Article

The individual and combined effectiveness of virtual reality and interval Nordic walking on the cardiorespiratory hemodynamic and central adiposity among internet addiction adolescents

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Abstract: Physical Inactivity caused by internet addiction (IA) in adolescents is one of the world's most serious health issues and technology-based intervention and exercise training methods are being developed to control it. This study sought to examine the potential influences of 2- and 4-week-virtual-reality (VR) training program with/without interval Nordic walking (INW) on hemodynamical-cardiorespiratory and central adiposity indices among internet-addicted adolescents. A randomized controlled trial design was conducted among 150 individuals randomly assigned to VR, INW, VR + INW, and control groups regarding sexes. In every specific group, participants performed one of three exercise protocols (i.e., VR, INW, and VR + INW) of three 60-minute sessions/week for 2 and/or 4 weeks, except for control group. The measurements were conducted at different phases (i.e., the baseline, 2- and 4-week-protocol interventions). Following VR and INW training protocols, a significant increase and decrease were detected in VO2max and MVO2 respectively, especially among girls ($p < 0.001$). BAI values showed significant improvements ($p < 0.01$), especially in the VR-boy group following 4 weeks of intervention ($p < 0.001$). The VR with INW training protocols has potential benefits for health status and could be considered an important non-pharmacologic strategy to prevent sedentary and maintain wellness in adolescents.

Keywords: interval exercise; virtual reality technology; cardiorespiratory fitness; abdominal obesity; Nordic walking

1. Introduction

Undoubtedly, the rate of applying the internet through smartphones, tablets, laptops, and other digital devices has been widely developing due to doing some activities such as gaming, purchasing products, searching and sharing scientific information, etc. People are actively using social media apps including WhatsApp, Facebook Messenger, WeChat, QQ, Telegram, and Snapchat to communicate [1]. Despite the convenience of swiftly accessing extensive information, critical concerns about internet addiction (IA) complications have been raised among students which include distance from family members and friends, mental-physical health disorders, and academic performance drop [2]. Additionally, a negative correlation has been found between IA and self-esteem. Regarding ages and genders, it is particularly considered that children and adolescents are the vulnerable groups being affected by problematic issues of IA. This susceptibility is because of a psychological-developing process among children and adolescents that makes them emotionally unstable and less self-regulating, which leads to being easily influenced by virtual reality and increasing the prevalence of addiction habits [3–5].

Evidence illustrates that IA is associated with overweight and obesity [6–8], and health-related problems such as the risks of cardiovascular [9], nervous [10], and musculoskeletal [11–13] systems. For instance, Tsitsika et al. (2016) expressed that internet overuse is associated with overweight/obesity (12.4%) and dysfunctional internet behavior (14.1%), especially in boys [7]. Other researchers also reported similar results [11–13]. On the contrary, it is reported that there is no association between gender and IA [3]. Some treatment strategies have been recommended to modulate/control the harmful effects of IA, including psychological, medicine, and exercise treatments [14]. There are already psychotherapeutic methods and manuals (also published) for the treatment of Internet addiction (IA) [15,16], including cognitive behavioral therapy [17,18], motivational interviewing [19,20], emotion regulation [21,22]; which may take a long time based on previous study [14]. Whereas, it also has been reported that medical therapy may have side effects, which would influence a person's mental and physical health (especially among children and adolescents) [14]. On the other hand, treatments regarding physical training would be more practical and logical [14], and their physio-psychological advantages are confirmed [10,23]. Koçak (2019) stated that performing physical activity could significantly reduce the duration of being online (the severity of internet addiction) which generally leads to a decrease in the harmful internet overuse impacts [23]. Despite this, children and teenagers do not have a great desire to do long-term physical activities due to these ages' specific behavioral characteristics, therefore, designing and providing a special training program for them is vital.

Every individual can perform Nordic walking (NW) at various physical-fitness levels without any age limitations due to its easy learning and low vulnerability, which results in adopting a healthy lifestyle, preventing diseases, and improving physical fitness impacts [24]. Compared to regular walking, the entire body (about 90% of all muscles) is included during NW and the burnt calories can be elevated depending on the speed [25,26]. For instance, it is stated that performing two 60-minute NW training sessions per week for 3 months can improve body composition and maintain good health conditions, especially in the women population [27]. It has been confirmed the positive impacts of NW on improving body composition and the performance of upper and lower limbs [28]. Evidence also declared that NW is advantageous for quality of life (QoL) and cardio-respiratory indices such as blood pressure (BP), resting heart rate (RHR), myocardial oxygen consumption (MvO2), and maximal oxygen consumption (VO2max) [9,29]. Compared to regular walking, it is illustrated that NW beneficially impacts cardiovascular-cognitive physiological indices and traditional body composition parameters including body mass index (BMI), waist-to-hip ratio (WHR), and/or body fat percentage among middle-aged [27] and particularly elderly people [25,30], while its effects on new body composition indices such as abdominal volume index (AVI), body adiposity index (BAI), cone index (CI), body shape index (ABSI) and waist-to-height ratio (WHtR) are still not crystal clear. Plus, it should be highlighted that these new indices represent central obesity status and metabolic-syndrome-related problems [31]. Based on our knowledge, assessing the effects of NW on mentioned indicators is a novel aspect. Additionally, evaluating the influences of such exercise protocol on health-related indices among internet-addicted children and adolescents has been overlooked.

On the other hand, over the last few years, training while wearing virtual reality (VR) glasses has made a new approach to improving health through performing physical activities [32]. Recent technological advances have also made VR more ubiquitous, flexible, portable, and affordable [32]. Despite requiring a lot of physical and mental effort, the capability of distracting players from physical activity by making time flow and motivating them to continue the game process engaging is another main reason for VR technology's success, especially among children and adolescents [32]. Previous studies declared that VR might boost the potential long-term participation in physical activities and create a positive mindset about exercise [33]. To illustrate, Park and Lee (2023) expressed the positive impacts of VR Pilates training including increasing the duration of body-posture maintenance and a significantly higher coordination of the body (i.e., upper and lower limbs), among eighteen 24-year-old youths [33]. Evidence reported that the VR training program is appropriate for improving body composition, endurance, and strength performances while elevating exercise satisfaction and enjoyment regarding individual differences and levels [34]. Similarly, it has been observed that sympathetic activity (i.e., diastolic blood pressure and heart rate) boosted during and after speed-strength physical exercise among IA adolescents in comparison with non-internet-addicted individuals [9]. Since VR software is becoming more accessible, affordable, and highly attractive among teenagers, it seems this technology has great potential to be applied for health purposes among adolescent populations [35].

Altogether, according to the relationship between internet addiction and sedentary [36], the association among sedentary, obesity, health-problem [9,37], and quality of life [38] among teenagers, and also the sedentary stemmed from cultural and indoor-sport facility issues for girls in Iran, it is hypothesized that a combined VR-INW training protocol will result in a greater synergic influences central obesity indices and hemodynamical cardio-respiratory parameters among IA-adolescent, especially the girls. Therefore, the purpose of the present study was to evaluate the impacts of VR training programs with/without INW on visceral obesity parameters (i.e., WHtR, AVI, BAI, CI, and ABSI) and hemodynamical cardio-respiratory indices (i.e., heart rate (HR), BP, MvO2, heart rate recovery (HRR), oxygen pulse (O2puls), blood oxygen saturation (SpO2), and VO2max) among internet-addicted-teenage boys and girls along a four-week timeline.

2. Methods

2.1. Research design and ethical approval

In this investigation, the semi-experimental protocol was conducted in the form of one pre-test session and two post-test sessions (i.e., 2- and 4-week interventions) among adolescent boys and girls.

All methods and data collection were reviewed and approved by the local institutional ethics committee (Ethical code: IR.UMZ.REC.1401.008), which were performed according to the latest edition of the Helsinki guidelines [39]. Accordingly, all individuals had the opportunity to participate, obtain informed consent, and were familiarized with the testing procedures, protocols, and equipment. Additionally, the participants could ask about any part of the research progress whenever it was not clear. It should be noted that they also had the right to either withdraw or leave the experiment at any stage of the research process without any consequences.

2.2. Inclusion, and exclusion criteria and classification of participants

In this study, 150 healthy qualified-volunteered-teenage boys and girls participated (age range 12 to 18 years old). Participants were recruited via various ways and channels in virtual space, city communities, schools, and academic institutes.

