EFFECTS OF ACTIVE VIDEO GAMES ON PHYSICAL ACTIVITY, PSYCHOLOGICAL DISTRESS, EXERCISE MOTIVATION, AND BODY COMPOSITION AMONG OVERWEIGHT AND OBESE COLLEGE STUDENTS IN CHINA

By

ZHAO YUE

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

March 2025

FPP 2025 15

DEDICATION

Dedicated With Love

To

My Parents,

My Friends.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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March 2025

Chairman : Professor Soh Kim Geok, PhD
Faculty : Educational Studies

Active video game training has been extensively studied in children, adolescents, and older adults. However, its benefits for college students with overweight and obesity remain unclear. This study evaluated the effects of 12 weeks of active video game training on physical activity, psychological distress, motivation, and body composition in Chinese college students with overweight and obesity. This is a true pre-test and post-test experimental design study, where the cluster randomised controlled trial was conducted in Jining City, Shandong Province, China. Two districts were randomly selected from the nine districts of Jining City and one university was randomly selected within each district. One university was randomly set as the experimental group (active video game training) and the other as the control group (standard training). The study screened college students based on the criteria for overweight and obesity in adults set by the World Health Organisation. Body mass index was used as the screening criterion, with BMI ≥25 kg/m² defined as overweight and BMI ≥30

kg/m² defined as obesity. All college students who met this criterion were eligible to participate in this study. Eventually, 63 college students (age range: 18-22 years) participated in the study. Each group participated in three weekly training sessions for twelve weeks (36 sessions). These training sessions were conducted during physical education lessons in both universities. In addition, those test protocols measured changes in the dependent variables at baseline, week 6, and week 12.

Generalised estimating equations (GEE) were used to analyse between and within group differences, and the significance level was fixed at $p<0.05$. Results showed no statistically significant differences ($p>0.05$) between groups for baseline physical activity, psychological distress, exercise motivation and body composition. Between-group comparisons at week 12 showed significant differences in all variables except external regulation, introjected regulation, and lean body mass, which were not significantly different ($p>0.05$). In physical activity, step counts increased significantly ($\chi^2=53.92$, $p<0.001$). In psychological distress, depression ($\chi^2=16.00$, $p<0.001$), anxiety ($\chi^2=33.53$, $p<0.001$), stress ($\chi^2=76.93$, $p<0.001$) and overall psychological distress ($\chi^2=116.76$, $p<0.001$) were significantly reduced. In exercise motivation, amotivation was reduced considerably ($\chi^2=10.41$, $p=0.005$). Identified regulation ($\chi^2=26.83$, $p<0.001$) and intrinsic regulation ($\chi^2=19.35$, $p<0.001$) were significantly increased. In body composition, body mass index ($\chi^2=89.81$, $p<0.001$), body fat percentage ($\chi^2=31.59$, $p<0.001$), and waist-to-hip ratio ($\chi^2=16.03$, $p<0.001$) were significantly reduced. Active video game training has a large effect size on physical activity ($d=0.94$). Among psychological distress, stress had the most significant effect size ($d=1.64$). In addition, for exercise motivation, identified regulation had the largest effect size ($d=1.17$). Meanwhile, for body composition, the

waist-to-hip ratio demonstrated the largest effect size (d=0.81). The results showed that active video game training could benefit both physical and mental health in Chinese college students with overweight and obesity. Active video game training uses its rich content to continually increase physical activity in college students with overweight and obesity while improving mental health. This increases exercise motivation and ultimately enhances body composition. It is recommended that active video games be included as part of physical education activities in college, especially for the overweight and obese group, because it can effectively help them physically and psychologically. Future studies should further explore the effects of gender differences and active video game training time on exercise motivation and explore the optimal training dosage applicable to Chinese college students with overweight and obesity to improve long-term participation and intervention outcomes.

Keywords: Exergame, physical activity, mental health, body composition, obesity, young adult

SDG: GOAL 3: Good Health and Well-Being, GOAL 4: Quality Education

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

KESAN PERMAINAN VIDEO AKTIF TERHADAP AKTIVITI FIZIKAL, KESUSAHAN PSIKOLOGI, MOTIVASI SENAMAN, DAN KOMPOSISI BADAN DALAM KALANGAN PELAJAR KOLEJ YANG BERLEBIHAN BERAT BADAN DAN OBES DI CHINA

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Latihan permainan video aktif telah dikaji secara meluas dalam kalangan kanak-kanak, remaja, dan warga emas. Namun, manfaatnya terhadap pelajar universiti yang mengalami berat badan berlebihan dan obesiti masih belum jelas. Kajian ini menilai kesan latihan permainan video aktif selama 12 minggu terhadap aktiviti fizikal, tekanan psikologi, motivasi, dan komposisi badan dalam kalangan pelajar universiti di China yang mengalami berat badan berlebihan dan obesiti. Ini adalah kajian eksperimen sebenar dengan reka bentuk praujian dan pascaujian, di mana ujian kawalan rawak kelompok telah dijalankan di Bandar Jining, Wilayah Shandong, China. Dua daerah telah dipilih secara rawak daripada sembilan daerah di Bandar Jining, dan satu universiti telah dipilih secara rawak dalam setiap daerah. Satu universiti secara rawak ditetapkan sebagai kumpulan eksperimen (latihan permainan video aktif), manakala universiti yang lain sebagai kumpulan kawalan (latihan standard). Kajian ini menapis pelajar universiti berdasarkan kriteria berat badan berlebihan dan obesiti bagi orang dewasa yang ditetapkan oleh Pertubuhan Kesihatan Sedunia (WHO).

Indeks Jisim Badan (BMI) digunakan sebagai kriteria saringan, dengan BMI ≥ 25 kg/m^2 ditakrifkan sebagai berat badan berlebihan dan BMI ≥ 30 kg/m^2 ditakrifkan sebagai obesiti. Semua pelajar universiti yang memenuhi kriteria ini layak menyertai kajian ini. Akhirnya, seramai 63 pelajar universiti (julat umur: 18-22 tahun) menyertai kajian ini. Setiap kumpulan menjalani latihan tiga kali seminggu selama dua belas minggu (36 sesi). Sesi latihan ini dijalankan semasa kelas pendidikan jasmani di kedua-dua universiti. Selain itu, protokol ujian ini mengukur perubahan dalam pemboleh ubah bersandar pada peringkat asas, minggu ke-6, dan minggu ke-12.

Persamaan anggaran umum (GEE) digunakan untuk menganalisis perbezaan antara dan dalam kumpulan, dan tahap kepentingan ditetapkan pada $p<0.05$. Keputusan menunjukkan tiada perbezaan yang signifikan secara statistik ($p>0.05$) antara kumpulan pada titik dasar untuk aktiviti fizikal, tekanan psikologi, motivasi senaman,

dan komposisi badan. Perbandingan antara kumpulan pada minggu ke-12 menunjukkan perbezaan yang signifikan dalam semua pembolehubah kecuali regulasi luaran, regulasi introjek, dan jisim badan tanpa lemak, yang tidak menunjukkan perbezaan yang signifikan ($p>0.05$). Dalam aktiviti fizikal, kiraan langkah meningkat dengan ketara ($\chi^2=53.92$, $p<0.001$). Dalam tekanan psikologi, kemurungan ($\chi^2=16.00$, $p<0.001$), kebimbangan ($\chi^2=33.53$, $p<0.001$), tekanan ($\chi^2=76.93$, $p<0.001$), dan tekanan psikologi keseluruhan ($\chi^2=116.76$, $p<0.001$) dikurangkan dengan ketara. Dalam motivasi senaman, amotivasi dikurangkan dengan ketara ($\chi^2=10.41$, $p=0.005$). Regulasi yang dikenalpasti ($\chi^2=26.83$, $p<0.001$) dan regulasi intrinsik ($\chi^2=19.35$, $p<0.001$) meningkat dengan ketara. Dalam komposisi badan, indeks jisim badan ($\chi^2=89.81$, $p<0.001$), peratusan lemak badan ($\chi^2=31.59$, $p<0.001$), dan nisbah pinggang-ke-pinggul (χ^2=16.03, p<0.001) dikurangkan dengan ketara. Latihan permainan video aktif mempunyai saiz kesan yang besar terhadap aktiviti fizikal (d=0.94). Dalam tekanan psikologi, tekanan mempunyai saiz kesan paling besar (d=1.64). Selain itu, untuk motivasi senaman, regulasi yang dikenalpasti mempunyai saiz kesan terbesar (d=1.17). Sementara itu, bagi komposisi badan, nisbah pinggang-ke-pinggul menunjukkan saiz kesan terbesar (d=0.81). Keputusan menunjukkan bahawa latihan permainan video aktif dapat memberi manfaat kepada kesihatan fizikal dan mental dalam kalangan pelajar kolej yang mempunyai berat badan berlebihan dan obes di China. Latihan permainan video aktif menggunakan kandungannya yang kaya untuk terus meningkatkan aktiviti fizikal dalam kalangan pelajar kolej yang mempunyai berat badan berlebihan dan obes sambil memperbaiki kesihatan mental. Ini meningkatkan motivasi senaman dan akhirnya memperbaiki komposisi badan. Adalah disarankan bahawa permainan video aktif dimasukkan sebagai sebahagian daripada aktiviti pendidikan jasmani di kolej, terutamanya untuk kumpulan yang mempunyai berat badan berlebihan dan obes, kerana ia dapat membantu mereka secara fizikal dan psikologi dengan berkesan. Kajian masa depan harus meneroka lebih lanjut kesan perbezaan jantina dan tempoh latihan permainan video aktif terhadap motivasi senaman serta meneroka dos latihan yang optimum yang sesuai untuk pelajar kolej di China yang mempunyai berat badan berlebihan dan obesiti bagi meningkatkan penyertaan jangka panjang dan hasil intervensi.

Kata Kunci: Permainan aktif, aktiviti fizikal, kesihatan mental, komposisi badan, obesiti, dewasa muda

SDG: MATLAMAT 3: Kesihatan dan Kesejahteraan yang Baik, MATLAMAT 4: Pendidikan Berkualiti

ACKNOWLEDGEMENTS

I have received a lot of enthusiastic help during my studies. I can't express my gratitude enough to those who helped me. Firstly, I would like to thank my supervisor, Prof Soh Kim Geok. She gave me a lot of help and courage at every critical moment to keep me going. I have benefited from her enthusiasm, her love, her guidance, and encouragement. She is not only a mentor in academics, but also in life, teaching me not only about studies, but also many philosophies of life. Secondly, I would like to thank my associate supervisor, Associate Professor Hazizi Abu Saad. He gave me a lot of academic advice and gave me the confidence to face any

academic difficulties. Finally, I would like to thank my family and friends for their support which enabled me to complete my studies with determination. They have given me unlimited support to get where I am now, and I thank them for all they have done for me.

