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The effect of virtual reality exercise on physical fitness

Wpływ ćwiczeń z wykorzystaniem wirtualnej rzeczywistości na sprawność fizyczną u osób zdrowych

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Key words
virtual reality, exergaming, Senior Fitness Test, physical fitness

Abstract
Introduction: The aim of this study was to assess physical fitness (PF) in healthy volunteers using the Senior Fitness Test (SFT) after a series of training sessions in virtual reality (VR) using the X-box 360 Kinect System.
Materials and methods: This pilot study consisted of 32 healthy subjects aged 19 to 24 years (12 males and 20 females) with the mean age of 20.6±1.4 years and the mean BMI of 23.29±2.3. The subjects participated in the study for 2 weeks, at a frequency of 4 sessions weekly. Each session comprised 4 Kinect Adventures games: 20 000 Leaks, Curvy Creak, Rally Ball and Reflex Ridge. The Senior Fitness Test was used to assess physical fitness.
Results: Analysis of data showed improvement in Arm-Curl (30.0 repetitions (rep.)) vs. 35.8 rep., $p<0.001$), Chair Stand (26.6 rep. vs. 30.2 rep., $p<0.001$), Back Scratch (3.1 cm vs. 6.1 cm, $p<0.033$), Chair Sit-and-Reach (1.0 cm vs. 5.3 cm, $p<0.001$), Up-and-Go (3.5 sec. vs. 3.2 sec., $p<0.001$) and 6-Minute Walk Test (731.3 m vs. 747.8.m, $p<0.220$). Statistically significant improvement was noted in 5 out of 6 STF trials. Only the 6-Minute Walk test results were not statistically significant.
Conclusions: Training using a console with the Kinect motion sensor had positive effects on the physical fitness of the healthy volunteers.

Słowa kluczowe
wirtualna rzeczywistość, exergaming, Senior Fitness Test, sprawność fizyczna

Streszczenie
Wstęp: Celem badań była ocena sprawności fizycznej (SF) u osób zdrowych z wykorzystaniem Senior Fitness Testu (SFT) po serii sesji treningowych w wirtualnej rzeczywistości (WR) z wykorzystaniem systemu X-box 360 Kinect.
Materiał i metody: W badaniu pilotażowym wzięły udział 32 zdrowe osoby w wieku od 19 do 24 lat (12 mężczyzn i 20 kobiet), ze średnią wieku 20,6 (±1,4) lat oraz ze średnim BMI 23,29 (±2,3). Badani uczestniczyli w projekcie przez okres 2 tygodni, z częstotliwością 4 dni w tygodniu. Każda sesja obejmowała 4 gry Kinect Adventures: 20 000 Przecieków, Rwąca Rzeka, Odbijana Piłka, Grań Refleksu. Do oceny sprawności fizycznej wykorzystano Senior Fitness Test.
Wyniki: Analiza danych wykazała poprawę wyników w próbach: Podnieś Ciężarek (30,0 powtórzeń (rep.)) kontra 35,8rep., $p<0,001$), Wstań i Siądź (26,6 rep. kontra 30,2 rep., $p<0,001$), Złącz Dłonie (3,1 cm kontra 6,1 cm, $p<0,033$), Sięgnij Ręką Stopy (1,0 cm kontra 5,3 cm, $p<0,001$), Wstań i Idź (3,5 sec. kontra 3,2 sec., $p<0,001$) i 6-Minutowym Marszu (731,3 m kontra 747,8 m, $p<0,220$). Istotna statystycznie poprawa nastąpiła w 5 z 6 prób testu SFT. Jedynie wyniki próby 6-minutowego marszu okazały się nieistotne statystycznie.
Wnioski: Trening z wykorzystaniem konsoli z sensorem ruchu Kinect wpłynął na poprawę sprawności fizycznej u osób zdrowych.

