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Using Ankle Weights as an Effective Way to Increase the Intensity of Physical Activity While Playing Immersive Virtual Reality Games on an Omnidirectional Treadmill

Jacek Polechoński [1,*], Karolina Kostorz [1] and Piotr Polechoński [2]

[1] Institute of Sport Sciences, The Jerzy Kukuczka Academy of Physical Education in Katowice, 40-065 Katowice, Poland; karolinakostorz@o2.pl
[2] Student Scientific Circle of Physical Activity and Tourism in Virtual Reality "ACTIVE VR", The Jerzy Kukuczka Academy of Physical Education in Katowice, 40-065 Katowice, Poland; piotr.polechonski.kontakt@gmail.com
* Correspondence: j.polechonski@awf.katowice.pl

Abstract: Active virtual reality games (AVRGs) have become more and more popular. As the intensity of this form of physical activity (PA) may be insufficient to achieve health-related benefits, it is worth looking for solutions that increase the intensity of PA. The main aim of the study was to evaluate the effect of leg loading in the form of ankle weights (AWs) on the PA intensity of young adults playing AVRGs using an omnidirectional treadmill. The enjoyment of the game and users' perceptions of the usefulness of this type of exercise were also evaluated. The study involved 26 university students. Each participant played an AVRG game on an omnidirectional treadmill twice, without and with ankle weights (2 kg per leg). The intensity of PA was evaluated using a heart rate monitor. The attractiveness of the game was assessed using the Physical Activity Enjoyment Scale (PACES). The study found that the percentage of maximum heart rate in participants playing AVRGs without ankle weights was significantly lower than that observed when playing with the weights. In both cases, PA intensity was high. A survey showed that the weights attached to the ankles did not affect the perceptions of the enjoyment of the game. The use of ankle weights appears to be an effective and simple way to increase the intensity of physical exercise during AVRGs based on locomotor movements performed with the lower limbs, especially since, according to study participants, such a procedure does not negatively affect the enjoyment of the game. Due to the high intensity of PA while playing VR games using an omnidirectional treadmill, it can be assumed that regular use of this solution is likely to provide health benefits.

Keywords: virtual reality; physical activity; treadmill; ankle weights; enjoyment

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1. Introduction

Immersive virtual reality (VR) has grown rapidly over the past several years and is widely used in many areas of life and science. It is used in healthcare, education, engineering, manufacturing, and entertainment, among others [1–5]. There is also a growing interest in using this technology in athletic training to diagnose and control athletes' motor skills and improve their sports performance [6–9]. Active virtual reality games (AVRGs), which require the user to do a physical exercise, are also becoming popular [10]. This type of physical activity (PA) offers an alternative to typical computer games, practiced in a sitting position that is unfavorable to health. Potential health-promoting effects of AVRGs can be expected if the accompanying PA is sufficiently high. According to current World Health Organization (WHO) guidelines, the health benefits come from aerobic exercise that is at least moderate in intensity [11]. Therefore, studies have been conducted to assess the intensity of PA during AVRGs and its determinants [12–20].

Currently, popular consumer VR headsets consist of a head-mounted display (HMD) and a pair of controllers that are held in the hands of the user. The most common ways to use such equipment are to play sitting or standing, with movements performed mainly using the upper limbs. Unfortunately, this form of exercise may not guarantee appropriate PA intensity for health-related benefits [14]. The question arises of how to solve this problem. One solution is to use trainers that are compatible with VR headsets, such as cycle ergometers, rowing ergometers, and treadmills. Recent studies using this type of equipment have shown promising results [21,22]. Cyclic locomotor movements promote PA intensity and enhance the immersion experience. The first studies on biomechanical analysis of movement in a virtual environment have also been conducted [21,22]. It was observed that PA using exercise machines in a virtual environment can be more intense than similar traditional training [17]. Another simple way that can increase the intensity of exercise for individuals using AVRGs is to add external load, provided that it does not interfere with the use of the application. Preliminary studies using wrist-mounted Velcro-fastened handheld weights (HHWs) showed that this solution could be comfortable for users and significantly increase the intensity of physical exercise (based primarily on arm movements) from low to moderate [23].

Given the effectiveness of these two solutions, it was assumed that their combination should help reach the high PA intensity needed during AVRGs. Evaluating the effects of such an approach was the inspiration for the experiment described in this paper. However, ankle weights (AWs) were used instead of HHWs, as the AVRGs connected with the omnidirectional treadmill primarily engaged the lower limbs. It should be emphasized that AWs are sports equipment used in jogging, fitness, rehabilitation, etc., and wearing AWs can help improve gait, lower limb strength, and balance [24–26]. Although AWs are commonly used in training, there is a lack of research into their impact on improving the effectiveness of exercises in VR. It is also unknown whether their use will be comfortable for users playing AVRGs on an omnidirectional treadmill and whether it will reduce the attractiveness of virtual entertainment and, consequently, the motivation to exercise. It is also difficult to determine whether and to what extent this will affect the intensity of PA.