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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Date: 8 May 2025

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LIST OF ABBREVIATIONS

AVG	Active Video Game
PA	Physical Activity
PD	Psychological Distress
EM	Exercise Motivation
BC	Body Composition
SC	Step Counts
BMI	Body Mass Index
BF%	Body Fat Percentage
LBM	Lean Body Mass
WHR	Waist to Hip Ratio
CRCT	Cluster-Randomized Control Trials
GEE	Generalised Estimation Equations
ICC	Intraclass Correlation Coefficient
CITC	Corrected Item-Total Correlation
PAR-Q	Physical Activity Readiness Questionnaire
DASS-42	Depression Anxiety Stress Scales-42
BREQ-2	Behavioural Regulation in Exercise Questionnaire-2
BIA	Bioelectrical Impedance Analysis
RFA	Ring Fit Adventure
DDR	Dance Dance Revolution
JD	Just Dance
PE	Physical Education

CHAPTER 1

INTRODUCTION

This chapter focuses on the study's background, problem statement, objectives, hypotheses, significance, limitations, delimitations, and conceptual and operational definitions.

1.1 Study Background

With the progress of time and the development of science and technology, the integration of the world economy and the globalisation of trade have become trends. Global economic exchanges are expanding (Bekun & Ozturk, 2024; Papanikos, 2024), and the earth has gradually become a "global village." Although the recent epidemic has dramatically affected the global economy (Panda et al., 2024; Priya et al., 2021), the world economy is still moving towards greater stability and prosperity. China's economic and social development have also been rapid, as it serves as an essential link in the global economic chain. In recent years, China has experienced sustained economic growth, a significant increase in per capita disposable income, and an upgrading of consumption levels and structures (Chen et al., 2024; Sagheer & Ashraf, 2024). Infrastructure developments, such as motorways, high-speed railways, subways, airports, and internet penetration, have enhanced the convenience of daily life. Additionally, the quality of education and medical services has gradually improved. In short, economic development has led to an overall improvement in material life, education, and healthcare, significantly raising the quality of life for the Chinese people. However, as the quality of life improves, Chinese people's eating habits and entertainment preferences are also changing dramatically (Ye et al., 2024;

Yang et al., 2021). One of the most pressing and far-reaching consequences of these changes is the problem of obesity.

Overweight and obesity have long been global public health and economic issues (Albuquerque et al., 2017; Mohajan & Mohajan, 2023; Sweis, 2024). As early as 1948, the World Health Organization (WHO) prioritised obesity for international action (Gajewska et al., 2024). Obesity is a complex, multifactorial disease (Chooi et al., 2019), which was once thought to exist only in high-income countries. Since 1980, however, the global prevalence of overweight and obesity has increased exponentially, with nearly one-third of the world's population classified as overweight or obese (Cheng, 2024). The prevalence of overweight and obesity is now growing in both developed and developing countries and across low-, middle-, and high-income populations (Lingvay et al., 2024; Jackson-Morris et al., 2023). The growing global obesity problem has also reached China (Bai et al., 2020).

Obesity has gradually become a significant public health issue in China (Zhu & Yin, 2023). According to China's criteria for determining overweight and obesity, the *Report on the Nutrition and Chronic Disease Situation of Chinese Residents* (2020), released by the Information Office of the State Council of the People's Republic of China, states that 34.3% of Chinese adults are overweight and 16.4% are obese (Zeng et al., 2021). The Chinese government has made substantial efforts to address the obesity problem, introducing various policies, regulations, and guidelines to promote healthy lifestyles and combat the dangers of obesity (Wang et al., 2021; Zhang & Ma, 2018). However, despite these efforts, the problem of obesity remains severe and has not been well-curbed.

Among all obese populations, the college population is of particular concern. College students face various pressures and challenges during their academic years (Wang et al., 2021). These years are a critical period in life, and the habits formed during this time can persist throughout adulthood (Martinez-Lacoba et al., 2018). Therefore, a healthy lifestyle is crucial for college students. However, in recent years, the physical activity levels of college students have been declining globally (Bertrand et al., 2021), while obesity rates have been increasing (Szemik et al., 2024). Overweight and obesity are prevalent among college students in both developed (Kauffman et al., 2020) and many developing countries (Guedes & Silva, 2021). The situation among Chinese college students is also concerning (Zhou & Hazel, 2024). One study found that 23.5% of male and 11.9% of female college students were classified as overweight or obese (Chen et al., 2020). As the number of college students in China continues to grow, the rate of overweight and obesity among them is expected to rise (Wang et al., 2022).

Modern technology is advancing rapidly, and electronic products have significantly changed people's lifestyles (Anderson, 2018). Smart devices play a central role in learning, socialising, and entertainment (Han & Yi, 2019), providing convenience for college students (Lian et al., 2016). However, these devices also have adverse effects. Increasing numbers of college students are addicted to the internet and video games, leading to the phenomenon of e-addiction (Baloğlu et al., 2020; Christakis et al., 2011). E-addiction increases static screen time, leading to sedentary behaviour. Numerous studies have shown that sedentary behaviour and low levels of physical activity are major risk factors for obesity, with college students being a particularly high-risk group (Castro et al., 2018; Moulin et al., 2021). Data indicate that the proportion of Chinese college students with reduced physical fitness, overweight, and obesity is on the rise, much of which is attributed to sedentary lifestyles (Guo et al., 2022; Wang et al., 2023).

A new type of game, active video games (AVGs), may help change this by allowing college students to move while playing. AVGs combine physical activity with interactive video games by capturing the player's movements and translating them into in-game actions through cameras, sensors, etc. (Scheer et al., 2014). AVGs have become widely popular in the global marketplace and among college student populations (Brown, 2017; Lin, 2015). In conclusion, AVGs offer a novel form of exercise that differs from traditional sports and could serve as an alternative to conventional exercise to help college students with overweight and obesity improve their physical and mental health.

1.2 Problem Statement

The problem of overweight and obesity in adults continues to receive widespread attention from all sectors of society. Overweight and obesity are usually measured using the body mass index (BMI). According to the World Health Organization (WHO), a BMI greater than or equal to 25 is defined as overweight, and a BMI greater than or equal to 30 is defined as obese (Organization, 2000). Since the 1980s, the obesity rate in China has increased rapidly. According to Chinese official data, more than one in two Chinese adults will be overweight or obese by 2020 (Pan et al., 2021). As more obesogenic environments accompany economic development, the growing momentum of obesity rates is difficult to reverse in the short term (Wang et al., 2017).

Among all the overweight and obese people in China, the prevalence of overweight and obesity among college students is particularly serious, with the obesity rate of college students exceeding 28.6% and increasing at a rate of 2%-3% every five years (Zang et al., 2024). Research studies in various provinces and cities in China corroborate this trend (Zhang & He, 2016). A sample of college students in Urumqi, Xinjiang, showed that the percentages of overweight and obesity were 15.25% and 16.53% for male students and 32.61% and 4.45% for female students, respectively (Reyla-Jugeti et al., 2020). The detection rate of overweight and obesity among college students in Jiangxi Province reached 13.6% (Chen et al., 2022). The prevalence of overweight and obesity among college students in Jilin Province is as high as 31% (You, 2021). The seriousness of overweight and obesity among Chinese college students has reached a worrying level.

Overweight and obesity can bring immeasurable harm to college students during their time in college. In terms of physical health, overweight and obesity reduce college students' physical activity (Karabulut et al., 2018), cause high blood pressure (Seravalle & Grassi, 2017), high blood lipids (Liao et al., 2009), and diabetes (Amuta et al., 2016), and lead to a series of chronic diseases and even cancer (Liu, 2021).

Obesity, as a metabolic syndrome, can lower metabolic levels, causing metabolic disorders that further exacerbate weight problems (J.-P. Després & Lemieux, 2006; Oh, 2011). In terms of mental health, overweight and obesity often lead to decreased self-identity and well-being among college students (Schafer & Ferraro, 2011), increasing the risk of depression, anxiety, and stress (Li, 2022; Wang & Zhang, 2016).

Obese individuals are often highly stigmatised, prejudiced against, and discriminated against (Duan & Feng, 2018). This environment, in turn, can further increase psychological distress among college students with overweight and obesity (Puhl & Heuer, 2009; Vartanian et al., 2014). In terms of body composition, overweight and obesity lead to the excessive accumulation of fat in the body (J. Després, 2006) and are often accompanied by a decrease in lean body mass and maximal oxygen uptake, resulting in increased BMI and percentage body fat (%BF) among college students (Pribis et al., 2010). Therefore, being overweight and obese not only diminishes college students' exercise capacity, increasing exercise risk, but also makes weight management more difficult.

The leading causes of overweight and obesity among Chinese college students are genetic, dietary, and physical activity factors. Genetic factors are among the most critical contributors to obesity (Morassut et al., 2020), and different genes can cause obesity to manifest differently in various populations (Loos & Yeo, 2022). However, genetic factors are the least likely to be changed. On the other hand, college students' irregular diets after entering college, along with long-term intake of high-calorie, high-salt, and high-sugar foods, contribute to dietary factors (Gao, 2020; Yang et al.,2022).

Although genetic and dietary factors may influence college students with overweight and obesity (Mu et al., 2022), lack of physical activity coupled with sedentary habits are the most critical factors leading to college students' overweight and obesity (Yang et al., 2022).

Lack of physical activity leads to a chronic imbalance between energy intake and expenditure, which is a major driver of weight gain and fat accumulation (Bosy-Westphal et al., 2021). While genetic predisposition may increase susceptibility to obesity, research suggests that environmental and behavioural factors (e.g., level of physical activity) play a greater role in determining body composition (Mustelin et al., 2009). Sedentary behaviours, particularly staring at a screen for long periods of time, not only reduce calorie consumption, but also negatively impact metabolic health, which can further exacerbate weight gain (Thyfault et al., 2015). With the advent of the information age, smartphones and computers have become essential for college students. College students often use these devices to watch short videos, use social media, and play video games (Li et al., 2020; Gan et al., 2015). The COVID-19 pandemic resulted in college students being able to attend only online classes from home, exacerbating their reliance on electronic devices and the internet (Li & Liang, 2023). This dependence has led to an increase in static screen time and a reduction in physical activity among Chinese college students, which has further contributed to the development of overweight and obesity (Du & Zhang, 2022).

In response to the problem of overweight and obesity among Chinese college students, the Chinese government has issued several policies and guidelines. Chinese experts and scholars from various fields have provided suggestions to address the issue.

China's State General Administration of Sport has issued the China Physical Activity Guidelines, which outline the recommended levels of physical activity for different groups. The guidelines suggest that adults need to engage in 2.5 to 5 hours of moderate-intensity or 75 to 150 minutes of vigorous-intensity aerobic activity per week, along with muscle-strengthening activities two days per week (Wang, 2022; Chen et al., 2022). China's Health and Wellness Commission has released a guidance document, Action for a Healthy China (2019-2030), which promotes health through the popularisation of healthy lifestyles, optimisation of health services, and the creation of healthy environments (You et al., 2022; Chen et al., 2020). Various scholars and experts in China have also proposed methods, mainly focusing on traditional approaches.

