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# Does Xbox 360 Kinect Training Improve Postural Balance in Young Healthy Adults? A Preliminary Study

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**Keywords**
postural balance, virtual reality, exercise, rehabilitation

**Abstract**

**Background:** Balance training in young adults may increase coordination, cognitive function or strength symmetry on both sides of the body. It is an essential tool for injury or fall prevention and a precondition for becoming a professional athlete.

**Objective:** The aim of this study was to assess the effect of Xbox 360 Kinect training on postural balance in young, healthy individuals.

**Material and methods:** The study comprised 75 individuals who were randomly assigned to three equal groups. The first group (Group VR) performed exercises on an Xbox 360 Kinect console, and the second group (Group T) performed conventional all-round exercises. The third group was the control (Group C). Each group underwent balance assessments on the Biodex Balance posturographic platform, including the Balance Error Scoring System test, before and after the training cycle. The level of statistical significance was set at $p<.05$.

**Results:** Group VR and Group T achieved statistically significant improvement in sway index compared to baseline. Group T gained significant decrease in the sway index on the unstable surface ($p=0.002$). Group VR and Group T demonstrated significant decreases in the mean sway index on stable and unstable surfaces (Group VR – $p=0.035$; Group T – $p=0.001$) Group C did not achieve statistically significant improvement in sway index. None of the groups demonstrated a statistically significant decrease in the test error count.

**Conclusions:** Virtual reality in the form of video games played on an Xbox 360 Kinect console may be an effective method of balance training in healthy individuals.



## INTRODUCTION

Computer technology has been rapidly evolving over the past few decades. Virtual reality has come to be used in many aspects of everyday life, including physiotherapy. The use of video games to promote physical activity is an extensive field associated with virtual environment-based rehabilitation[1]. Video games may be used as a form of training for healthy individuals or as a form of physiotherapy for patients diagnosed with musculoskeletal disorders.

Video games are employed in rehabilitation to increase muscle strength, general fitness, balance, motor coordination and for other purposes. They may be combined with conventional rehabilitation or used as an alternative[2].

Balance is defined as the ability to control the line of gravity against the base of support, which facilitates planning and performing movements to maintain vertical posture[3]. Balance enables the human body to maintain upright posture even in unfavourable external conditions. There is an association between balance, gait and activities of daily living[4]. The perfect combination of static and dynamic balance is essential to normally perform activities of daily living[5]. It is applied in both older[6] and young people who use specific mechanisms underlying balance control to maintain balance during ADLs[7].

Balance enables humans to stand still despite perturbations[8] and is essential to prevent falls in such conditions[9]. Postural balance is also fundamental for proper gait. If balance is affected, it might be compensated in gait by adjusting step length, width or time to prevent falls, even among young healthy individuals[10]. Apart from the basics, such as fall prevention, proper gait and ADL, good pos-

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tural balance is associated with better athletic performance[11].

An important issue is the need to motivate either healthy young or ailing elderly individuals to perform balance exercises. This is a reason for increasing the use of new, more patient-engaging methods of training or physiotherapy, such as virtual rehabilitation. Examining the effects of using virtual reality in training and physical therapy is critical, especially because there are already existing reports in which it is shown that VR training may be not only an effective tool in ameliorating different motor skills, but it can also be enjoyed more than other forms of training/rehabilitation[12,13,14]. As a product of the considerable progress in virtual reality and the development of portable devices, video games differ substantially from the expensive systems and robots used in virtual rehabilitation. Gaming systems provide the user with an avatar, i.e. an icon representing the person on a screen. Different game scenarios are available, varying according to the task performed. By using controllers while performing appropriate movements, the user can control an avatar displayed on the screen.

