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Effects of virtual Reality-Based Training and aerobic training on gaming disorder, physical activity, physical fitness, and anxiety: A randomized, controlled trial

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ABSTRACT

Background and aim: The effects of physical activity and exercise on gaming disorder severity in individuals with gaming disorder are unknown. The present study aimed to address the empirical gap in the current literature by comparing the effects of virtual reality-based training (VRT) and aerobic training (AT) exercise programs on gaming disorder severity, physical activity, physical fitness, and anxiety versus control group.

Materials and methods: Forty-four young male adults (18–28 years) with gaming disorder and a sedentary lifestyle were included in the study. The primary outcomes of the study were changes in gaming disorder severity and physical activity, and secondary outcomes included changes in physical fitness and anxiety levels. The participants were randomly assigned to VRT (n = 15), AT (n = 14) and control (n = 15) groups. Training sessions were performed at 50–70% of the maximal heart rate. Exercise programs consisted of 6 weeks of training 3 times a week for 30 min.

Results: There was a decrease in the severity of gaming disorder as well as an increase in the level of physical activity in the VRT and AT exercise groups compared to the control group. In addition, a reduction was observed in the gaming time and sedentary time in both exercise groups versus control group. VRT group experienced greater improvements in physical fitness parameters than the AT group.

Conclusion: VRT and AT were effective in reducing gaming time and the severity of gaming disorder in individuals with gaming disorder. The therapeutic effects of VRT and AT can be used for reducing the severity of gaming disorder.

1. Introduction

Gaming disorder is defined as a behavioral disorder characterized by an individual's loss of control over video gaming and increasing priority given to video gaming over daily activities and other life interests (World Health Organisation, 2021). Excessive online gaming has negative effects on physical and mental health, and represents a major public health issue, which is associated with loneliness and problems such as depression, anxiety and sleep problems. (D Griffiths, J Kuss, & L King, 2012; Krossbakken et al., 2018). The prevalence of gaming disorders has been reported to range between 1 and 10% in Western countries and 10–15% in Far East countries (Saunders et al., 2017).

Internet gaming can be considered as a risk factor that reduces participation in sports and exercise. At the same time, failure to engage in sports and exercise on a regular basis can increase the time spent playing online games (Henchoz et al., 2016). As with other sedentary behaviors, online gaming is associated with decreased physical activity and contributes to a sedentary lifestyle (Ballard, Gray, Reilly, & Noggle, 2009; Mutz, Roberts, & Vuuren, 1993). Reduced muscle strength, flexibility and lower exercise capacity have been reported as a result of physical inactivity and sedentary lifestyle (Mansoubi, Pearson, Biddle, & Clemes, 2014). Altered body composition as well as musculoskeletal problems can be seen in relation to increased screen time, especially in physically inactive individuals with gaming disorder (Hong et al., 2020;

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Tremblay et al., 2011). Moreover, it is a remarkable finding that anxiety is observed in many individuals with gaming disorders (Wang et al., 2017).

Active video game or video-based exercise (exergame/virtual reality training) are video games that encourage physical activity of players, involving the transfer of body movements to game commands (Osorio, G., Moffat, D. C., & Sykes, 2012). In some studies, aerobic training (AT) and virtual reality training (VRT) have been suggested as methods to combat sedentary lifestyle (Fogel, Miltenberger, Graves, & Koehler, 2010; Jenney, Wilson, Swanson, Perrotti, & Dougall, 2013). VRT was reported to produce similar effects to AT, increasing oxygen consumption by causing a significant increase in heart rate (Peng, Lin, & Crouse, 2011). There are also studies showing that VRT improves physical fitness and quality of life, increases muscle strength and reduces anxiety (Bakar, Tugral, Ozel, & Altuntaş, 2020; Viana & de Lira, 2020; Viana et al., 2017).

A limited number of studies are available in the literature that investigated the effects of exercise training in gaming disorder (Hong et al., 2020). Considering the impact of gaming disorder on public health, this study was prompted by the fact that there are no published studies examining the effects of VRT and AT, nor data on the outcomes of any exercise program in individuals with gaming disorder. We