In terms of dietary adjustments, experts have recommended that college students control their calorie intake and increase their consumption of vegetables and fruits (Zhang, 2017). Regarding physical activity, some scholars have suggested aerobic exercises such as running, swimming, and cycling, as well as strength training to increase muscle mass and metabolic rate, which can aid in weight control (Li, 2020; Guo & Zuo, 2019). Others have advocated for sports like basketball (Mao & Chen, 2018), football (Chen & Ning, 2016), and badminton (Liu, 2020) to improve cardiorespiratory fitness. Some experts have recommended traditional Chinese exercises, such as Baduanjin and Taijiquan, as methods to reduce overweight and obesity among college students (Zhang et al., 2023). Despite the efforts of the Chinese government, scholars, and experts, and the recognition by college students of the benefits of these interventions, their implementation still faces several challenges. Many overweight and obese college students lack motivation or confidence to engage in regular exercise due to poor body image, past failures in sports activities, or a lack of social support. In addition, academic pressure and busy schedules make it difficult for students to allocate sufficient time for structured exercise programs. The accessibility and affordability of sports facilities may also be a barrier, especially for students living in urban areas with limited open space. Therefore, although these measures are theoretically effective, they do not match the actual needs and lifestyle of overweight and obese college students, resulting in limited persistence and practice.

The growing popularity of electronic entertainment and emerging fitness trends has made Chinese college students more inclined to participate in novel sports that are convenient and exciting, such as video game-based activities (An & Zhang, 2022). Among the emerging sports, active video games have gained attention, blending video games with physical activities (Staiano et al., 2012). Unlike traditional video games, which are typically played in a seated position, AVGs require physical movement to play (Maddison et al., 2012; Peng et al., 2011). AVG training can leverage college students' enthusiasm for gaming to increase their physical activity while playing.

The effectiveness of AVGs has been demonstrated in various ways. Training children and adolescents using AVGs can improve their physical activity levels (Biddiss & Irwin, 2010), exercise motivation (Staiano et al., 2017), and physical fitness (Gao et al., 2015; Oliveira et al., 2020). AVG training can also enhance mobility and balance in older adults (Taylor et al., 2018), facilitating physical rehabilitation and improving quality of life (Rosenberg et al., 2010; Taylor et al., 2012). For special populations, AVGs can provide rehabilitation training for children and adolescents with cerebral palsy (Valenzuela et al., 2021; Qian, 2021) and improve stroke patients' motor ability, balance, and walking function (Bang et al., 2016; Li et al., 2023). Although AVGs have been widely adopted and are well-suited to the needs of college students with overweight and obesity in China, there has been a significant lack of focus on this group, and the games currently used for AVG training are outdated (products released before 2010; Perron et al., 2011). Additionally, there is a lack of attention to novel AVGs.

Therefore, this study aims to use a novel AVG (Ring Fit Adventure) to train college students with overweight and obesity in China over 12 weeks. The goal is to investigate the effects of AVG on physical activity, psychological distress, exercise motivation, and body composition among these college students. This study aims to explore the use of AVGs to address the physical and mental health issues of o Chinese college students with overweight and obesity and to provide a theoretical foundation for implementing AVGs on college campuses.

1.3 Research Objectives

1.3.1 General Objective

The general objective of this study is to examine the effects of active video games on physical activity, psychological distress, exercise motivation and body composition among college students with overweight and obesity in China.

1.3.2 Specific Objectives

Based on the above general objectives, four specific objectives have been formulated. The following is a list of the specific objectives:

(1) To examine the effects of 12 weeks of active video game training across baseline, week-6, and week-12 on step counts among college students with overweight and obesity in China.

(2) To examine the effects of 12 weeks of active video game training cross baseline, week-6, and week-12 on depression, anxiety, stress, and

psychological distress among college students with overweight and obesity in China.

(3) To examine the effects of 12 weeks of active video game training across baseline, week-6, and week-12 on external regulation, amotivation, introjected regulation, identified regulation, and intrinsic regulation among college students with overweight and obesity in China.

(4) To examine the effects of 12 weeks of active video game training across baseline, week-6, and week-12 on body mass index, body fat percentage, lean body mass, and waist-to-hip ratio among college students with overweight and obesity in China.

1.4 Research Hypothesis

Assessing physical activity, psychological distress, exercise motivation, and body composition among college students with overweight and obesity in China requires testing the following null hypotheses. This study proposes four primary and fourteen secondary research hypotheses to investigate the topic further.

1.4.1 General Research Hypotheses

The main hypothesis of this study is to examine the effects of twelve weeks of active video game training on physical activity, psychological distress, exercise motivation, and body composition among college students with overweight and obesity in China.

1.4.2 Specific Research Hypotheses

The specific hypotheses are all related to the null hypothesis. Hypothesis 1 for the first objective pertaining to physical activity was step counts. Hypotheses 2-5 for the second objective related to psychological distress are depression, anxiety, stress, and psychological distress. Hypotheses 6-10 for the third objective related to exercise motivation are external regulation, amotivation, introjected regulation, identified regulation, and intrinsic regulation. Hypotheses 11-14 for the fourth objective related to body composition are body mass index, body fat percentage, lean body mass, and waist-to-hip ratio.

H_o1: There are no significant differences between EG and CG at baseline, week-6, and week-12 on step counts among college students with overweight and obesity in China.

H_o2: There are no significant differences between EG and CG at baseline, week-6, and week-12 on depression among college students with overweight and obesity in China.

H_o3: There are no significant differences between EG and CG at baseline, week-6, and week-12 on anxiety among college students with overweight and obesity in China.

H_o4: There are no significant differences between EG and CG at baseline, week-6, and week-12 on stress among college students with overweight and obesity in China.

H_o5: There are no significant differences between EG and CG at baseline, week-6, and week-12 on psychological distress among college students with overweight and obesity in China.

H_o6: There are no significant differences between EG and CG at baseline, week-6, and week-12 on external regulation among college students with overweight and obesity in China.

H_o7: There are no significant differences between EG and CG at baseline, week-6, and week-12 on amotivation among college students with overweight and obesity in China.

H_o8: There are no significant differences between EG and CG at baseline, week-6, and week-12 on introjected regulation among college students with overweight and obesity in China.

H_o9: There are no significant differences between EG and CG at baseline, week-6, and week-12 on identified regulation among college students with overweight and obesity in China.

H_o10: There are no significant differences between EG and CG at baseline, week-6, and week-12 on intrinsic regulation among college students with overweight and obesity in China.

H_o11: There are no significant differences between EG and CG at baseline, week-6, and week-12 on body mass index among college students with overweight and obesity in China.

H_o12: There are no significant differences between EG and CG at baseline, week-6, and week-12 on body fat percentage among college students with overweight and obesity in China.

H_o13: There are no significant differences between EG and CG at baseline, week-6, and week-12 on lean body mass among college students with overweight and obesity in China.

H_o14: There are no significant differences between EG and CG at baseline, week-6, and week-12 on waist-to-hip ratio among college students with overweight and obesity in China.

1.5 Significance of the Study

The significance of the study is presented in theoretical and practical terms. The explanation is presented subsequently in more detail.

1.5.1 Theoretical Significance

There is a societal consensus that appropriate physical activity improves mental health and weight management (Swift et al., 2014; VanKim & Nelson, 2013). Both WHO and ACSM guidelines recommend weekly moderate to vigorous intensity physical activity (DiPietro et al., 2020; Medicine, 2013). Experts suggest that suitable physical activity can be achieved through traditional sports such as cycling, basketball, or running (Buehler et al., 2011; Hespanhol Junior et al., 2015). However, college students prefer not to participate in these traditional physical activities due to a lack of motivation and venues (Keating et al., 2005; Zhang & He, 2022). Active video games' rich content is popular among college students (Pasco et al., 2017). Different categories of AVGs have now been shown to enable moderate to vigorous physical activity (MVPA) (Monedero et al., 2017; Miyachi et al., 2010). Regular training with active video games can be an excellent way to increase physical activity in college students and compensate for the lack of traditional exercise. However, there is minimal research on college students with overweight and obesity as a target population, and it does not thoroughly investigate the combined effects of AVG on the physical and mental health of college students with overweight and obesity in China.

In this regard, the comprehensive effects of active video game training on college students with overweight and obesity in China have yet to be fully understood. This study aims to investigate the effects of active video games on various aspects of the physical and mental health of college students with overweight and obesity in China to explore the potential value of active video games and enrich the scenarios of active video game use. Based on the models provided by Bouchard (Bouchard, 1994) and Lieberman et al. (Lieberman et al., 2011), combined with self-determination theory

(Deci & Ryan, 2008) and the FITT principle (Frequency, Intensity, Time, Type) (Bayles, 2023), this study seeks to clarify how active video game training affects the physical activity of college students with overweight and obesity in China, as well as how it alters their motivation for exercise and psychological distress through the transformation of different motivation types, which ultimately impacts body composition. We will find new training tools and appropriate training methods for college students with overweight and obesity in China and provide valuable insights to bring active video games to college campuses.

1.5.2 Practical Significance

This study has two critical components of practical significance. The first part is that school administrators, college physical education teachers, and researchers can benefit from it. The second part is that college students with overweight and obesity in China can benefit from a practical approach to training, gain a new approach to training that promotes physical and mental health, and make a meaningful contribution to the literature on integrating AVG into athletic training.

Firstly, this study can provide college administrators, college physical education teachers, and trainers with new training ideas and methods. It inspires them not to rely solely on traditional physical exercise but to adopt AVG as a new training method in the college classroom or after-school training. This approach can maximise the subjective initiative of college students, thereby improving the training effect. Secondly, the main objective of this study is to improve the physical activity and body composition of college students using AVG training and to reduce their psychological distress while increasing their motivation to exercise. Future studies could implement a unique training programme of 40 to 60 minutes of AVG training three times a week for 12 weeks (Appendix H). The programme has been pre-registered on ClinicalTrials.gov (ID: NCT06078150, Appendix B) and reviewed by six experts to ensure its validity. This programme allows college students with overweight and obesity in

China to increase their physical activity while playing AVG. By fostering self-satisfaction and enjoyment during each training session, the programme continues to shift their motivation type, increasing their motivation to exercise and improving psychological distress. If this programme proves effective, it is recommended that it be adopted for college students with overweight and obesity in China.

Secondly, according to previous literature, the effectiveness of AVG on physical activity, mental health, and health-related physical fitness has been validated (Comeras-Chueca et al., 2022; Marks et al., 2015; Nguyen et al., 2018; Santos et al., 2021). AVG has played an essential role in promoting physical activity among children and adolescents with obesity (Comeras-Chueca et al., 2020), as well as in treatment and rehabilitation in other specialised groups (Sabel et al., 2017; Zheng et al., 2022). However, there is a lack of focus on college students with overweight and obesity. Therefore, exploring the advantages and outcomes achieved by college students with overweight and obesity participating in AVG training could contribute to the current body of knowledge in subjects such as athletic training.