Two types of video games are utilised in physiotherapy. One comprises systems developed specifically for physiotherapeutic purposes[15], such as the Virtual Balance Clinic System[16], its use devoted to rehabilitation in postural balance disorders. The other type includes existing systems intended for entertainment, e.g., Nintendo Wii, Sony Play Station 2 Eye Toy and Microsoft Kinect[15]. The Xbox 360 Kinect used in the present study allows its users to control the console and interact with it through their natural movements, without having to touch the controllers. The device uses an RGB (red, green, blue) camera and a motion sensor to enable 3D detection of each movement performed by the user's body and recognise gestures[17].

The examination was executed on a young healthy population, which is a good reference group in investigating the effects of balance training. According to Cone et al., young healthy people are a good material for assessment because it is less common for them to have comorbidities and balance impairments, thus, even subtle improvement can be revealed. Additionally, it is likely that the improvement would be augmented in a population with impaired balance[7]. Although differently demonstrated, Heijnen et al. also suggested that young adults may provide a perfect population for establishing training parameters that are most efficient at reducing falls due to the high fall rates observed in their research among a young healthy population[18].

## OBJECTIVE

The aim of the present study was to assess the effects of Xbox 360 Kinect training on balance in young healthy individuals and compare virtual reality-based training to conventional exercises against a control group who did not perform any form of training. The following research questions were posed in the study:

Primary research question:

1. Does two-week Xbox 360 Kinect whole-body training improve postural balance on stable and unstable surfaces (measured by the Balance Error Scoring System (BESS) test) in young healthy adults?

Secondary research questions:

2. Does two-week conventional all-round training designed in the study improve postural balance on stable and unstable surfaces (measured by the BESS test) in young healthy adults?
3. Does two-week Xbox 360 Kinect whole-body training have a comparable or greater effect on postural balance on stable and unstable surfaces (measured by the BESS test) compared with two-week conventional all-round training designed in the study?

## METHODS

The study was approved by the Bioethics Committee of the Medical University of Warsaw on 18th February 2014, chaired by professor Bożena Tarchalska-Kryńska (approval No. KB/28/2014). Informed verbal consent was obtained from subjects. The procedures were performed in accordance with the ethical standards of the 1975 Declaration of Helsinki, as revised in 2008. The data were collected in the years 2016-2017 at the Division of Rehabilitation, Department of Physiotherapy, Faculty of Medical Sciences, Medical University of Warsaw.

The present study comprised 75 individuals (52 women, 23 men) who were recruited from students of the Medical University and randomly assigned to three equal groups by simple random sampling. The first group – Group VR, consisting of 25 participants (17 women, 8 men) performed whole-body exercises with an Xbox console; the second group – Group T, including 25 participants (15 women, 10 men) performed conventional all-round exercises. The third group – Group C, totalling 25 participants (20 women, 5 men) was the control. The inclusion criteria were age between 19 and 30 years and the absence of mechanical injuries sustained in the period of 3 months preceding the study. Before the examination was carried out, all participants completed a questionnaire concerning personal information, such as age, sex, body mass and height (from which BMI was calculated), frequency and type of physical activity, as well as type of work.

All study participants underwent two balance assessments on the Biodex Balance System posturographic platform. The experimental groups underwent Examination 1 before the commencement of the training programme, which lasted for 2 weeks. Examination 2 took place upon completion of the training programme. Group C was re-examined two weeks after Examination 1. The examination on the platform utilised the BESS test, which consists of the subject maintaining three positions:

1. double leg stance (feet together; hands on the hips);
2. single leg stance (standing on the non-dominant leg, hands on the hips);
3. tandem stance: standing heel to toe (the heel of the dominant foot

touching the toe of the non-dominant foot, with the hands on the hips)[19].

Each position was assumed twice on a firm and on a foam surface. In the course of each 20-second attempt, the subject had their eyes closed, and the examiner recorded the number of errors made during the attempt. The errors involved opening the eyes, taking the hands off the hips, making a step, stumbling or failing to maintain the testing position, lifting the forefoot or heel off, abducting the hip beyond 30° and the inability to regain the testing position for more than five seconds. Apart from recording the error count, sway index was calculated on the basis of the COG oscillation. In the period between the examinations, each group took part in a different type of training or no training.