In current study, to prevent possible impacts of disturbing interventions, some existing requirements were also noticed due to be eligible for participating in the research process, including neither history of smoking nor exposure to any second-hand smoke (hookah and cigarette); no drugs, medicine, and alcohol consumption; no neurological disorders; no psychoactive drug consumption; no history of chronic physical and mental diseases, or any other medical contraindications such as physical disability and limited mobility; having sedentary lifestyles (lack of regular exercise activities; less than 2 sessions per week); and being an internet-addicted (IA). It should also be mentioned that the girls were in the follicular phase during the present study. To be eligible as an IA, IA status was screened in two phases. In the first phase, individuals were questioned about having two main habits for at least two years to be considered to be internet addicted [40]; including 1. the least time spending of surfing the internet and using social media (Telegram, Instagram, WhatsApp, Viber, Facebook, Twitter, LinkedIn, YouTube, Imo Messenger, Line, WeChat, Snapchat, Tango, Soroush, Rubica, Shad) by smartphones and computers were settled at five hours a day and/or more than 38 h per week; and 2. Having a late-sleep schedule (going to sleep after midnight) [41]. In the second phase, they took Young's Internet Addiction Test, thus, they had to obtain a minimal sufficient score to participate in this study.

On the other hand, any reasons making a participant remain sedentary and/or avoid taking tests during the research period caused the person to leave the whole process. Additionally, if a person performed the exercise sessions less than 75% of the expected amount based on the formula (Equation (1)), he/she was removed from the program and exited from the research. Plus, it should be noted that we also scheduled a non-internet-addicted group and since no difference was observed in the data gathered from the young questionnaire [42] between IA and non-internet-addicted groups, this group was prohibited from participating in the study.

$$expected\ performed\ exercise\ sessions = \frac{expected\ number\ of\ exercise\ sessions}{total\ exercise\ sessions} \times 100 \tag{1}$$

The eligible people were randomly divided into main training protocol groups including 1. Interval Nordic walking (INW); 2. Virtual reality (VR); 3. Combined INW and VR (INW + VR); and 4. Control; and gender subgroups (i.e., boys vs. girls). In INW groups, participants performed the selected training protocols 3 days/week for two and four weeks. Individuals performed the selected virtual reality training protocols in VR groups, while the INW + VR groups did a combination of the INW and VR training protocols 3 days/week for two and four weeks. Meanwhile, the control groups were not exposed to any of these training interventions. Therefore, the above groups were organized as 1) INW-BOY; 2) INW-GIRL; 3) VR-BOY; 4) VR-GIRL; 5) INW + VR-BOY; 6) INW + VR-GIRL; 7) Control-BOY; and 8) Control-GIRL. The participants' anthropometric and demographic characteristics are summarized in **Table 1**.

Table 1. Anthropometric and demographics characteristic (mean ± standard deviation) of participants in different groups.

Groups		Age (years)	Body Mass (kg)	BMI (kg.m^{-2})	WHR	IAD (years)	DIU (hours)	STAN	WPA (day)
Boys	INW (*n* =14)	15.2 ± 2.3	75 ± 16	26 ± 4.2	0.88 ± 0.03	3–4	5–6	1–2 h after midnight	Less than one
	VR (*n* =14)	14.7 ± 2.9	71.8 ± 3.9	23.8 ± 3.7	0.87 ± 0.04	3–4	6–7	1–2 h after midnight	Less than one
	INW + VR (*n* = 13)	14.3 ± 2.5	69 ± 9.4	23.3 ± 1.5	0.88 ± 0.04	3–4	6–7	1–2 h after midnight	Less than two
	Control (*n* = 7)	15.3 ± 1.9	71.8 ± 9	24.6 ± 3.3	0.91 ± 0.03	3–4	6–7	1–2 h after midnight	Less than one
Total (*n* =51)									
Girls	INW (*n* = 14)	14 ± 2.44	65.26 ± 2.21	28.24 ± 0.33	0.78 ± 0.04	3–4	5–6	one hour after midnight	Less than one
	VR (*n* = 14)	15 ± 1.5	64.56 ± 1.5	33.2 ± 1	0.75 ± 0.04	3–4	6–7	1–2 h after midnight	Less than one
	INW + VR (*n* = 14)	14 ± 0.4	64.42 ± 0.93	28.33 ± 0	0.78 ± 0.06	3–4	6–7	one hour after midnight	Less than one
	Control (*n* = 10)	14 ± 2.82	64.34 ± 0.76	28.33 ± 0	0.77 ± 0.08	3–4	6–7	1–2 h after midnight	Less than one
Total (*n* = 52)									

BMI, body mass index; WHR, waist-hip ratio; IAD, internet-addiction duration; DIU, daily internet usage; STAN, sleep time at night; WPA, weekly physical activity; INW, Interval Nordic walking training; VR, Virtual reality.

2.3. Interval Nordic walking (INW) exercise training protocol with a pedometer

In this study, the INW training protocol was designed based on assessing previous Nordic walking research [43,44] while we applied some modifications. To evaluate the practicability of the protocol, we conducted a preliminary study among several teenagers, and the distance of 3000 steps was considered as the baseline step range. Under the researcher's supervision, the subjects performed three sessions of interval Nordic walking in green spaces and/or at parks for four weeks. Briefly, the incremental overload principle was increased during the following weeks by altering the number of training sets, rest duration, and training periods. Also, the number of baseline step ranges (i.e., 3000 steps in the first session) elevated to 7000 steps in the last session (at the end of the fourth week), while the net duration was kept constant at 30 min.

Accordingly, during these consecutive weeks, the number of steps was increased daily in the first, second, third, and fourth weeks by 200, 300, 400, and 500 steps, respectively, to follow the overload principle for the 30-min INW protocol. It should be noted that the protocol contained five sets of six minutes and a three-minute rest between sets during the first and third weeks, while four sets of 7.5 min, a three-minute rest, and a 5-min rest between sets during the second and fourth weeks, respectively. Every training session started and ended with stretching exercises, called warm-up and cool-down parts, for five to ten min. To control the speed of training performance (walking) in the 30-min time range, we applied pedometer devices (Omron hj-152-e) to measure the number of steps taken by individuals, thus, they were asked to wear the pedometer at the waist area. In addition, the participant's heart rate was maintained in the range of 60% to 75% of the maximal heart rate during training sessions through the first to fourth week, respectively.

2.4. Virtual reality (VR) training protocol

Before commencing the study, the VR groups were taught the correct method of performing VR training protocol during a learning session. The all-in-one VR headset device (Oculus Quest 2) was applied for the VR protocols. Also, VR groups performed three 30-min sessions/week for four weeks. Plus, the VR training protocol was designed to assess previous research [45,46] while we applied some modifications. Every session consisted of a five-min warm-up and a 30-min training. The 30-min training part included three types of games, such as Beat Saber, Ohshape, and Creed: Rise to Glory, in which the time of playing each game was about ten minutes. After the time range of each game was completed by the participant, the researcher changed it to the next one. These exercise games were randomly selected for each person in different sessions and participants were allowed to perform required movements in various directions so that mostly all their muscles were involved during the games. Needless to say, the individuals' heart rate approximately reached 180 beats per minute (bpm) during training time. **Figure 1** shows the schematic image of the VR device and the selected games.

To play the Beat Saber game, individuals performed a rhythm-based average level, in which the participant applied virtual lightsabers (laser sabers) to cut through blocks (as upper body movement) or to escape large blocks by sideway and crouching gestures (as whole-body movement). During the game, the blocks were moving toward the player (participant) according to the background music rhythm. Meanwhile, the music speed was changeable and adjustable. As for the Ohshape game, it can be considered a suitable fitness game that would meet the required intensity of high-intensity-interval (HIIT) training. This game has various difficult levels that were selected based on the physical ability and conditions of the participants. On the other hand, the Creed: Rise to Glory is a boxing game. During this game, the individual was allowed to perform several training types in a virtual gym (e.g., punching a punching bag and ball) as well as choosing 'competition mode' which offered a competitive fight against a computer opponent.