Taking into account all the aforementioned issues, the main purpose of the present study was to evaluate the effect of external leg loading in the form of AWs on the intensity of physical exercise in young, physically fit adults playing AVRGs on an omnidirectional treadmill that allows for performing locomotor movements. In addition, it was also decided to assess users' satisfaction with PA in VR and check whether AWs would not negatively affect the participants' feelings by reducing the attractiveness of the exercises performed. These goals allowed us to formulate the following research questions:

1. Will the use of additional ankle load (2 kg AWs) result in a significant increase in PA intensity while playing an AVRG that is based mainly on leg movements?
2. What is the level of user satisfaction during the game on an omnidirectional treadmill in VR?
3. Will the use of AWs reduce satisfaction with PA in VR?

2. Materials and Methods

The research was carried out at the Jerzy Kukuczka Academy of Physical Education in Katowice (AWF) at the certified Laboratory of Research on Healthy Physical Activity (PN-EN ISO 9001:2015 [27], certificate validity: 7 December 2021–16 December 2024).

The empirical study was conducted in a group of 26 students from AWF, including 13 women (age: 23.4 $\pm$ 1.0 years, body height: 166.5 $\pm$ 5.3 cm, body mass: 60.0 $\pm$ 6.2 kg) and 13 men (age: 23.3 $\pm$ 2.0 years, body height: 182.0 $\pm$ 6.0 cm, body mass: 77.5 $\pm$ 12.5 kg). According to the accepted inclusion criteria, the study participants were healthy and physically fit volunteers. However, the study excluded those sensitive to flashing lights or image sequences found in programs and video games, suffering from epilepsy, having symptoms of motion sickness or balance disorders, with physical limitations (e.g., injuries) that could hinder exercises in a virtual environment, taking any medications that affect heart rate, and those who had previously used the application. The subjects' previous experience with immersive VR technology varied. Nine people (34.6%) had previously used it, while the remaining 17 people (65.4%) had never experienced it. None of the participants had previously walked on the multidirectional treadmill connected with VR used in the study. The study was approved and reviewed by the Research Ethics Committee of the AWF (protocol number 9/2018).

The study used the HTC Vive Pro VR headset, Omni omnidirectional treadmill (Virtuix; www.virtuix.com (accessed on 17 October 2023), and an AVRG game TRAVR Training Ops. The game consisted of overcoming obstacles in a virtual tunnel and shooting at designated moving and stationary targets with a laser weapon held in both hands. However, you should only shoot at the yellow targets marked with the "O" symbol and ignore those marked "X" symbol. The aim of the game is to score as many points as possible. The game result consists of several elements such as the speed of completing the stage, accuracy (the number of targets shot down and missed), and the number of shots fired. At the end of each stage, the participant runs to the board, where they write down their nickname and the number of points they have obtained, and the results of other players are shown, which may provide additional motivation for the user. The necessity to cover a designated route forces the player to perform locomotor movements (running, walking), engaging primarily leg muscles. The research involved two fifteen-minute sessions of AVRGs. There was a 30 min break between sessions, during which the participants rested in a sitting position. Two 2 kg AWs (one for each leg) fastened to the ankles of the left and right lower limbs were used to load the legs. Figure 1 shows the participant playing TRAVR Training Ops and the test stand, whereas Figure 2 shows a screenshot depicting the game environment.

(**a**) (**b**)

Figure 1. Study participants playing TRAVR Training Ops game in immersive VR using an Omni treadmill: (**a**) with AWs; (**b**) without AWs.

Heart rates (HRs) were measured while playing active video games using an HR monitor (Polar Vantage V, Kempele, Finland). PA intensity was estimated based on the average % HR_{max}. Before the measurement, HR_{max} was calculated according to the formula proposed by Tanaka et al.: 208–0.7 × age [28]. Exercise load was estimated based on the American College of Sports Medicine classification (average HR < 64% HR_{max}—low intensity, 64% $HR_{max} \leq$ average HR < 77% HR_{max} is moderate intensity, and $HR_{avg} \geq 77\%$ HR_{max} means high intensity) [29]. PA intensity was categorized into HR zones using the Polar Flow software (v.6). The absolute time of HR spent in each of the following zones was estimated: 0—<50% HR_{max}, I—50–59% HR_{max}, II—60–69% HR_{max}, III—70–79% HR_{max}, IV—80–89% HR_{max}, and V—≥90% HR_{max}.