Group VR performed exercises on the Xbox 360 Kinect console. Training was performed three times a week over a period of two weeks, with each training session lasting 30 minutes. Exercises were performed for 21 minutes because of the time needed for transitioning between games and the breaks needed for the participants who were playing games that were designed to be played in shifts. We assumed that during the 30-minute training session, transitions between games took approximately six minutes (approximately 45 seconds for one transition), while intervals during shifts took approximately three minutes. There were no planned sessions during the training; the breaks were applied according to the game's course. The study employed the Kinect Sports game, which simulates authentic sport games. The study used games such as boxing, track-and-field (in pentathlon form comprising the sprint, javelin throw, long jump, discus throw and hurdle race), table tennis, beach volleyball and football. These games were general strengthening exercises based on upper limb movements, body mass distribution and jumping. Through those movements, a user was thrown off balance and thus, had the opportunity to train balance. The games were played in pairs, which allowed competition between participants and seemingly led to greater enjoyment of the training. The Xbox Kinect console and sensor were arranged in specific orientation. The playing area was three x four metres, and the distance between the participants and the Kinect sensor was approximately two metres. Group T performed conventional all-round exercises in the form of circuit station training. The training also included general strengthening exercises, which affected a user in a manner similar to that of the virtual training. A list of all performed exercises in group T is presented in Table 1. As in the previous group, the training took place three times a week over a period of two weeks; each training session lasted approximately 23 minutes, and the exercises were performed for 21 minutes. The subject performed exercises at each station for one minute. Seven exercises were performed during each training session. Each exercise was repeated three times during one training session. There was one minute of rest between every set. In Week 1, the participants performed a different set of exercises on each day. In Week 2, the exercise sets from Week 1 were repeated in the same order in which they were performed in the previous week. The workout load was increased by increasing the level of difficulty of the exercises. All of the participants in the experimental groups had an approximately five-minute warm-up before the exercises began and five minutes of cool-down after the training, both of which were self-directed. Group C did not perform any form of exercise. The difference in training duration for the experimental groups was due to the time needed for transitions between games and the break for the VR group during games played in shifts.

Statistical analysis of the results was conducted with Statistica 13.1 software, the level of statistical significance set at 5% ($P$-value<.05). The key parameters of those listed above were tested to determine if the distribution of the values obtained in the study approximated normal distribution. The Shapiro-Wilk test was used as a test for normality. As eight out of a total of 36 parameters studied were not distributed normally, we decided to use nonparametric tests for the analysis. Thus, Wilcoxon's signed-rank test was used to compare pa-



**Table 1**

**Conventional group workout**

| Day one | Day two | Day three |
|---|---|---|
| Sprinting in place | Sideway lunges, switching legs | Jumping in place on one leg with arm circles |
| Boxing in the air with both arms | Scissors with both legs and arms | Arm circles with one arm forward and the other arm backward |
| Forward lunges, switching legs | Jogging in place with backwards arm circles | Jumping upwards with a 180-degree turn |
| Gluteal bridges | Side plank, switching sides halfway through the exercise | Front plank |
| Ball throw – throw ball upwards, clap 3 times, catch ball | Jumping sideways in place | Handing a ball from one hand to the other in front of and behind the trunk |
| Tennis ball bounce, switching hands | Tennis ball throw with one hand, catch with the other hand | Tennis ball throw from one hand to the other |
| Jumping in place on both legs | Trunk rotations | Bent trunk rotations |

rameter changes between Examinations 1 and 2, while the Kruskal-Wallis ANOVA was implemented to compare differences among the groups (it served to show whether the groups differed prior to the intervention).

## RESULTS

Demographic characteristics and physical activity frequency for all groups are presented in Table 2.