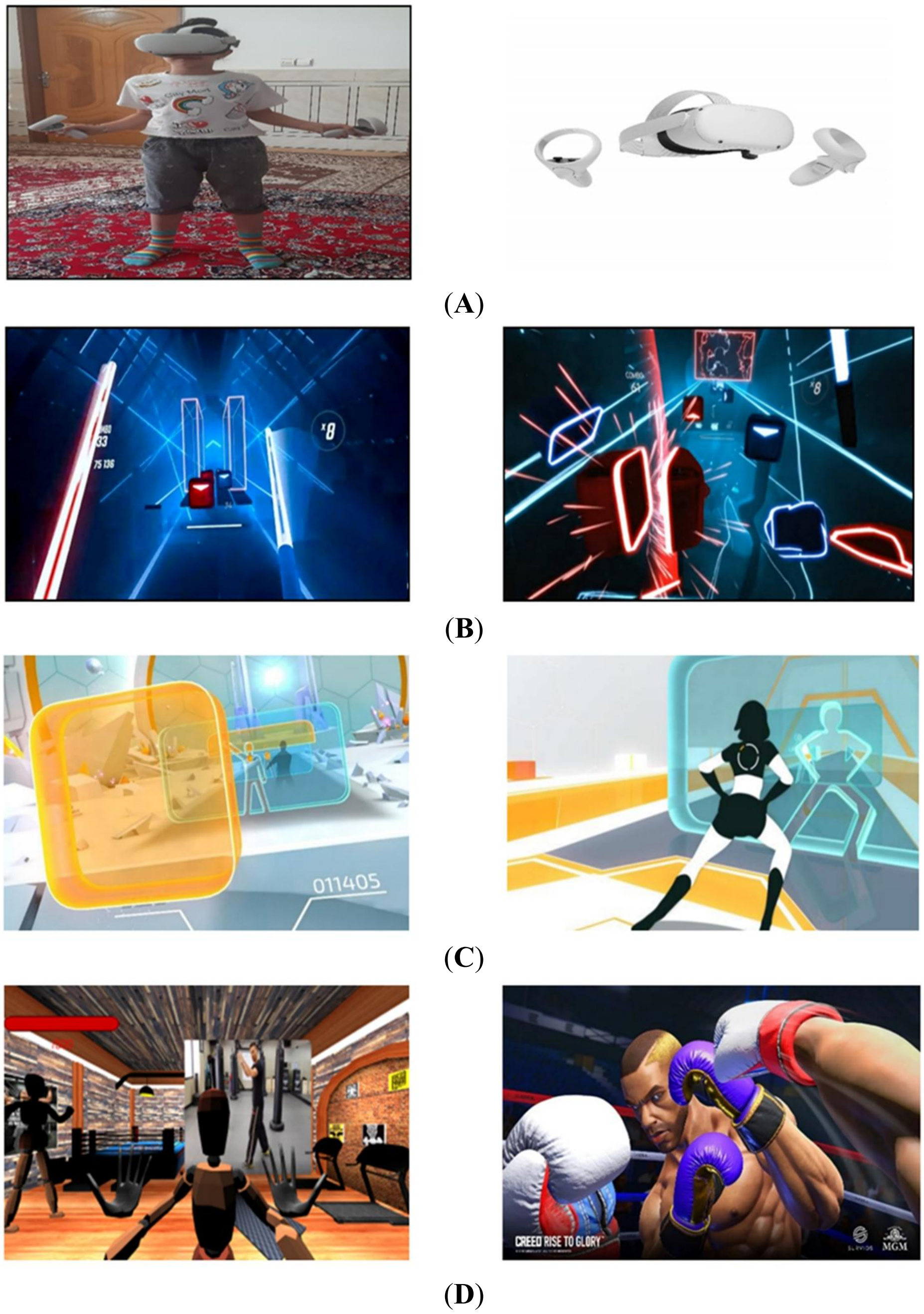

Figure 1. The schematic image of the VR device and the selected games. **(A)** Oculus Quest 2; **(B)** Beat Saber; **(C)** Ohshape; **(D)** Creed: Rise to Glory.

2.5. Data collection methods

To implement the training interventions and collect data, a preliminary study was conducted about the time and duration of the entire testing protocol for each person. Then, individuals were invited to attend at the reserved times to have better time management. All tests were applied and recorded in three phases, including the pre-test phase (baseline), the second-and fourth-week exercise-intervention implementation phases (as two post-test sessions).

2.5.1. Young's Internet Addiction Test (YIAT)

In this study, the YIAT test was used to evaluate the internet-addicted level of individuals [47]. This questionnaire is the first valid and reliable source to measure internet addiction, which contains 20 self-report items. Also, it classifies IA levels into three categories (i.e., Mild, Moderate, and Severe). Each item is scored by using a six-point Likert-type scale such as 1. Not Applicable ($_0$); 2. Rarely ($_1$); 3. Occasionally ($_2$); 4. Often ($_4$); 5. Always ($_5$). In this regard, scores between 31 and 49 illustrate the presence of a mild level of Internet addiction (mild IA), 50 to 79 indicate moderate Internet usage (moderate IA), and 80–100 show excessive Internet use (severe IA). This questionnaire has been standardized and its validity and reliability have been reported in previous studies with Cronbach's alpha of 0.9. The reliability of this scale has been confirmed by Cronbach's alpha coefficient of 0.88 in students [48].

2.5.2. Central obesity indices

As mentioned previously, all measurements were done in three phases (i.e., baseline, second-, and fourth-week phases) by an expert while the participants were standing barefoot and wearing minimal clothes. Their body weight (BW) was measured by a digital scale (ROYSA SCALE; having an accuracy of 0.5 kg) while their bladder was empty. Participants' height (H) was measured by a stadiometer with an accuracy of 0.1 cm. In addition, waist circumference (WC) was measured by placing a measuring tape (having an accuracy of 0.1 cm) on the horizontal surface between the lower rib and the umbilicus crown (the line above the navel), while hip circumference (HC) was evaluated as the greatest distance around the hips. Subsequently, the values of BMI, WHtR, and WHR were calculated using the following equation (Equations (2)–(4)) [49].

Abdominal Volume Index (AVI) predicts the fat distribution in the body's central region which is known as one of the best indices of central obesity evaluation [31]. On the other hand, other indices were calculated using the following equation (Equations (5)–(8)), including body adiposity index (BAI, called an independent-weight index) [31,50], cone index (CI, known as a model for evaluating obesity and body fat distribution) [31,49], and body shape index (ABSI, being useful to identify visceral obesity along overweight and obese people) (see Equations (5)–(8)) [49,51].

$$\mathrm{WHR} = \mathrm{WC\ (cm)} \div \mathrm{HC\ (cm)} \tag{2}$$

$$\mathrm{BMI(kg/m^2)} = \mathrm{BW\ (kg)} \div \mathrm{H^2\ (m^2)} \tag{3}$$

$$\mathrm{WHtR} = \mathrm{WC\ (cm)} \div \mathrm{H\ (cm)} \tag{4}$$

$$\mathrm{AVI} = \frac{2(\mathrm{WC})^2 + 0.7(\mathrm{WC}-\mathrm{HC})^2}{1000};\ \mathrm{WC\ (cm);\ HC\ (cm)} \tag{5}$$

$$\mathrm{BAI} = \frac{\mathrm{HC\ (cm)}}{\mathrm{H}^{\frac{3}{2}}\ (\mathrm{cm}) - 18} \tag{6}$$

$$\text{CI index} = \frac{\text{WC (m)}}{0.109\sqrt{\frac{\text{BW (kg)}}{\text{H (m)}}}} \quad (7)$$

$$\text{ABSI} = \frac{\text{WC (m)}}{\text{BMI}^{\frac{2}{3}} \times \text{H}^{\frac{1}{2}}\ \text{(m)}} \quad (8)$$

2.5.3. Cardiorespiratory hemodynamic indices

The selected hemodynamic and cardiorespiratory indices were measured at three conditions; pre-exercise (rest), immediate after Queen's College Step Test (maximum), and at the third minute of post-exercise (recovery) status in three phases (i.e., baseline, second-, and fourth-week phases) while the participants were in the seated position. The blood pressures (i.e., systolic (SBP) and diastolic (DBP); mmHg), and the heart rate (HR) were assessed after 5 to 10 min of rest status in a seated position via an automatic pneumatic blood pressure machine having an appropriately sized cuff (Roosmax, Model ME701, Switzerland). Subsequently, the myocardial volume oxygen (MvO_2), known as the index of myocardial oxygen consumption, was calculated by multiplying SBP by HR. Continuous peripheral blood oxygen saturation (SpO2) was measured via a wearable finger pulse oximeter (Brisk, Model PO16, China). Therefore, individuals were asked to wear the pulse oximeter on the index finger of their non-dominant hands. The constructor has reported an accurate SpO2 measurement of about ± 2% [52].