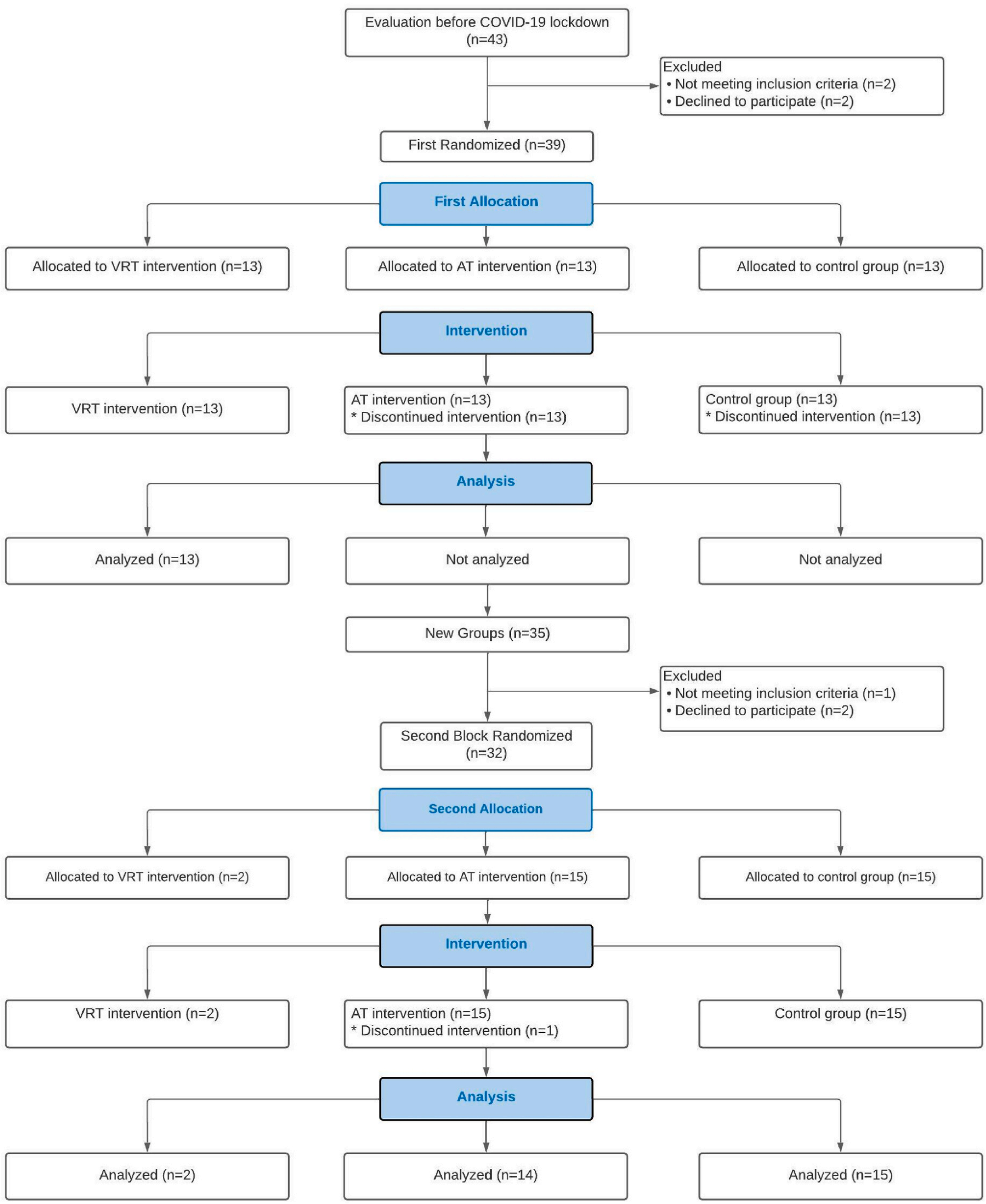

Fig. 1. Flow chart.

assessed therapeutic effects of VRT, which involves active game movements, and AT, which involves normal aerobic activity, on the severity of gaming disorder and on physical activity, physical fitness and anxiety in comparison to a control group. Thus, the aim of the study was to investigate therapeutic effects of VRT and AT on gaming disorder, physical activity and anxiety.

