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INVESTIGATING EXERCISE INTENSITY IN VIRTUAL REALITY AMONG HEALTHY VOLUNTEERS

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ABSTRACT

Purpose. Currently, few studies have presented comprehensive reports on exercise intensity in virtual reality among healthy subjects. The aim of the paper was to evaluate the energy expenditure of young individuals during an active game in virtual reality.

Methods. A total of 32 healthy adults, 12 males and 20 females, were examined. Their mean age was 20.6 (± 1.4) years. The average BMI equalled 23.29 (± 2.3) kg/m^2. The subjects participated in 15-minute training sessions, with the frequency of 4 sessions weekly, for 2 weeks. Xbox 360® and Kinect® Adventures software were used for the virtual reality training. Energy expenditure expressed in kcal, metabolic equivalent of task (MET), and the number of steps were the primary outcomes. The SenseWear Armband was used to assess energy expenditure. The study applied the Xbox 360 console along with a Kinect motion sensor.

Results. During one day of training, the average energy value was 3.7 MET and 46 kcal. During one session, 318 steps were noted. The analysis of all predictors between trainings of each single day did not show any statistically significant difference.

Conclusions. Training in virtual reality with the application of the Kinect system provides health benefits and can be an alternative to traditional physical activity. However, 15 minutes of daily training cannot be the only basis for physical activity.

Key words: virtual reality, energy expenditure, active video games

Introduction

With the beginning of the 21st century, the era of technological progress has contributed to the development of virtual reality. Virtual reality can be explained as an artificial scenario generated by a technological system which combines specialized software and hardware [1]. We begin to perceive virtual reality in everyday life, and it enters the regions of science, particularly strongly as an unlimited didactic aid, which allows students to discover new opportunities in learning and improving their skills [2, 3]. Also in the field of physiotherapy, it is possible to notice the benefits offered by virtual reality. The advantages of this technology include graded levels of difficulty, ability to monitor task duration and intensity, as well as provision of feedback on errors and of tips and guidance on the movements performed. The points, badges, or distinctions that are gained while playing the games motivate the player to get fully involved and discover the next stages. Colours, sounds, and interesting designs of the virtual surroundings stimulate the interest of the player, who no longer pays attention to the actual physical activity and effort re-

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quired to play. This form of rehabilitation is much more interesting than traditional exercises, it can also bring greater effects [4–7].

More and more everyday activities can be done with a single click of the mouse or smartphone screen, which is the reason for a decrease in physical activity. Sedentary lifestyle has a harmful effect on health; it significantly increases the risk of metabolic syndrome [8, 9] and cardiovascular disease [10, 11] and indirectly affects mortality [12]. The new virtual reality technology provides support for novel and attractive forms of physical activity such as games or workout sessions. In addition, the system of rewards and achievements increases engagement and motivates participants to engage more actively in training sessions [13, 14]. High quality graphic design influences and reinforces the perception and can improve the mood. Active participation attracts people of all ages, providing a basis for health-related physical activity maintenance.

Physical activity includes all kinds of even the smallest movement causing energy expenditure. Thus, it is not only related to specific sports disciplines: an important role is also played by activities of daily living. According to the World Health Organization (WHO), 18–64-year-of-age categories should undergo daily physical activity and are recommended approximately 150 minutes per week of moderate physical activity. However, this can be replaced by 75 minutes of intense physical activity [15]. Physical activity has a positive effect on mood, it also leads to a number of beneficial consequences, in particular, it reduces stress [16] and improves wellbeing and memory [17]. WHO guidelines report that moderate energy expenditure is in the range of 3–6 metabolic equivalents of task (MET). A level below 3 MET is considered as mild physical activity, vigorous activity is an expense of 6–9 MET, and intensive effort is a level above 9 MET [15]. The division of activities can also be considered in terms of the number of steps taken during the day or the amount of burned kilocalories (kcal). Literature suggests that moderate physical activity occurs during the combustion of 3.5–7 kcal/min. Moreover, burning more than 7 kcal/min denotes an intensive effort. Some other recommendations defining the intensity of physical activity stated in the number of steps indicate that healthy people aged 20–50 years should perform 7000–13,000 steps a day. Those over 50 years should perform 6000–8500 steps a day, while children aged 12–16 years should perform 11,000–12,000 steps a day. It has also been shown that ⩾ 5000 steps per day are equivalent to no activity and a sedentary lifestyle, ≥ 10,000 steps imply active and ≥ 12,500 steps per day stand for highly active lifestyle [18].