To evaluate the cardiorespiratory fitness index (VO2max), we used the method of Queen's College step test (QCST) reported previously [53], which is illustrated in Equations (9) and (10).

$$\text{Girls}: \ \text{VO2 max}\ (\text{mL/kg}^1.\text{min}^1) = 65.81 - 0.1847(\textit{Average Heart Rate}) \quad (9)$$

$$\text{Boys}: \ \text{VO2 max}\ (\text{mL/kg}^1.\text{min}^1) = 111.33 - 0.42(\textit{Average Heart Rate}) \quad (10)$$

Afterward, the oxygen pulse values were calculated based on Wasserman et al.'s formula (Equation (11)) [54].

$$\text{O2 Pulse}\ (\text{mL/kg}^1.\text{min}^1.\text{bmp}^1) = \frac{\text{VO2max}}{\textit{Maximal Hear Rate}} \quad (11)$$

2.6. Statistical analysis

All statistical analyses were performed with SPSS software (version 28.0 for Windows, IBM, Armonk, NY, USA) while GraphPad Prism®, version 10 (GraphPad Software, Inc., La Jolla, CA, USA) was used for creating figures. Initially, the Shapiro-Wilk test was used to measure the normality distribution of data. The parametric statistical test of variance analysis in repeated measurements was used to investigate the possible changes in the parameters at different phases (i.e., baseline, 2 and 4 weeks of training interventions). If significant changes were observed, the Bonferroni test was conducted to determine the between-group comparisons. Data are expressed as mean standard deviation. The significant value was set at $p < 0.05$.

3. Results

Although 150 participants registered in the current study, 103 individuals (51 boys, 52 girls) accomplished the protocols, completely. 47 persons were left aside stemming from some reasons, including; a) 26 individuals could not participate due to parental issues (i.e., their rejection, disallowance, and refusal); b) 11 persons participated in less than nine sessions of the training protocols (< 75% of total sessions); c) 10 individuals were not able to participate because of conflict scheduling and timing of this program with their other classes and plans. Therefore, the tests and their following analysis were applied to 103 subjects.

On the other hand, it should not be neglected that one specific expert collected the data, who was also responsible for checking the related calibration of applied devices.

3.1. Alternation of central obesity indices following various training protocol interventions

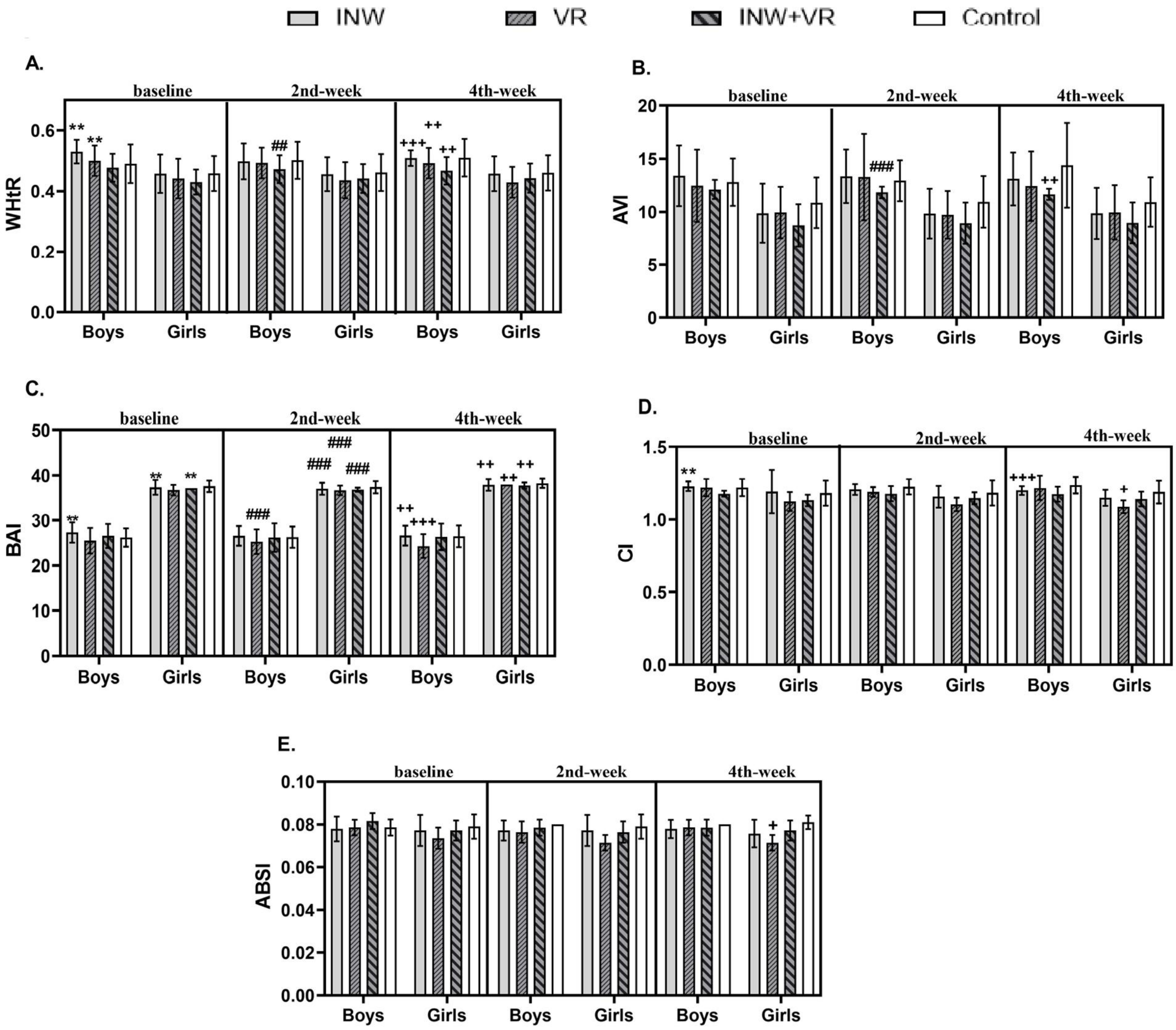

Figure 2. Impact of various training protocols (i.e., INW, VR, and INW + VR) on central obesity indices (mean ± standard deviation) among internet-addicted boys and girls. **(A)** The influences of different training interventions on WHtR values in IA boys and girls following the four weeks of training protocols; **(B)** The influences of different

training interventions on AVI values in IA boys and girls following the four weeks of training protocols; **(C)** The influences of different training interventions on BAI values in IA boys and girls following the four weeks of training protocols; **(D)** The influences of different training interventions on CI values in IA boys and girls following the four weeks of training protocols; **(E)** The influences of different training interventions on ABSI values in IA boys and girls following the four weeks of training protocols.

Abbreviations; INW, interval Nordic walking protocol; VR, virtual reality training protocol; INW + VR, combined INW and VR training protocols; WHtR, waist-to-height ratio; AVI, abdominal volume index; BAI, body adiposity index; CI, cone index; ABSI, body shape index. * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$, Differences between baseline and 2nd-week; + $P < 0.05$, ++ $P < 0.01$, +++ $P < 0.001$, Differences between baseline and 4th-week; # $P < 0.05$, ## $P < 0.01$, ### $P < 0.001$, Differences between the 2nd-week and 4th-week.

The WHtR values lessened significantly among boy groups that performed training protocols compared to their control group after two and four-week timelines (**Figure 2A**; $p < 0.01$, $p < 0.001$). As for AVI, the values did not change among all boy-exercise-protocol groups (**Figures 2B**; $p > 0.05$**).** Regarding the training protocols (i.e., INW, VR, and INW + VR), In addition, generally, BAI values showed a significant drop following performing either INW or VR training protocols for four weeks compared to two-week exercise protocols, especially in girls (**Figure 2C**, $p < 0.001$). Whereas, all boy-exercise-protocol groups did not have any significant differences in central obesity (i.e., CI and ABSI) during the training interventions (**Figure 2D**,**E**; $p > 0.05$).