2. Methods

2.1. Participants and procedure

This randomized, controlled study was conducted at Hasan Kalyoncu University Physiotherapy Practice and Research Center (Turkey) between the dates of 2019 and 2021 on individuals with gaming disorder. Participants of the study consist of university students and were formed as a result of a survey of individuals with gaming disorders after general evaluation. After an overall evaluation of the individuals playing games by the clinical psychologist, they were included in the study on a voluntary basis. Given higher prevalence estimates of Internet Gaming Disorder in males (Stevens, Dorstyn, Delfabbro, & King, 2021), only male participants were included in the study. The inclusion criteria were as follows: (i) young adults from 18 to 28 years of age, (ii) a smoking history of less than 10 pack-years, (iii) playing online games for at least 2 h a day, (iv) meeting the Diagnostic and Statistical Manual of Mental Disorders (DSM–5) (American Psychiatric Association, 2013), and 11th Revision of the International Classification of Diseases (ICD) criteria for gaming disorder in the past 12 months (as assessed by a clinical psychologist) (World Health Organisation, 2021). The exclusion criteria were as follows: (i) use of any medication on a regular basis (that could alter the effects of exercise training) or receiving any treatment (including psychotherapy), (ii) presence of a psychological, orthopedic or chronic condition, (vii) those meeting the following criteria from the *International Physical Activity Questionnaire (IPAQ)-Short Form:* a) Vigorous intensity activity on 3 or more days achieving a minimum total physical activity of at least 1500 MET minutes a week, b) 7 or more days of any combination of walking, moderate intensity or vigorous intensity activities achieving a minimum total activity of at least 3000 MET minutes a week.

As shown in Fig. 1, a total of 43 individuals were included in the study before the COVID-19 lockdown began. Among them, two subjects refused to participate in the study, and 2 subjects were excluded due to high physical activity levels. Since 13 subjects from the VRT group started receiving the intervention earlier (before the onset of the pandemic) than those in the other groups, they completed the study. Due to the restrictions imposed during COVID-19 lockdown, a total of 26 subjects (n = 13 each for AT and control groups) could not receive training and dropped out from the study. After the end of the COVID-19 lockdown, 35 other individuals were included in the study. Two of these subjects did not participate in the study and one subject was excluded due to high physical activity level**.**

In total, 78 individuals playing online games were screened for this study. Of the eligible subjects, 45 males were included in the study. Ultimately, the study subjects were assigned to VRT (n = 15), AT (n = 15) and control (n = 15) groups using block randomization. In the first randomization, 39 individuals were randomly numbered. Then, three blocks were used. In the second randomization, 32 individuals were randomly arranged. For each block, six blocks were made. A subject from the AT group in the second allocation who did not complete exercise training was excluded from the study. A total of 44 subjects completed the study (Fig. 1).

The study protocol was approved by Hasan Kalyoncu University Ethics Committee (protocol ID: 2019/111). Before initiation of the study, written informed consent was obtained from all subjects. The study is registered on clinicialtrials.gov (clinicialtrials.gov ID: NCT04226677).

2.2. Interventions

VRT and AT groups received training sessions for 30 min, 3 days a week over a period of 6 weeks (18 sessions in total). All interventions were performed at the same place, under the same conditions and at the same time of the day. Both interventions were supervised by a physiotherapist. Warm up training at the beginning and cooldown training at the end of VRT and AT sessions were provided on a treadmill. The workload determined at both trainings was evaluated using the Borg Rating of Perceived Exertion (RPE) 6–20 scale (Borg, 1982). The subjects were asked to report their RPE in the middle and at the end of each game to maintain a RPE range of 12–14. A heart rate range of 50–70% of maximum heart rate was targeted during training sessions. Control subjects were asked to continue their habitual activities of daily living, with no intervention applied. After the study, control subjects who wished to receive training were provided either VRT or AT their choosing.

2.2.1. Aerobic training

In the AT group, training sessions consisted of warm up, loading and cooldown phases. Intervention was carried out individually by the subjects in the AT group. AT was initiated on a treadmill with a 5-min warm up period under workload. During the loading period, the treadmill speed was adjusted depending on how much effort the participants perceived during the exercise to keep it at an intensity between 12 and 14 on the RPE scale. The training was completed with a 5-min cooldown phase on the treadmill under workload.

2.2.2. Virtual Reality Training

VRT group received training with an Xbox Kinect 360^0 (Microsoft, Washington, USA) device. For training, the infrared camera sensor of the Xbox 360^0 Kinect device was positioned and the subjects were asked to stay about 1.5 or 2 m away from the screen. The games involved simultaneous body movements of the subjects. All games were played in the standing position in pairs. Random pairs were created to achieve a different pairing at each session. Switch between the games was taken into account for the training period. In the VRT group, the workload was applied at an RPE of 12–14. The movement patterns of the games were as follows:

1. Boxing: It is a competitive game played in pairs. During the game, the players try to knock out their opponents with elbow and shoulder flexion movements in a virtual environment. Each game was played in three rounds.
2. Hurdles: Paired participants tried to overcome the hurdles and reach the finish line by simulating both jumping and running movements.
3. Beach Volleyball: This type of volleyball is played by two teams of two players and involves jumping and hitting movements with full shoulder flexion. The teams tried to earn three set points.

