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Exergaming as a Means of Increasing Physical Activity Among Adolescents.

Abstract

Background: Exergaming is a new genre of videogame that is geared toward promoting Physical Activity (PA) and mental fitness. In other words, it is a digital game that requires bodily movements to play, stimulating an active gaming experience to function as a form of physical activity. Consequently, PA can improve quality of life, extend life expectancy, and lower the risk of certain cancers. On top of that, it can reduce cardiovascular diseases, depression, etc., and the opposite is true for insufficient physical activity. Moreover, low maximal oxygen uptake (VO_{2max}) has an increased risk of premature death and the development of numerous chronic diseases, adolescent with a high VO_{2max} have a lower risk of developing chronic diseases, all-cause mortality, and coronary artery disease. Therefore, active videogame (exergaming) systems have an auspicious effect on health improvement. This study aims at providing inactive adolescents with free access to a cycling exergaming platform for 24 weeks.

Method: A written informed consent was obtained from all participants before participation. The subjects were given a Sensewear armband (SWA) to wear for one week before being tested for blood pressure, body composition, VO_{2max}, height, and weight. The assessments were carried out at baseline, after 12 weeks, and on the 24th week, and were conducted as similarly as possible in order to reduce any potential sources of error. Except for the PA assessment, all the tests were performed on the same day and lasted approximately 1–1.5 hours. The subjects were advised not to engage in any vigorous activity for 48 hours before the tests. Data were analyzed using SPSS, version 22, and the level of significance was set at 0.05. Two-way mixed ANOVA was used to examine the interaction between the dependent and independent variables.

Results: There was no significant difference between the groups ($p = 0.059$) after 24 weeks for MPA. VPA and VVPA levels after 24 weeks show no significant difference between groups ($p = 0.563$) and ($p = 0.170$), respectively. But MPA at 12 weeks showed significant difference between groups ($p = 0.048$). VPA at 12 weeks also had significant difference between groups ($p = 0.049$). No significant difference between the groups with respect to VO_{2peak}, but a trend in statistical analysis showed some level of significance after the intervention ($p = 0.137$) and within the play group from baseline to post-tests ($p = 0.100$).

Conclusion: No significant change was detected for PA levels after 24 weeks, only a slight significant showed at 12 weeks. 24 weeks of exergaming improved VO_{2peak}. The change in VO_{2peak} had a trend towards significance in both control and play group. The long-term effects of exergaming on adolescents require further studies.

Keywords: VO_{2peak}, Cardiorespiratory fitness, Physical activity, sedentary behavior, and exergaming.

Abbreviations

PA	Physical activity
SD	Standard deviation
SDs	Standard deviations
Anova	Analysis of variance
CRF	Cardiorespiratory fitness
CVD	cardiovascular disease
MPA	Moderately physical activity level
VPA	Vigorously physical activity level
VVPA	Very vigorously physical activity level
VO_{2max}	Maximal oxygen consumption
VO_{2peak}	Peak oxygen consumption
DDR	Dance Dance Revolution
ACSM	American College of Sports Medicine
WHO	World Health Organization
SB	Sedentary behavior
METs	Metabolic equivalents
AVGs	Active video games
HRMs	Heart rate monitors
EE	Energy expenditure
SWA	Sensewear armband

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1.0 INTRODUCTION AND BACKGROUND

1.1 Physical Activities, Sedentary Behaviors, and Cardiorespiratory fitness

Physical activity (PA) among adolescents can improve quality of life, extend life expectancy, and lower the risk of certain cancers such as colon and breast cancers. In addition, PA can reduce cardiovascular diseases, depression, obesity, diabetes type 2, and hypertension. PA is an intentional movement that alters the body's energy balance and hence reduces the chance of becoming overweight (1). In light of the above, PA can be defined as any physiological action that is performed by skeletal muscles. Doing so maximizes energy consumption and reduces the all-cause mortality.

Insufficient physical activity is a significant predictor of non-communicable diseases such as cardiovascular disease, diabetes mellitus, stroke, and cancers and health outcomes such as mental health injuries and as well as obesity(2). Nevertheless, frequent exercise is strongly associated with a decrease in cardiovascular mortality as well as the risk of developing cardiovascular disease. Physically active individuals have lower blood pressure, higher insulin sensitivity, and a more favorable plasma lipoprotein profile. Even though moderate levels of exercise have been found to be consistently associated with a reduction in cardiovascular disease risk, there is evidence to suggest that continuously high levels of exercise (e.g., marathon running) could have detrimental effects on cardiovascular health (3). However, a specific dose-response relationship between the extent and duration of exercise and the reduction in cardiovascular disease risk and mortality remains unclear.

On one hand, cardiovascular disease (CVD) is the leading cause of morbidity and mortality worldwide. For instance, in the United States, CVD accounts for ~600,000 deaths (25%) each year and after a continuous decline over the last 5 decades, its incidence is increasing again (4). Among the many risk factors that predispose CVD development and progression, sedentary behavior, characterized by consistently low levels of physical activity, is now recognized as a leading contributor to poor cardiovascular health. On the other hand, regular exercise and physical activity are associated with remarkable widespread health benefits and a significantly lower CVD risk. Several long-term studies have shown that increased physical activity is associated with a reduction in all-cause mortality and may modestly increase life expectancy, an effect that is strongly linked to a decline in the risk of developing cardiovascular and respiratory diseases (4).

Moreover, better fitness levels in both men and women can partially reverse the elevated rates of all-cause mortality as well as CVD mortality associated with high body mass index (5). Recent work from cardiovascular cohorts shows that sustained physical activity is associated with a more favorable inflammatory marker profile, decreases heart failure risk, and improves survival at 30 years of follow-up in individuals with coronary artery disease (6). What is more, fitness is a strong and independent predictor of cardiovascular disease, as well as all-cause mortality and morbidity, in adults. Cardiovascular fitness is essential for everyday activities like walking, running, and stair climbing. According to research, people with a low VO_{2max} have an increased chance of premature death, as well as the development of numerous chronic diseases, while individuals with a high VO_{2max} have less chance of developing chronic diseases, all-cause mortality, and coronary artery disease. The VO_{2max} has a wide range of applications, from elite athletes to persons with different pathologic conditions(7). The VO_{2max} is the gold standard for determining a person's cardio-respiratory endurance.