The individual division of this paper was as follows: A – research work project; B – data collection; C – statistical analysis; D – data interpretation; E – manuscript compilation; F – publication search

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INTRODUCTION

According to the World Health Organization (WHO), people aged 18-64 years should perform at least 150 minutes of moderate-intensity physical activity (PA) weekly, which can be estimated at about 30 minutes a day. The definition of PA is all bodily movement produced by the skeletal muscles that requires energy expenditure. To gain additional profits and health benefits, it is recommended to achieve at least 300 minutes of moderate-intensity activity weekly and muscle-strengthening activities at least 2 days per week[1,2]. Physical activity allows to avoid excessive body fat[2-4]. Regardless of age, regular physical activity has many benefits, including those preventive against injuries and diseases. It also allows improvement of musculoskeletal condition, muscle strength and their endurance, reducing the risk of heart diseases and carcinogenic changes, improving psychophysical conditions[1,5]. Physical activity can be divided into two forms of movement. First is a group of different activities which include those recreational, such as shopping, walking, getting to work or housekeeping, but also sport participation and exercising that is planned, structured and repetitive PA, the purpose of which is to improve one or more components of physical fitness. The second form of PA is spontaneous physical activity (SPA), which means every kind of low-energy body motion during the day that is not motivated by any goal or even an individual's consciousness[1,6].

Technological development has been observed during the last decade in many fields of science. Computer games generally used to focus a gamer's attention and concentration on the virtual scenarios were mostly limited to mouse or keyboard control. Nowadays, important changes can be observed in this field, games have improved in terms of virtual interaction engaging players through their immersion. Despite having to learn to control the character with one's own body which requires time and practice, it is not an obstacle for young or older people to participate in this kind of physical activity and can be treated as an additional challenge[7].

Nowadays, virtual reality can be used as an unusual type of physical activity defined as more attractive than standard type of training[8,9]. Moreover, VR has the potential to aid weight loss and encourage initiation of regular physical activity through the new stimuli it provides the mind and body of the player[8,10-12]. Also, in the field of rehabilitation, it has been observed that a potential of VR can be innovative treatment in a way to promote better patient outcomes and their engagement in PA. It is mainly used in neurological diseases such as stroke to promote re-learning of activities of daily living, functional recovery and patients' independence. Treatment is focused on practicing movements, improving motor control and restoring or re-educating function. It is worth drawing attention to new stimuli that patients receive via VR and which they can not experience in reality. In this way, VR motivates them to move and achieve lost function. Such a form of rehabilitation stimulates the neuromuscular system by training the neuroplasticity of patients' brains which can help them to improve their PF[13-18]. It can be assumed that VR is a type of physical activity that might be undertaken more often and more preferably than usual exercises. The advantages of VR as a way to promote movement activity has been noted, but the question is of how it affects the body's condition and how it influences the physical fitness of young, healthy people?

STUDY AIM

The aim of this study was to assess physical fitness in healthy volunteers after a series of exergame training sessions in virtual reality using the Xbox 360 console with the Kinect motion sensor.

MATERIALS AND METHODS

The study consisted of 32 people aged 19 to 24 years (12 males and 20 females). In the study group, the mean age was 20.6±1.5 years and the mean BMI was 23.3±2.3 (Table 1). This study included females and males aged 19-24 years that did not undertake regular physical activity and were non-users of any exergames. The exclusion criteria in this study included diseases and injuries of the musculoskeletal system impairing locomotion function which would preclude active participation in the study and testing. All participants agreed to participate in the study and informed consent was obtained from all of the subjects. The study was conducted at the Faculty of Physical Education and Physiotherapy at Opole University of Technology. The subjects participated in the study for 2 weeks, at a frequency of 4 days a week. The study was approved by the Bioethics Committee of the Opole Chamber of Physicians in Opole based on Resolution No. 243 from April 6, 2017. The study was conducted using the Kinect Adventures game, provided by the manufacturer, Microsoft. The game was played using the XBOX 360 console with the Kinect motion sensor. The Kinect motion sensor records the player's movements and creates a body map which is then animated into his/her character in the game, replicating his/her every movement. Each game was played at the basic level, targeted at a specific physical activity such as lateral weight shifting, side/forward/backward stepping, squatting, and coordinated upper limb movements[19]. The study was based on 4 games, each engaged different forms of activity listed below:

1. 20,000 Leaks

The player was locked in a glass cube at the bottom of the ocean. The play-

Table 1

Demographic characteristics. Standard Deviation (*SD*)

Group	Age±*SD*	BMI±*SD*
Women	20.45 ±1.5	23.1 ±2.42
Men	20.83 ±1.47	23.65 ±2.13

er's task was to clog the cracks created underwater with his/her limbs, head or chest. The player received feedback in form of a score which was related to the velocity of movement. In this game, movement tasks were focused on improving agility, dynamic balance, strengthening the lower and upper limbs and improving endurance.