2.3. Measurements

The age, height, body weight and body mass index (BMI) data were collected from the participants, all of whom were young male adults. In addition, smoking status (pack-years) and average daily time spent online gaming (in minutes) were questioned and recorded. Since comorbidities are less common in individuals with a history of smoking less than 10 pack-years, individuals with a smoking status below this cutoff value were included in the training (Tommola et al., 2019). All assessments were performed before and after 6-week training.

2.3.1. Primary outcomes

The Internet Gaming Disorder Scale – Short Form (IGDS9-SF) consists of 9 questions. The lowest possible score is 9 points and the highest possible score is 45 points. Higher scores indicate a higher risk of online gaming disorder/addiction. Individuals scoring greater than 36 points

Table 1
Descriptive statistics and baseline group differences.

	VRT Group (n = 15)	AT Group (n = 14)	Control Group (n = 15)			
	M ± SD	M ± SD	M ± SD	F	p	η^2
Demographics						
Age (years)	23.8 ± 1.7	22.1 ± 2.2	22.2 ± 1.4	3.28	.040*	.143
Height (cm)	177.6 ± 6.1	176.6 ± 5.2	175.8 ± 7.3	0.40	.670	.019
Body weight (kg)	78 ± 16	73.7 ± 12	76.1 ± 11.5	0.37	.693	.018
BMI (kg/m^2)	24.6 ± 4.1	23.3 ± 3.3	24.5 ± 2.9	0.61	.545	.029
Smoking (Pack-years)	2.8 ± 3.3	3.3 ± 1.6	2.1 ± 2	0.83	.439	.039
Gaming time (min/day)	212 ± 144	252 ± 91	296 ± 141	1.59	.216	.072
IGDS9-SF score	23.4 ± 5.9	24 ± 5.3	23.2 ± 4.5	0.08	.919	.004
IPAQ						
Physical Activity (MET-h/wk)	986 ± 497.1	886 ± 582.9	1098 ± 539.4	0.56	.575	.037
Sedentary Time (min/day)	368 ± 95.8	441.4 ± 148.1	446.6 ± 109.7	2.02	.145	.090
Senior Fitness Test						
6-MWT distance (m)	634.6 ± 63.8	593.1 ± 40.5	617.6 ± 60	1.98	.150	.088
CST (number of repetitions)	20.5 ± 4.3	21.7 ± 3.7	21.8 ± 4.5	0.44	.647	.021
ACT (number of repetitions)	22 ± 2.3	24.7 ± 3.6	25 ± 3	4.46	.018*	.179
CSRT (meter)	7.5 ± 8.4	7.17 ± 7.6	6.5 ± 8.2	0.08	.946	.003
BST (meter)	3.6 ± 5.8	0.07 ± 4.9	1.9 ± 5.4	1.51	.224	.057
Predicted VO_2max (ml/kg/min)	28.9 ± 5.1	28.17 ± 3.4	29.9 ± 5.1	0.50	.606	.023
BAI score	15 ± 11.1	13.7 ± 9.6	13.8 ± 7.6	0.07	.925	.003

M: mean, SD: standard deviation, BMI: Body Mass İndex, IGDS9-SF: The Nine-İtem Internet Gaming Disorder Scale–Short Form, IPAQ: The International Physical Activity Questionnaire, 6-MWT: *6-Minute Walk Test, CST: Chair Stand Test, ACT: Arm* Curl *Test, CSRT: Chair Sit and Reach Test, BST: Back Scratch Test, BAI: Beck Anxiety Inventory, *p < 0.05: One-way analysis of variance (ANOVA*-Bonferroni post-hoc tests).

are considered to be at a higher risk of addiction. It is one of the most popular measurement tools developed on the basis of DSM-5 in order to measure game addiction at the international level. Cronbach Alpha internal consistency reliability coefficient was 0.82, Guttman test-half reliability coefficient was 0.75 and test-retest reliability coefficient was 0.78 (Arıcak, Dinç, Yay, & Griffiths, 2018).

The International Physical Activity Questionnaire (IPAQ)-Short Form assesses physical activity level and time spent sitting daily. The IPAQ is a valid and reliable scale used in many countries (Craig et al., 2003). Consisting of 7 items, the questionnaire is used to estimate the time periods with a duration of 10 min or more spent sitting, walking, and doing moderate intensity and vigorous physical activities per day over the last 7 days. A total score in metabolic equivalent of task (MET) minutes/week is obtained by multiplying the MET values by the minute and day values for each activity. A score of 8 METs was assigned for vigorous physical activity, 4 METs for moderate intensity physical activity and 3 METs for walking. Daily sitting time (sedentary time) was recorded as a separate parameter (Saglam et al., 2010).