Various configurations of systems enabling active gaming, so called exergaming, are available on the market. Some manufacturers have focused on involving only the upper limbs, using sensors placed in the hands of the players, while some require whole bodily movement during gameplay. Thus, different systems can offer various exercise intensity. Currently, few studies have presented comprehensive reports on exercise intensity in virtual reality; those studies concern mainly children. Therefore, it seemed justified to examine students as young people in a different age category according to WHO standards. It is assumed that students will achieve an intensive energy expenditure during active play in virtual reality and thus training in virtual reality will allow to obtain the recommended weekly physical activity.

The aim of the study was to evaluate the level of energy expenditure of young individuals during an active game in virtual reality. On this basis, the following hypothesis was adopted: H. Training in virtual reality for 5 days a week can lead to achieving intensive effort during 15 minutes of active gaming, thus contributing to the WHO weekly recommendations.

Material and methods

Participants

A total of 32 healthy adults, 12 males and 20 females, were examined. Their mean age was 20.6 (± 1.5) years. The average BMI of the group equalled 23.3 (± 2.3) kg/m^2. The subjects participated in the study for 5 days. The inclusion criteria were as follows: female or male aged 19–24 years, not practising regular physical activity and not practising sports for more than 30 minutes per week. The exclusion criteria involved diseases and injuries of the locomotor system impairing the function of locomotion, surgical procedures, diagnosed chronic disease, hospitalization within the 24 months before the study. The study was conducted at the Faculty of Physical Education and Physiotherapy at Opole University of Technology in April 2018.

Exercise intensity analysis

The SenseWear Armband was used to assess energy expenditure. Energy expenditure expressed in kcal, MET, and the number of steps were the primary outcomes. The device was placed on the arm of the dominant upper limb. It continuously measured physiological variables through algorithms which determined the number of steps, MET, energy expenditure, and kcal [19]. The validity of the SenseWear Armband was established in a previous study [20].

Virtual reality training

The study was conducted with the use of the Kinect Adventures game, provided by the manufacturer, Microsoft. The game involved the Xbox 360 console with a Kinect motion sensor. The Kinect motion sensor recorded the player's movements by mapping the body position. Afterwards, the player's avatar was visualized in the game, thus replicating each real movement. The study considered 4 mini-games (Kinect Adventures), which involved balance and coordination, speed and agility, reflexes, and fitness [21]. The main goal of each game was to avoid errors and complete the task in the shortest possible time. The minigames lasted about 3 minutes, and one training session did not exceed 15 minutes. Each participant played at the same level of difficulty.

20,000 Leaks

The player was locked in a glass cube at the bottom of an ocean. The task was to clog the cracks caused by underwater creatures with the player's limbs, head, or chest. The player received feedback in the form of a score related to the velocity of movement. In this game, movement tasks were focused on improving agility, dynamic balance, and endurance, as well as strengthening the lower and upper limbs.

Curvy Creak

The player stood on a raft which flowed with the current of the river. The 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 had to use their whole body, transferring the weight, moving from one side to the other, and jumping. In this game, movement tasks were focused on improving trunk control, weight-shifting, and endurance while leaning and reaching along the body.

Rally Ball

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

Reflex Ridge

The player stood on a moving platform. The 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; these were also situated on the tracks. An important aspect of this game was reflex and getting to the end of the tracks as soon 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, raising lower extremity strength and endurance, and developing balance and weight-shifting while avoiding obstacles.