The American College of Sports Medicine (ACSM) recommends that most adults should be involved in moderate-intensity cardiorespiratory strength training(8). Thus, an adult need at least (or ≥ 30 $min \cdot d^{-1}$ on ≥ $5d \cdot wk^{-1}$ for a total of ≥ 150min·wk-1) moderate-intensity cardiorespiratory strength training(9). For what concerns vigorous-intensity cardiorespiratory strength training, an adult requires at least (or ≥ 20 $min \cdot d^{-1}$ on ≥ $3d \cdot wk^{-1}$ for a total of ≥ $75min \cdot wk^{-1}$). Finally, for total energy expenditure of ≥ 500 – 1000 $MET \cdot min \cdot wk^{-1}$, a combination of moderate- and vigorous-intensity strength training is recommended. Besides, adults who are unable or unwilling to meet the exercise targets outlined here still can benefit from engaging in amounts of exercise less than recommended. It is worthy of note that these guidelines apply to anyone, regardless of nationality, income level, or gender(10). The following section discusses the influence of industrialization and automation on tertiary employees' health. Also, clear definitions of the following terms: physical activity, physical inactivity, and sedentary behaviors will be discussed. Finally, to emphasize the urgent need to address sedentary behaviors. In other words, recommendations are needed to improve tertiary employees' health.

1.2 Occupational health implications, sedentary behavior, physical activity, and inactivity

In the early stages of fostering an active and healthy lifestyle, research and guidelines mostly focused on the total amount of physical activity. However, research over the last decade has demonstrated that sedentary behavior (SB) is a reliable health indicator regardless of the amount of PA(11). Therefore, lifestyle interventions should focus not only on improving PA but also on minimizing SB. Our societies' industrialization and automation have favored the emergence and growth of sedentary possibilities and habits in the last century. A worker’s activity has evolved throughout the last century, clearly shifting to more sedentary occupational tasks. This Sedentariness has recently been identified as a major mortality risk factor independent of physical activity (11), and physical inactivity accounts for roughly 5.3 million deaths (12). The adverse effect of seated occupational activities on overall mortality has been well demonstrated in recent research, including meta-analyses(12).

Some studies have also demonstrated that the mortality rate rises by 2% for every hour spent seated. And this can increase by 8% per hour when the total continuous time spent seated is greater than 8 hours per day (12). Furthermore, humans are currently living in a paradoxical time in which our society has become more "technophilic," favoring ways of avoiding and/or minimizing physical effort with more time devoted to sedentary behaviors; whereas, on the other hand, there is a growing interest and concern for healthy lifestyles. In order to avoid any equivocal and misinterpreted messages across the concepts of sedentary behaviors, physical activity, and inactivity, there is a need to provide a clear definition to distinguish these.

Table 1 Definition of terms(12)

Terms	Definition
Physical activity	Any body movement generated by the contraction of skeletal muscles raises energy expenditure above the resting metabolic rate. It is characterized by its modality, frequency, intensity, duration, and context of practice.
Physical inactivity	Represents the non-achievement of physical activity guidelines
Sedentary behaviors	Any waking behavior is characterized by an energy expenditure ≤1.5 metabolic equivalents (METs) and a sitting or reclining posture. Here, two behavioral components are emphasized by his definition: an intensity/energy expenditure component and a postural component.

It is noteworthy that PA and SB are not the opposite of each other. Individuals are deemed active when they meet physical activity recommendations for their age, although this does not exclude them from spending a significant amount of time on sedentary activities. Thus, individuals can be classified as active and sedentary. Tertiary employees, for example, are the most sedentary inclined, as they spend the majority of their time seated in front of a computer screen (13).

The "tertiarization" of work has emphasized the urgent need to address sedentary behaviors and sedentary time during working hours. Recent studies have shown that health indicators such as waist circumference, body mass index (BMI), and fat mass are not improved among active employees who spend at least 7 hours per day seated at their desks mostly in front of a screen compared to inactive employees. This indicates that sedentary time has a negative impact on physical activity levels (12). To break up this sedentary time, standing workstations have been recommended. According to the Sedentary Behavior Research Group's framework, passive standing corresponds to 2 METs, which is more than the 1.5 METs threshold used to characterize sedentary behaviors, which are considered low physical activity (14).

1.3 Exergaming

The lack of movement (hypokinesia) is a major cause of non-communicable chronic diseases, accounting for 71% of all deaths each year (15). Hence, active videogame (exergaming) systems, such as Nintendo Wii and Xbox Kinect have recently gained in popularity. Exergaming is a new genre of video games that is geared toward promoting PA, and its effect on EE (16). Exergaming has pierced the technology and physical activity scenes with a twist and has led to technology and "screen time" now being viewed as catalysts for increasing PA (17).

This type of game is declared by 53% of the European population (15) and 58% of the North American population (15). Besides traditional video games, an increasing number of active video games (AVGs), in which the user controls the game by moving their entire body, are on the rise.

Many studies have found that physical efforts made during AVGs have a favorable effect on health improvement. (18) These games account for higher motor activation in players than traditional games (19). AVGs are also being studied for their effectiveness in adjuvant therapy (20, 21), particularly in patients who have had a stroke, are depressed, have multiple sclerosis, or have cancer (22). Sessions during AVGs can increase health-promoting PA, therefore this type of game could be a supplement to the daily dose of recommended physical activity. Furthermore, the high level of pleasure experienced during AVGs boosts the attraction of PA undertaken in its course. As a result, it may more effectively drive people to engage in it on a regular basis (23).

Today, there are many consoles that allow practicing exergames. The most well-known is Xbox Kinect. This consists of the Xbox video game console and a self-adjustable camera, which acts as a sensor to detect entire body movements. The Xbox gaming system allows for a controller-free type of gaming in which the user controls the games with his or her body movements. Generally, exergames that focus on the lower body and the entire body expend more energy than those that just focus on the upper body alone.

1.4 Physical Activity Measurement

The goal of assessing PA is to determine the frequency, duration, intensity, and types of behaviors performed over time. The rudiment of PA assessment is the quantification of EE. On the one hand, self-reported PA assessments include the establishment of questionnaires as well as the completion of detailed diaries and brief logs. Direct measures, on the other hand, include motion sensors, accelerometers, pedometers, heart rate monitors, and multiple-sensor devices (24). Self-reported questionnaires are commonly used as PA measures in epidemiological studies, which demonstrate that PA has obvious health benefits. Pettee-Gabriel et al.(25) introduced a framework to classify the components of human movement that guides PA assessment(24). Generally, self-reported tools are accepted by both researchers and the medical community. The tools are highly flexible, cost-effective, and low-burden for the subject. Subjective reporting with regards to self-reported methods can lead to either overestimation and/or underestimation of PA and sedentary time. On the other hand, direct PA assessment methods, including accelerometers, heart rate monitors, and pedometers, are thought to improve on estimates of exercise volume, intensity, and EE and can verify subjective reporting. Human errors in reporting bias and PA recall have decreased since the introduction of direct PA evaluation methods for PA assessment. In summary, the main objective of a PA assessment is to determine an effective exercise dose for minimizing health risk in the general populace and to tailor exercise prescription to the individual.