2. Curvy Creak

The player stood on a raft which flowed with the current of the river. The player's task was to control the raft in order to avoid obstacles and collect as many points as possible. In order to control the raft, the player must use his/her whole body, transferring his/her weight, moving from one side to the other and jumping. In this game, movement tasks were focused on improving trunk control and weight-shifting while leaning and reaching along the body. The aim was also improving endurance.

3. Rally Ball

The player stood in a small tunnel at the end of which there were wooden crates. The player's task was to hit the ball with the limbs, head or trunk to destroy the crates as quickly as possible. The player received points for every destroyed crate, the faster s/he destroyed the crate, the more points were collected. In this game, movement tasks were focused on increasing eye-hand coordination, motor planning and timing while reaching for balls. It was also aimed at improving endurance.

4. Reflex Ridge

The player stood on a moving platform. The player's task was to avoid the obstacles placed on the tracks by dodging, squatting and jumping. Simultaneously, the player had to collect as many points as possible which were also situated on the tracks. An important aspect of this game was reflex and getting to the end of the tracks as quickly as possible. In this game, movement tasks were focused on improving motor planning and timing during movement transitions. Increasing body awareness and coordination while dodging obstacles was also of importance, as well as increasing lower limb strength and endurance. Improving balance and weight-shifting while avoiding obstacles was also taken into account.

Senior Fitness Test

The SFT, previously known as the Fullerton Test, was used to evaluate physical fitness and assess 6 motor abilities: strength, flexibility, body efficiency, agility, balance and coordination. SFT was widely used as an assessment tool in research related to the effects of specific training programmes among healthy adults or in rehabilitation[20, 21, 22, 23, 24].

The Senior Fitness Test consists of the following tests:

1. The Arm Curl Test

Evaluation of upper body strength. The subject sat with his/her back straightened, feet resting against the floor. This test requires repeatedly lifting a 2 kg (women)and 3.5 kg (men) weight using the stronger upper limb.

2. The Chair Stand Test

Evaluation of lower body strength. The number of full uprisings from a chair within 30 sec. with the upper limbs crossed on the chest was measured.

3. The Back Scratch Test

Evaluation of upper body flexibility. The participant tried to bend one upper limb over the shoulder and straighten the opposite side up the middle of his/her back, both bent at the elbow. The distance between the tip of the fingers was measured (+ or -).

4. The Chair Sit-and-Reach Test

Evaluation of lower body flexibility. The subject sat on the edge of a chair with one leg extended forward with the knee straightened. Subsequently, the subject bent at the hip and the distance between the tip of the fingertips and the toes (+ or -) was measured.

5. The Up-and-Go Test

Evaluation of agility and dynamic balance. The time it took the subject to stand up, walk 8 feet (2.44 m), return back and sit down was measured.

6. The 6-Minute Walk Test

Evaluation of exercise tolerance. The distance covered by the participant during the 6-minute period was measured.

Statistical methods

The test results were collected on an Excel spreadsheet and then submitted to the STATISTICA 13 programme for statistical analysis. The basic characteristics were the measurable features, i.e. mean and standard deviation. Variable analysis was performed and after testing, the sample size normality of distribution was tested with the Shapiro-Wilk test. Analysis of the differences in the Senior Fitness Test results was evaluated with the use of Wilcoxon signed rank test. The statistical test significance was set at $p<0.05$. In order to evaluate the changes for each of the measured parameters before and after the intervention in both groups, the relative (percentage) change rate was