2.3.2. Secondary outcomes

The Senior Fitness Test (SFT) comprises six test batteries that evaluate arm and leg endurance, flexibility and functional capacity. It is a frequently used test, especially in sedentary individuals. Five parameters of the SFT were used for the study. *6- Minute Walk Test (*6-MWT*)* was used to assess the functional capacity of the study subjects. The test was conducted using a 30 m straight corridor. The participants were asked to walk as fast as possible and cover the maximum distance. The distance covered at the end of the test was recorded. *The Chair Stand Test (CST):* In order to measure the lower extremity muscle strength, the subjects were asked to get up from a chair in 30 s and sit down again and the number of repetitions was recorded. *The Arm* Curl *Test (ACT)* was used to assess upper body strength and the number of biceps curls completed in 30 s was recorded. *The Chair Sit and Reach Test (CSRT):* Lower limb flexibility was evaluated using this test. *The Back Scratch Test (BST)* was used for the assessment of upper limb flexibility (Rikli & Jones, 2013).

The 20-m Shuttle Run Test was used to obtain predicted maximum oxygen uptake (VO_2max) of the subjects. The participants were asked to run on a 20 m track, starting at a velocity of 8 km/h and increasing 0.5 km/h per minute, when signaled by the recorded beeps. The test was terminated when the subject failed to reach the cones at two runs consecutively on the beep sound. Maximal oxygen consumption values estimated from predicted post-test maximum oxygen uptake (VO_2max) levels were recorded. Predicted VO_2max value was calculated using the following formula: $VO_2max = 31.025 + (3.238 \times velocity) - (3.248 \times age) + (0.1536 \times age \times velocity)$ (Ahmaidi, Collomp, Caillauce, & Prefaut, 1992). Test-retest reliability coefficients were 0.95 for adults (Leger, Mercier, Gadoury, & Lambert, 1988).

Beck Anxiety Inventory (BAI); Anxiety level of the subjects in the previous week was assessed using the 21-item Beck Anxiety Inventory (BAI). In BAI, each item is assigned a score between 0 and 3 and overall score ranges from 0 to 63 points. Higher total scores indicate greater anxiety level (Ulusoy, Sahin, & Erkmen, 1998). The BAI showed high internal consistency (Cronbach's alpha = 0.94) (Fydrich, Dowdall, & Chambless, 1992).

2.4. Statistical analysis

Statistical analyses were performed using the SPSS 25 software package. For descriptive statistics, numerical variables were presented as arithmetic mean and standard deviation (X ± SD). Whether the data followed a normal distribution was checked using the Kolmogorov–Smirnov test. One-way ANOVA was used to compare the parametric data among the groups (see Table 1). Pre-test/post-test comparisons were done using the paired samples *t*-test. Repeated measures ANOVA analysis with Bonferroni post hoc test was used to evaluate the difference between the measurements at different times (group, time, time*group). Statistical significance level was set at $p < 0.05$. For the ANOVA-type statistics, the effect size (ES) was reported using the partial eta-squared (η2p) representing the amount of variance explained by a related effect in dependent variables. The effect size was calculated with the "$d=t/\sqrt{N}$" formula using the *t*-test (Lakens, 2013). The sample size of the study was calculated using G*Power (Kang, 2021). The G*power analysis was used to estimate the minimum sample size needed. It was found that a sample size of 13 subjects in each group (post power; $\alpha = 0.05$, power = 0.8, effect size = 0.72) would be needed for the study (Li & Wang, 2013). The multiple analysis of variance (MANOVA) was used for comparison of the study groups in Senior Fitness Test parameters and predicted VO_2max.

3. Results

An overview of mean and standard deviation values for all variables is presented in Table 1. No demographic differences were found among the groups except age (VRT > AT = Control group, p = 0.040 see Table 1). Approximately 63% of the participants were smokers. There was no difference among the groups in terms of mean gaming disorder severity and daily gaming time (see Table 1). All participants were physically inactive or minimally active (VRT, n = 4, inactive; n = 11, minimally active; AT, n = 5, inactive; n = 9 minimally active; Control group, n = 4, inactive; n = 11, minimally active). Except for ACT, there was no difference in other physical fitness parameters (Senior Fitness Test, predicted VO_2max) between the groups (Control group = AT > VRT, p = 0.018, see Table 1).

3.1. Effect of VRT and at on gaming disorders, physical activity, physical fitness, and anxiety

The comparison of pre/post test measurement results of the groups as well as comparisons of the groups by time (time, group, time*group) are shown in Table 2.