1.4.1 PA Assessment

Today, wearable monitors are on the rise in the field of PA evaluation to directly measure various components of PA. Wearable monitors provide more accurate assessments of physiological parameters than self-reported methods. The most common types of wearable monitors are Pedometers, accelerometers, heart rate monitors, and multi-sensor systems.

1.4.2 Pedometers

With the improvement of computing technologies and the willingness to monitor and assess PA, pedometers have become more and more complex recently. Karabulut et al (26). investigated the accuracy of two Omron pedometer models (HJ-720IT-E2 & HJ-113-E) on a treadmill at different walking speeds (2–4 mph) and discovered that both monitors were within 1.5% of actual steps taken. Crouter et al (27), also examined the accuracy of ten (10) different hip-worn pedometers and observed that eight (8) of the ten (10) devices had impressive test-retest accuracy and reliability that were greater than 95% and increased as walking speed increased. The pedometer's primary disadvantages are its inability to measure non-ambulatory activities, posture, and EE, as well as its reliance on proprietary algorithms to determine steps.

1.4.3 Accelerometers

Accelerometers are small, wearable devices that record accelerations in gravitational units on one or more planes at sampling rates greater than one time per second (typically 40–100 hz) (24). While most accelerometers are worn on the hip, some are fixed to the wrist or ankle. Even though recent studies have shown only minor differences in accuracy between the hip and wrist. The hip-worn accelerometers are assumed to provide the most comprehensive evaluation of normal ambulation. The attractiveness of an accelerometer for assessing PA and sedentary behaviors is the thorough and comparatively precise way, with minimal invasiveness, in which the frequency, duration, pattern, and intensity of activity can be monitored over days, weeks, and even months or longer (24).

1.4.4 Heart rate monitors

Heart rate monitors (HRMs) are excellent choices for activities such as cycling, swimming, and other non-ambulatory activities that may not be well measured with an accelerometer. HRM is widely used in direct physiological measures in unrestricted environments. Moreover, there is a high correlation between heart rate and EE in the moderate and vigorous-intensity ranges of PA, though this relationship is relatively weak in the light-intensity range. However, HRMs are not without considerable limitations. Some of these limitations include the necessity to account for blood pressure attenuating medications (i.e., β-blockers), focus of relative over absolute intensity, and potential discomfort of wearing the unit for long periods. Overall, there is no gold standard objective wearable monitor. Many factors influence the selection of objective wearable monitors, including the particular PA component of interest, the rapid and evolving evolution of technology and computational methods, and economic considerations.

1.4.5 Sensewear Armband

Sensewear armband (SWA) is a wireless, sleek, and wearable body monitor that allows continuous physiological monitoring outside the laboratory (28). The device is worn on the posterior side of the master arm and uses an exceptional combination of sensors. SWA is a component that measures PA and EE. This monitor combines data from a variety of sensors, including biaxial accelerometers, heat flux (body heat dissipation), galvanic signal (onset, peak, and recovery of maximal sweat rates), and skin temperature (29). The data is integrated and processed by software with advanced algorithms, which use individual demographic features such as sex, age, height, and weight to provide minute-by-minute estimates of EE during various levels of PA. When compared to other portable monitors, the SWA has good psychometric properties and has the advantage of assessing PA at low intensities and during activities that do not require ambulation, as well as unstructured or intermittent PA. As a result, the device can classify certain activities as “vigorous”, though the count level of the accelerometer is low. According to research, the error of SWA is lower in standing than in sitting. To minimize the sources of error, the SWA should be further developed and improved (30). For what concern validation, Zorrilla-Revilla et al. (31) discovered a significant overestimation (41.31%) of EE when walking with a load, whereas Tucker et al. (32) also discovered a significant underestimation (18%) of EE in multiple trials (SWA version 7.0).

1.5 Maximal oxygen Uptake

Cardiorespiratory fitness is the total capacity of the cardiovascular and respiratory systems and the ability to carry out prolonged intensive exercise (2). Cardiorespiratory fitness is essential for everyday activities like walking, running, and stair climbing. Fitness is a strong and independent predictor of cardiovascular disease, as well as all-cause mortality and morbidity, in adolescents. To determine fitness levels and monitor intervention effects, an accurate measurement of cardiorespiratory fitness is necessary.

VO_{2max} is a measure of cardio-respiratory fitness that can be achieved during high-intensity exercise. The World Health Organization has long considered the VO_{2max} attained during a graded maximal exercise to voluntary exhaustion as the single best indicator of cardiorespiratory fitness.

Basset & Howley (33) define VO_{2max} as: "the highest rate at which oxygen can be taken up and utilized by the body during severe exercise". VO_{2max} is the maximum amount of oxygen an individual can take, and it remains constant over time despite an increase in workload. VO_{2max} is expressed as liters/min as an absolute value or in milliliters /kg/min as relative VO_{2max}. The VO_{2max} can be estimated using maximal or submaximal tests, by direct and indirect methods. Moreover, walking/running tests are the most common, followed by cycling and step tests(34). VO_{2max} has a wide range of applications, from elite athletes to persons with different pathologic conditions(7). The VO_{2max} is the gold standard for determining a person's cardio-respiratory endurance. People with a low VO_{2max} have an increased chance of premature death, as well as the development of numerous chronic diseases, while individuals with a high VO_{2max} have less chance of developing chronic diseases, all-cause mortality, and coronary artery disease. The primary criterion for the attainment of VO_{2max} is a plateau in VO_2 (35). If a VO2 plateau is not reached, secondary criteria including a rise in respiratory exchange ratio (RER) above 1.15, blood lactate concentration above 8 m mol/l, and an increase in heart rate to age-predicted maximum exist (36).

Maximal or submaximal tests, as well as direct and indirect methods, can be used to estimate a person's maximum aerobic power (VO_{2max}).