1.6 Limitations of the Study

This study has a few limitations, which are described below.

(1) Prior studies suggest that demographic characteristics, such as age, height, and weight, may act as potential constraints affecting the efficacy of interventions (Bauman et al., 2012; Fernandez-Fernandez et al., 2020). For instance, research has indicated that the effectiveness of intervention programs like AVG training may vary between obese and non-obese college students (Davoodeh et al., 2020). To address this, statistical methods were employed to analyse these demographic factors as covariates, using Levene's test. Measures were taken to ensure homogeneity in the demographic characteristics of the participants to prevent any impact on the study results.

(2) Individual characteristics such as daily habits, sleep quality, and energy intake were considered limitations in the study. The study was conducted in northern China with participants from the same province who shared similar eating habits, predominantly eating at the college canteen. Although various cafeterias were available on campus, they offered similar food choices, ensuring a consistent energy intake for all participants. Prior to the intervention, participants were instructed by the researcher and physical education instructor to maintain their daily routines, eating habits, and sleeping patterns throughout the study. Participants were required to sign a consent form on-site and were asked to monitor their diet using the KEEP app daily. Researchers and assistants supervised and documented the participants' diets weekly during the training sessions to minimize the influence of individual characteristics on the study (Jeffries et al., 2022).

(3) The study involved a 12-week period of AVG training, during which uncontrollable environmental factors, such as social engagements, academic performances, and extracurricular activities of college students, might impact their mental well-being. To mitigate these effects, the researcher planned to stay informed about participants' other activities and closely monitor their well-being during the weekly training sessions. Data collection efforts were

aimed at avoiding critical measurements during high-stress periods, such as exam weeks, to uphold the reliability of the experiment.

(4) Physical activity was assessed using a pedometer to count the number of steps, although pedometers have certain limitations. Internationally, accelerometers are commonly used to measure physical activity, offering insights into activity intensity and energy expenditure (Imboden et al., 2018; Santos-Lozano et al., 2013). However, accelerometers are costly and typically used in laboratory settings. Given the need for long-term physical activity assessment over 12 weeks for college students with overweight and obesity in this study, pedometers were deemed the most appropriate and practical device available. Pedometers are becoming increasingly portable and accurate and have shown reliable performance in various physical activity assessments (Clemes & Biddle, 2013; Freak-Poli et al., 2020; Mendoza et al., 2015).

1.7 Delimitations of the Study

The scope of the current investigation is outlined as follows:

(1) The study population consisted of college students with overweight and obesity in Shandong Province, China. According to Chinese college admission policies, college students are typically aged 18-22. Hence, the study participants were overweight or obese college students within the 18 - 22 age group.

(2) Existing literature indicates a noticeable increase in mental health issues among Chinese college students, with the current mental health situation being less than ideal (Wan et al., 2024; Fan et al., 2024). Mental health problems encompass various conditions affecting mood, cognition, and behaviour. The predominant mental health issues among Chinese college students revolve around psychological distress, notably depression, stress, and anxiety (Zhao et al., 2021; Wang & He, 2024; Mu et al., 2024; Cai et al., 2024). The study focused on exploring the impact of Active Video Games

(AVG) on these mental health issues, particularly depression, anxiety, and stress, as vital indicators of psychological distress. The study analysed these negative emotional states together to evaluate overall psychological distress, aiming to provide a thorough understanding of the effects of AVG on the mental health of overweight and obese college students.

(3) While various body composition parameters could have been chosen for evaluation, the study concentrated on BMI, body fat percentage, lean body mass, and waist-to-hip ratio to assess the body composition of college students with overweight and obesity in China. This selection was based on prevalent issues in body composition among Chinese college students, such as elevated BMI and body fat percentage (Chen et al., 2024; Ma et al., 2024), inadequate lean body mass (Chen, 2018), and irregular waist-to-hip ratio (Zhu et al., 2019). By examining these body composition variables, a comprehensive assessment of the impact of AVG on the body composition of college students with overweight and obesity in China was conducted.

(4) Previous research suggests that for various populations, including physical and mental health training using AVG, sessions lasting 40 to 60 minutes, three times a week for twelve consecutive weeks, are most effective (Hwang et al., 2023; Yu et al., 2023; Huang et al., 2019; Nguyen et al., 2016). However, the AVGs utilized in this study were those powered by gaming platforms such as Xbox, Wii, or PlayStation (Ghobadi et al., 2019; Parent & Comtois, 2019; Thirumalai et al., 2018). There is a lack of research on interventions for college students with overweight and obesity employing Ring Fit Adventure (RFA) on the Switch platform, indicating the need for further investigations on the effects of this AVG intervention.

1.8 Conceptual and Operational Definitions of Terms

This section provides conceptual and operational definitions of active video games, physical activity, psychological distress, exercise motivation, body composition, overweight and obesity, and Chinese college students.

1.8.1 Active Video Game

Conceptual Definition: In the 1980s, new types of games based on regular video games, such as active video games, emerged (Johnson et al., 2016). These games are called 'exergames' (a portmanteau word combining 'exercise' and 'game') (Merino-Campos & Del Castillo Fernández, 2016). Unlike typical static games, Active Video Gaming (AVG) combines video games and movement to motivate sedentary individuals to exercise (Merino-Campos & Del Castillo Fernández, 2016). When engaging with AVGs, players need to interactively use their arms, legs, or whole-body movements, while on-screen avatars mimic the player in various sports, such as running, jumping, and shooting (Höchsmann et al., 2016). Therefore, AVGs are video games used during physical activities and can be employed to increase physical activity levels (Maddison et al., 2013).

Operational Definition: In this study, an active video game is defined as an interactive video game in which the participant can synchronize their movements with the images displayed on the screen. The active video game in this study was hosted on Nintendo's mainframe (Switch) and featured the game Ring Fit Adventure. Active video game training includes a 5-minute warm-up, 5-minute cooldown, and 30 to 50 minutes of gameplay. The game modes included an adventure mode, a training combo mode, and a mini-game mode. Prior research informed all training components, and all exercise routines were crafted with the game's content in mind. Further details are available in Appendix H.

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1.8.2 Physical Activity

Conceptual Definition: "Physical activity" is delineated as any bodily movement executed by skeletal muscles resulting in energy expenditure (Caspersen et al., 1985).

Sustaining regular physical activity is imperative for college students to preserve physical and mental function (Maselli et al., 2018). The most prevalent form of physical activity among college students is walking to class.

Operational Definition: "Physical activity" encompasses the actions of the human body. Hence, this study defines physical activity as any voluntary conscious movement and requisite exercise like walking in daily routines and engaging in various sports. The study utilized pedometers to track all physical activities and quantified them as step counts.

1.8.3 Psychological Distress

Conceptual Definition: In the medical field, psychological distress is the general concept of maladaptation of psychological functioning in the face of stressful life events (Abeloff et al., 2008). Psychological distress is widely used in the fields of medicine, psychology, and social sciences (Ridner, 2004) and is often used in the context of depression, anxiety, stress, tension, and distress (Murray & Huelskoetter, 1983; Préville et al., 1995; Selye, 2013). Psychological distress (anxiety, sadness, emotional vulnerability) is strongly associated with reduced longevity and physical morbidity (Lahey, 2009).

Operational Definition: In this study, psychological distress is defined as an unpleasant emotional state experienced by college students with overweight and obesity in their lives, mainly including depression, anxiety, and stress. These three dimensions of emotional state together constitute the core components of psychological distress (Lovibond & Lovibond, 1995). (Lovibond & Lovibond, 1995).

1.8.4 Exercise Motivation

Conceptual Definition: Exercise motivation is often considered the reason and motivation for an individual to participate in and sustain physical activity or exercise (Plonczynski, 2000). Good exercise motivation has important implications for physical activity (Duncan et al., 2010). Exercise motivation is a complex psychological phenomenon often defined in different theories based on exercise motivation. Self-determination theory (SDT) is used to look at motivation and is frequently applied to exercise (Deci & Ryan, 2013). It suggests that specific sports motivational variables can be intrinsic or extrinsic. Intrinsic motivational variables are associated with ability and interest in enjoyment, whereas extrinsic motivational variables focus on achieving outcomes unrelated to exercise participation (Deci & Ryan, 1985).

Operational Definition: In this study, five forms of regulation (external regulation, amotivation, introjected regulation, identified regulation, and intrinsic regulation) of intrinsic motivation, extrinsic motivation, and amotivation were linked to form a continuum of motivation based on self-determination theory. The assessment of these five forms of regulation provides a valuable insight into the types of motivation that college students with overweight and obesity experience at different times of the intervention, as well as changes in motivation from one to the next (Deci & Ryan, 2000; Hassel et al., 2015; Murcia et al., 2007).

1.8.5 Body Composition

Conceptual Definition: Body composition refers to the various biological components of a person's body, including different types of cells, tissues, organs, and compounds of a physiological nature. In medicine and biology, body composition is commonly used to describe the various substances that make up the human body, from the cellular level to the level of entire organ systems (Heymsfield, 2005).

Operational Definition: This study focused on body composition in health-related physical fitness (Caspersen et al., 1985). Body composition mainly involves body mass index, body fat percentage, lean body mass and waist-to-hip ratio. The components involved in these variables are most relevant to the physical health of college students with overweight and obesity. Measurement of these variables can provide an objective understanding of what happens to the physical functioning of college students with overweight and obesity after an active video game intervention, as well as the effects of weight loss and slimming achieved.

1.8.6 Overweight and Obesity

Conceptual Definition: Overweight and obesity are usually measured using the body mass index (BMI) calculated from a person's weight and height. Later, body mass index (BMI) was widely used to screen, diagnose, and classify overweight and obesity. The World Health Organization standards are widely accepted (Zierle-Ghosh & Jan, 2018). Among them, BMI of 25-29.9 kg/m^2 indicates overweight, and BMI ≥ 30 kg/m^2 indicates obesity. A BMI of 30-34.9 kg/m^2 is defined as grade I obesity, a BMI of 35-39.9 kg/m^2 is defined as grade II obesity, and when a BMI ≥ 40 kg/m^2, it can be judged as grade III obesity (Timothy Garvey, 2019).

Operational Definition: In this study, Chinese college students will be classified as overweight and obese based on BMI according to the international standards set by the World Health Organization. The specific standard is that a BMI greater than 25 is overweight, and greater than 30 is obese.

1.8.7 Chinese College Student

Conceptual Definition: In China, a college student is a student who enters higher education. According to the academic level classification, they can be divided into specialists, undergraduates, and postgraduates (master's and doctoral). According to the classification of the type of discipline, they can be divided into arts and sciences and so on. According to the classification of training mode, it can be classified as ordinary full-time or part-time students. In China, undergraduates are usually 18-22 years old, postgraduates are usually 22-25, and doctoral students are generally 25-30.