Table 2

Evaluation of Senior Fitness Test

SFT indicator	Pre	Post	*p*-value	Percentage improvement
Arm Curl	30.0 ±6.1	35.8 ±8.0	0.000	19.3%
Chair Stand	26.6 ±7.1	30.2 ±5.9	0.001	13.5%
Back Scratch	3.1 ±7.8	6.1 ±6.0	0.047	96.8%
Chair Sit-and-Reach	1.0 ±9.2	5.3 ±10.0	0.000	430%
Up-and-Go	3.5 ±0.5	3.2 ±0.4	0.001	9.4%
6-Minute Walk Test	731.3 ±74.0	747.8 ±103.1	0.064	2.3%

used. Percentage change in the tested parameter was derived from the following formula:

$$x\ [\%] = \frac{x_k - x_p}{x_p} \times 100\ [\%]$$

x – percentage change
x_k – average value before treatment
x_p – average value after treatment

RESULTS

Within the group, analysis of the Senior Fitness test showed statistically significant improvement in 5 of its components. Only in the 6-Minute Walk Test the were results not statistically significant (Table 2) (Figure 1).

DISCUSSION

In all SFT components, the average values of indicators determining physical fitness improved. In 5 out of the 6 tests were the results statistically significant. Only in the 6-Minute Walk Test did the results not show statistical significance. It is probable