Direct Method: (Laboratory approach) measures a person's expired gases to analyze their pulmonary ventilation, inspired oxygen, and expired carbon dioxide. Direct measures, such as breath-by-breath analysis, accurately determine a person's maximum oxygen consumption. **Indirect Method** including field tests evaluates a person's aerobic capacity based on their heart rate, their distance covered, and or their time of trial when using a certain protocol (37) Field tests, which use mathematical models to predict VO_{2max}, are an attractive alternative for cardio-respiratory evaluation because they offer significant benefits such as low operating costs, easy operation, and access to test locations, and the ability to evaluate a large number of subjects at once. **Field tests** for assessing cardiorespiratory fitness, on the other hand, use indirect methods to estimate VO_{2max}, resulting in significant measurement errors. (38)

Direct Test: In the laboratory, VO_{2max} can be easily measured and reliably by analyzing the gases involved in pulmonary ventilation directly while performing progressive and maximal tests on various treadmills or cycle ergometers using various Protocols (38). Direct VO_{2max} measurement is highly valid and reliable.

1.5.1 $VO_{2plateau}$

The upper limits of cardiovascular capacity are thought to be identified by a plateau in oxygen consumption (VO_2) at the end of an incremental exercise test. The measure of cardiovascular capacity, (VO_{2max}), is a widely used measured variable in exercise physiology (39). VO_{2max} is thought to be attained when oxygen consumption (VO_2) reaches a ceiling during an incremental exercise test beyond which no further increase in work rate results in an increase in VO_2. Following the classic work of Taylor et al., (40) this leveling off of VO_2 became known as the VO2 "plateau phenomenon." The rudimentary requirement for attaining VO_{2max} despite an increase in work intensity is the start of a plateau in VO_2. It is essential to consider some cut-off values when determining what constitutes a plateau (40). If the cut-off value is too high, the plateau may underestimate VO_{2max}, whereas too low cut-off values may make determining the plateau difficult. The ability to reach a plateau may be reduced in untrained people, children, and the elderly (41). Howbeit, trained people may be more accustomed to pushing themselves increasing their chances of reaching a plateau and VO_{2max} (42).

1.5.2 Borg scale

The Borg scale is a widely used instrument for self-perceived exertion. Although the Borg scale is essential for evaluating the intensity of an activity, its validity should be considered when using it as a VO_{2max} criterion. Sex, fitness level, different types of activity, and exercise protocol can influence the validity of the Borg scale.

1.6 Research, questions, aims, and hypothesis

1.6.1 Hypothesis

In this study, it is hypothesized that exergaming will increase physical activity after 24 weeks as well as cardiorespiratory fitness in adolescents.

1.6.2 Research questions

1) Can exergaming encourage physical activity and fitness?
2) Does exergaming affect adolescents' sedentary behavior?
3) Can exergaming be a supplement to the daily dose of recommended physical activity?

1.6.3 Objectives

I. To examine exergaming as a catalyst for increasing physical activity with a positive impact on health.

II. To investigate if exergaming leads to increased maximal oxygen uptake in adolescents who do not regularly participate in endurance training.

2.0 METHODS

2.1 Design

This study was a randomized controlled study and was undertaken at the Norwegian University of Science and Technology (NTNU) at St. Olav's University Hospital in Trondheim, Norway. The study was approved by the Regional Committee for Medical and Health Research Ethics in Central Norway in (2021). Written informed consent was obtained from all participants before participation. Here, the subjects were given an SWA to wear one week before being tested for testing blood pressure, body composition, VO_{2max}, height, and weight. The assessments were carried out at baseline, after 12 weeks, and the 24th week, and conducted as similarly as possible in order to reduce any potential sources of error. Except for the PA assessment, all the tests were performed on the same day and lasted approximately 1-1.5 hours. The subjects were advised not to engage in any vigorous activity for 48 hours before the tests. They were also advised not to consume any caffeine or alcoholic beverages for 8 hours before the tests and too fast for 3 hours prior to the tests. The subjects were confirmed as being told.

2.2 Subjects

29 (12-18 years) healthy adolescents were recruited to participate in this study. From February 11, 2019 to April 7, 2021) the subjects were recruited through social media platforms, St Olav hospital website, posters and via word-to-mouth. The inclusion criteria were < 19 years, physical inactive and/or not conducting regular endurance training, able to run on a treadmill and ride a bicycle, and live in or near Trondheim. Exclusion criterium was any history of cardiovascular diseases and Type I diabetes. All the necessary information was given to the participant in advance of the study, and the participants had to give written consent for participating. This study was approved by the Regional Committee for Medical and Health Research Ethics in Central Norway.

2.3 Interventions

After baseline testing, participants were randomly allocated to an exergaming or a control group using a computer random number generator developed by the Unit for Applied Clinical Research, Norwegian University of Science and Technology. There were no required exergaming sessions; instead, participants chose how frequently they wanted to use the exergaming platform and scheduled their exergaming sessions using an online calendar. Participants were paired up and randomized, resulting in an uneven distribution of the groups. (17 control / 13 play). All exergaming sessions were monitored, and participants wore (heart rate monitors) (SAW) (Polar A300/H10, Polar, Kempele, Finland) throughout. Heart rate data was recorded for use in exercise intensity analyses. Furthermore, after each exergaming session, all participants completed three separate questionnaires: the Physical Activity Enjoyment Scale (PACES), the Feelings Scale, and a modified 0–10 Borg-Scale to assess perceived enjoyment and exertion. After the study, the participants in the control group were interested to try the exergame. Figure 1 demonstrates a flow chart of the study.

2.4 Measurements PA

The Sense Wear armband (SWA) developed by BodyMedia Inc was used to measure each participant's PA level. The criteria for using the SWA PA data were > 50% of the day, three weekdays (Monday-Friday), and two weekend days (Saturday and Sunday). In this study, SWA had a PA threshold of EE > 3 METs. The SWA define the intensity of the activity as; sedentary (0-1.5 METs), light (1.5-3.0 METs), moderate (3.0-6.0 METs), vigorous (6.0-9.0 METs) and very vigorous (>9.0 METs). All activity with an EE > 3 METs was used as the total PA, e.g., total time spent in moderate, vigorous, and very vigorous intensities.

2.5 Blood pressure

To avoid exhaustion or arousal, resting blood pressure was measured before the VO_{2max} test. Before taking their vitals, the participants sat in a chair and rested for about 10-15 minutes. Resting blood pressure was measured three times, with a two-to-three-minute interval between each measurement. There was no form of communication between measurements. The mean of the three measurements was then used to calculate the resting blood pressure. A fourth measurement was performed in the case of a significant deviation between each measurement (> 10 mmHg). Resting blood pressure measurements were taken to rule out hypertension and to see if there was a difference after the intervention. All participants had normal blood pressure (123/81 ± 11/9 mmHg).