None of the groups achieved a statistically significant change in the error count on the BESS test or a change in the sway index on the stable surface. Group T was the only one to demonstrate a statistically significant decrease in the sway index on the unstable surface ($p=0.002$). The experimental groups (VR and T) showed statistically significant decreases in the mean sway index in the test on both the stable and unstable surfaces (group VR – $p=0.035$; group T – $p=0.001$), while Group C did not achieve any statistically significant change. Moreover, the error count on the unstable surface and the total error count in group VR was of borderline statistical significance (as follows: $p=0.061$; $p=0.063$). The changes in the mean sway index in individual groups between Examination 1 and Examination 2 are shown in Figure 1. The statistical significance of the changes in specific parameters between Examinations 1 and 2 is demonstrated in Table 3.

The Kruskal-Wallis ANOVA revealed that some of the results were significantly different between the groups at baseline. Error count on an unstable surface (the difference occurred between group T and group C); sway index on an unstable surface (the difference occurred between group VR and group C and between group T and group C) and the mean sway index (the difference occurred between group VR and group C and between group T and group C). Consequently, it was impossible to compare the parameter changes that occurred between Examinations 1 and 2 among the individual groups.

## DISCUSSION

A review of the literature shows that the majority of studies including balance training are focused on elderly populations, but there are several reasons why balance training should be implemented in young healthy populations. First of all, even though balance disorders are usually associated with the elderly population, they may also be a serious issue among young adults. Calderon-Garcidueanas et al. proved that approximately 75% of 575 seemingly healthy young urbanities exhibited gait and balance dysfunctions, which was associated with air pollution. Calderon-Garcidueanas et al. stated that there is a need for early recognition of gait and balance dysfunctions. In the study, it has been demonstrated that balance impairment may be present even if it is not expected[20]. This might be a reason for introducing young seemingly healthy subjects to the balance training programme. Balance disorders can cause an increased risk of falls, which may also affect young adults. Heijnen et al. noted that over half of the examined healthy subjects aged 19-20 experienced falls during a 16-week period of time. Interestingly, the falls were not correlated with weather conditions, the use of tox-

**Table 2**

**Average and standard deviation (SD) of specific demographic characteristics and the physical activity frequency**

| Group | Average age, standard deviation (*SD*) | Average BMI, standard deviation | Average physical activity frequency, standard deviation (*SD*) |
|---|---|---|---|
| Group VR | 21.68 ±1.75 | 22.15 ±3.07 | 2.68 ±1.52 |
| Group T | 23.0 ±1.23 | 22.31 ±2.71 | 2.42 ±1.42 |
| Group C | 20.96 ±1.88 | 22.80 ±2.83 | 3.0 ±1.22 |

Group VR – group that performed virtual reality exercises; Group T – group that performed conventional exercises; Group C – control group. BMI – body mass index.