Operational Definition: This study divides and defines Chinese college students by age. Since the age span of Chinese college students is relatively large, the external factor of age should be controlled. Therefore, in this study, college students are defined as full-time students aged between 18 and 22 with a bachelor's degree.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter comprehensively reviews the existing literature to provide a detailed understanding and explanation of the following four parts: the first part introduces the health issues of college students with overweight and obesity worldwide and further explores the characteristics, health problems, and existing solutions for college students with overweight and obesity in China. The second part introduces active video games, providing definitions and methods for measuring dependent variables. The third part describes the impact of active video games on physical and mental health. The fourth part proposes a theoretical framework and a conceptual framework.

2.2 Characteristics and Health Issues for College Students with Overweight and Obesity

The first part discusses the global obesity situation, overweight and obesity prevalence, and health problems among college students worldwide. The second part delves into the characteristics, health problems, existing solutions, and challenges concerning overweight college students in China.

2.2.1 Health Issues of College Students with Overweight and Obesity

Overweight and obesity have emerged as a 21st-century epidemic (Štempeľová et al., 2023), with globalization accelerating at an unprecedented pace (Reger et al., 2024), leading to increased obesity rates in both developed and developing countries (Morgen & Sørensen, 2014). Overweight and obesity place a strain on healthcare systems, affecting personal lives and economic productivity (Dai et al., 2020; Khabazkhoob et al., 2017; Tsai et al., 2011). While overweight and obesity rates remain high among children and adolescents (Alhamed et al., 2023), the situation is more severe among adults. According to the World Health Organization, global obesity prevalence more than doubled between 1990 and 2022. By 2022, an estimated 2.5 billion adults worldwide will be overweight, with 890 millions of them obese (Islam et al., 2024). Of particular concern are overweight and obese adults in college populations.

Firstly, overweight and obesity rates among college students have consistently been high on a global scale, with a survey across 22 countries revealing that over 22% of college students are overweight or obese (Peltzer et al., 2014). This trend is observable not only in developed nations like the United States (Nelson et al., 2007) but also in various developing countries such as Mexico, Brazil, Bangladesh, and Thailand (De

Faria et al., 2023; Cuevas-Ramos, 2010; Zamsad et al., 2019; Pengpid & Peltzer, 2015). The upward trajectory of overweight and obesity rates among college students is concerning. Secondly, college students are highly influenced by their environments, which can contribute to overweight and obesity, even among medical students who may have higher fitness awareness (Thomas & Geethadevi, 2019; Shafiee et al., 2024).

Overweight and obesity can have serious implications for college students, who are at a pivotal stage of physical and mental development, not yet fully matured physically or emotionally. Excessive weight can lead to a complex array of health problems that are diverse and often long-term and severe (Sira & Pawlak, 2010). Firstly, overweight and obesity significantly reduce physical activity levels (Edelmann et al., 2022), increasing the risk of cardiovascular diseases such as hypertension, coronary heart disease, and atherosclerosis (Hlaing et al., 2007; Al-Majed & Sadek, 2012; Klein et al., 2022; Wilson et al., 2022). Regarding mental health, undergraduate college students globally exhibit a high prevalence of mental health issues (Misra & McKean, 2000; Shaikh et al., 2004), with psychiatric disorder prevalence among college students ranging from 12% to 50% (Mowbray et al., 2006; Blanco et al., 2008). Overweight and obese college students are particularly vulnerable to psychological distress, facing increased risks of anxiety, depression, and low self-esteem (A. A. A. AlQahtani et al., 2015).

Moreover, overweight and obesity significantly impact the body composition of college students. Body fat percentage directly correlates with metabolic and cardiovascular diseases (Tanaka et al., 2002; Cho et al., 2009). High body fat percentage and muscle mass loss in college students with overweight and obesity can hinder their involvement in physical activities and lead to sports injuries. Understanding the health challenges encountered by college students with overweight and obesity globally enhances the analysis of specific health issues faced by Chinese college students due to overweight and obesity, facilitating the development of tailored solutions.

2.2.2 Characteristics and Health Issues among Chinese College Students with Overweight and Obesity

This section describes several unique characteristics of college students with overweight and obesity in China, as well as their existing health issues.

2.2.2.1 Characteristics for Chinese College Students with Overweight and Obesity

Overweight and obesity rates among Chinese college students remain high and are displaying a continuous upward trend. A study revealed that the obesity rate among 19-22-year-old college students in China surged from 8.93% in 2000 to 23.53% in 2019 (Zhang et al., 2024). Another study utilizing data from the Ministry of Education of China discovered that in 2020, the rates of overweight and obesity among Chinese college students were over 20.1% and 5.3%, respectively, significantly higher than in previous years. Additionally, the number of provinces where the rate of overweight college students exceeded 25% increased from two in 2016 to seven in 2020 (Zhang et al., 2023).

Not only do overweight and obesity prevail in the northern region of China (Wang, 2011; Zhang, 2013), but they also affect the southern part of the country (Li & Cao, 2023). It is noteworthy that the challenges related to overweight and obesity among college students in China are particularly complex and unique, distinct from those in other countries. These characteristics are closely intertwined with China's social, economic, and technological milieu.

Primarily, the rapid economic growth in China in recent years has significantly elevated living standards and dietary conditions among college students. This economic progress has led to the proliferation of environments conducive to overweight and obesity (Li & Wang, 2022). In traditional Chinese dietary culture, food typically leans towards being healthy, low-fat, and high in fiber. However, with economic advancement, high-calorie and high-fat foods have become more prevalent in the market (Zhu et al., 2023). The widespread availability of foods such as fast food, fried items, and sugary beverages has caused a fundamental shift in college students' dietary patterns. College students in China are now consuming more energy than necessary, contributing to overweight and obesity.

Moreover, the rapid expansion of the Internet and the widespread adoption of mobile payment technologies in China have ushered in significant lifestyle changes among college students (Liu et al., 2021). Particularly concerning eating habits, various food delivery apps have emerged, becoming an essential part of college students' daily routines (Lai & Yang, 2024). Through their mobile phones, students can swiftly and conveniently order food and beverages, receiving them almost instantly at any time (Lei et al., 2020). The ease of food delivery has led many students to rely on such services for their daily meals, making their eating habits increasingly erratic. The convenience of accessing food anytime, anywhere has resulted in more frequent eating episodes for college students, disrupting the timing and nutritional content of their meals, thereby affecting metabolic rhythms and leading to weight gain.

Lastly, it is paramount to note that China has achieved a leading global position in Internet usage, especially within the college student demographic, where mobile phone penetration stands at 100% (Tian, 2017), with high and prolonged usage frequency (Li & Pan, 2023). Electronic devices have become indispensable in the daily lives of college students, shaping their lifestyles and behaviours. Many students exhibit addiction to mobile phones (Cheng, 2024; Hui et al., 2024), especially when engaging in activities like watching short videos and playing video games, generating a significant level of interest and dedication (Bai et al., 2024). The allure of video games has steered Chinese college students towards a sedentary way of life. The rise in sedentary behaviour reduces opportunities for physical activity and diminishes their motivation to engage in exercise. The lack of physical activity, driven by the prevalent use of electronic devices and the Internet, is a distinguishing factor in the overweight and obesity crisis among Chinese college students.

2.2.2.2 Health Issues for Chinese College Students with Overweight and Obesity

In China, the issue of overweight and obesity among college students, primarily caused by a lack of physical activity, manifests with a variety of significant health concerns. These health issues predominantly revolve around three main areas. Firstly, college students exhibit a more sedentary lifestyle compared to the general population (Pengpid & Peltzer, 2019). The widespread use of the Internet and electronic devices has led to college students with overweight and obesity in China spending extended periods sitting in front of computers or mobile phones engaging in video games or other online activities (Wu, 2022; Zhao et al., 2022). This sedentary behaviour resulting from the fascination with electronic devices significantly reduces their daily physical activity (Liu, 2024; Jin et al., 2023). Obesity arising from physical inactivity not only results in hypertension (Fagard, 2005), type 2 diabetes (He et al., 2022), kidney disease, and neurological issues (Koye et al., 2018) but also elevates the risk of cancer (Calle et al., 2003).

Secondly, the prevalence of mental disorders among Chinese college students has notably risen (Sun et al., 2022). The lack of physical activity has contributed to increased psychological distress among college students with overweight and obesity in China, predominantly manifesting as depression, stress, anxiety, and loneliness among college students (Wan et al., 2024; Zhu et al., 2024). The psychological strain of obesity can result in decreased academic performance, impaired social relationships, and a reluctance to engage in physical exercise (Sharp & Theiler, 2018a; Alhazmi et al., 2021). This often leads to a detrimental cycle where reduced physical activity heightens psychological distress. Negative emotions such as depression and stress can, in turn, further exacerbate sedentary behaviour. Over time, many Chinese college students with overweight and obesity begin to lose interest and motivation to exercise due to a persistent lack of physical activity.

Lastly, Chinese college students with overweight and obesity typically exhibit a higher body fat percentage, lower muscle mass, and unhealthy waist-to-hip ratios, all of which directly impact their physical capabilities and metabolic health (Lin, 2023). These college students often have a higher body fat percentage due to their sedentary lifestyle (Yi et al., 2022), amplified by their affinity for video games and internet browsing (Ma et al., 2023). A higher body fat percentage heightens the risk of developing metabolic diseases and may lead to increased inflammatory responses and decreased immune function (Huang, 2024; Sheridan et al., 2012). Diminished muscle mass, in turn, can affect essential bodily movements, leading to fatigue and reduced exercise endurance (Ramírez-Vélez et al., 2019). Additionally, an unhealthy waist-to-hip ratio is strongly linked to an elevated incidence of cardiovascular disease and diabetes (Zhu et al., 2002). In conclusion, the health challenges faced by college students with overweight and obesity in China are diverse, chronic, and intricate.

2.2.3 Current Solutions and Problems of Health Issues among Chinese College Students with Overweight and Obesity

Based on the characteristics of college students with overweight and obesity in China and the health problems they face, the Chinese government has acknowledged the seriousness of the health situation within this group. In response, it has developed a series of policy measures and guiding documents. In 2015, China's National Health and Family Planning Commission (NHFPC) released the 'Chinese Citizens' Health Literacy Basic Knowledge and Skills,' advocating for Chinese residents to possess fundamental health knowledge and concepts, promoting a lifestyle that includes moderate exercise (Wang, 2024).

In 2019, China's State Council issued the Circular of the General Office of the State Council outlining the Construction of a Stronger Sporting Nation, aiming to implement widespread fitness activities, enhance youth sports initiatives, and foster competitive sports development (Wu, 2023). The Healthy China Action (2019-2030) similarly emphasizes the improvement of health literacy among college students and encourages active engagement in physical activities (Song, 2022). The National Fitness Programme (2021-2025), issued by the State Council of China in 2021, emphasizes enhancing the physical education curriculum in schools and ensuring that students have a total of 2 hours of physical activity daily, both on and off school premises (Chen & Pan, 2024). Furthermore, China established the National Physical Fitness Standard for Students to promote sports participation among college students, mandating physical fitness assessments for students within colleges and universities (Wu & Li, 2024). These policies and guidance documents aim to guide college students in increasing physical activity levels, improving health, and combatting the prevalence of overweight and obesity.