VO_{2max} was determined using a gasmask on a treadmill (Woodway pps 55) to measure exhalation and inhalation. The Cortex Metalyzer II equipment was used and calibrated at the start of each day and between every third test. The subjects were advised to warm up for about 10 minutes before the tests and to stay between 10 and 12 on the Borg scale, which indicates light to moderate difficulty (i.e., until they felt warm and slightly sweaty). The subject was equipped with a suitable gas mask connected to the Metalyzer II after the warm-up. After that, the test began right away. The test began at the pace (km/h) and incline (%) as the warm-up. Almost every minute, the incline (2%) and pace (1km/h) were increased, starting with an increase in incline. When the subjects reached a 10% incline or a speed of 10 km/h, the incline and pace were both increased by 1% and 0.5%, respectively. When the participants were about to reach their absolute maximum, they were asked to raise one hand, and the treadmill was then stopped after 20 seconds. The subjects continued to breathe through the mask until their VO_2 level fall satisfactorily. For what concern the VO_{2max}, the VO_{2max} was accepted when two out of the three criteria were met; a decrease in VO_2 despite increased workload, self-reported values > 19 using the Borg scale, and RER > 1.15. Heart rate measurement The Polar H10 Heart Rate Sensor was used to measure HR during the VO2max test and the exergame session. HRmax was calculated using the highest HR reached during the VO_{2max} test to determine which HR zone the participants were in during exergaming. The Polar Flow app was used to record HR measurements during the exergame sessions. Body composition The InBody 720 bioelectrical impedance analysis was used to determine weight and body composition (InBody 720 Biospace CO, Korea). This analysis provides data on bodily fluid, fat-free mass, body fat in kg and %, and body mass in kg. Here, only weight and body mass are considered.

2.6 Exergame:

A cycling exergame developed by PlayPulse was considered in this study. There were four bicycles available, allowing for single-player or multiplayer play (accommodating). Each round lasted 1–4 minutes.

2.7 Primary Outcomes

The primary outcome concerns VO_{2max} and PA levels (at baseline, 12, and 24 weeks). Here, PA is classified as sedentary (0.0–1.5 metabolic equivalents (METs), light (1.5–3.0 METs), moderate (3.0–6.0 METs), vigorous (6.0–9.0 METs), and very vigorous (>9.0METs). In addition, Body mass index (BMI) was determined as weight in kilograms divided by the square of height in meters (kg/m^2). The systolic and diastolic blood pressures, as well as the resting heart rate, were measured in a seated position after 10 minutes of supine resting. Blood pressure was taken trice at every 1- 4 minutes and the mean of the reported values was recorded.

2.8 Statistical Analysis

2.8.1 IBM SPSS_22: Two-way mixed ANOVA

Data were then analyzed using SPSS, version 22, and the level of significance was set at 0.05. A two-way mixed ANOVA was used to examine the interaction between the dependent and independent variables. Here, the different groups were the independent variables, and the post-measurements were the dependent variables. It was used to determine if there was a two-way interaction between the within-subject and between-subject factors (i.e., time*group). The assumptions for conducting a two-way mixed ANOVA were all fulfilled for VO_{2peak} (ml/min/kg). No outliers were detected, assessed by examination of a box plot. Assumption of a normal distribution of the data was satisfied, evaluated by a Shapiro-Wilk test ($p > 0.05$), and by a normal Q-Q plot. Variances were homogeneous, determined by Levene's test of equality of error variance ($p > 0.05$). The last assumption, homogeneity of covariances, was assessed using the Box's test of equality of covariance matrices. The assumption was fulfilled ($p > 0.001$).

3.0 RESULTS AND DISCUSSIONS

3.1 Results

3.1.1 Study Design

The figure 1 illustrates the flow chart of the study for 29 participants.