3.2. Alternation of resting hemodynamic indexes following various training protocol interventions

Although the heart rate considerably decreased among all boy training groups (i.e., boy-INW, boy-VR, and boy-INW + VR), especially after four-week workouts (**Figure 3A**; $p < 0.001$). Whereas, only girls who performed INW showed significantly lower heart rate values at rest status (**Figure 3A**; $p < 0.001$). As for systolic blood pressure at rest condition, almost all girl- and boy-training protocol groups (i.e., INW, VR, and INW + VR) noted lower values right after four weeks (**Figure 3B**; $p < 0.01$). Contrarily, resting diastolic blood pressure significantly lessened among boys who performed either INW or VR training protocols following four-week workouts (**Figure 3C**; $p < 0.001$, $p < 0.01$). In addition, the resting SpO2 values considerably increased among boys who performed both INW and INW + VR training protocols after four-week workouts (**Figure 3D**; $p < 0.001$, $p < 0.01$). As for MvO2, only VR training groups (i.e., girl-VR and boy-VR) showed lower values after four-week workouts (**Figure 3E**; $p < 0.001$, $p < 0.01$).

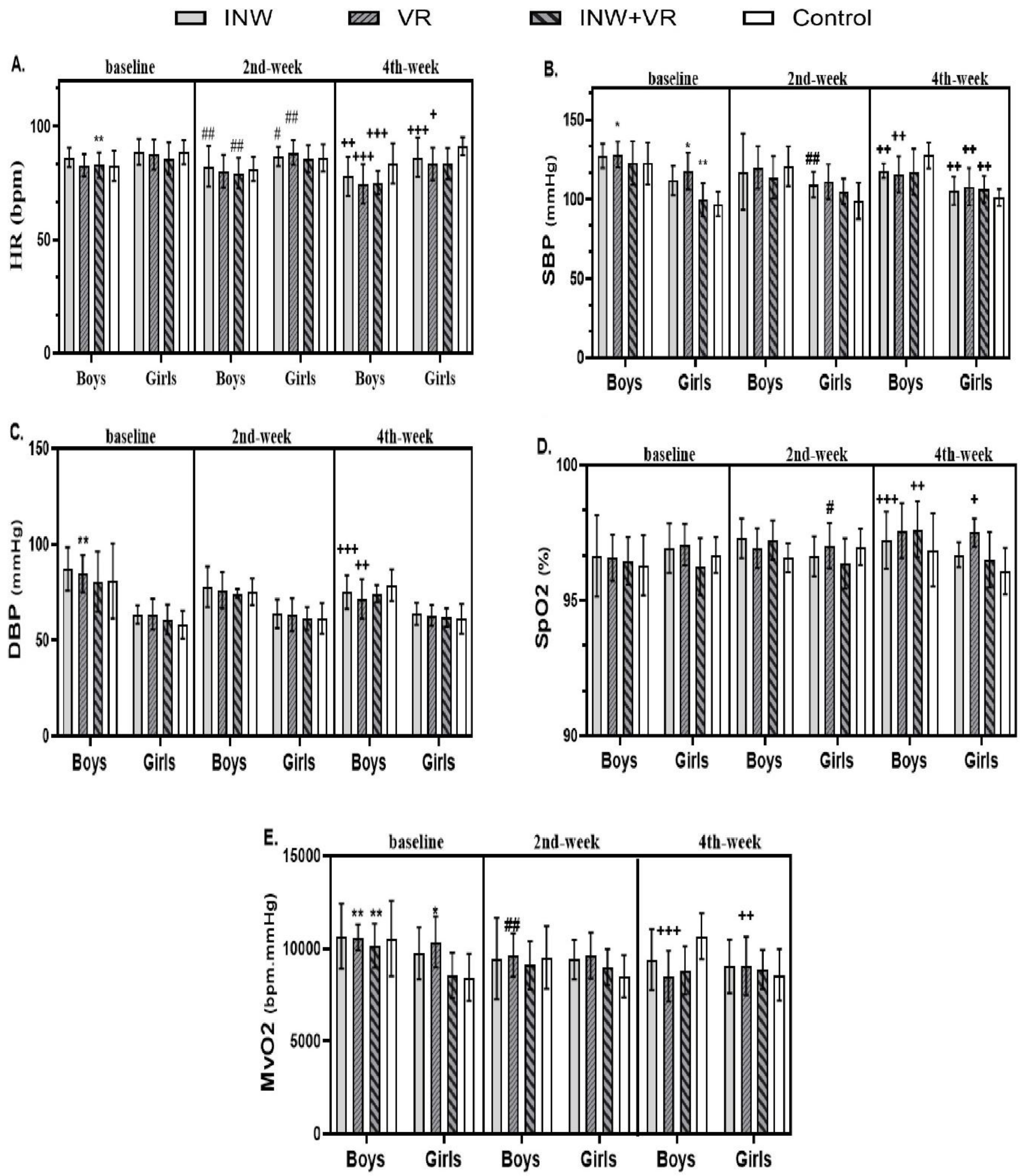

Figure 3. Impact of various training protocols (i.e., INW, VR, and INW + VR) on resting hemodynamic indexes (mean ± standard deviation) among internet-addicted girls and boys. **(A)** The influences of different training interventions on resting HR values in IA boys and girls following the four weeks of training protocols; **(B)** The influences of different training interventions on resting SBP values in IA boys and girls following the four weeks of training protocols; **(C)** The influences of different training interventions on resting DBP values in IA boys and girls following the four weeks of training protocols; **(D)** The influences of different training interventions on resting SpO_2 values in IA boys and girls following the four weeks of training protocols; **(E)** The influences of different training interventions on resting MvO_2 values in IA boys and girls following the four weeks of training protocols.

Abbreviations; INW, interval Nordic walking protocol; VR, virtual reality training protocol; INW + VR, combined INW and VR training protocols; HR, heart rate; SBP, systolic blood pressure; DBP, diastolic blood pressure; SpO2, blood oxygen saturation; MvO2, the myocardial volume oxygen.

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$, Differences between baseline and 2nd-week; + $P < 0.05$, ++ $P < 0.01$, +++ $P < 0.001$, Differences between baseline and 4th-week; # $P < 0.05$, ## $P < 0.01$, ### $P < 0.001$, Differences between the 2nd-week and 4th-week.