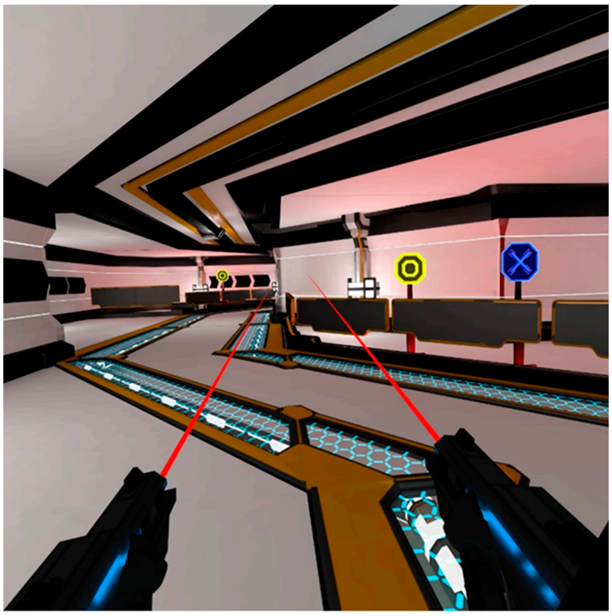

Figure 2. TRAVR Training Ops active video game (screenshot).

In addition to objective measurements, a subjective survey based on a questionnaire was also conducted. Perceived exertion was estimated using the Borg RPE scale (6–20) [30], and its correlation with objective measurements was assessed. The Physical Activity Enjoyment Scale (short form) (PACES) was used to collect data about the participants' subjective perceptions of satisfaction with PA in VR under lower limb loading and no additional loading conditions [31]. This research tool consists of 8 statements, each indicating a different aspect of the enjoyment of the PA undertaken in a broad sense: "I find it pleasurable", "It's a lot of fun", "It's very pleasant", "It's very invigorating", "It's very gratifying", "It's very exhilarating", "It's very stimulating", and "It's very refreshing". A seven-point Likert scale was assigned for each statement, with one meaning "strongly disagree" and seven meaning "strongly agree". The study participants' task was to mark, for each statement, the value that best reflected their perceptions of the activity considered in a given situation. The score was the mean of the points scored for all questions. Furthermore, a proprietary survey questionnaire, which consisted of 7 items, was conducted to assess students' attitudes toward PA in VR and their opinions on the potential of VR to support PA (Table 1). The Likert (1–7) scale was used in the questionnaire.

Statistical calculations were performed using Jamovi (v. 2.2.3.0) and Statistica (v.13) software. Arithmetic means and standard deviations were calculated. The Shapiro–Wilk test was used to examine the normality of distribution. The significance of differences was evaluated using Student's *t*-test or Wilcoxon test, depending on data distribution. The effect size was estimated using Cohen's d for the Student's *t*-test and the rank-biserial correlation coefficient (r_{rb}) for the Wilcoxon test. Spearman correlation analysis was employed to assess the correlations.

Table 1. Opinion of survey participants on the potential of VR to support PA.

Questions	Strongly Disagree		Disagree		Somewhat Disagree		Neither Agree Nor Disagree		Somewhat Agree		Agree		Strongly Agree	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
1. Would you be involved in PA in VR if you had the right hardware and software?	0	0	0	0	0	0	2	7.7	9	34.6	5	19.2	10	38.5
2. Would you recommend practicing PA in VR to others?	0	0	0	0	0	0	2	7.7	7	26.9	7	26.9	10	38.5
3. Do you think that practicing PA in VR is more enjoyable than performing conventional training exercises?	3	11.5	3	11.5	1	3.8	9	34.6	4	15.4	2	7.7	4	15.4
4. Do you think practicing PA in VR can have health-promoting benefits?	0	0	0	0	0	0	1	3.8	5	19.2	5	19.2	15	57.7
5. Do you think practicing PA in VR can complement a person's leisure-time PA?	0	0	0	0	0	0	0	0	3	11.5	5	19.2	18	69.2
6. Do you think practicing PA in VR can satisfy a person's needs for leisure-time PA?	3	11.5	2	7.7	0	0	0	0	4	15.4	8	30.8	9	34.6
7. Do you think PA in VR can replace conventional forms of real-world leisure-time PA?	5	19.2	2	7.7	4	15.4	4	15.4	6	23.1	2	7.7	3	11.5

3. Results

3.1. PA Intensity during Playing an AVRG Game (TRAVR Training Ops) with and without Ankle Weights in Light of Health-Related Recommendations

The study found that $\%Hrmax_{max}$ was significantly lower ($t = -4.23$; $p < 0.001$; Cohen's $d = 0.83$) for all participants playing AVGR without ankle weights ($79.8 \pm 6.5\%$ HR_{max}) than when the ankles were loaded with the weights ($82.3 \pm 6.2\%$ HR_{max}). Similar statistically significant relationships were observed in the separate analyses of the results obtained by men and women. For women playing without AWs, this parameter was $78.1 \pm 5.9\%$ HR_{max} and was significantly lower ($t = -2.43$; $p < 0.05$; Cohen's $d = -0.67$) than while training in VR with AWs ($80.5 \pm 5.7\%$ HR_{max}). Men were also significantly less fatigued ($t = -3.69$; $p < 0.01$; Cohen's $d = 1.02$) exercising without ($81.5 \pm 6.9\%$ HR_{max}) than with ankle weights ($84.2 \pm 6.3\%$ HR_{max}). It should be stressed that regardless of the additional load on the legs, the intensity of PA during the game was at a high level recommended for health benefits (Figure 3).