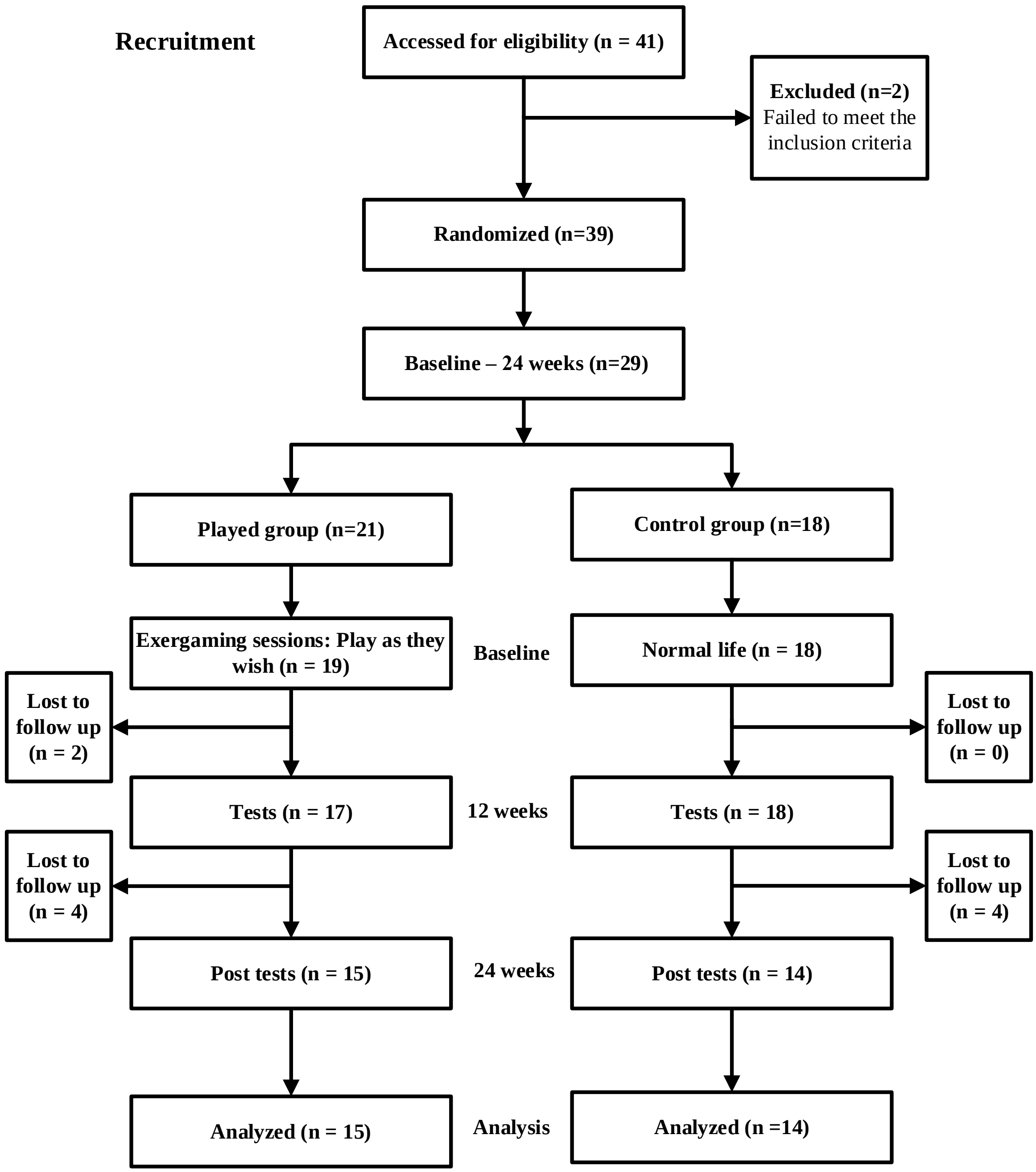

Figure 1. Flow chart of the study for 29 participants.

Table 2. bassline statistical characteristics of treatment and control group

	Treatment (N = 15)	Control (N = 14)
Variable	Mean (SD)	Mean (SD)
Gender		
Male	12(80%)	13(90%)
Female	3(20%)	1(10%)
Age(years)	15.0(2.1)	14.0(1.8)
Height(cm)	173.8(11.7)	168.9(11.2)
Weight(kg)	67.8(14.1)	56.9(6.6)
BMI (kg/m^2)	22.4(3.4)	20.1(1.7)
VO_{2peak}($mLkg^{-1}min^{-1}$)	47.5(6.0)	40.1(10.4)
Moderate(min/day)	10.2(6.0)	10.7(6.3)
vigorous(min/day)	0.4(0.6)	0.56(0.6)
Very vigorous(min/day)	0.0(0.0)	0.0(0.0)

Data are mean (SD) Body mass index (BMI), peak oxygen uptake ($VO_{2\ peak}$), and moderate to very vigorous physical activity.

Table 3 shows group differences for PA at different levels and at different times. Figures 2-4 also present the moderate, vigorous, and very vigorous physical activity levels at baseline, 12, and 24 weeks for treatment and control. Descriptive statistics for different variables are reported by different performing groups in Tables. The mean MPA after 24 weeks was 7.8 (SD = 5.0) and 6.8 (SD = 6.8), respectively for both the treatment and control groups, with no significant difference between the groups ($p = 0.059$). Turning to the MPA after 12 weeks, 11.5 (4.7) and 8.47(6.29), respectively for treatment and control with a significant difference between groups ($p = 0.048$). The mean of VPA after 24 weeks was 0.49 (SD = 0.69) and 0.05 (SD = 0.11) for the treatment and the control group respectively, with no significant difference between the groups ($p = 0.563$). There was a significant difference between groups after 12 weeks ($p = 0.049$). The VVPA after 24 weeks, the mean value was 0.00 (SD = 0.02) and 0.00 (SD = 0.00) for the treatment and control groups, respectively, with no significant between-group differences ($p = 0.170$). At 12 weeks the mean value was 0.013 (SD = 0.03) and 0.03(0.04), for both treatment and control, respectively with no significant difference between groups ($p = 0.218$). Finally, the mean VO_{2peak} after 24 weeks for the exergaming and control groups is respectively 49.0 (SD = 5.3) and 43.8 (SD = 5.3), with no significant between-group differences ($p = 0.100$). There was no significant between-group difference after 12 weeks ($p = 0.137$), with a mean of 46.3 (SD = 5.1). No significant difference between the groups with respect to VO_{2peak}, although a trend in statistical analysis showed some level of significance after the intervention and within the play group from baseline to post-tests.

Table 3 shows group difference for PA at different levels and at different times

		Treatment (N = 15)	Control (N = 14)	p-value
Variable	weeks	Mean (SD)	Mean (SD)	
Moderate	0	10.2(5.9)	10.7(6.3)	
	12	11.5(4.7)	8.47(6.29)	0.048
	24	7.8(5.0)	6.8(6.8)	0.059
Vigorous	0	0.43(0.57)	1.39(0.51)	
	12	1.1(1.0)	0.11(0.23)	0.049
	24	0.49(.69)	0.05(0.11)	0.563
Very vigorous	0	0.00(0.00)	0.00(0.00)	
	12	.013(0.03)	0.03(0.04)	0.218
	24	0.00(.02)	0.00(0.00)	0.170

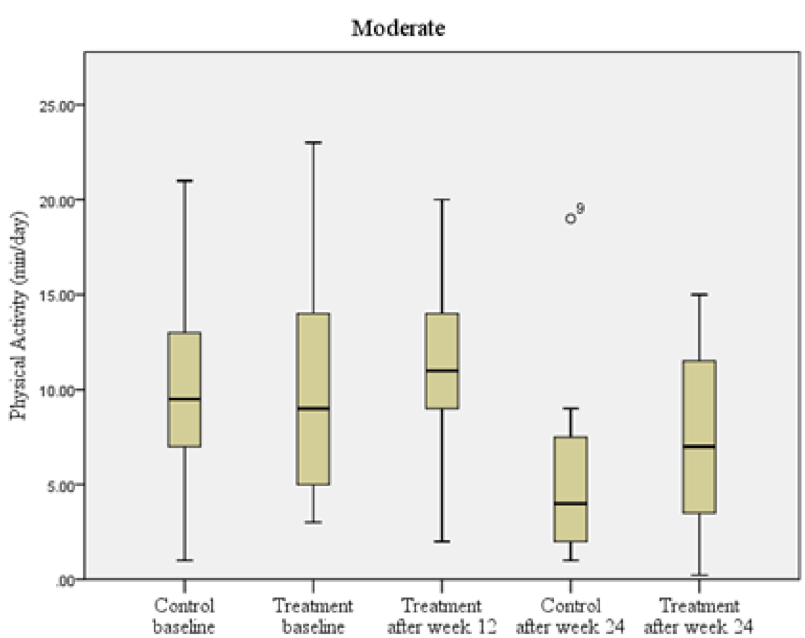

Figure 2. The moderate physical activity level at baseline, 12 and 24 weeks for treatment and control.