3.3. Alternation of maximal hemodynamic indexes following various training protocol interventions

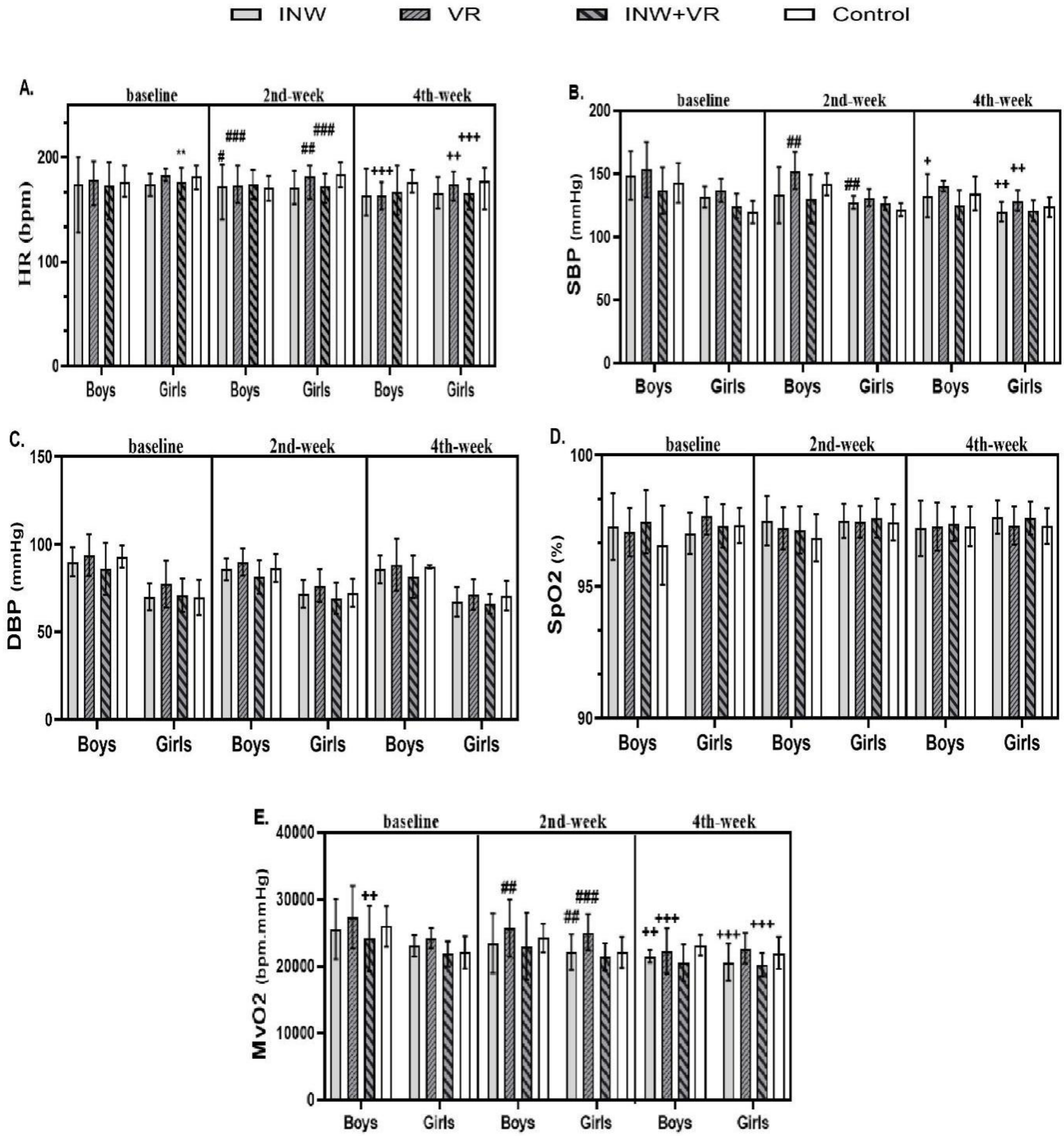

Figure 4. Impact of various training protocols (i.e., INW, VR, and INW + VR) on maximal hemodynamic indexes (mean ± standard deviation) among internet-addicted girls and boys. **(A)** The influences of different training interventions on maximal HR values in IA boys and girls following the four weeks of training protocols; **(B)** The influences of different training interventions on maximal SBP values in IA boys and girls following the four weeks of training protocols; **(C)** The influences of different training interventions on maximal DBP values in IA boys and girls following the four weeks of training protocols; **(D)** The influences of different training interventions on maximal SpO_2 values in IA boys and girls following the four weeks of training protocols; **(E)** The influences of different training interventions on maximal MvO_2 values in IA boys and girls following the four weeks of training protocols.

Abbreviations; INW, interval Nordic walking protocol; VR, virtual reality training protocol; INW + VR, combined INW and VR training protocols; HR, heart rate; SBP, systolic blood pressure; DBP, diastolic blood pressure; SpO2, blood oxygen saturation; MvO2, the myocardial volume oxygen.
* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$, Differences between baseline and 2nd-week; + $P < 0.05$, ++ $P < 0.01$, +++ $P < 0.001$, Differences between baseline and 4th-week; # $P < 0.05$, ## $P < 0.01$, ### $P < 0.001$, Differences between the 2nd-week and 4th-week.

The maximal heart rate considerably decreased only in the boy-VR group after four weeks (**Figure 4A**; $p < 0.001$). As for girls, those performed either VR or INW + VR training protocols showed significantly lower heart rate values (**Figure 4A**; $p < 0.001$). Plus, girls performing either INW or VR training protocols had lower maximal systolic blood pressure values after four-week (**Figure 4B**; $p < 0.01$). On the other hand, maximal diastolic blood pressure and SpO2 values had not altered among all boys and girls regarding various training protocols following four-week training protocols (**Figure 4C**,**D**; $p > 0.05$). Contrarily, as for maximal MvO2 values, four training groups (i.e., boy-INW, boy-VR, girl-INW, and girl-INW + VR groups) had significantly lower values after four-week workouts (**Figure 4E**; $p < 0.001$).

3.4. Alternation of hemodynamic indexes at post-exercise (recovery) status following various training protocol interventions

At recovery condition, the heart rate values did not change among girls and boys following different four-week training protocols (i.e., INW, VR, and INW + VR) (**Figure 5A**, $p > 0.05$). As for recovery systolic blood amounts, the values dropped among individuals who performed VR training protocol (i.e., girl-VR and boy-VR groups) following four-week workout (**Figure 5B**; $p < 0.01$). Whereas, some hemodynamic parameters (i.e., diastolic blood pressure, and SpO2) did not change among girls and boys following different four-week training protocols (i.e., INW, VR, and INW + VR) (**Figure 5C**,**D**; $p > 0.05$). On the other hand, resting MvO2 had significantly lower amounts among girls who performed either VR or INW + VR training protocols as well as boys who performed VR training protocol after four-week workouts (**Figure 5E**, $p < 0.001$).

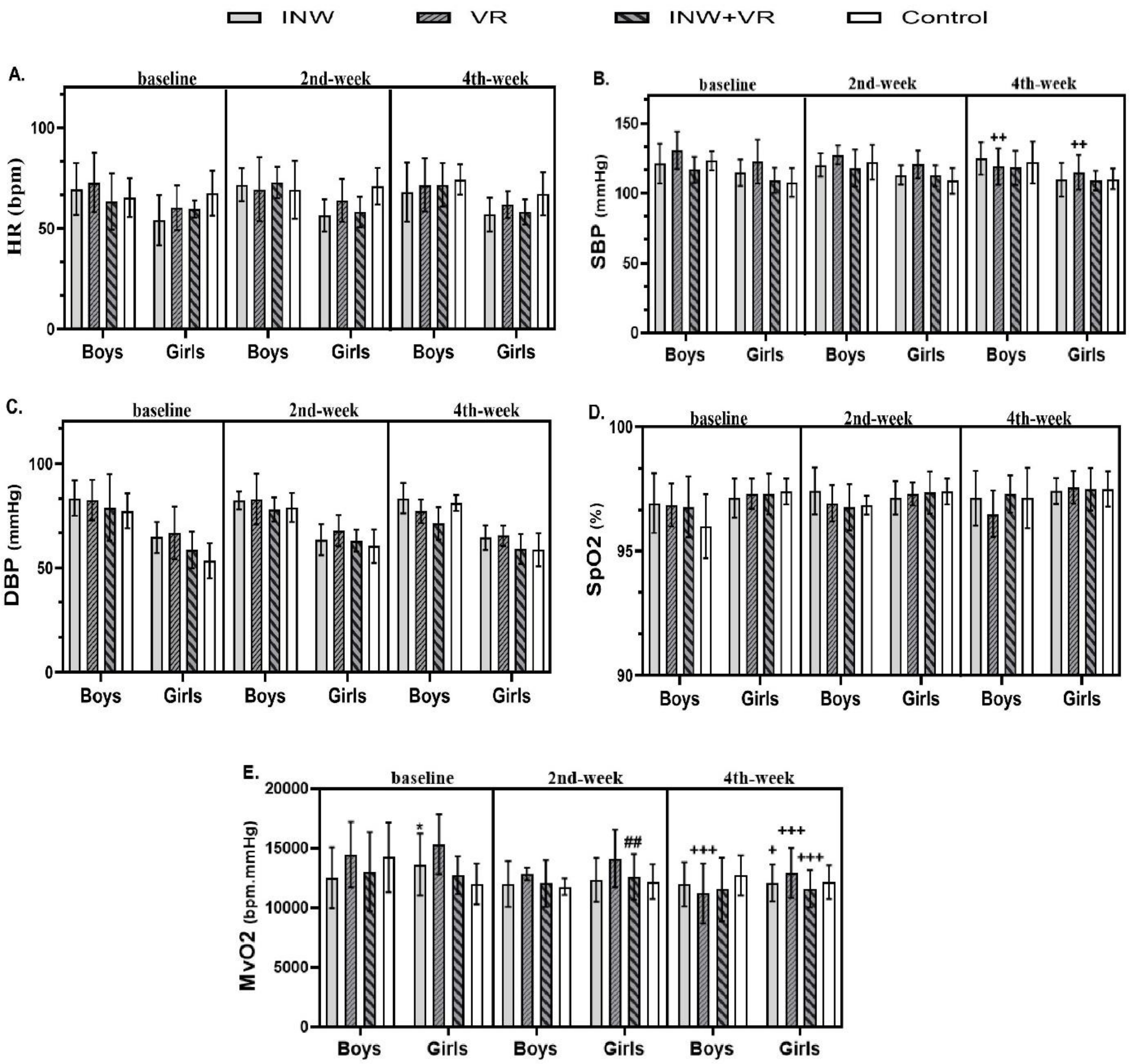

Figure 5. Impact of various training protocols (i.e., INW, VR, and INW + VR) on recovery hemodynamic indexes (mean ± standard deviation) among internet-addicted girls and boys. **(A)** The influences of different training interventions on recovery HR values in IA boys and girls following the four weeks of training protocols; **(B)** The influences of different training interventions on recovery SBP values in IA boys and girls following the four weeks of training protocols; **(C)** The influences of different training interventions on recovery DBP values in IA boys and girls following the four weeks of training protocols; **(D)** The influences of different training interventions on recovery SpO_2 values in IA boys and girls following the four weeks of training protocols; **(E)** The influences of different training interventions on recovery MvO_2 values in IA boys and girls following the four weeks of training protocols.