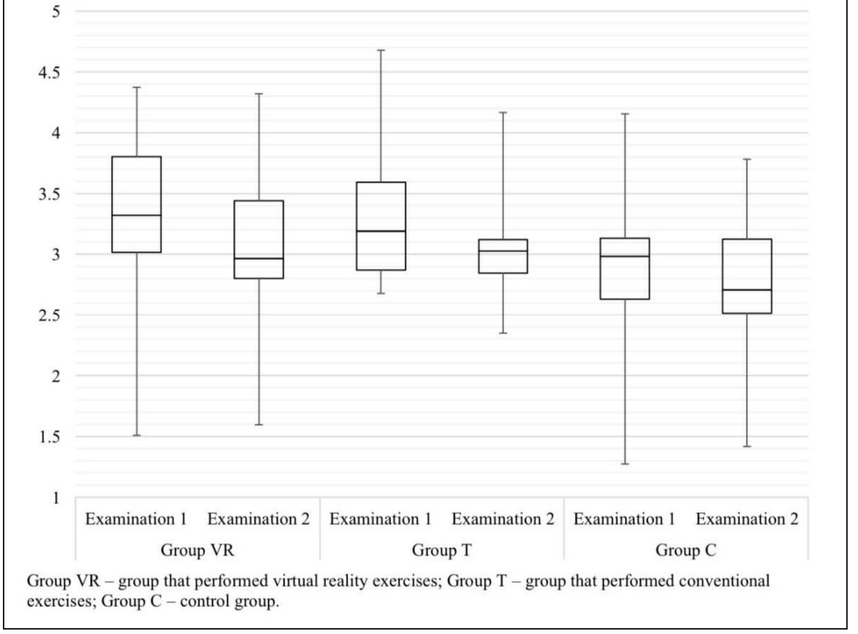


**Figure 1**

**Changes in sway index between Examination 1 and 2 in Group VR, Group T and Group C on the basis of the maximum, quartile 1 minimum values**

**Table 3**

**Specific parameter values (average and standard deviation) during Examinations 1 and 2**

| Group name | Parameter compared in Examination 1 and 2 | Examination 1 (average ± *SD*) | Examination 2 (average ± *SD*) | *p*-value |
|---|---|---|---|---|
| Group VR | Total error count on a stable surface | 3.3 ±2.3 | 2.7 ±2.5 | 0.279 |
| | Total error count on an unstable surface | 13.1 ±3.5 | 11.8 ±3.6 | 0.061 |
| | Total error count | 16.5 ±4.8 | 14.5 ±5.3 | 0.063 |
| | Mean sway index on a stable surface | 2.4 ±0.5 | 2.2 ±0.5 | 0.072 |
| | Mean sway index on an unstable surface | 4.1 ±0.9 | 4.0 ±0.7 | 0.074 |
| | Mean sway index | 3.3 ±0.6 | 3.1 ±0.6 | *0.035* |
| Group T | Total error count on a stable surface | 3.8 ±2.6 | 3.7 ±3.4 | 0.553 |
| | Total error count on an unstable surface | 14.1 ±3.3 | 13.3 ±3.3 | 0.143 |
| | Total error count | 18.0 ±4.2 | 16.9 ±5.5 | 0.225 |
| | Mean sway index on a stable surface | 2.4 ±0.5 | 2.3 ±0.6 | 0.093 |
| | Mean sway index on an unstable surface | 4.2 ±0.7 | 3.8 ±0.4 | *0.002* |
| | Mean sway index | 3.3 ±0.5 | 3.0 ±0.4 | *0.001* |
| Group C | Total error count on a stable surface | 3.3 ±2.5 | 2.4 ±2.6 | 0.127 |
| | Total error count on an unstable surface | 11.3 ±3.6 | 11.7 ±4.4 | 0.549 |
| | Total error count | 14.6 ±5.1 | 14.1 ±5.7 | 0.549 |
| | Mean sway index on a stable surface | 2.3 ±0.6 | 2.1 ±0.4 | 0.158 |
| | Mean sway index on an unstable surface | 3.5 ±0.7 | 3.4 ±0.7 | 0.074 |
| | Mean sway index | 2.9 ±0.6 | 2.8 ±0.5 | 0.074 |

Group VR – group that performed virtual reality exercises; Group T – group that performed conventional exercises; Group C – control group. The *p*-value is based on the Wilcoxon signed-rank test