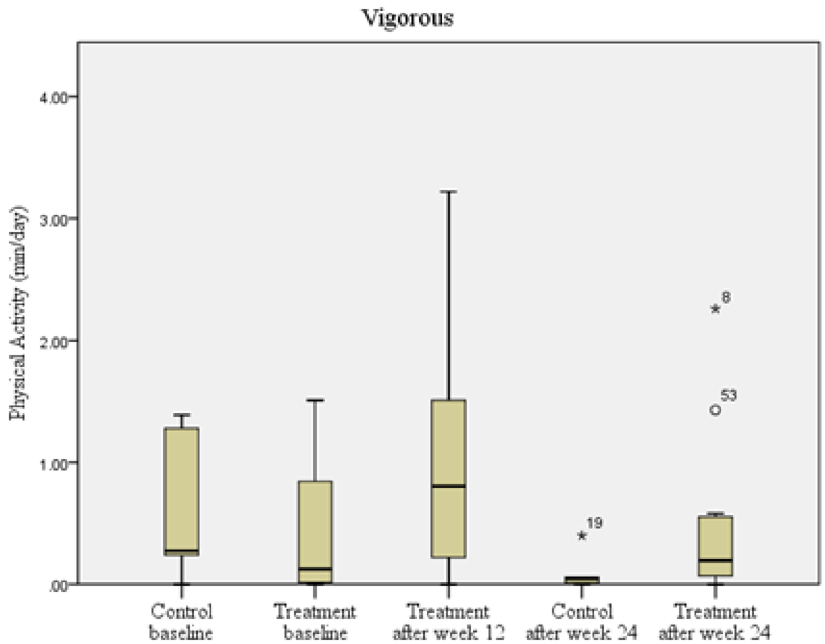

Figure 3. The vigorous physical activity level at baseline, 12 and 24 weeks for treatment and control.

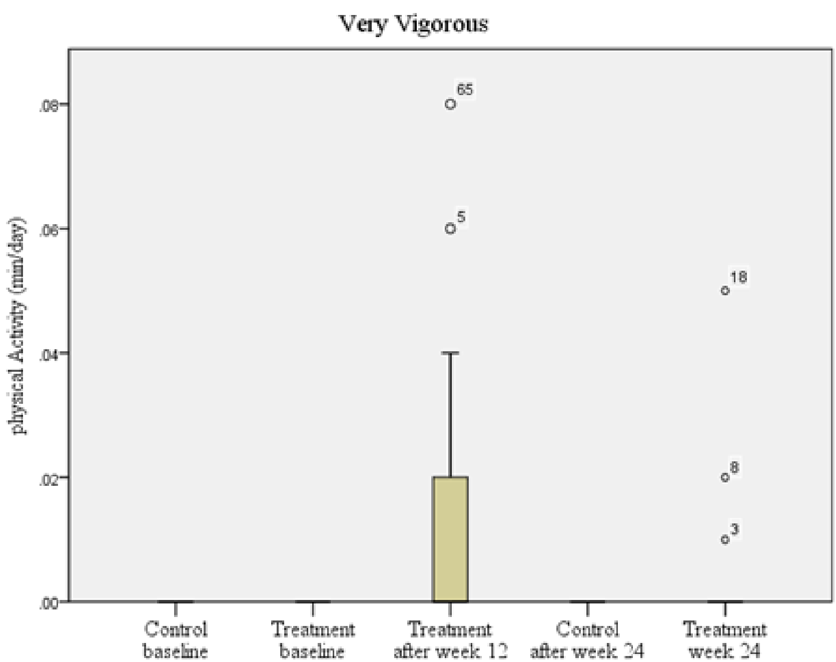

Figure 4. The very vigorous physical activity level at baseline, 12 and 24 weeks for treatment and control.

3.2 VO_{2peak}

The results obtained based on p-values (P = 0.137 and 0.100) show no significant differences between the exergaming group and the control group in VO_{2peak} at either 12 or 24 weeks (table 4 and figure 5).

Table -4 Cardiorespiratory values at baseline, 12 and 24 weeks for treatment and control group.

Variable	weeks	Treatment (N = 15) Mean (SD)	Control (N = 14) Mean (SD)	p-value
VO_{2peak} (mlkg^{-1}min^{-1})	0	47.5(6.0)	41.0(10.5)	
	12	46.3(5.1)		0.137
	24	49.0(5.3)	43.8(5.3)	0.100

Mean (SD) is descriptive data, and the effect estimate is from the regression analysis model. Peak oxygen uptake (VO_{2peak}).

Furthermore, figure 5 shows the relationship between the treatment and control groups at baseline, 12 weeks, and 24 weeks. In this figure, there is no significant difference between the two groups, and are uniformly distributed.

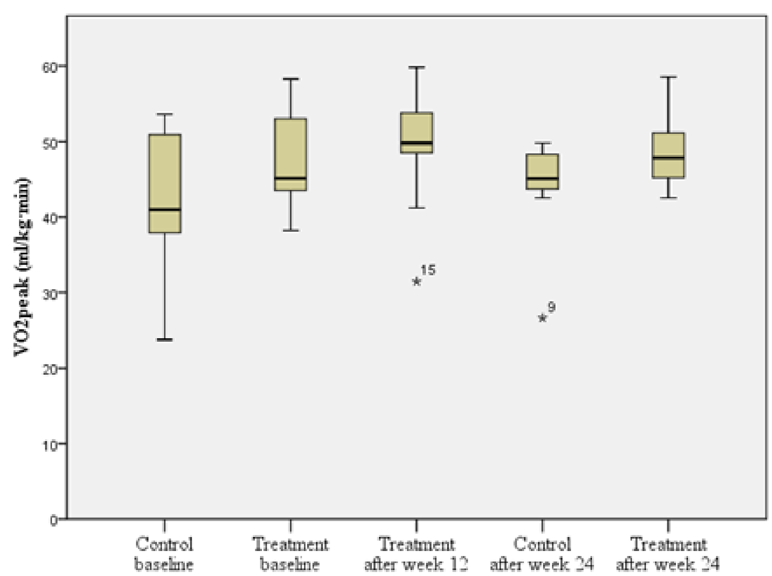

Figure 5. Cardiorespiratory fitness at baseline, 12 and 24 weeks for treatment and control: Peak oxygen uptake (VO_{2peak}) expressed ml·kg^{-1}·min^{-1}.