During both 15 min sessions, users' HR remained for the longest time within the range of 80–89% HR_{max}. When playing without AWs, an effort of this intensity lasted 320.71 s, whereas for playing with AWs, users maintained this HR for 334.1 s. A comparison of the time spent in each HR zone in the two sessions revealed the greatest discrepancy in zone 5 (109.3 s) and the smallest in zone 0 (1.4 s). Statistically significant differences in results were observed for zone 1 ($Z = 2.92$; $p < 0.01$; $r_{rb} = 0.71$), zone 2 ($Z = 2.80$; $p < 0.01$; $r_{rb} = 0.64$), zone 3 ($Z = 2.44$; $p < 0.01$; $r_{rb} = 0.52$), and zone 5 ($Z = 3.42$; $p < 0.001$; $r_{rb} = 0.82$) (Figure 4).

In the subjective rating of perceived exertion (RPE 6–20 scale) made by all students, playing without AWs was also found to be significantly less intense ($Z = -3.92$; $p < 0.001$; $r_{rb} = -1.00$) than playing with AWs. The intensity was rated 15.12 ± 2.29 and 17.12 ± 1.70 points, respectively. Similar relationships were observed in both women ($Z = 2.67$; $p < 0.01$; $r_{rb} = -1.00$) and men ($t = -4.05$; $p < 0.01$; Cohen's $d = -1.12$). Women rated the intensity of exercise during AVRG without AWs at 15.15 ± 2.30 points and with AWs at 17.15 ± 1.41 points. The men estimated the intensity of playing without leg load at 15.08 ± 2.36 points and with load at 17.08 ± 2.02 points. Relating these values to the classification of physical exercise intensity [32] shows that the students rated physical exercise as vigorous both with and without AWs (Figure 5).

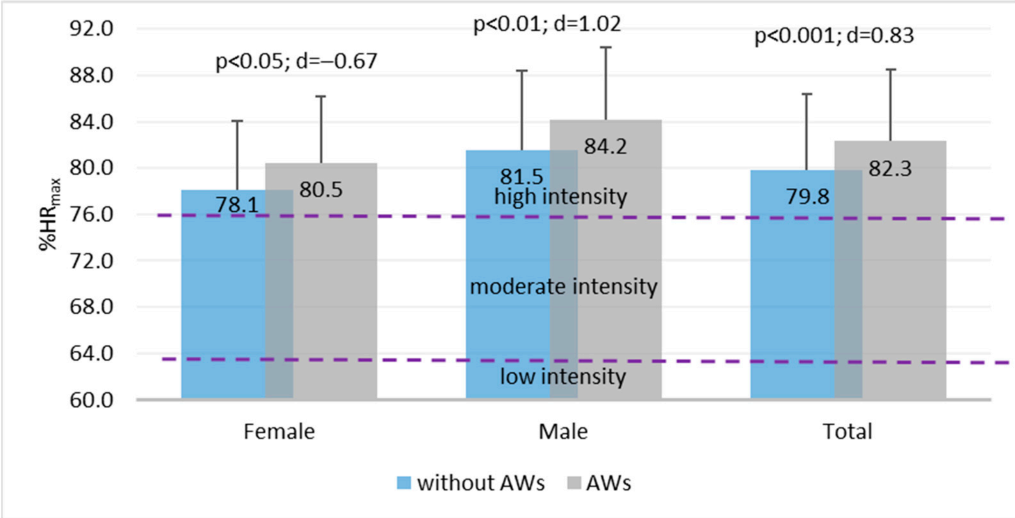

Figure 3. Intensity of PA while playing TRAVR depending on leg loading: AWs—ankle weights; *p*—*p*-value; d—Cohen's d.