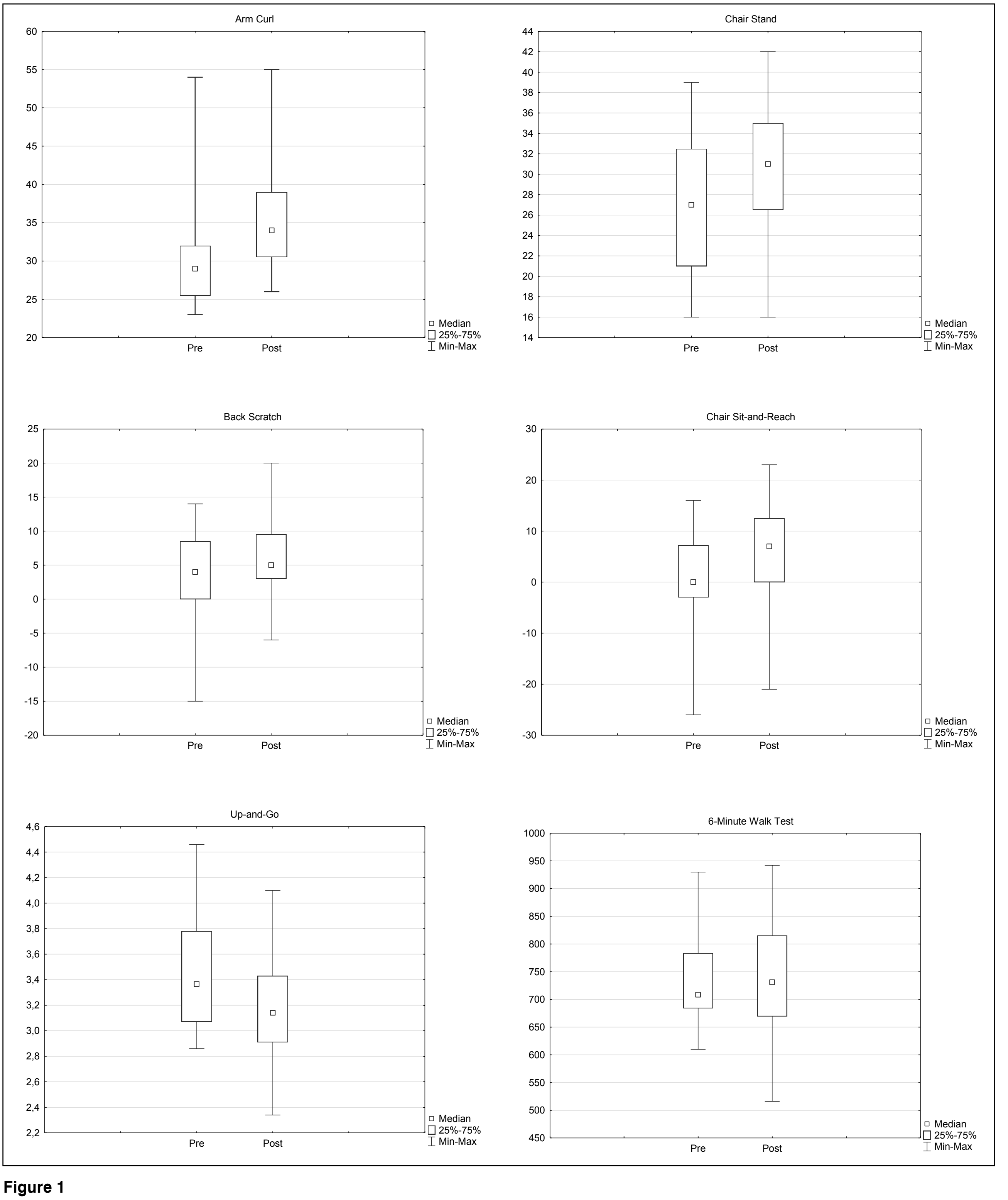

Figure 1
Evaluation of Senior Fitness Test

that the training session was not long enough to improve volunteers' exercise capacity.

The findings of this research are relative to previously conducted studies in this field and predict positive results of using virtual reality as a form of physical activity. It was observed that even a short period of VR interaction improved physical fitness in healthy young people. Several studies showed that the use of VR training could be promising for future exercise implementation and encourages carrying out physical activity by the younger generation[11,12]. The reviews by Gao and Sween et al. show that nowadays, exergaming is chosen more often and more preferably than usual video games[25,26].

Gao et al. conducted a study using the Dance Dance Revolution (DDR) exergame, testing its effectiveness on overweight Latino school children who participated in a 30-minute DDR-based exercise programme 3 times per week for 9 months. The data analysis showed improvement in children's cardiorespiratory endurance over time[5]. Similar results were obtained by Chen et al., comparing the effect of a Kinect active videogame with the Sports, Play and Active Recreation for Kids (SPARK) intervention. The main performance tests were the 15-m Progressive Aerobic Cardiovascular Endurance Run, curl-ups, and push-ups. The study showed children's improved cardiorespiratory fitness while maintaining PA enjoyment which was higher than in the SPARK group[27]. Roopchand-Martin et al. studied students' sedentary lifestyle and applied VR training for a 6-week period using the game Just Dance 4 on the Xbox 360 with Kinect motion sensors. Significant improvement was noted in maximal oxygen consumption and resting heart rate. Moreover, participants' flexibility improved, which is in line with our findings[28]. A study conducted by Ni et al. precisely describe effects on physical activity after a VR intervention using the Kinect Adventures. This study suggests that regularly playing active video games, in the short term, may have positive effects on children's overall physical activity levels reducing sedentary screen time while satisfying the need to play computer games. Furthermore, it was proven that even a short exergame session leads to the recommended intensity of PA[29].

A study conducted by McNarry et al. comprised of 34 prepubertal children who completed an exergame session using the Kinect Adventures. The physical activity yielded 5.7±1.5 and 5.5±1.4 metabolic equivalents (MET)[30]. Similar effects were observed in a study conducted by Reading and Prickett comprised of children aged 5-12 years who participated in a Kinect Adventures game session. The study found that average energy expenditure during the game yielded >3MET[31]. PA in both exergame training studies was specified as moderate-intensity which overlaps with physical activity guidelines[1].

Previous research comprised mostly young and healthy volunteers. However, virtual reality demonstrates a promising future not only in this scope but also in therapy or the field of rehabilitation field. A study conducted by Vernadakis et al. proved that VR exercise using the Kinect motion sensor has a positive effect on the level of enjoyment from exercising. The enjoyment was measured using the Physical Activity Enjoyment Scale (PACES). The level of satisfaction was statistically greater in the group using the Kinect motion sensor than in the group that underwent traditional physiotherapy[9].

Positive results were obtained in the study by Pompeu et al. The study comprised of 7 people with state 2 and 3 Parkinson's disease playing 4 games of the Kinect Adventures using the XBOX 360 Kinect motion sensor. Significant improvement was noted in the game scores as well as in the 6-Minute Walk Test and the clinical tests used to assess the physical performance of people with Parkinson's disease[32]. Similar effects were demonstrated in a study conducted by Jo et al. conducted among Koreans with schizophrenia using Nintendo WiiFit. The study found that virtual reality can be used to improve physical fitness and as an alternative form of regular physical exercise for patients with schizophrenia[33].

