0,078051
TEST 3	0,802614*	0,274197
TEST 4	0,016148	-0,974128*
TEST 5	-0,487253	-0,570637
Expl. Var	2,053169	1,503126
Prp. Totl	0,410634	0,300625

Legend: V – variable; F1 – First factor extracted from statistical analysis; F2 – Second factor extracted from statistical analysis; * - p > 0.05 indicates statistical significance and correlation of the test to the extracted factor

Table 3. Correlation matrix of the tests

V	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5
TEST 1	1,000000	0,457498	0,240379	-0,177342	-0,152217
TEST 2	0,457498	1,000000	0,698472*	0,194150	-0,436598
TEST 3	0,240379	0,698472*	1,000000	-0,174272	-0,442531
TEST 4	-0,177342	0,194150	-0,174272	1,000000	0,348817
TEST 5	-0,152217	-0,436598	-0,442531	0,348817	1,000000

Legend: V – variable; * - p > 0.05 indicates statistically significant correlation

Discussion

By observing participants' results we can assume that the sixth test was hardest to complete as none of the participants were able to finish it (the best result was 35 seconds out of a maximum of 90). In the dynamic virtual reality, the roller coaster ride went suddenly downhill in the simulation and with a sudden increase in acceleration. This alone proved that the participants were very reliant on visual input while balancing on the BBS. When viewing the results of the Overall Stability Index (OSI) in the descriptive statistics (Table 1), it is important to understand that the lower result in the OSI parameter is considered better overall balance performance. The standard deviation of the OSI parameter indicates that the more the COM of the participants is "dancing" around the screen, the higher the deviation and movement of the platform. This number could indicate the rate of engagement of the muscles used, but further studies and incorporation of perhaps electromyography could be needed to prove this thesis. Factor analysis (Table 2) extracted two factors (latent dimensions). In the first factor, test 2 and 3 contributed the most. In the second factor, test 4 contributed the most. Although this pilot study was of an explorative nature, it was expected that at least two factors were to be extracted, which proved to be true. It could be said with assurance that the factors extracted were balance with eyes open (first factor) and balance with eyes closed (second factor). This study, along with previous ones, proved that the BBS is a good apparatus for identifying balance as a latent dimension (Cachupe et al., 2001; Kararti et al., 2021), as well as differentiating between balance with eyes open and eyes closed as two separate dimensions (Maciaszek, Osinski, Szeklicki, Salomon, & Stemplewski, 2006; Sherafat et al., 2013). It was also expected that a third factor would be extracted because of the incorporation of VR technology and when viewing the correlation matrix (Table 3) it is visible that the first and fifth test are not significantly correlated, and it is logical why a third factor was not extracted. These results suggest that a static VR environment differently influences the balance of the participants but not enough to be extracted as an independent factor. The correlation matrix also indicates that participants who have a good result in the first three tests could have worse results in the fifth test which indicates that participants who are "good" in balancing with visual input are worse in the eyes closed test, which could be explained in their dependency on visual input for maintaining balance. This was observed to be true in all groups of athletes when assessing balance with eyes closed versus eyes open (Hammami et al., 2014). There was also some clear confusion for the participants in test 5 which could of interfered with the true correlation between these two tests (the weight of the headset, the headset cable pulling up on the head, birds flying in the VR environment, people blocking the sensors from the headset which caused the static environment to turn black, looseness of the headset around the eyes which caused latency of movement, the latency of the visual input of VR in regard to real life movement, the fear of falling). Fatigue from previous test (especially the fourth test, which clearly was challenging for the participants), the familiarization of testing in the first test could also have been limiting factors in assessing the true correlation between the open eyes tests with the VR tests. Other study limitations were a small sample size and inappropriate height of the screen in relation to the eye level of the participants (screen was lower than the participants eye level). In this study, balance with eyes open and eyes closed could be differentiated as separate abilities on the settings used on the BBS. The sixth test proved that the participants strongly relied on visual input for maintaining balance on the BBS which could imply that the HTC Vive and the accompanying software for creating the virtual environment are a good representation of reality.

Conclusion

The findings of this study suggest that maintaining balance on BBS with open eyes is a different ability than maintaining balance on BBS with eyes closed. Participants cannot maintain balance on BBS if they are immersed in a dynamic virtual environment because they obviously rely on visual input.

Conflict of Interest
Authors declare no conflicts of interest.