ic substances, multi-tasking or physical activity level, and most of them occurred during walking[18]. Prevention is a key factor in minimising the possible negative consequences of a fall. In the study by Park et al.[21], it was demonstrated that there are some postural sway and spatial gait measures that show a linear deterioration across the adult age span, starting at the young age of 21. The prevention of balance disorders can start at any moment of a person's life, regardless of the moment when the first falls occur. Therefore, implementing balance training is essential among young adults and elderly individuals. Implementing balance training in young healthy adults is also a good tool for the prevention and treatment of mechanical injuries[22]. Muscle fatigue is one of the few factors deteriorating postural balance parameters in young healthy subjects as well as in elderly individuals. The effects of fatigue are even more pronounced for young people[23]. General and local muscle fatigue may cause postural balance deficits among young, healthy athletes, which may lead to a higher risk of injuries. Adaptations, such as proper rest after aerobic exercises and inclusion of postural balance practice, are needed for injury prevention[24]. Balance training is essential for young athletes. In their systematic review on the effects of balance training on balance performance and their dose–response relationship in youth, Gebel et al.[25] indicated that balance training improves static and dynamic balance in youth and that balance performance is a prerequisite for becoming a professional athlete. Furthermore, there is a serious civilization issue – a sedentary lifestyle – which is associated with the use of modern technologies. In research on the subject, it has been shown that a prolonged duration of smartphone or computer use by young healthy subjects may result in a faulty posture, which leads to a reduction in postural balance ability[26,27]. A sedentary lifestyle causes a decline in postural balance among young healthy individuals compared to their physically active peers[28,29]. This suggests that physical activity and balance training should be encouraged in young healthy populations. Good balance performance is needed for a large number of recreational activities with extensive movements in different directions, as they result in large displacement of centre of mass. Balance training helps improve balance maintenance in such conditions[30]. Balance training in young and healthy people is also important from the perspective of balance disorder prevention in an older age. Sundstrup et al.[31] suggested that lifelong training may influence postural balance in the future. Prasertsakul et al.[32] proved that balance training in virtual reality performed by healthy adults can act as fall prevention in the future. Moreover, balance training among young adults can improve motor coordination[33], cognitive functions, such as memory or spatial cognition[34], the symmetry of strength on both sides of the body[35], proprioceptive input, reaction time, specified muscular strength[30] or jumping height[36].

A review of the literature allows to indicate that virtual reality-based training may be successfully administered in old[37,38] young[12,13,14,39,40,41], healthy[12,13,14,37,40,41] and ailing[42] individuals, or those who have sustained a mechanical injury[39]. Virtual reality training has also been found to be effective in improving balance as well as gait, reach and muscle strength[43] as well as cognitive function in elderly individuals[44]. Among young adults with a sedentary lifestyle, virtual reality training increases physical activity, improves physical and motor skills as well as self-perception[45] and provides enjoyment to users[46]. The results of the present study were compatible with other research, in which improvement was shown in maintaining balance for both virtual reality and traditional training groups measured among young healthy adults[12,13,40], whereas different types of virtual reality equipment were used – Nintendo Wii[12,40] and wobble board exergaming system[13]. Similar findings were described by Cone et al.[7] – although the study did not involve a traditional training group, dynamic balance in young healthy adults was significantly improved in the Wii Fit exergaming group. One of the main limitations of the present study was the impossibility of comparing both training groups and the control group due to the differences between groups of these groups at baseline. Accordingly, Ibrahim et al.[12], Fitzgerald et al.[13] and Vernadakis et al.[40] indicated that despite the improvement of balance, there were no significant differences between the two training programmes[12,13,40]. There is much less research about balance training among young healthy adults, which used the Xbox Kinect console for exergaming. Barry et al.[14] showed a significant between-group postural control improvement in favour of exergaming. Interestingly, in the study by Barry et al.[14], exactly the same exercises were used in virtual reality and traditional-based training; the only difference between interventions was the presence and absence of virtual stimuli, while the present study used similar exercises; they slightly differed between groups. Similar to the present study, Su et al.[41] investigated the effect of video games on agility and balance in young healthy individuals, but their study consisted of two groups – the Xbox Kinect group and the control group, which received no training. Despite improved dynamic balance in the Xbox Kinect group, the study did not reveal any between-group differences in static balance, in contrast to the present study, which demonstrated improvement in sway index with regard to static balance in both experimental groups, unlike the control group. An interesting approach was presented by Su et al.[41], who conducted a follow-up examination after two and four weeks of a six-week training programme. They found incremental improvements in balance parameters at each examination.