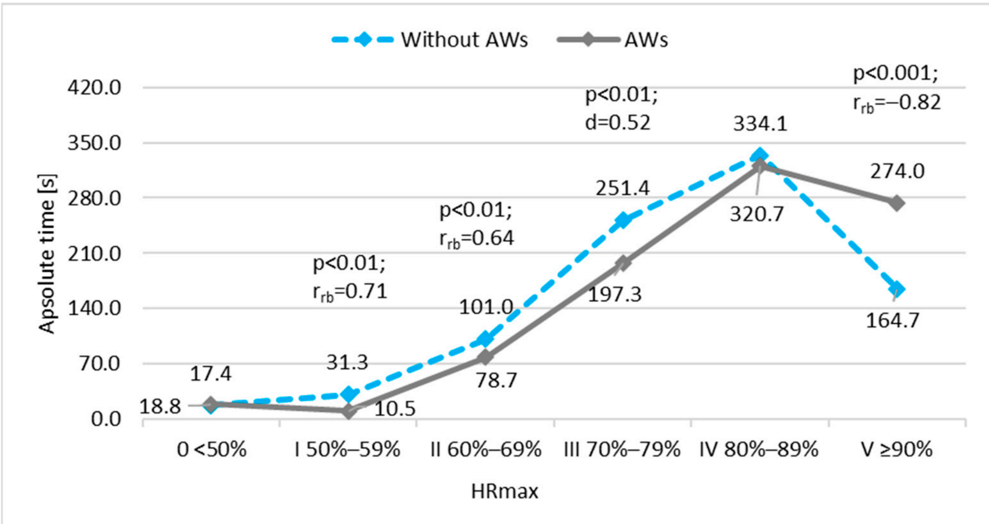

Figure 4. Average time spent in individual HR zones by all students playing TRAVR Training Ops with and without leg loading: AWs—ankle weights; *p*—*p*-value; d—Cohen's d; r_{rb}—Wilcoxon rank-biserial correlation coefficient.

The Spearman correlation analysis between objective and subjective measures of exercise intensity indicated a significant ($p < 0.001$) correlation between $\%HR_{max}$ and the RPE (6–20) scale for physical activity in VR without ($r_S = 0.52$) and with AWs ($r_S = 0.53$).

3.2. Satisfaction with PA in Users Playing AVRG, Their Attitudes toward Virtual Active Entertainment, and Their Opinion of the Potential of VR to Support PA

Based on the PACES survey (on a scale from 1 to 7), students rated PA while playing TRAVR Training Ops as high, regardless of whether they exercised without (6.15 ± 0.81) or with loading (6.04 ± 0.64). There were also no statistically significant differences in the evaluation made by users of either sex. Women rated the PA in VR without AWs at 6.15 ± 0.69 points and with AWs at 6.03 ± 0.67 points. For men, the results were very similar, with 6.15 ± 0.94 and 6.05 ± 0.63 points, respectively (Figure 6).

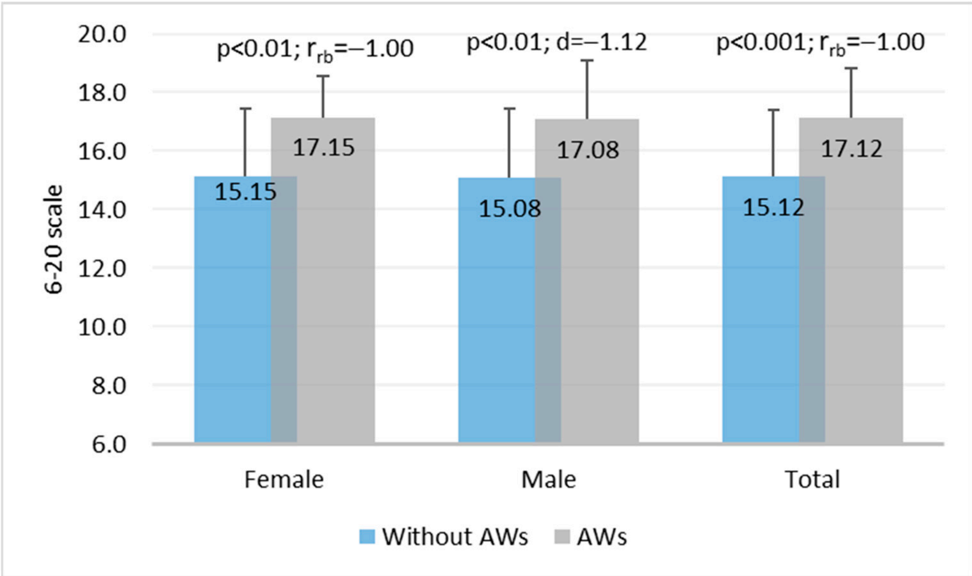

Figure 5. RPE depending on leg load: AWs—ankle weight; *p*—*p*-value; d—Cohen's d; r_{rb}—Wilcoxon rank-biserial correlation coefficient.