In recent years, scholars and researchers in various fields have conducted extensive studies to enhance the physical activity of college students with overweight and obesity through interventions involving traditional sports and physical activities. These efforts aim to improve both physical and mental health outcomes (Yang et al., 2024; Ma, 2021; Liu, 2020; Gao, 2023). The studies have explored a range of physical activities, including running, swimming, and callisthenics. For instance, running, as a straightforward and effective aerobic exercise, targets enhancing the physical fitness of college students (Li & Gao, 2020; Huang, 2021). Swimming, a whole-body exercise, has been incorporated in various studies as an intervention, showing effectiveness in reducing body fat percentage and enhancing muscle strength and balance (Yang et al., 2022). Additionally, group-based exercises like callisthenics, combined with music, aim to inspire college students to participate and enhance body composition (Li, 2017).

Despite the government interventions and scholarly endeavours to boost the physical health of college students, the outcomes in practical implementation remain unsatisfactory. This can be attributed to the failure of policies and guidelines to fully consider the genuine interests and behavioural habits of college students with overweight and obesity. Several reasons contribute to this issue. Firstly, the availability of suitable sports venues significantly impacts participation in physical activities (Zi et al., 2023).

However, college students with overweight and obesity in China are burdened with heavy academic workloads and significant academic pressure (Zhu et al., 2023), restricting their access to specialized sports venues.

Secondly, many universities lack a variety of sports equipment, rely on outdated and poorly maintained equipment, have sports fields that are inefficiently utilized, and provide limited opportunities for ordinary students to access sports facilities (Xia & Liu, 2024; Wang et al., 2016). This shortage of sports resources hampers regular exercise for ordinary college students who struggle with limited venues and suboptimal training environments (Wei & Yin, 2014; Yang, 2019).

Moreover, research indicates a strong affinity for video gaming, particularly active video games, among college students with overweight and obesity, which caters to their gaming interests while providing physical activity. However, most college physical education programs still follow conventional teaching methods centered on ball games and track and field sports, necessitating modern sports integration and innovation (He & Liu, 2024). Neither college instructors nor researchers have been able to align exercise programs with the true interests of college students with overweight and obesity, failing to effectively engage students and undermining the efficacy of exercise interventions. Given the current challenges and the potential of active video gaming (AVG) among college students, there is a need to explore the application of AVG, especially within Chinese campus settings.

2.2.4 Applications of Active Video Game

Currently, active video games (AVG) are widely utilized in various regions globally. They are particularly successful in family entertainment and have become common in school classrooms. Notably, in primary and secondary education, many developed countries and regions have incorporated AVG into their educational systems. In a study conducted in England, a six-week intervention involving Wii sports among children aged 10-11 during recess showed that AVG could increase physical activity levels, specifically step counts, in the initial stages (Duncan & Staples, 2010). Another study observed school children playing PlayStation 2 games during lunchtime daily.

This study found that AVG enabled primary school students to achieve approximately 10% of the recommended healthy steps and engage in moderate-to-vigorous physical activity (MVPA) (McDougall & Duncan, 2008). In Poland, 11 obese school children were assessed, revealing that children preferred playing AVG over traditional sports and were able to achieve higher physical activity levels (Polechoński et al., 2020). In Sweden, children in mandatory schools participated in Just Dance on Wii during physical education classes, highlighting AVG's potential as a virtual teacher to teach physical education and enhance students' understanding of sports (Nyberg &

Meckbach, 2017). Moreover, in the United States, 30 children utilized Wii Fit and EA Sports Active in school to monitor their heart rates, indicating that AVG could assist them in meeting recommended physical activity levels (Perron et al., 2011). Another study involved elementary school students from grades 3 to 6 in AVG during physical education classes, showing that these students enjoyed playing AVG (such as Dance Dance Revolution) more than traditional games, offering increased gameplay and fostering an engaging information technology environment for physical activity (Mohnsen, 2005).

Physical education teachers are encouraged to incorporate AVG into their teaching modules to promote enjoyable class participation in physical activity (Gao et al., 2014). AVG is also beneficial for teenagers. Studies have illustrated that integrating Dance into physical education classes in the United States enables minority adolescent students to exercise, leading to improved MVPA and student enjoyment (McDonough et al., 2021). For adolescents, engaging in AVG (such as Kinect) during breaks can expend more energy compared to sitting and playing games, proving effective for weight management (Gribbon et al., 2015; Simons et al., 2014). A literature review further suggests the use of innovative methods to stimulate physical activity behaviour in adolescence. Using AVG in schools has been shown to enhance adolescents' physical activity and is more sustainable and acceptable than traditional methods (Williams & Ayres, 2020). These AVGs increase physical activity among elementary and middle school students through interactive and enjoyable gameplay, yielding positive effects on their physical and mental well-being.

Additionally, AVGs are commonly used in European and American universities, with research indicating their effectiveness in enhancing college students' physical and mental health (Vernadakis et al., 2012). Integrating AVG into college classes and extracurricular activities aids students in maintaining an active lifestyle amid academic pressures and improving overall health. Research demonstrates that college students using AVG (such as Dance Dance Revolution) can increase physical activity levels as effectively as traditional exercise, appealing to students for its enjoyable nature and promoting persistence in exercise (Kraft et al., 2011). Similarly, games like AVG (e.g., Wii boxing) have been shown to address low physical activity levels among college students in the UK (Mackintosh et al., 2016). In terms of psychology, playing games in a virtual environment, as opposed to traditional sports (e.g., stationary cycling), results in less fatigue and offers enhanced fun and self-efficacy to college students (McDonough et al., 2020). Permitting college students to engage in regular exercise with AVG in universities enhances their vitality and well-being (Huang et al., 2017). Notably, prolonged participation in AVG activities among college students has been found to reduce psychological distress (depression, anxiety, stress) and improve sleep quality (Wan Yunus et al., 2020). From a body composition perspective, training with AVG on campus can facilitate weight loss and increase lean body mass among college students (Howe et al., 2015; Zurita-Ortega et al., 2018).

Conversely, the application of AVG in China primarily focuses on patient rehabilitation, notably in hospitals and rehabilitation centers (Yang & Ju, 2024; Wang, 2023; Jin et al., 2020). These applications assist patients in recovering physical strength, enhancing mobility, and improving overall health (Liu et al., 2022; Xu & Hu, 2024; Du et al., 2023). Although these studies have yielded specific outcomes, their implementation on campuses requires enhancement. Limited studies have explored the use of AVGs in primary and secondary school settings in China, emphasizing the improvement of physical activity levels, health status, innovation, and physical training among students (Shan & Wei, 2024; Zhu et al., 2022; Wang et al., 2023; Lai, 2023). However, the application of AVGs on Chinese college campuses remains underdeveloped, despite college students being a demographic that would likely benefit significantly from this interactive health promotion tool.

The potential for AVG in Chinese universities is vast for several reasons. Firstly, Chinese college students represent a significant user group of AVG (Xia, 2021), as many overweight and obese students are sedentary and have a fondness for electronic games, making AVG an appealing tool that combines entertainment and exercise to align with their interests (Liu et al., 2020). Secondly, AVG can effectively address the unique physical and mental health challenges faced by Chinese college students with overweight and obesity by improving body composition, mental health, and daily physical activity levels. Lastly, as an innovative tool, AVG is well-suited for the current environment in Chinese college classrooms (Peng & Liu, 2021).

With China's rapid economic growth, many universities have started integrating information and projection technologies into teaching practices, rendering traditional physical education teaching models inadequate for the current needs of college students, especially those who are overweight or obese (Yu & Jing, 2019). Given the affinity of Chinese college students with overweight and obesity for AVG, the potential applications and effects of AVG in various contexts, particularly on campuses, have been validated. Nevertheless, the utilization of AVG in Chinese universities remains limited, necessitating further examination of its actual impact on college students. Thus, by considering the characteristics and health issues of Chinese college students with overweight and obesity, adopting targeted interventions such as active video games to enhance physical activity, exercise motivation, reduce psychological distress, and improve body composition is a feasible approach that warrants exploration.

2.3 Introduction to Active Video Games

This section primarily introduces the following topics: Firstly, AVG's development and operational principles. Secondly, the characteristics, types, and game modes of AVG. Thirdly, the popularity of AVG. Finally, the game Ring Fit Adventure is introduced.

2.3.1 Development of Active Video Games

The development of Active Video Games (AVG) is primarily explained in terms of game creation and development, as well as the definition and principles of AVG. The origins and evolution of active video games can be traced back to the 1970s and 1980s, with the appearance of simple somatosensory interactive devices. In 1972, engineer

Ralph Baer patented a video game console called Magnavox Odyssey (Lowood, 2021). Then, in 1983, Nintendo released the FC game console in Japan, featuring games like Duck Hunt and Frisbee that required a peripheral (an electronic gun), which became the original prototype of somatosensory gaming (Liu, 2011).

In 1988, Atari released the first active video game, Foot Craz, allowing players to simulate running on a track (Montfort & Bogost, 2009). Nintendo's World Class Track and Field Match in 1988 featured players jumping on power pads and moving through sensors on foot pads to interact with the game (Bogost, 2010). However, it was not until 1998 when Dance Revolution, an active video game, caught players' interest (Chamberlin & Maloney, 2013). As technology continued to advance, active video games underwent significant development and enhancement both in terms of games and equipment.

In the mid-to-late 2000s, several groundbreaking somatosensory gaming devices were introduced (Gao, 2017). In 2004, Sony's PlayStation 2 was equipped with the EyeToy somatosensory device, capturing player movements through a camera to mirror real-world motions in the game (Rand et al., 2008). In 2006, Nintendo's Wii game console featured the Dance Revolution somatosensory device (Chamberlin & Maloney, 2013). Also in 2006, the Remote somatosensory device for the Nintendo Wii provided players with a new interactive experience by allowing them to engage with the game through physical movements (Ma, 2010). During this time, AVGs gained popularity worldwide and were deemed a significant innovation in gaming history. Games like Wii Sports and Wii Fit from the Wii series became immensely popular and continue to be used across various applications, appealing to diverse age groups and introducing somatic gaming to home entertainment (Deutsch et al., 2011).

Subsequently, Microsoft entered the active gaming market by introducing Kinect in 2010, which allowed gamers to play without controllers, enabling full-body movement (Andrews & Baker, 2006). A recent popular AVG is Ring Fit Adventure from Nintendo in 2019. In China, the development of "Active Video Games" started later but is now mainly based on imitation and independent research and development (Liu, 2015). It primarily includes embedded somatosensory games for TV set-top boxes, mobile phone somatosensory games using smartphones as control terminals, and host games like PS and Xbox, with the more prominent brand being Taishan Online's Idong (Tan, 2011). As consumer demands evolve and technology advances, AVGs continue to innovate, progressing from game content to interactive methods, attracting a broader user base and catering to players of different age groups and interests.