Post-training comparisons among the groups with regard to gaming time and sedentary time showed similar values in VRT and AT groups. Both training groups had significantly shorter gaming time (p = 0.04 and p = 0.039, respectively) and sedentary time (p = 0.000 and p = 0.025, respectively) compared to control group. After completion of the VRT and AT programs, weekly physical activity MET values increased significantly compared to the control group (p = 0.032 and p = 0.042, respectively). Post-intervention comparison among the groups showed a reduction in the IGDS9-SF score in the VRT and AT groups versus control group (p = 0.041 and p = 0.045 respectively).

Reduced anxiety levels were found after training in VRT and AT groups (see Table 2). Increased number of ACT repetitions was observed post-training in the VRT and AT groups (see Table 2). Both training programs provided increases in 6-MWT distance and predicted VO_2max value (see Table 2). The VRT group showed reductions in CSRT and BST values, indicating increased flexibility in both lower and upper extremities.

Significant time*group interaction effects were found for gaming time, IGDS9-SF score, physical activity, sedentary time, 6-MWT distance, CST number of repetitons, ACT number of repetitons, CSRT, BST and predicted VO_2max measurements (see Table 2).

On the multivariate analysis of physical fitness measurements (Seniour Fitness Test parameter, predicted VO_2max), it was observed that CSRT (meter) affected BST in the control group (p = 0.004, η2p2 = 0.212). None of the other physical fitness parameters showed interactions on MANOVA analysis.

4. Discussion

This study aimed to compare the therapeutic effects of VRT and AT interventions on physical activity, physical fitness and anxiety in gaming disorder and to determine changes in these measures versus control group. It is known that physical activity and exercise enhance psychological well-being by reducing anxiety and relieving tension. In our study, VRT training was as effective as the AT program, which is a routine exercise approach, in reducing the level of gaming disorder and anxiety. In addition, the VRT program was found to improve physical fitness.

It has been stated that the most effective exercise dose for psychological well-being is moderate intensity, especially in exercise training programs (Penna, Kim, de Brito, & Tavares, 2018). In the study of Douris et al. comparing VRT and AT exercise programs in sedentary young adults, it was reported that VRT can be prescribed as an alternative to traditional moderate intensity aerobic exercise (Douris, McDonald, Vespi, Kelley, & Herman, 2012). In our study, moderate intensity exercises were included in both AT and VRT programs to achieve more or less equal effects.

A previous study reported increased severity of gaming disorder with longer gaming time (Mihara & Higuchi, 2017). Additionally, in the study of Hong et al. (2020), one group received Cognitive Behavioral Therapy (CBT) only, while the other group received both CBT and aerobic training. The aerobic training consisted of running, rope jumping and basketball performed at 60% of the maximal heart rate. A greater reduction in the severity of gaming disorder and time spent gaming was shown in the group receiving CBT in combination with AT. Several treatment approaches and strategies for gaming disorder were investigated in former studies using gaming time and the level of gaming disorder as a measure of the effectiveness of treatment (Stevens, King, Dorstyn, & Delfabbro, 2019). Similarly, shorter gaming time and reduced severity of gaming disorder were observed following VRT and AT in the present study. These findings may be related to the fact that, for both training groups, the participants might have had less time to play video games due to more time spent exercising. In contrast, control subjects continued to play video games, which can explain the lack of any difference in their gaming times.

It has been reported that online gaming is a factor that increases physical inactivity (Mutz et al., 1993). Moreover, video gaming severity was found to affect the level of sport and exercise activity in adults (Henchoz et al., 2016). In particular, VRT was suggested as a new exercise approach and a good way to engage individuals in physical activity in the future (Farič et al., 2021). Similarly, according to Roure, Pasco, Benoît, and Deldicque (2020), VRT was shown to provide increases in physical activity metrics. It was stated by Rodriguez-Hernandez that walking programs improve physical activity (Rodriguez-Hernandez & Wadsworth, 2019). The significant increase in post-training IPAQ score observed in VRT and AT groups can be explained by increased functional capacity of these individuals as a result of being physically more active in daily life (McGavock, Anderson, & Lewanczuk, 2006).