Statistical methods

The test results were collected in an Excel spreadsheet and then submitted to the Statistica 13 software for statistical analysis. The basic characteristics were the measurable features, i.e. mean and standard deviation. Variable analysis was performed and after testing, the normality of sample size distribution was verified with Shapiro-Wilk test. Parametric tests were used. The one-way ANOVA was applied to assess the differences in the value of results. Statistical significance of the results was accepted at $p < 0.05$. The G*Power 3.1.7 software served to calculate the sample size. Calculation was based on ANOVA, repeated measures, within-factor type I error rate was set at 5% (alpha level: 0.05), the effect size of the main outcomes was 0.2, and type II error rate gave 90% power, correlation among repeated measures was 0.5, and non-sphericity correction e equalled 1.0. With the consideration of a 15% drop-out rate, the appropriate minimum sample size for the study was 30 subjects.

Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Bioethics Committee of the Opole Medical Chamber on the basis of Resolution No. 243 of April 6, 2017.

Informed consent

Informed consent has been obtained from all individuals included in this study.

Results

The analysis of the results showed that during the 5 days of training, the mean energy expenditure was 230 kcal, giving an average 46 kcal per training session. A declining trend of the results was observed. Energy expenditure presented no statistically significant difference between the trainings on each single day ($p < 0.148$). Also, energy expenditure expressed as MET did not reveal statistically significant differences between training days ($p < 0.073$); the mean of 3.7 MET was noted (Figure 1). Each participant executed 318 steps on average and the differences between training days were not statistically significant ($p < 0.334$) (Figure 2, Table 1).

Discussion

When analysing the number of steps, the highest score was recorded during the first day of training. On the next day, a decrease was noted. On the following days, the number increased slightly and remained at a similar level. Within the first days of the study, the participants attempted to perform the task mainly by shifting the weight; during subsequent days, they improved their technique and tried to find a balance between deflections and dynamics of movements. Similarly, changes in energy expenditure expressed in kcal were reported. During the first day, the subjects performed many unnecessary movements, which could have affected the higher uptake of kcal; nonetheless, on the following days, they strived to perform the task accurately and effectively. The analysis of energy expenditure expressed in MET showed that