The definition of Active Video Games (AVGs) can be traced back to a descriptive review related to Atari Joyboard in 1982 (Yun, 2024). With the introduction of Foot Craz in 1989, researchers began to recognize active video games as a relatively new field of study (Montfort & Bogost, 2009). Subsequently, AVGs were given new definitions and connotations. Some scholars defined AVGs as providing a unique exercise experience by merging physical exertion with interactive games (Maddison et al., 2013). Because AVG blends exercise and gaming, researchers have coined the term "Exergame" by combining Exercise and Game to refer to active video games (Lieberman, 2006).

In 2013, ACSM defined AVGs as technology-driven physical activities that require participants to exercise (Witherspoon, 2013). Research has redefined AVG as combining gaming technology with daily exercise (Kappen et al., 2019). Some scholars have summarized the different definitions in health and non-health domains, defining AVGs as games that require physical activity, including strength training, balance, and flexibility exercises (Oh & Yang, 2010). This definition merges physical activity with gameplay, extending sports games into the realm of physical activity and is widely accepted (Merino Campos & Del Castillo Fernández, 2016).

The mechanics of AVGs can be better explained through the contrast between seated video games and traditional movement. AVG involves controlling on-screen images with arm, leg, or whole-body movements, differing from conventional seated games (operated by a gamepad) (Graf et al., 2009). This is achieved through several means. Firstly, somatosensory controllers capture the player's body movements by employing sensors like accelerometers, gyroscopes, and others to detect the direction, speed, and angle of movement (Wang et al., 2016; Khoury, 2018).

Secondly, depth-sensing cameras and infrared sensors, such as those in Kinect and EyeToy, capture the player's full-body movements in real-time without requiring a handheld controller (Maddison et al., 2007). This contactless sensing allows the player's body to function as the game controller, enhancing immersion (Rosenberg et al., 2016; Barry et al., 2016). Finally, devices like motion sensors, cameras, and controllers work together to translate the player's movements into in-game actions and render them on-screen. Thus, movements in 3D space are effectively converted to a 2D screen (Staiano & Calvert, 2011).

2.3.2 Types, Characteristics, and Gameplay of Active Video Games

AVGs' genres are categorized in various ways, with this section focusing on categorization through game content and objectives. Two main types of AVGs are structured AVGs and unstructured AVGs (De Brito-Gomes et al., 2016). Unstructured AVGs mainly aim to provide an entertaining experience, motivation, or rehabilitation assistance. They are designed to be more flexible and open-ended, allowing players to explore and interact freely (Taylor et al., 2012). This type of game focuses more on fun and engagement, often stimulating player motivation and interest, especially when engaging players through a competitive or entertaining format (Hurkmans et al., 2010). These highly motivational games have a significant advantage in attracting and maintaining active player participation.

Some of the more representative unstructured AVGs are as follows: Wii Sports and Kinect Sports, both sports simulation games that enable sports and competitions to be played in virtual environments. Wii Sports is played with a handheld controller allowing for five simulated games (Baseball, Boxing, Golf, Tennis, and Bowling) (Keogh et al., 2014). Conversely, Kinect Sports can simulate six real-life sports (bowling, boxing, track and field, table tennis, beach volleyball, and football) and allows players to compete by standing directly in front of the Kinect (Naito & Kobayashi, 2012).

Dance Dance Revolution (DDR) and Just Dance (JD) are two styles of dance games. DDR involves following the arrows of the song cues on the screen and stepping on the directional arrows of the dance carpet (Smith et al., 2011; Kloos et al., 2013). Just Dance offers more varied gameplay, including a wide range of popular music and dance styles where the player chooses their favourite song and dances by mimicking the dance moves on the screen to achieve a high score. Ring Fit Adventure is the latest AVG that includes both a storyline and fitness combo modes, and it is popular among college students (Mingxuan et al., 2021).

In contrast, structured AVGs are designed to be more systematic and scientific, primarily used to simulate sports training in virtual environments to help players improve their physical fitness (Warburton et al., 2007). These games usually adhere to strict principles of sports training and contain straightforward training programs or goals that require players to follow step-by-step exercises. Although structured AVGs may not be as motivationally prominent as unstructured AVGs, they can provide consistent and effective physical training for users with clear health or fitness goals through systematic training design (Tripette et al., 2017).

Some of the more representative structured AVGs include cycling games (game bikes combined with racing video games) that can simulate cycling training when combined with other platforms (Monedero et al., 2015) (Adamo et al., 2010). Nike Kinect Training focuses on real-life trainers based on simulations on the screen. Wii Fit (Plus) is a strength, aerobic, and balance training game (Nitz et al., 2010) that can be played in single or multiplayer mode using the Wii Balance Board and remote control (Janssen et al., 2013). Your Shape: Fitness Evolved, on the other hand, is used in conjunction with Kinect to follow a virtual trainer to exercise specific muscle groups and more by selecting different game difficulties (Sultan et al., 2023).

2.3.3 Popularity and Reasons for Active Video Games

Understanding the current popularity of Active Video Games (AVGs), particularly among the college student population, is crucial for showcasing their potential value. The American College of Sports Medicine (ACSM) notes that AVGs were once primarily found in wellness facilities such as playgrounds and fitness gyms; however, nowadays, they are ubiquitous, present in locations like doctor's offices, hospitals, schools, and homes (Skjonsberg, 2014). In the United States, sales of computer and video game software reached $7 billion in 2005, with 83% of console game purchasers being over 18 years old (Bonetti et al., 2010). The popularity of AVGs has been further amplified by the COVID-19 pandemic.

The global outbreak of the COVID-19 pandemic in 2019 rapidly spread across the world, fundamentally altering people's ways of life (Bhat et al., 2021). Whether individuals are office workers or students, most of their activities have shifted online.

Among these individuals, college students have been significantly impacted (Adedoyin & Soykan, 2023). The sudden transition from in-person to online instruction compelled colleges and universities to swiftly adopt virtual learning. Instead of commuting to campuses daily, college students now attend classes from the comfort of their homes through the Internet and computer screens (De' et al., 2020). The isolation experienced by Chinese college students at home has reshaped their perspectives and limited their outdoor pursuits (Han et al., 2022; Vučković et al., 2022). Consequently, there has been a substantial surge in the demand for home-based exercise (Zhao, 2023). The popularity of AVGs is also indirectly boosted by the fact that they can be played at home owing to their portability.

As of 2021, the console gaming market has reached $60 billion globally (including console hardware and game software). Nintendo's consoles have outperformed Xbox and PlayStation, with the Wii being Nintendo's highest-selling console, having sold approximately 101 million units, including the AVG Wii Fit, which has sold over 22 million units (Suire et al., 2022). By 2022, the Nintendo Switch series had sold 110 million units, surpassing both the PlayStation series (86.7 million) and Microsoft's Xbox series (40.2 million) during the same timeframe (Zhou & Wei, 2023). The Switch has since exceeded the Wii as the top-selling gaming console. The AVG Ring Fit Adventure, available on the Switch, has sold 15 million units in three years, becoming the most popular AVG among college students.

The primary reasons for the appeal of AVGs to college students include:

1. Entertainment: AVGs merge the enjoyment of gaming with physical activity, injecting excitement into traditional sports, and appealing to college students' passion for video games while promoting exercise unconsciously within the gaming experience.

2. Convenience in Time and Location: AVGs offer flexibility in terms of when and where they can be played, enabling college students to engage in them in their dormitories, at home, or any other convenient location without the need to adhere to a gym or sports facility's operating hours.

3. Social Engagement: Many AVGs feature multiplayer modes or online interactions, facilitating exercising with friends and classmates. By participating in these games together, students can foster or enhance social connections, enhancing the overall enjoyment of the activity.

2.3.4 Ring Fit Adventure

The popularity of home Active Video Games (AVGs) has experienced its peak with the success of Nintendo Wii Fit. However, the release of another Nintendo game, Ring Fit Adventure (RFA), has presented a significant challenge to this phenomenon. When RFA debuted in 2019, it quickly gained traction, selling over 60,000 copies in Japan within the first week, securing the top spot in the country (Famitsu Sales, 2019). In the span of just three years, RFA has sold 15.38 million copies, nearing the success of Wii Fit (Doolan, 2022). Wii Fit has established itself as a cultural and commercial juggernaut, and RFA is witnessing a similar surge in popularity.

Given the rise of RFA and the appeal of innovative AVGs among college students, these games are proving to be effective in promoting physical exercise (Wu et al., 2022). In light of this, it is essential to introduce RFA, an AVG released by Nintendo in 2019 for the Switch console. At the core of the game is a unique accessory called the 'Ring-Con,' a flexible ring-shaped device that users can squeeze and stretch to execute various somatosensory commands. To use the Ring-Con, players must insert the Switch's Joy-Con controller, which captures the player's strength and movement. Another crucial component is the leg strap, which holds the other Joy-Con on the player's thigh to track lower body movements like running and squatting (Wu et al., 2021; Lu et al., 2021).

RFA offers three primary game modes. The adventure mode places players in the role of a character exploring virtual maps and engaging enemies. Battles involve executing fitness moves like squats, push-ups, and rowing to attack or defend against foes (Chan et al., 2024). Custom Mode allows players to tailor workouts to their preferences and goals, focusing on specific body parts. The mini-game mode features short fitness games for entertainment or competitive play with friends and family.

Presently, RFA's applications primarily target improving body composition and health in adult women and the elderly (Roger Eston et al., 2012; Suire et al., 2022), alleviating chronic low back pain (Sato et al., 2021), and assisting in the rehabilitation of elderly individuals with musculoskeletal conditions (Takei et al., 2024). Some studies have demonstrated higher energy expenditure with RFA among overweight and obese children and adolescents compared to other AVGs like Wii and Xbox (Comeras-Chueca et al., 2020). Among college students with overweight and obesity in China, RFA appears particularly suitable due to its enhanced interactivity, personalized workout experience, and adaptability to college settings.

RFA innovatively merges role-playing and adventure game elements, integrating fitness actions into the storyline to engage players and enhance exercise enjoyment and continuity (Koivisto & Hamari, 2019). This dynamic differs significantly from traditional single sports modes in AVGs, offering a fresh experience for college students.

Furthermore, RFA's design allows players to adjust exercise intensity based on their fitness levels and goals, providing tailored training plans and real-time feedback to enhance effectiveness and safety while reducing the risk of injuries (Macák, 2021). The game's flexible sports modes enable players to blend their favourite activities, boosting enthusiasm for exercise.

Unlike Wii Fit and Xbox Kinect, which demand more space and equipment, RFA only necessitates a simple exercise ring and minimal home space, making it ideal for Chinese college students exercising in dormitories. Consequently, RFA offers an effective and sustainable fitness solution for Chinese college students with overweight and obesity due to its entertainment value, convenience, and adaptability. Given RFA's potential to enhance physical activity, mental health, and physical fitness, especially among college students with overweight and obesity in China, it was selected as the intervention method in this study. The study focuses on critical health issues among Chinese college students, including physical activity, psychological distress, exercise motivation, and body composition.