Villafaina, Borrega-Mouquinho, Fuentes-García, Collado-Mateo, and Gusi (2020) presented that examining the effects of VR training versus control in a different population, an increase in the distance covered on 6-MWT was observed post-training in the group receiving VR training for a total of 24 weeks weeks. VRT has also been suggested as an alternative to moderate intensity aerobic training (Douris et al., 2012). Consistently, in our study, moderate intensity training performed as part of VRT and AT programs provided an increase in the 6-MWT distance, which reflects the functional capacity in those groups. Roopchand--Martin, Nelson, Gordon, Sing, and Care (2015) reported considerable improvements in flexibility following 6 weeks of VR training in a group of sedentary university students. In the study of Bakar, Tuğral, Özel, and Altuntaş (2020), muscle strength, flexibility and gait speed were evaluated in young adults who received VR training for 12 weeks and improvements in muscle strength and gait speed were found following training without any significant increase in flexibility. The absence of improvement in flexibility was attributed to the fact that the features of the games included in VR training were not sufficient to provide an increase in flexibility. In the current study, the games used as part of VRT included functional exercises targeting upper extremities, resulting in increased muscle strength. Improved upper limb muscle strength with AT may be explained by an increase in oxidative capacity in peripheral muscles as a response to aerobic training or by physical activities not reported by the subjects. In addition, the positive effects of VR training on lower limb flexibility may be attributed to the functional exercises simulated by the games that the participants played, which in turn improved flexibility of the lower extremities. For the control subjects, staying in a sitting position for a long time might have caused shortening of the lower extremity muscles and consequently reduced flexibility. During VR training, movements such as running and jumping were simulated together with upper limb movements. This suggests that VRT had a greater impact on physical fitness parameters in comparison to

Table 2
Pre/post-training comparisons of parametric values among the groups.

Variables	VRT Group (n = 15)					AT Group (n = 14)					Control Group (n = 15)								
	Pre	Post				Pre	Post				Pre	Post							
	M ± SD	M ± SD	t	p	d	M ± SD	M ± SD	t	p	d	M ± SD	M ± SD	t	p	d	F	time η^2	group η^2	time* group η^2
Gaming time (min/ day)	212 ± 144	150 ± 144	5.76	.000$^{\#}$	1.48	252 ± 91	184 ± 82	4.24	.001$^{\#}$	1.13	296 ± 141	296 ± 126	−0.05	.958	0.01	32,79	.444*	.155*	.321*
IGDS9-SF score	23.4 ± 5.9	16.9 ± 5,6	4.28	.001$^{\#}$	1.10	24 ± 5.3	19.8 ± 5.9	3.75	.002$^{\#}$	1.0	23.2 ± 4.5	23 ± 3,2	0.13	.897	0.03	25.34	.382*	.143*	.253*
PA(MET-h/wk)	986 ± 497.1	1955.6 ± 1315.9	−2.79	.014$^{\#}$	0.72	886 ± 582.9	1926 ± 711.5	−5.09	.000$^{\#}$	1.36	1098 ± 539.4	1014.3 ± 547	1.48	.160	0.38	24.53	.374*	.187*	.284*
Sedentary Time (min/day)	368 ± 95.8	255 ± 88	6.16	.000$^{\#}$	1.59	441.4 ± 148.1	287 ± 159	4.04	.001$^{\#}$	1.07	446.6 ± 109.7	500 ± 99	−1.94	.073	0.50	18.52	.311*	.307*	.418*
Senior Fitness Test																			
6-MWT *distance (m)*	634.6 ± 63.8	673.7 ± 53.3	−3.80	.002$^{\#}$	0.98	593.1 ± 40.5	636,2 ± 43,5	−7.37	.000$^{\#}$	1.97	617.6 ± 60	614.7 ± 57	0.40	.693	0.10	32.24	.440*	–	.329*
CST (number of repetitions)	20.5 ± 4.3	24.1 ± 4.6	−4.23	.001$^{\#}$	1.09	21.7 ± 3.7	23 ± 4	−1.87	.083	0.49	21.8 ± 4.5	22.13 ± 3.8	−0.70	.494	0.18	19.27	.320*	–	.237*
ACT (number of repetitions)	22 ± 2.39	26.2 ± 4.3	−4.77	.000$^{\#}$	1.23	24.7 ± 3.6	26 ± 3.3	−2.95	.011$^{\#}$	0.76	25 ± 3	24.6 ± 3.3	1.17	.260	0.30	0.82	.349*	–	.420*
CSRT (meter)	7.5 ± 8.43	4.8 ± 7.2	2.90	.012$^{\#}$	0.74	7.1 ± 7.6	8.2 ± 8.1	−0.66	.518	0.17	6.5 ± 8.2	9 ± 7.8	−4.01	.001$^{\#}$	1.03	1.21	–	–	.231*
BST (meter)	3.63 ± 5.85	1 ± 3.9	3.52	.003$^{\#}$	0.90	0.07 ± 4.9	−0.39 ± 6.2	0.82	.423	0.21	1.9 ± 5.4	3.4 ± 5.9	2.17	.047$^{\#}$	0.56	1.80	–	–	.316*
*Predicted VO2*max *(ml/kg/min)*	28.94 ± 5.1	30 ± 4.3	−2.24	.041$^{\#}$	0.57	28.1 ± 3.4	29.1 ± 3.4	−2.41	.032$^{\#}$	0.64	29.9 ± 5.1	29.6 ± 4.3	0.76	.459	0.19	7.13	.148*	–	.139*
BAI score	15 ± 11.1	9.4 ± 8.8	2.26	.040$^{\#}$	0.58	13.7 ± 9.6	9.5 ± 6.8	2.95	.011$^{\#}$	0.78	13.8 ± 7.6	12 ± 4.9	1.44	.170	0.37	13.69	.250*	–	.055