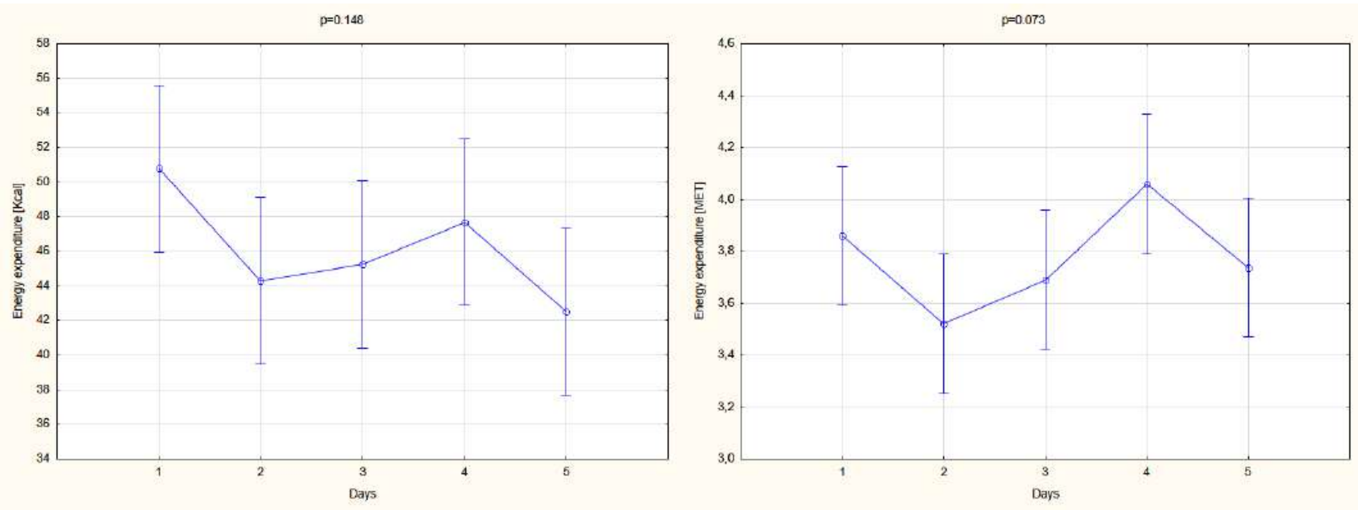

Figure 1. Evaluation of energy expenditure

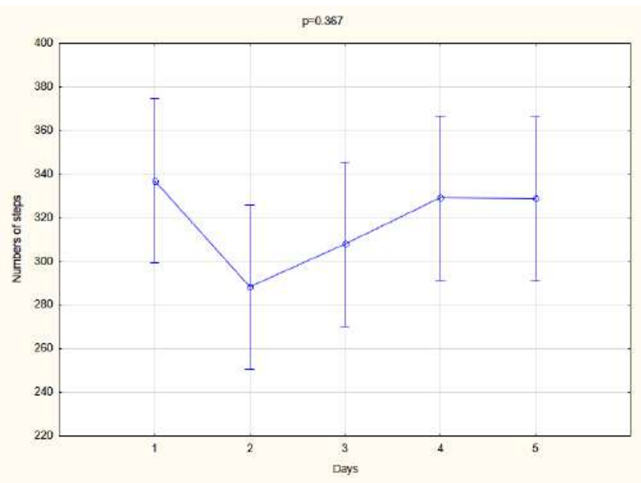

Figure 2. Evaluation of numbers of steps

Table 1. Evaluation of exercise intensity

Day	Kcal mean (± *SD*)	MET mean (± *SD*)	Steps mean (± *SD*)
1	50.8 (± 15.5)	3.9 (± 0.7)	337.0 (± 125.4)
2	44.3 (± 12.7)	3.5 (± 0.7)	286.4 (± 87.4)
3	45.3 (± 13.0)	3.7 (± 0.7)	308.0 (± 106.3)
4	47.7 (± 15.6)	4.1 (± 0.9)	329.2 (± 111.4)
5	42.5 (± 11.8)	3.7 (± 0.8)	328.8 (± 108.9)

Kcal – kilocalorie, *SD* – standard deviation,
MET – metabolic equivalent of task

the activities were performed with the mean of 3.7 MET, which is considered as moderate physical activity. Moreover, it was noted that during the games, 90% of males and 60% of females in training peaked an energy expenditure > 6 MET; such activity is referred to as vigorous physical activity. The study proved that exergaming at the basic level of difficulty did not trigger intensive energy expenditure. This means that the energy expenditure during training with the use of virtual reality did not reach the WHO recommendation level for intensive trainings (75 minutes per week). Likewise, if the individuals played these games or similar games regularly enough to spend at least 150 minutes per week, they would fulfil the recommended guidelines for weekly energy expenditure.

Similar results were reported by McNarry and Mackintosh [22]. They conducted studies using Kinect Adventures in children. They examined 34 children aged 10.8 ± 1.0 years playing 2 games for 30 minutes. The results showed an average moderate expenditure of 5.6 ± 1.45 MET during games; moreover, 36% of activity was maintained at > 6 MET. Also, Rosenberg et al. [23] assessed energy expenditure among children while exergaming. They investigated 47 children aged 10–15 years who participated in five 1-hour sessions playing 6 games of Microsoft Xbox 360 Kinect: MotionSports Adrenaline™, Sonic Free Riders™, Virtua Tennis 4™, Kinect Sports™, Kinect Adventures™, and Just Dance 3™. The results showed the average energy expenditure of 3.0 ± 0.17 MET while 15 minutes of exergame. Additionally, it was proved that boys gained higher energy expenditure than girls. The study implied that active games led to moderate physical activity. Similar results were achieved by Reading and Prickett [24], whose study comprised children aged 5–12 years. They performed their research using Xbox 360 and the Kinect Adventures game. During a 20-minute session, the children achieved the average of 4.4 ± 0.9, 3.2 ± 0.7, and 3.3 ± 0.6 MET. The authors proved that active games led to moderate physical activity but suggested further research. The study did not reveal an intensive physical activity level among young adults; nevertheless, it may be an additional part of traditional physical activity. It was shown that in 15-minute exergame training, moderate physical activity is achievable, which corresponds with the presented study. The authors propose increasing the game difficulty level as a way to achieve intensive energy expenditure.