4.0 DISCUSSION

4.1 VO_{2peak}

The were no significant between-group differences ($p = 0.100$) after the study period. The results are in line with Owens et al (43), study where 3-months of access to an exergame did not result in any significant change in VO_{2peak}. In addition, Berg Jonathan et al (44) observed similar results in their studies. they observed no significant difference between exergame at 3 and 6 months. According to Wenger and Bell (45), the effectiveness of an exercise program to induce changes in VO_{2peak} is dependent upon the intensity, duration, and frequency of exercise. Though the duration of the exergaming session fulfills the American College of Sports Medicine’s (ACSM’s) recommendations to enhance VO_{2peak} (10).

4.2 Exergame

The exergaming group had increased their physical activity levels more than the control group with no statistically significance difference except at 12 weeks. The participants rated the enjoyment of exergaming high. For example, Warburton et al. (46), found that playing the Game-Bike, exergame increased 14 college males' participation in activity training, implying that exergames are engaging and enjoyable. Indeed, exergames are frequently more entertaining than sedentary games. Fery and Ponserre (47), found that 62 male college students who learned to put a golf ball from playing a golf exergame transferred the skill best when they focused on a specific goal, such as putting a virtual golf ball into an onscreen virtual hole. Moreover, among 168 college students, exercise groups who played an exergame for 10 min maintained higher positive moods after completing the exercise than a control group who played the video game without exercising(48). 20 West Virginia schools implemented DDR in physical education classes, Barker (49), discovered that some students lost 5–10 pounds following daily DDR game play. DDR is now taught in all 765 West Virginia public schools' physical education classes. Finally, to sustain interest, Sweetser and Wyeth (50) suggest that exergames require concentration, challenge, skill improvement, deep but effortless immersion, and opportunities for social interaction.

The exergaming is not without considerable limitations on the physical activity level of people as compared to outdoor exercising. Besides, long-term engagement in exergaming is difficult to attain (51); however, the enormous significance of exergaming on the VO2, HR, RER etc. from this study cannot be overlooked. Exergames can be expensive to set up but it is far better in investing in them in the sense that more resources will be required to manage the health conditions of participants who were inactive in their childhood period (52).

4.3 Physical activity level

There was a statically significant difference after 12 weeks from moderate to vigorous intensity and respectively (P = 0.048) and (P= 0.049). This could account for the following reasons; First, many of the benefits of physical activity are observed with an average of 60min of moderate-to-vigorous physical activity (MVPA) daily, and activity beyond 60min of MVPA daily provides additional health benefits (53). Or many of the benefits of physical activity are observed within average weekly volumes of 150–300min moderate-intensity or 75–150min of vigorous-intensity(53). Second, it could be accounted for the fact that the participant was so motivated and it was their first time exercising under supervision. On the other hand, the non-significant difference at week 24 could be due to a lack of motivation. In other words, the participants had become familiar with the exercise and it wasn't new anymore. So, the participants could not participate in the exercise to their full capacity. This is evidence that, along the line, the participants lost interest in following. Thus, about 12 participants stop to follow and they may not perform the activity with their full potential.

4.4 Strengths and limitations

4.4.1 Study design

10 subjects dropped out throughout the follow-up period. The study was completed by 15 and 14 participants in the play group and control group respectively. The study group was diverse due to the recruitment methods used, which included social media platform, St Olav hospital website, posters and via word-to-mouth. Due to the large sample size and age range, the results are deemed suitable for the adolescent population in general and can be used as reference for further studies.

Due to randomization, the study crew did not know which group the subjects would be assigned to during the baseline test. Randomization helps to avoid selection bias and startle bias. The randomization in this study was done by a computer, and the subject allocation was unpredictable and done without the assistance of the study staff. Once the subjects were enrolled in a group, there was no way to change it. This decreased the chances of systematic errors favoring one outcome over another (54). Besides, the subject's randomization ensured that the age distribution in the different groups was equal.

4.4.2 Subjects

As already mentioned, 29 (12-18 years) healthy adolescents were recruited to participate in this study via social media platforms, St Olav hospital website, posters and, word-to-mouth. The inclusion criteria were < 19 years, physical inactive and/or not conducting regular endurance training. Exclusion criterium was any history of cardiovascular diseases. The recruited participants wore an SWA for 1 week before and after the study, and to attend the baseline tests and post-tests. The exergaming sessions were supervised each week throughout the study. Each session lasted between 45-60 minutes and no injuries was recorded. The participants in the control group were asked to live their lives as usual. The study was approved by the Regional Committee for Medical and Health Research Ethics in Central Norway.

4.4.3 Measurements

To avoid the impact of improving the work economy, the VO_{2peak} test was performed on a treadmill and the exergaming session on a bicycle ergometer. The change in VO_{2peak} was the main emphasis. The participants might have had an active lifestyle, even though the participants did not conduct any regular exercise. However, SWA has the advantage of being able to measure the level of activity in the individuals' environment.

4.4.4 Exergaming

A large group of muscles must be active to improve VO_{2peak} because when large groups of muscles are active, the oxygen supply is constrained, and the heart must work harder to provide more oxygen. Jordan, Donne, and Fletcher. (55), state that the lower limbs must become more active in order to improve VO_{2max}. This requirement is met because PlayPulse is a cycle exergame. Nevertheless, the game is still under development and has room for some improvements.

4.5 Limitation (rewrite the limitation)

The exergaming is not without considerable limitations. The limitation of the exergame was that it couldn't detect the resistance in the pedals. The primary factor that determined how quickly the tank moved in the game was the frequency. This indicates that if you pedal at the lowest possible resistance on the bike, you could go as quickly as those who pedaled at a higher resistance, provided their frequency was the same. Another significant drawback is that people who were new to biking forgot to adjust the resistance during the workout session. This could have resulted in some of the subjects' intensity not being high enough to improve their VO_{2peak}. To overcome these bottlenecks, HR power-ups should be included in the game, as pointed out by Berg and Moholdt (56).

4.6 Recommendation

Since exergaming is relatively new in the field, there is a need to explore its long-term effects on adolescents and the general population including children and adults. From the results of this study, it is recommended that to improve cardiorespiratory fitness, the intensity of exercise needs to reach a certain level as well as having a well-scheduled plan of at least 3-5 times a week.

It is therefore recommended exergaming as a supplement to the daily dose of physical activity for both adolescents and children or the general population.

5.0 CONCLUSION

In conclusion, exergaming can increase physical activity and thus positively impact physical, cognitive, and psychosocial target factors. It was also observed that the participants participated in the exergaming to their full capacity since it was an enjoyable game but lost motivation afterward. This accounted for no health benefit difference between the control and the treatment, particularly after 24 weeks. It is therefore recommended exergaming as a supplement to the daily dose of physical activity for both adolescents and children or the general population.

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