Based on the results of this study and an overview of literature, it appears that the use of virtual reality and exergaming contributes to increasing the level of physical activity and physical fitness in healthy people. Moreover, it seems that VR has positive effects on people with various diseases and is also successfully used in the field of rehabilitation. Nonetheless, further research should be carried out on the effectiveness of long-term effects of this type of training or rehabilitation.

Limitations

The Senior Fitness Test used in this study was a non-specific test due to the overall fitness presented by young people. Further research should be carried out using more reliable tests or indicators to asses youth physical fitness. This study did not involve a control group, which is the next step in this research.

CONCLUSIONS

Training using a VR console with the Kinect motion sensor had positive effect on physical fitness in young healthy people.

Conflicts of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

References

1. Global Recommendations on Physical Activity for Health. Geneva: World Health Organization; 2010. Available from: https://www.ncbi.nlm.nih.gov/books/NBK305057/?fbclid=IwAR1txSCJWNW8KvTX4aCSIS0AUR8-PG-PSVZNicQVtI6CkbVF4YWH1t6qQQ0A.
2. Haskell W.L., Lee I.M., Pate R.R., Powell K.E., Blair S.N., Franklin B.A., et al. Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. Med Sci Sports Exerc 2007; 39(8): 1423-1434.
3. Chin S.H., Kahathuduwa C.N., Binks M. Physical activity and obesity: what we know and what we need to know. Obes Rev 2016; 17(12): 1226-1244.