The interest in dynamic games is constantly increasing. Many studies on the effectiveness of such trainings, taking into account different parameters, are being conducted. The premises that exergaming could replace traditional physical activity are becoming more and more apparent. Numerous studies show that an interactive game can provide a sufficient level of activity.

Haddock et al. [25] determined the caloric expenditure during Jackie Chan Studio Fitness® games for overweight kids. The research was carried out with the use of the Cosmed K4b2 device. The average energy expenditure was 4.08 ± 1.18 kcal. Graph et al. [26] analysed the differences in energy expenditure during watching TV and actively playing Dance Dance Revolution (DDR) and Wii Sports Nintendo in relation to walking on a treadmill. The results showed a 2–3 times higher energy expenditure when playing and walking on a treadmill compared with sitting in front of a TV set. Heart rate analysis revealed that such games were safe for children and offered appropriate activity. DDR is a dance game popular among young people. It requires coordinated movements and quick reactions. Noah et al. [27] examined 12 adult volunteers, assessing the intensity of exercises. During the game at an advanced level, the analysis showed an average energy expenditure of 8 MET and 9 kcal/min, thus demonstrating an intensive energy expenditure of the exercise. Lee et al. [28] pointed to DDR as one of the most active virtual reality games. In their opinion, games such as DDR, Kinect Sports, or Kinect Adventures are very popular among children. The authors stated that these games were a good way to promote physical activity and extracurricular activities among children. Research carried out at the GoKids research centre in Boston [29] showed that active games increased energy expenditure to moderate and intensive. The aim of the study was to evaluate the energy expenditure during exergaming among 39 children whose mean age was 11.5 ± 2.0 years. The authors used 6 different platforms to determine the energy expenditure. The children played one game on each device and achieved the following results: 4.2 ± 1.6 MET for Wii; 5.4 ± 1.8 MET for DDR; 6.4 ± 1.6 MET for LightSpace; 7.0 ± 1.8 MET for Xavix; 5.9 ± 1.5 MET for Cybex Trazer; 7.1 ± 1.7 MET for Sportwall. The outcomes for the Wii, DDR, and Cybex Trazer platforms were within the range of moderate physical activity. LightSpace, Xavix, and Sportwall showed intensive physical activity. A number of studies relate to the difference between the intensity of energy expenditure during active games and traditional exercises, indicating significant changes [30, 31]. The research attempts to activate healthy adults and fight obesity, especially among young people. Trost et al. [32] analysed the problem of obesity among children. In the investigated group of 75 overweight children, there was a significant decrease in the percentage of overweight after a 16-week training. As noticed by Clevenger and Howe [33], satisfaction seems to be an important aspect during active games. The research was focused not only on energy expenditure, but also on game enjoyment. Moderate physical activity and enjoyment of the game were observed. This remained in line with a study by Verhoeven et al. [34], who revealed moderate physical activity and considerable satisfaction during active play. The new trend is also spreading in the field of physiotherapy as a method of disease prevention and rehabilitation in elderly people [35].

Virtual reality, through its unconventional form, attracts more and more people of all ages. Active games provide an opportunity to encourage people to be physically active. However, this method is not fully understood and further research is needed to systematize and deepen the evidence base [36, 37].

The studies showed that exergaming at the basic level of difficulty did not trigger an intensive energy expenditure. This means that the energy expenditure level did not fulfil the WHO recommendation level. It seems probable that an intensive work load will be achieved after increasing the level of game difficulty. Additional research should be carried out to confirm these assumptions.

Conclusions

Training in virtual reality with the application of the Kinect system provides health benefits and can be an alternative to traditional physical activity. However, 15 minutes of daily training cannot constitute the only basis for physical activity.

Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

The authors state no conflict of interest.

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