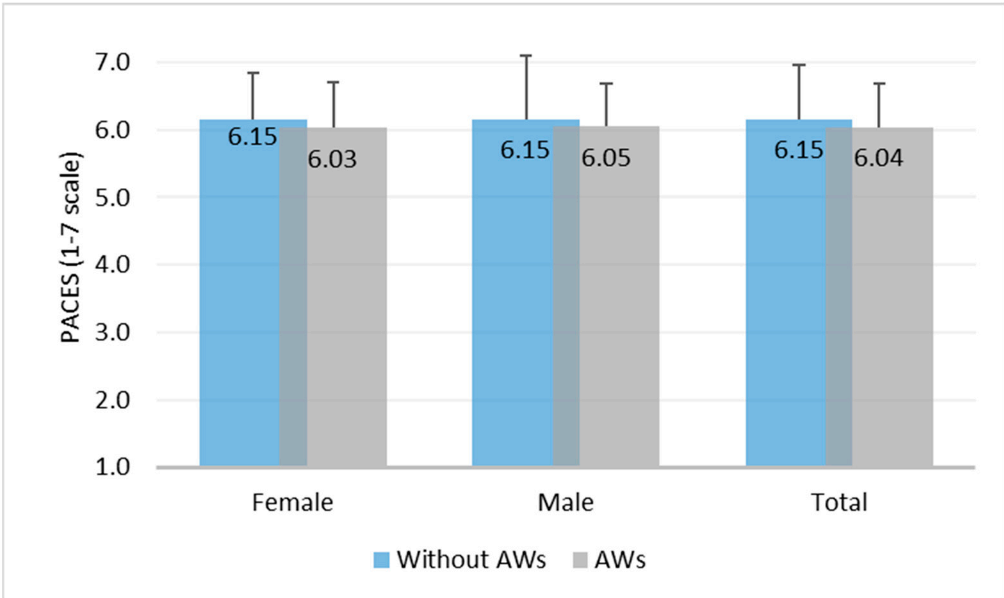

Figure 6. Satisfaction with PA on an omnidirectional treadmill in VR depending on lower limb loading: AWs—ankle weights; PACES—Physical Activity Enjoyment Scale (short form).

The high rating of satisfaction with PA in users playing AVRG translates into their declaration of future use of VR technology for exercise (Table 1). When responding to the question "With the right hardware and software, would you practice PA in VR?", almost all respondents (62.3%) answered in the affirmative, with only two people (7.7%) having no opinion. The positive attitude of students toward PA in VR is evidenced by the responses to the next question: "Would you recommend practicing PA in VR to others?" Also, in this case, except for two participants (7.7%) who did not respond, others were willing to recommend exercising in a virtual environment. Answers to the question "Do you think that practicing PA in VR is more enjoyable than performing conventional training exercises?" varied. Seven respondents (26.8%) disagreed with the statement, nine (34.6%) had no opinion on the issue, while the remaining ten (38.5%) answered in the affirmative. Almost all respondents (96.2%) agreed that practicing exercise in a virtual environment can have health-promoting benefits. Only one person (3.8%) was unclear. In contrast, 100% of respondents believed that training in a virtual environment can complement a person's leisure-time physical activity. There were varied responses to the question, "Do you think practicing PA in VR can satisfy a person's needs for leisure-time PA?". Although the majority of respondents (80.8%) supported this statement, five people (19.2%) held the opposite view. The responses to the question "Do you think PA in VR can replace conventional forms of real-world leisure-time PA?" also varied. Eleven participants (42.3%) answered in the negative, four respondents (15.4%) refrained from making a clear statement, while the responses of the remaining eleven students (42.3%) were positive.

4. Discussion

Based on the results obtained, it can be concluded that the proposed research hypothesis about the significant effect of external leg loading on the intensity of physical exercise in young, healthy, physically fit adults playing AVRG on an omnidirectional treadmill has been confirmed. AWs of 2 kg have proven to be an effective way to increase exercise load during the performance of locomotor movements in VR. Furthermore, it was shown that the use of an omnidirectional treadmill as a device coupled with a VR headset is a promising solution that allows for creating conditions and tools for vigorous training in a virtual environment.

Although many recent studies have assessed PA intensity in VR [13,15,16,19,33,34], few of them addressed exercise using an omnidirectional treadmill. This is probably due to the fact that this type of equipment is still relatively expensive and not widely available. A study evaluating the intensity of exercise in VR on a treadmill was recently conducted by Polechoński et al. [35]. The experiment was conducted in a group of eleven children with obesity aged 8 to 12 years. The objective of the study was to evaluate the intensity of PA during 15 min of playing two different AVRGs. The authors also evaluated whether the games' storyline could motivate children to engage in locomotor activity (moving in a confined space vs. having to follow a set route). The intensity of PA in obese children was high for both games, but it was significantly higher during the game in which the players had to follow a set route than during the game whose storyline involved moving in a confined space. The parameters for physical exercise intensity were, therefore, similar to those obtained by the participants in the present study. However, it should be noted that obese children and AWF students with above-average fitness differ in their exercise capacity. According to the authors, AVRGs practiced on a treadmill regularly by overweight children may be a health-promoting form of PA for them. Similar studies using a multidirectional treadmill were also conducted by Dębska et al. [13]. One of several aspects of their study was a comparison of PA intensity during 10 min sessions of physical exercise using AVRGs and two innovative training devices (an omnidirectional treadmill and the Icaros Pro flight simulator). The authors studied eleven young men. The mean exercise intensity during training on the omnidirectional treadmill was at a high level and was higher than while training on the flight simulator. According to the authors, their preliminary research indicated that these trainers, coupled with AVRGs, offer an effective tool for increasing participation in health-related PA.