M: mean, SD: standard deviation, $^{\#}p < 0.05$: paired samples *t*-test, $^{*}p < 0.05$: results for the ANOVA with repeated measurement (time, group, time x group), η^2: eta-squared, d: cohen d effect size, PA: Physical Activity, CST: Chair Stand Test, ACT: Arm Curl Test, CSRT: Chair Sit and Reach Test, BST: Back Scratch Test, BAI: Beck Anxiety Inventory F: Repeated measures ANOVA analysis.

aerobic training.

A separate study by Roopchand-Martin et al. (2015) on sedentary university students reported significant improvements in maximum oxygen consumption following 6 weeks of VR training. Peng et al. (2011) reported that VR training was not significantly different from conventional moderate intensity physical activities in increasing maximum oxygen consumption. In the present study, although VRT and AT involved different exercises, changes in maximum oxygen consumption following moderate intensity VRT and AT were not different since 50–70% of maximal heart rate was achieved with both training methods at specified workloads. As the control subjects did not engage in vigorous physical activities requiring excessive effort, there was no change in their maximum oxygen consumption.

A positive correlation was reported between exercise and the serotonin hormone, which plays a key role in anxiety (So-Hyung & Wi-Young, 2018). So-Hyung et al. (2018) demonstrated that examining serotonin levels in individuals with gaming disorder, a competitive exercise group and a non-competitive exercise group were formed, and comparable serotonin levels were found in both groups after training. The positive effects of regular exercise on mood and symptoms of gaming disorder have been correlated with increased serotonin levels. While competitive paired games were included in VR training, aerobic training was designed individually in the current study. As reported by a study on healthy individuals, VR training was reported to help reduce anxiety levels (Viana et al., 2017). Likewise, Wagener, Fedele, Mignogna, Hester, and Gillaspy (2012) presented positive effects of regular exercise and VR training on overall psychological well-being in their study. In parallel with aforementioned studies, similar positive effects were observed on anxiety with both types of regular exercise training in our study. This finding may be explained with an improvement in overall well-being as a result of exercise. In contrast, no change was found in the anxiety level at 6 weeks post-training in control subjects who did not receive any intervention.

Thompson et al. (2020) revealed that addressing the effects of changes in physical activity on addiction, it was stated that it would provide the opportunity to develop behavioral skills in managing addiction. In the current study, both exercise programs may have helped to reduce the severity of gaming disorder by providing changes in physical activity through therapeutic effects.

4.1. Limitations

A number of important limitations need to be considered. First, the study was conducted during COVID-19 lockdown, which limited our ability to use a wider range of measurement methods. As an example, due to the potential risk of coronavirus transmission, cardiopulmonary exercise test could not be done for the study subjects. Also, the pandemic might have affected gaming time, physical fitness as well as the levels of anxiety and physical activity (King, Delfabbro, Billieux, & Potenza, 2020). The study sample consisted of young males only, physical activity could not be measured objectively (e.g., using pedometer), and the intervention period was relatively short, which constitute other limitations. Post-training long-term follow-up of VRT and AT could not be performed in individuals with gaming disorders. Also, smart devices that provide instant heart rate and calorie expenditure value could have been used to better track the intensity of training. Finally, VRT group received training in pairs, whereas AT group performed training individually, and this might have caused potential bias in measurement of training effects.

5. Conclusion

In conclusion, VRT and AT programs may be beneficial for alleviation of adverse psychological and physiological effects of gaming disorder and prevention of the development of more severe gaming addiction through improvements in physical fitness and anxiety. VRT and AT programs can also be useful in the treatment of gaming disorder.

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Author statement

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

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