Apart from the balance examination, only in a few studies were the psychological aspects of the training evaluated[12,13,14,47]. Most of them indicated a considerable difference with regard to psychological aspect in favour of virtual reality training[12,13,14], despite no between-group differences in training effectiveness on balance[12,13]. The differences were: a greater score in interest and enjoyment[12,13], lower sense of fatigue[12], higher performance expectancy, behavioural intention and social influence[14]. Additionally, in the study by Barry et al.[14], flow experience (task concentration, ease in playing, clear feedback, action awareness, altered perception of time and feeling immersed in the activity) was significantly higher in the Xbox Kinect group. The results show that virtual reality-based training may be an interesting and encouraging way to insert balance exercises in the training of young healthy adults. In contrast, Kliem et al.[47] did not demonstrate any improvement in the well-being of the individuals exercising with the Wii Nintendo console. This divergence may result from a difference in the mean age of examination participants – while in the first three studies[12,13,14] mostly young adults in their twenties and thirties were examined, the study by Kliem et al.[47] involved subjects with a vast age range – 18-67 years old. Interestingly, according to Subramanian et al.[48], motivational factors for playing exergames differ between young and older adults. While older people are motivated by the joy of playing and anticipated positive health effects, younger people's motivation is based on a game challenge, in-game rewards and the ability to personalise games. With reference to the above, the present study used Kinect Sports with a competitive mode, providing a game challenge for young people. Kinect Sports also uses in-game rewards, such as visual information about competition victory, scoring a goal, breaking a record, etc., followed by a celebratory music piece. Moreover, at the end of each performance, users can watch a short video clip of their best achievement, which can be downloaded or shared on social media. This fulfils the need of young players to personalise games.

The present study had a few limitations. One of them was the impossibility to compare the effects of the intervention between groups due to the differences that occurred between the groups at baseline. The randomisation did not work possibly due to an unknown variable, which appeared as a confounder. According to Saint-Mont's[49] mathematical models, in small and medium-sized samples, random allocation generally demonstrates between-group imbalance.

Another limitation of the present study is the fact that some of the results, such as the error count on the stable surface, total error count and mean sway index on the stable and unstable surfaces in Group VR, as well as the mean sway index on the stable surface in Group T, were of borderline statistical significance. It is probable that, with a larger sample, the changes could be statistically significant and show a decrease in both the total error count and sway index, which should be confirmed in further research.

Additionally, the duration and intensity of the training was a limitation of the present study. In studies investigating virtual reality balance training effectiveness on young healthy adults, four[12,13,14], six[7,41] or even eight weeks of training were applied[40]. The above overview of the literature reveals that the shortest number of studies involved three weeks of training[47]. If the training programme administered in this study had lasted longer or been more intensive, the results would have probably revealed a more pronounced difference between the interventions. Further studies should be performed to establish how the increased frequency or intensity of training affects balance. The differences between the two experimental groups under the same conditions should also be compared.

Although in the majority of studies it is demonstrated how effective balance training is after four or more weeks, there are reports indicating that it may be effective even after two weeks[50]. Su et al.[41], who investigated the effect of video games on agility and balance in healthy individuals, showed that virtual reality can improve balance after six, four or even two weeks. The present study was focused on two weeks of training to measure the shortest possible training time for balance improvement in young healthy adults.

## CONCLUSIONS

In the study, primary and secondary research questions were verified. In conclusion, the study results allow to confirm that two-week Xbox 360 Kinect whole-body training improves postural balance on stable and unstable surfaces in young healthy adults. Also, two-week conventional all-round training designed in the study improved postural balance on stable and unstable surfaces. Unfortunately, the comparison between these two types of training was impossible due to the identified differences between the groups at baseline.

Concluding, virtual reality in the form of video games played on the Xbox 360 Kinect console may be an effective method of balance training in young healthy adults. Additionally, it is likely that video game-based balance training may increase the motivation to exercise. This aspect requires further research.

The results obtained in the present study provide a basis for continuing randomised prospective studies on the use of virtual reality techniques in balance training, both as "monotherapy" and in combination with conventional exercises.

**Supporting Information**

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