To date, there have been no studies on PA with AWs in VR. Therefore, our results can be only related to papers on exercises in RL that have assessed the effects of the external loading of the lower limbs on PA intensity. Bhambhani et al. [36] evaluated the effects of ankle and wrist loading on physiological responses while running on a treadmill. The authors used weights of 1.6, 3.2, and 4.8 kg. The magnitudes of these responses were significantly higher with the weights at the ankles than at the wrists. The participants' perceived exertion also increased under the additional load. According to the authors, since AWs increase energy expenditure and training intensity during treadmill running, they are likely to result in greater increases in cardiovascular fitness and greater weight loss than during training without the weights. According to Miller and Stamford [37], applying additional load during walking can make its intensity similar to that of faster running.

Furthermore, Kunugi et al. [38] studied the effects of different gait speeds and ankle joint loads on metabolic and neuromuscular responses of the lower limbs during gait. Their findings suggest that the effect of ankle loading on exercise intensity and neuromuscular responses is higher for higher gait speeds. Benefits can also come from the long-term use of AWs. According to Narouei et al. [39], 3-month lower-limb weighted walking affected local neuromuscular control of the rectus femoris muscle in older adults. Hwang et al. [40] indicated that 6-week training with AWs can favorably alter the walking patterns of young, healthy individuals. A study by Yaacob et al. [41] demonstrated that regular use of AWs contributes to improvements in certain anthropometric parameters (waist circumference, waist-to-hip ratio) and body composition (body fat percentage, skeletal muscle percentage), which, according to the authors, can potentially reduce the risk of cardiovascular disease. The efficacy of AWs in increasing PA intensity found in the abovementioned studies and other benefits associated with the use of additional lower limb loading during locomotion in RL point to the need for similar research in VR, especially since virtual treadmills and applications that stimulate lower limb activity in a virtual environment are likely to be increasingly used.

However, there are studies on the use of external arm loading in the form of handheld weights (HHWs) to increase the intensity of PA in an immersive virtual environment [23]. The authors studied young adults playing an AVRG game called Beat Saber without and with HHWs. The study showed that small weights (0.5 kg) caused a statistically significant increase in exercise load during the abovementioned game based mainly on arm movements (cutting virtual objects with lightsabers). The low intensity of PA while playing the AVRG studied increased to a moderate level. According to the authors, the use of HHWs while playing AVRGs based mainly on upper limb movements appears to be an effective and simple way to increase PA intensity, and, according to users, it does not cause discomfort while using the game. It is worth mentioning that new-to-the-market accessories for VR headsets are special disk-shaped overlays for the Oculus 2 controllers, which, when attached to the controllers, allow adjustment of their weight to increase the intensity of the exercise while using the application. Therefore, it turns out that manufacturers consider the extra weight on upper limbs as a method to improve the effectiveness of exercise in VR. Perhaps, in the near future, consumer leg weights dedicated to PA in VR will also be developed. In view of the fact that both upper and lower limb loading can be an effective way to increase the physical exercise of AVRG users, it would be worthwhile to conduct a study on the simultaneous effects of arm and leg loading on PA intensity in a virtual environment.

Another aspect of our study was that the students made subjective ratings of perceived exertion on the Borg 6–20 scale. It was found that playing with AWs was perceived as significantly more intense than playing without AWs. Relating the obtained values to the classification of physical activity intensity [32], the respondents perceived both types of exercise as vigorous. Therefore, the objective results obtained using an HR monitor coincided with the subjective assessment of the participants. This may indicate that users engaged in physical exercise in a virtual environment can accurately estimate their own effort. This suggestion is supported by the relatively high significant correlation of the results of objective and subjective measures of exercise intensity for both PA in VR with and without AWs.