4. Meldrum D.R., Morris M.A., Gambone J.C. Obesity pandemic: causes, consequences, and solutions-but do we have the will? Fertil Steril 2017; 107(4): 833-839.
5. Gao Z., Hannan P., Xiang P., Stodden D.F., Valdez V.E. Video game-based exercise, Latino children's physical health, and academic achievement. Am J Prev Med 2013; 44(3 Suppl 3): S240-246.
6. Kotz C.M., Perez-Leighton C.E., Teske J.A., Billington C.J. Spontaneous Physical Activity Defends Against Obesity. Curr Obes Rep 2017; 6(4): 362-370.
7. Day B., Ebrahimi E., Hartman L.S., Pagano C.C., Robb A.C., Babu S.V. Examining the effects of altered avatars on perception-action in virtual reality. J Exp Psychol 2019; 25(1): 1-24.
8. Viana R.B., Vancini R.L., Vieira C.A., Gentil P., Campos M.H., Andrade M.S., et al. Profiling exercise intensity during the exergame Hollywood Workout on XBOX 360 Kinect®. PeerJ 2018; 6: e5574.
9. Vernadakis N., Derri V., Tsitskari E., Antoniou P. The effect of Xbox Kinect intervention on balance ability for previously injured young competitive male athletes: A preliminary study. Phys Ther Sport 2014; 15: 148-155.
10. Zeng N., Gao Z. Exergaming and obesity in youth: current perspectives. Int J Gen Med 2016; 9: 275-284.
11. McDonough D.J., Pope Z.C., Zeng N., Lee J.E., Gao Z. Comparison of College Students' Energy Expenditure, Physical Activity, and Enjoyment during Exergaming and Traditional Exercise. J Clin Med 2018; 7(11): 433.
12. Sun T.L., Lee C.H. An impact study of the design of exergaming parameters on body intensity from objective and gameplay-based player experience perspectives, based on balance training exergame. PLoS One 2013; 8(7): e69471.
13. Kiper P., Szczudlik A., Agostini M., Opara J., Nowobilski R., Ventura L., et al. Virtual Reality for Upper Limb Rehabilitation in Subacute and Chronic Stroke: A Randomized Controlled Trial. Arch Phys Med Rehabil 2018; 99(5): 834-842.e4.
14. Kiper P., Turolla A., Piron L., Agostini M., Baba A., Rossi S., et al. Virtual reality for stroke rehabilitation: assessment, training and the effect of virtual therapy. Med Rehabil 2010; 14(2): 23-32.
15. Kiper P., Szczudlik A., Mirek E., Nowobilski R., Opara J., Agostini M., et al. The application of virtual reality in neuro-rehabilitation: motor re-learning supported by innovative technologies. Med Rehabil 2013; 17(4): 29-36.
16. Kiper P., Szczudlik A., Venneri A., Stożek J., Luque-Moreno C., Opara J., et al. Computational models and motor learning paradigms: Could they provide insights for neuroplasticity after stroke? An overview. J Neurol Sci 2016; 369: 141-148.
17. Jastrzębski D., Żebrowska A., Rutkowski S., Rutkowska A., Warzecha J., Ziaja B., et al. Pulmonary Rehabilitation with a Stabilometric Platform after Thoracic Surgery: A Preliminary Report. J Hum Kinet 2018; 65: 79-87.
18. Mazurek J., Kiper P., Cieślik B., Rutkowski S., Mehlich K., Turolla A., et al. Virtual reality in medicine: Brief overview and future research directions. Human Movement https://doi.org/10.5114/hm.2019.83529
19. Paavola J.M., Oliver K.E., Ustinova K.I. Use of X-box Kinect Gaming Console for Rehabilitation of an Individual with Traumatic Brain Injury: A Case Report. J Nov Physiother 2013; 3: 129.
20. Jones J., Rikli R. Measuring functional fitness of older adults. J Active Aging 1 2002; 24-30.
21. Różańska-Kirschke A., Kocur P., Wilk M., Dylewicz P. Test Fullerton jako miernik sprawności fizycznej osób starszych. Med Rehabil 2006; 10(2): 9-16.
22. Rutkowska A., Rutkowski S., Pawełczyk W., Szczegielniak J. Test Fullerton w ocenie sprawności fizycznej chorych na POChP. Fizjoter Pol 2015; 4: 90-97.
23. Langhammer B., Stanghelle J.K. The Senior Fitness Test. J Physiother 2015; 61(3): 163.
24. Rutkowski S., Rutkowska A., Jastrzębski D., Racheniuk H., Pawełczyk W., Szczegielniak J. Effect of Virtual Reality-Based Rehabilitation on Physical Fitness in Patients with Chronic Obstructive Pulmonary Disease. J Hum Kinet 2019 DOI: https://doi.org/10.2478/hukin-2019-0022.
25. Gao Z. Fight fire with fire? Promoting physical activity and health through active video games. J Sport Health Sci 2016; 6(1): 1-3.
26. Sween J., Wallington S.F., Sheppard V., Taylor T., Llanos A.A., Adams-Campbell L.L. The Role of Exergaming in Improving Physical Activity: A Review. J Phys Act Health 2014; 11(4): 864-870.
27. Chen H., Sun H. Effects of Active Videogame and Sports, Play, and Active Recreation for Kids Physical Education on Children's Health-Related Fitness and Enjoyment. Games Health J 2017; 6(5): 312-318.
28. Roopchand-Martin S., Nelson G., Gordon C., Sing S.Y. A pilot study using the XBOX Kinect for exercise conditioning in sedentary female university students. Technol Health Care 2015; 23(3): 275-283.
29. Ni M.C., Maddison R., Jiang Y., Jull A., Prapavessis H., Rodgers A. Couch potatoes to jumping beans: a pilot study of the effect of active video games on physical activity in children. Int J Behav Nutr Phys Act 2008; 5: 8.
30. McNarry M.A., Mackintosh K.A. Investigating the Relative Exercise Intensity of Exergames in Prepubertal Children. Games Health J 2016; 5(2): 135-140.
31. Reading S.A., Prickett K. Evaluation of Children Playing a New-Generation Motion-Sensitive Active Videogame by Accelerometry and Indirect Calorimetry. Games Health J 2013; 2(3): 166-173.
32. Pompeu J.E., Arduini L.A., Botelho A.R., Fonseca M.B., Pompeu S.M., Torriani-Pasin C., et al. Feasibility, safety and outcomes of playing Kinect Adventures!™ for people with Parkinson's disease: a pilot study. Physiotherapy 2014; 100(2): 162-168.
33. Jo G., Rossow-Kimball B., Park G., Lee Y. Effects of virtual reality exercise for Korean adults with schizophrenia in a closed ward. J Exerc Rehabil 2018; 14, 39-48.

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