Abbreviations; INW, interval Nordic walking protocol; VR, virtual reality training protocol; INW + VR, combined INW and VR training protocols; HR, heart rate; SBP, systolic blood pressure; DBP, diastolic blood pressure; SpO2, blood oxygen saturation; MvO2, the myocardial volume oxygen.

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$, Differences between baseline and 2nd-week; + $P < 0.05$, ++ $P < 0.01$, +++ $P < 0.001$, Differences between baseline and 4th-week; # $P < 0.05$, ## $P < 0.01$, ### $P < 0.001$, Differences between the 2nd-week and 4th-week.

3.5. Alternation of cardiorespiratory index (VO2max) and O2 Pulse following various training protocol interventions

Regarding various training protocols (i.e., INW, VR, and INW + VR), VO2max elevated significantly among internet-addicted boys and girls compared to control groups, especially following four-week training protocols (**Figure 6A**; $p < 0.001$). Similarly, as for O2 Pulse, all girl-training protocol groups (i.e., girl-INW, girl-VR, and girl-INW + VR) and the boy-VR group showed significant values, especially after four-week workouts (**Figure 6B**; $p < 0.001$).

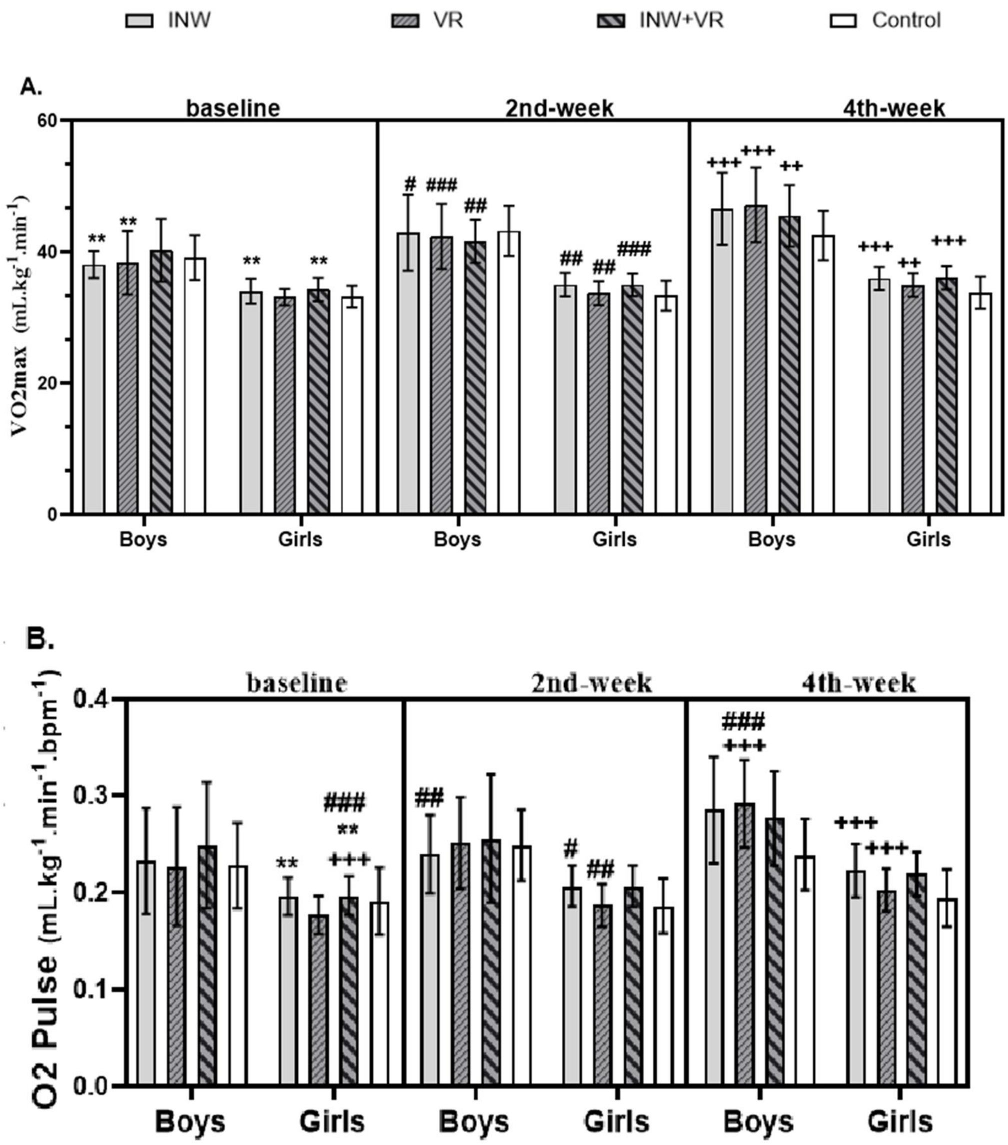

Figure 6. Impact of various training protocols (i.e., INW, VR, and INW + VR) on the cardiorespiratory index (VO2max) and O2 Pulse (mean ± standard deviation) among internet-addicted boys and girls. **(A)** The influences of different training interventions on VO2max values in IA boys and girls following the four weeks of training protocols; **(B)** The influences of different training interventions on O2 Pulse values in IA boys and girls following the four weeks of training protocols.

Abbreviations; INW, interval Nordic walking protocol; VR, virtual reality training protocol; INW + VR, combined INW and VR training protocols; VO2max, maximum oxygen consumption; O2 Pulse, oxygen pulse.

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$, Differences between baseline and 2nd-week; + $P < 0.05$, ++ $P < 0.01$, +++ $P < 0.001$, Differences between baseline and 4th-week; # $P < 0.05$, ## $P < 0.01$, ### $P < 0.001$, Differences between the 2nd-week and 4th-week.

4. Discussion

Regarding our knowledge, the current research is among the first VR studies that investigated the separated and combined effects of VR and INW on central obesity indices and VO2max among internet-addicted teenagers during 2- and 4-week training protocol interventions. The result illustrated that applying VR technology was beneficial for body composition and cardiorespiratory indices' improvements among boys and girls. Interestingly, the combination VR and INW (VR + INW) protocol did not have any significant differences compared to the separated VR and INW training protocols, which means each training protocol intervention (i.e., VR, INW, and VR + INW) positively altered central obesity indices and improved cardiorespiratory fitness among IA teenagers. This body composition improvement was consistent with increasing cardiorespiratory index (VO2max) among internet-addicted boys and girls. In addition, the greatest impact on central obesity happened when teenagers performed the long-term training protocols (4 weeks vs 2 weeks), which expresses the undeniable effectiveness of regular physical activities and training on controlling obesity and related problems, especially in a longer period.

In many societies, technological advances and some barriers have made people avoid participating in exercise activities, especially among children and adolescents (in terms of safety issues and occupied situation of families), resulting in the occurrence of problems related to poor mobility and sedentary lifestyles, which should be acknowledged that there is no escape from their consequences in many cases. Evidence declares that internet addiction is associated with problem occurrences in sleep quality and lifestyle [55], obesity and body-composition-related issues [6,56], musculoskeletal problems [11], and the decline of academic performance [57]. Similarly, studies express that there is a positive correlation between internet addiction, obesity, and weight gain, especially in teenagers [6]. Therefore, researchers are seeking qualified strategies to control/modulate the side effects of internet-related equipment overuse. Accordingly, during the last decade, it has been reported that targeted physical activities can be considered as a suggested therapy and also an alternative for medicine and psychological treatments of internet addiction among various groups [10,14,23]. To illustrate, regular physical activities reduced the internet-addicted consequences like decreasing the duration of being online and the internet addiction severity [23], body composition improvement [27,28,30], improving cardiometabolic indices [25], and VO2max [58].