Received: 06 June 2022 | **Accepted:** 18 June | **Published:** 15 July 2022

References

Bower, K. J., McGinley, J. L., Miller, K. J., & Clark, R. A. (2014). Instrumented static and dynamic balance assessment after stroke using Wii Balance Boards: reliability and association with clinical tests. PloS one, 9(12), e115282. DOI: 10.1371/journal.pone.0115282.

Cachupe, W. J., Shifflett, B., Kahanov, L., & Wughalter, E. H. (2001). Reliability of Biodex Balance System Measures, Measurement in Physical Education and Exercise Science, 5(2), 97-108. DOI: 10.1207/S15327841MPEE0502_3.

Fransson, PA., Patel, M., Jensen, H., Lundberg, M., Tjernström, F., Magnusson, M. & Hansson, E. (2019). Postural instability in an immersive Virtual Reality adapts with repetition and includes directional and gender specific effects. Scientific Reports 9. DOI: 10.1038/s41598-019-39104-6.

Hammami, R., Behm, D. G., Chtara, M., Ben Othman, A., & Chaouachi, A. (2014). Comparison of static balance and the role of vision in elite athletes. Journal of human kinetics, 41, 33–41. DOI: 10.2478/hukin-2014-0030.

Karartı, C., Özüdoğru, A., Basat, H. Ç., Özsoy, İ., Özsoy, G., Kodak, M. İ., Sezgin, H., & Uçar, İ. (2021). Determination of Biodex Balance System Cutoff Scores in Older People With Nonspecific Back Pain: A Cross-sectional Study. Journal of manipulative and physiological therapeutics, 44(1), 85–94. DOI: 10.1016/j.jmpt.2020.07.006.

Karimi, N., Ebrahimi, I., Kahrizi, S., & Torkaman, G. (2008). Evaluation of postural balance using the biodex balance system in subjects with and without low back pain. Pakistan Journal of Medical Sciences, 24(3), 372-377.

Kuczynski, M.P., Rektor, Z., & Borzucka, D. (2009). Postural Control in Quiet Stance in the Second League Male Volleyball Players. Human Movement, 10, 12-15. DOI:10.2478/v10038-008-0025-4.

Maciaszek, J., Osinski, W., Szeklicki, R., Salomon, A., & Stemplewski, R. (2006). Body balance parameters established with closed and open eyes in young and elderly men. Biology of Sport, 23(2), 185.

Palm, H. G., Waitz, O., Strobel, J., Metrikat, J., Hay, B., & Friemert, B. (2010). Effects of low-dose alcohol consumption on postural control with a particular focus on the role of the visual system. Motor control, 14(2), 265–276. DOI: 10.1123/mcj.14.2.265.

Perrin, P. P., Jeandel, C., Perrin, C. A., & Béné, M. C. (1997). Influence of visual control, conduction, and central integration on static and dynamic balance in healthy older adults. Gerontology, 43(4), 223–231. DOI: 10.1159/000213854.

Pollock, A. S., Durward, B. R., Rowe, P. J., & Paul, J. P. (2000). What is balance?. Clinical rehabilitation, 14(4), 402–406. DOI: 10.1191/0269215500cr342oa.

Ricotti, L., & Ravaschio, A. (2011). Break dance significantly increases static balance in 9 years-old soccer players. Gait & posture, 33(3), 462–465. DOI: 10.1016/j.gaitpost.2010.12.026.

Sherafat, S., Salavati, M., Ebrahimi Takamjani, I., Akhbari, B., Mohammadirad, S., Mazaheri, M., & Negahban, H. (2013). Intrasession and intersession reliability of postural control in participants with and without nonspecific low back pain using the Biodex Balance System. Journal of manipulative and physiological therapeutics, 36(2), 111–118. DOI: 10.1016/j.jmpt.2012.12.005.

Srivastava, A., Taly, A. B., Gupta, A., Kumar, S., & Murali, T. (2009). Post-stroke balance training: role of force platform with visual feedback technique. Journal of the neurological sciences, 287(1-2), 89–93. DOI: 10.1016/j.jns.2009.08.051.

Wilczyński J. (2018). Postural Stability in Goalkeepers of the Polish National Junior Handball Team. Journal of human kinetics, 63, 161–170. DOI: 10.2478/hukin-2018-0016.

Zając, P., Kuczyński, M., & Bieć, E. (2017). Balance control near to the limit of stability in young soccer players. Physiotherapy Quarterly, 25(2), 17-23. DOI:10.5114/pq.2017.74702.