Our research shows that PA in an immersive virtual environment on an omnidirectional treadmill is attractive to users. Using the PACES questionnaire (with a scale of 1 to 7 points), the respondents rated satisfaction with AVRG highly, both without (6.15 ± 0.81) and with ankle weights (6.04 ± 0.64). The finding of no statistically significant difference between the ratings indicates that the additional resistance did not bother the players and did not cause discomfort that could affect satisfaction with the exercise. Although there are studies that have assessed satisfaction associated with PA in VR [13,16,42–47], it is difficult to compare their results with ours, as they involved different exercises, or the enjoyment of physical exercise was measured with different scales. Most authors indicated a high level of user satisfaction with such forms of PA. It should be noted, however, that the existing scientific evidence on the potential of using VR to enhance enjoyment levels during exercise is limited and heterogeneous. It is known that the positive effects of the virtual environment on the perceptions of users practicing PA have been documented mainly for VR with a high degree of immersion [48]. Therefore, the use of trainers that enable free and natural movement in VR, such as the treadmill used in our study, which undoubtedly enhances the immersive experience, should promote their satisfaction. Due to the continuous and rapid development of VR and the training applications and trainers applicable to VR headsets, further research is warranted on the experiences and perceptions of people engaged in PA using this modern technology to identify the factors affecting the enjoyment of this form of exercise. This applies to both healthy and clinical populations. This will make it possible to optimize recreational and sports exercises and rehabilitation programs in VR and guide their further development. It should be borne in mind that satisfaction is an important motive for undertaking regular health-promoting PA. How people feel during exercise determines their future training commitment [49]. Identification of users' preferences for forms of PA in VR can make it easier for manufacturers to create attractive training apps and AVGs, which should translate positively into future behaviors of people using modern technology during exercise, increasing the likelihood of their regular practicing PA.

The final element of the research conducted here was to assess the respondents' attitudes toward PA in VR and to obtain their opinions on the potential of VR for supporting PA. To this end, seven survey questions were asked of participating AWF students who plan to become health and PA promoters. It was assumed that future professionals in the field of physical culture would be competent enough to respond to such questions. The survey showed that the respondents were positive about the prospects of using VR in PA. This can be inferred from the survey responses. They showed that students with the right equipment would be willing to use VR for exercise and recommend others to practice PA in VR, and some of them even claimed that this type of physical exercise is more enjoyable than conventional training. The latter finding may be confirmation of the high level of user satisfaction with the exercise while playing the AVRG used in the study, which was assessed using PACES. The great potential of VR technology for supporting PA can also be evidenced by the positive opinions of almost all students regarding the potential health-promoting benefits of practicing virtual exercise and the confirmation by all respondents that virtual training can complement leisure-time PA. The vast majority of students were also convinced that physical exercise in VR could meet the needs related to leisure-time PA. Quite surprising was the statement by more than 40% of respondents that exercise in a virtual world can replace conventional forms of real-world leisure-time PA. Given that these positive statements about VR come from future promoters of health and PA, it is to be expected that they will use modern information technology and virtual immersive environments in their future work. This is all the more likely as VR continues to develop rapidly, with apps and pointing devices becoming more and more advanced, increasing their potential to realistically practice various forms of PA.

Finally, the limitations of this research should be mentioned. The participants were young, healthy adults, but it would be worth expanding the research group to include children, adolescents, and the elderly. Moreover, given the relatively small group of participants, the results should be treated with caution. A more accurate method of evaluating exercise intensity, e.g., indirect calorimetry, would be useful in further studies. Heart rate measurement was used in our research because it was feared that the masks used in calorimetry might cause discomfort and prevent a subjective assessment of the attractiveness of the game. Another limitation is the use of an original survey questionnaire regarding the usability of the application and the potential of VR in PA support, which may make it difficult to compare our research with the results published by other authors in this aspect. It should be noted, however, that the survey was only an additional element of this study, and a similar questionnaire has not been found in the available literature.

5. Conclusions

In conclusion, the additional ankle loading with 2 kg AWs resulted in a significant increase in physical activity intensity while playing an AVRG (TRAVR Training Ops) that is based mainly on leg movements. Therefore, the use of AWs seems to be an effective and simple way to increase exercise load during AVRGs practiced on an omnidirectional treadmill, especially because, according to users, such a procedure does not reduce satisfaction with PA in VR, i.e., it probably does not cause discomfort while using the application. Due to the high intensity of PA while playing VR games using an omnidirectional treadmill, it can be assumed that regular use of this solution is likely to provide health benefits. The high evaluation of the attractiveness of this type of training and the increasing availability of trainers that engage the lower limbs and enable locomotion in VR leads to the conclusion that more and more users will enjoy active treadmill entertainment in VR. Our study may provide guidance to immersive VR equipment manufacturers and programmers on how to make exercise more effective during playing AVRGs based on lower limb movements and may also be useful for people planning training in a virtual environment. However, to confirm the health-related properties of this type of VR exercise, further research is needed using various existing applications and trainers that allow performing walking and running in an immersive virtual environment. It would be worth conducting similar experiments in the future with AWs of different weights to check which load brings the greatest training effectiveness without reducing the comfort and attractiveness of exercises in VR.

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