Although evidence has reported that boys are more active than girls [59–61], research literature shows conflicted regarding gender impacts on internet addiction [3]. For instance, Shek and Yu (2016) reported that internet addictive behavior was significantly higher among male high school adolescents [62]. Although Chiu et al. (2013) expressed that IA female college students were more addicted to smartphones compared to male students [63], Malik and Khan (2015) noted no gender predominance in Facebook addictions [64]. Similarly, it has been reported that problematic internet usage among university students without any gender differences [65]. Whereas, Alavi et al. (2011) illustrated that male university students are at three times greater risk of IA development compared to females [66]. Thus, regarding gender differences and internet addiction status, the varied outcomes could stem from multiple factors including cultural values, internet access, institutional policies, personal habits, and so on [3]. Additionally, province researches have illustrated that there is a negative relationship between physical activity levels and IA among adolescents regarding sex differences, which means internet-addicted boys and girls have similar less physical activity [67,68].

It is reported that performing an aerobic interval training causes the betterment aerobic capacity even following a short-term exercise protocol [69,70] because of challenging the heart's pumping ability [71]. Also, based on informal comments and compared to continuous training protocols, interval training could be more motivating for individuals since it has variety of training procedure per exercise session [71]. In our study, the central obesity parameters significantly lessened among girls in both groups performing INW training protocols (i.e., INW and VR + INW groups) for 4 weeks. These changes were aligned with increasing the cardiorespiratory fitness index (VO2max), which was observed in either internet-addicted girls or boys. Although the present study duration was relatively short due to some research limitations in female and male adolescent populations, study literature revealed that performing INW training protocols has greater influences on body calorie consumption rather than regular walking as it involves both upper- and lower-body [72,73], which subsequently affects body composition and cardiorespiratory fitness. Additionally, it is expressed that INW improves the strength of both lower [73,74] and upper limbs [58,73], considerably. These beneficial alternations stem from applying the canes while walking, which involves the majority of muscle mass in the upper body and arms during walking [25–27]. On the other hand, during performing NW, the upper-body muscular activities boosted the energy expenditure by increased oxygen consumption [75]. Subsequently, it elevates fat free mass and basal metabolism [72], which lead to weight loss and reduction of waist circumference, BMI [76–78], and percentage of body fat [76,77].

Likewise, NW protocol is considered as an easy-universal type of physical activity in which the activity pattern is suitable for all group populations regarding age, culture, gender, and educational or income level. On the other hand, unlike many sports and physical activities, it does not require expensive equipment and special skills, which can be often performed outdoors. In addition, performing physical activities outdoors such as parks and natural environments have greater advantages in reducing physical-mental stress and improving health levels compared to indoors [79,80]. Thus, its popularity has risen among people these days. Although long-term training courses are required for significant changes in body composition and performing one-month training protocol is too short for observing significant alternation of central obesity among IA girls and boys, in this study, it seems that the reduction of some central obesity indices (i.e., ABSI and CI) among IA girls during this relatively short time duration can be initially caused by the sedentary lifestyles, pattern of NW training (i.e., simultaneous involvement of upper and lower limbs), and also probable-less fatigue related to training in parks and/or applying interval NW pattern (i.e., recovery periods between exercises) in comparison with other researches.

Innovative technological advances (i.e., virtual reality glasses) have provided opportunities for promoting physical activities (PA) through attractive and entertaining methods. Several studies declared that VR activities could influence the mental and physical health of players, positively. In this study, the second aim was to investigate the effects of VR training on the body composition among IA girls and boys following 2- and 4-week training protocol. The results express that performing the VR training protocol for 4 weeks improved the body composition among IA girls, and also the combined VR and INW training protocol (i.e., VR + INW) caused a noticeable improvement in body composition among both IA girls and boys following the 4-week training intervention. Even though there are just a few investigations to compare the findings, Lee and Kim (2018) evaluated the effects of 4-week VR training on the body composition of 21 male university students and they noted a significant decrease in BMI and body fat percentage [34]. Recently, it has been reported that an 8-week VR training protocol can result in reduced BMI values in comparison with the baseline levels among overweight middle-aged women. Also, this study revealed that this VR training protocol can be considered an effective home exercise program for controlling obesity [81]. In addition, another study was conducted about the effectiveness of a controlled VR trial on fitness and cardiometabolic indices of 24-year-old women, which confirmed VR training significantly improved upper-and-lower muscular strength (1-RM), muscular endurance (85% 1-RM), peak leg power, and VO2max while lessened body fat%, systolic BP, and level of perceived exertion during workouts [82]. Evidence states that performing VR training activates the small muscles in the body, which are not often involved during regular physical activities such as regular walking. Plus, VR training is performed symmetrically and requires bilateral movements, therefore, it activates the central muscles and ultimately increases trunk stability [34,83]. In this study, it seems that the body composition changes can be attributed to the call of small muscles along with larger muscles during the combined VR + INW training protocol among sedentary-IA girls and boys.

Evidence illustrates that performing VR for a long time may be associated with its enjoyable impacts which distract the individuals' attention from body sensations resulting in discomfort feeling while any conventional exercise sessions [83,84], especially among overweight children [84]. To prove that, Deforche and De Bourdeaudhuij (2015) reported that music distraction can influence the extension of the running intensity and distance [85]. The evidence expressed that training under VR condition and environment would help to perform intense exercise while being distracted from the discomfort feeling resulted by such training protocols [86]. Moreover, Yao and Kim (2019) also reported that the individuals' psychological arousal and their presence level boosted during the training protocol [86]. Therefore, based on our knowledge, our study is aligned with other VR researches, which recommends considering VR method as a beneficial exercise training protocol.

5. Research limitations

This study was conducted among internet-addicted adolescent boys and girls, which faced some limitations. Firstly, the sample size of the teenage subjects was small because it was difficult to find IA individuals which led us not to be able of gathering a larger sample size. Secondly, the present study was conducted during the educational timeframe which resulted in considering the time limitation of students' academical duties, therefore, it was not possible to extend the study timeline. Another reason for short duration of the training protocols was due to the lack of parental cooperation, which itself stemmed from the cultural issues of the society and the logical concerns of the families, and also the lack of time to deal with the leisure activities because of their educational duties and responsibilities. Additionally, we were not able to control the individuals' diet, completely. In other words, although we generally recommended them to observance a healthy diet during the research timeline and kindly asked them not to change their eating habits, more strict control of diet was avoided since boys and girls were in the growth and puberty periods and also based on following the ethical issues. In addition, the current study aimed to track the physical-parameter changes following performing different training protocols among IA girls and boys, therefore, NO psychological tests related to measuring mental health were conducted. Subsequently, we kindly recommend that future investigation consider the mental health tests as well. Plus, with school co-operation, a combined VR + INW protocol can be applied as a physical education course during one semester which maybe solves parental concerns.

6. Conclusion

Our study contributes some improved hemodynamical cardiorespiratory indices and reduced central obesity following performing a 4-week VR training protocol among internet-addicted girls and boys, especially when it was combined with interval Nordic walking (INW) training protocol. These observations express that expected improvements depend on the long-term implementation (4 weeks vs. 2 weeks) of VR training interventions, especially for central obesity indices. Also, it could be recommended that a combined VR-INW training protocol would be associated with potential advantages on health status among internet-addicted girls and boys, which can be considered as a crucial non-pharmacological strategy to prevent a sedentary lifestyle and maintain health status. Regarding the existing limitations in sports spaces (i.e., gyms) and the financial problems of expensive costs of private sports clubs on the one hand, and the simplicity and low cost of interval Nordic walking in natural environments on the other hand, we recommend applying this training mode among children and teenagers for physical fitness related to health purposes. Similarly, the VR training protocols can also be used for longer periods in house environments all year long.

Author contributions: Study design, VDR; data management, VDR; data acquisition, ZSK and NNB; data analysis and figures, SP; draft of the article, SP and VDR; revision of the article, VDR, SP, ZSK and NNB. All authors have read and agreed to the published version of the manuscript.

Ethics approval: This study was approved by the Faculty of Physical Education Ethical Research Committee (Ethical code: IR.UMZ.REC.1401.008). The study was conducted in accordance with the Declaration of Helsinki

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Availability of data and materials: The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Conflict of interest: The authors declare no conflict of interest.

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