2.4 Definition and Measurement of Dependent Variables

This section defines and measures the dependent variable for this study.

2.4.1 Definition and Measurement of Physical Activity

Although scholars in various fields have offered different definitions of physical activity (Piggin, 2020), the widely accepted definition is the one put forth by Caspersen et al. in 1985, which states that physical activity is defined as 'any bodily movement produced by skeletal muscles that results in energy expenditure' (Caspersen et al., 1985). Physical activity can be categorized into two main types: subjective and objective measures (Ainsworth et al., 2015). Subjective measures include self-report questionnaires and activity logs.

On the other hand, objective measurements necessitate the use of instrumentation such as pedometers, heart rate monitors, and accelerometers (Dishman et al., 2001). Objective measurements can provide a more accurate representation of physical activity compared to subjective measurements (using questionnaires). Given that the participants in this study were college students with overweight and obesity in China whose daily routine primarily involves walking to class, pedometers are well-suited for this study as they can effectively track the frequency and amount of walking activities while being user-friendly and cost-effective. Hence, pedometers were selected as the measurement tool for physical activity in this study.

Regarding pedometer selection, this study reviewed various commercially available pedometers, evaluating their strengths and weaknesses before opting for the Yamax Digi-Walker® CW-700 pedometer due to its compact design, lightweight nature, and ease of use. Several studies have validated the accuracy of the Yamax Digi-Walker for step counting (Le Masurier et al., 2004). The Yamax CW 200 was chosen as the reference for assessing 13 pedometers for physical activity measurement and was deemed suitable and accurate for most studies (Chen et al., 2008). The Yamax Digi-Walker® pedometer has demonstrated accuracy in step counting for both low-speed and high-speed walking (Schneider et al., 2003). The precision in counting steps remains consistent at both low (Crouter et al., 2003) and high (Schneider et al., 2004) walking speeds (Strycker et al., 2007). Walking too slowly (Bassett, 2002; Tudor-Locke et al., 2002; Wilcox et al., 2001) or wearing the pedometer loosely can result in inaccurate measurements (Crouter et al., 2003). To address this issue, researchers found from previous studies that wearing the pedometer vertically around the waist led to more accurate and reliable measurements (De Cocker et al., 2012; Richardson et al., 2008; Jago et al., 2006). Additional clips were obtained to reinforce the pedometer's stability by attaching it securely around the waist, thereby enhancing measurement accuracy (Saris & Binkhorst, 1977). The measurement of steps by the Yamax pedometer, even with the accelerometer (GT3X+), was confirmed (Cruz et al., 2017). Therefore, the pedometer was worn around the waist as recommended, and additional clips were used to ensure stable attachment for accurate readings.

2.4.2 Definition and Measurement of Psychological Distress

Psychological distress is a broad term used to encompass unpleasant feelings or emotions (Karkhanis & Mathur, 2016) and is often associated with stress and anxiety (Ridner, 2004). It is a pervasive issue among college students globally (Vivekananda et al., 2011). In China, both adolescents and college students experience psychological distress (Boxiang Li et al., 2024), which commonly presents as depression, stress, and anxiety (Vázquez et al., 2012; Sharp & Theiler, 2018). Therefore, this study focuses on the psychological well-being of college students with overweight and obesity in China, specifically their experiences of depression, stress, and anxiety.

Questionnaires are widely used tools for assessing psychological distress. For instance, the Symptom Checklist 90 (SCL-90) is a self-report instrument that evaluates various psychiatric disorders, measuring the severity of symptoms experienced by the subject in the past week (Prinz et al., 2013). Conversely, the General Health Questionnaire (GHQ) is a self-administered scale employed to screen for mental health issues and identify individuals at risk for psychiatric disorders, with different versions ranging from 12 to 60 questions (Zulkefly & Baharudin, 2010).

The Beck Depression Inventory (BDI) is another commonly used self-report scale for evaluating depressive symptoms (Beck et al., 1961). This instrument is effective in identifying depression in both regular and college students (Steer & Clark, 1997; Al-Musawi, 2001). In China, psychological distress among college students is escalating due to academic and family pressures (Li et al., 2021), often leading to elevated levels of depression (Song et al., 2008) and increased stress levels coupled with anxiety (Zhan et al., 2021).

Considering the circumstances, the Depression, Anxiety and Stress Scale (DASS) was chosen for this study as it assesses depression, stress, and anxiety comprehensively, providing a holistic evaluation of psychological distress (Lovibond, 1995). The DASS is applicable across different cultures and populations and has been extensively validated for assessing the mental health of Chinese college students (Yu et al., 2022).

It comes in two versions: a 42-item version and a condensed 21-item version (Mellor et al., 2015). The 42-item version is more comprehensive and precise, while the 21-item version is a briefer assessment tool (Geethanjali & Adalarasu, 2014). To accurately evaluate the psychological distress of college students with overweight and obesity in China, this study utilized the DASS-42.

2.4.3 Definition and Measurement of Exercise Motivation

Motivation addresses the underlying factors driving human actions. Since actions are organized movements, the analysis of motivation encompasses the incentives, direction, regulation, and persistence of behaviour (Deci & Ryan, 1985). Motivation is a pervasive element in human life, with exercise often viewed as a clear illustration of motivation (Standage, 2012). Exercise motivation is frequently underpinned by specific theories, with Self-Determination Theory (SDT) standing out as a comprehensive theory explaining human motivation and behaviour (Deci & Ryan, 2013). SDT posits a spectrum of motivation for human behaviour ranging from externally controlled motivation to fully intrinsic motivation, with a particular emphasis on fostering intrinsic motivation and evaluating how it is either encouraged or hindered by the social context (Standage & Ryan, 2020).

Within SDT, it is proposed that individuals have three fundamental psychological needs, namely autonomy needs (the desire for self-directed and purposeful activities), competence needs (the drive to feel capable and effective when faced with challenges), and relatedness needs (the need to build meaningful relationships with others and experience a sense of belonging). The degree to which these needs are satisfied determines the nature and quality of an individual's motivation (Ryan, 2017).

Furthermore, according to SDT, an individual's motivation can be classified as intrinsic motivation, extrinsic motivation, and amotivation in a descending order. Extrinsic motivation can be further subdivided into various regulatory types, including external regulation, introjected regulation, identified regulation, and integrated regulation. External regulation represents the most externally driven form of motivation reliant solely on external rewards or punishments, such as monetary gain, while introjected regulation reflects behaviours driven by internal pressures. Identified regulation occurs when individuals identify certain behaviours as personally significant, and integrated regulation is manifested when individuals engage in activities that align with their internal beliefs (Teixeira et al., 2022).

In general, intrinsic motivation is deemed the most high-quality form of motivation as it signifies an individual's genuine interest and enjoyment in an activity. This type of motivation typically correlates with enhanced persistence, heightened engagement, and improved mental well-being. For instance, behaviours driven by the pleasure or satisfaction derived from physical activities are associated with intrinsic motivation (Tenenbaum & Eklund, 2007). In contrast, extrinsic motivation, where actions are performed to attain external rewards or avoid penalties, tends to be linked with lower levels of persistence (Deci & Ryan, 2008; Koestner et al., 1991). Individuals experience pleasure and intrinsic motivation when they have a positive experiential sense of their current activities. Conversely, when the experiential quality is poor and external regulation is present, motivation tends to diminish (Ryan & Deci, 2000).

Past research has explored the motivation and physical activity (PA) levels of Chinese college students, noting that a primary reason for a lack of motivation is their heavy reliance on the Internet and gaming, resulting in less interest in traditional sports or regular exercise (Wang et al., 2024; Liu et al., 2024). From the perspective of SDT, these forms of exercise need to be made more appealing to enhance motivation to engage in physical activities, thereby raising intrinsic motivation levels. However, some studies suggest that interactive video game formats and gameplay are more appealing to college students, increasing enjoyment and boosting exercise motivation (Wei Peng et al., 2015; Huang et al., 2019).

Presently, there are various scales available for assessing sports motivation, such as the Exercise Motivation Inventory-2 (EMI-2), which is a comprehensive scale suitable for investigating the multiple motivational factors among college students engaged in different types of sports activities, particularly useful for evaluating diverse sports motivation aspects (Kim & Cho, 2022; Campos et al., 2022). Another tool, the Sports Motivation Scale (SMS), can gauge different motivational components of individuals participating in sports and has been validated (Pelletier et al., 2013).

The most suitable questionnaire for the current study is the Behavioural Regulation in Exercise Questionnaire-2 (BREQ-2), comprising 19 items that evaluate exercise motivation through five subcategories (Baghurst et al., 2014). The choice of the BREQ-2 is based on several reasons. Firstly, this questionnaire is specifically designed to assess the types of exercise motivation in line with SDT, making it well-suited for this study (Mahony et al., 2019). The various game modes of the interactive video game can effectively fulfill the three basic psychological needs outlined in SDT, aligning well with this questionnaire. Moreover, the BREQ-2 enables measurement of different motivation dimensions, making it possible to directly assess changes in motivation types (e.g., from extrinsic to intrinsic motivation) among college students with overweight and obesity following interactive video game training, hence providing a detailed view of the effects of interactive video games on exercise motivation. Finally, the BREQ-2 is tailored to evaluate exercise motivation in the general population, making it suitable for assessing individuals involved in routine physical activities.

2.4.4 Definition and Measurement of Body Composition

According to the ACSM classification, Body Composition is categorized under health-related physical fitness (HRPF). It refers to the relative proportion of fat and fat-free tissue in the body, typically expressed as the percentage of total body fat (Medicine, 2013). College students with overweight and obesity exhibit lower physical activity levels and are predisposed to poorer body composition (Savegnago Mialich et al., 2014; Liao & Zhang, 2023).

BMI is a commonly used measure of an individual's overall body mass and is effective in screening for overweight and obesity, but may have limitations when used in isolation due to its inability to differentiate between adipose and muscular tissues (Frankenfield et al., 2001) Lean body mass reflects an individual's muscle level and mass, which is closely related to physical activity, basal metabolic rate, and muscular fitness (Arroyo et al., 2004). Higher lean body mass is generally associated with better metabolic health and fitness levels (Arroyo et al., 2004). Percentage body fat, on the other hand, measures the proportion of adipose tissue in total body mass and is an important indicator for assessing the extent of fat accumulation in an individual. Excessive body fat percentage may increase the risk of metabolic diseases such as cardiovascular disease and type 2 diabetes, whereas an appropriate body fat level helps to maintain normal physiological functions. The waist to hip ratio is used to evaluate the distribution pattern of fat, and its value is calculated from the ratio of waist circumference to hip circumference, specifically measuring the ratio of abdominal fat to hip circumference. Therefore, it can be used as an indicator to measure the degree of visceral fat accumulation (Doustjalal et al., 2016). WHR is a stronger predictor of cardiometabolic risk than BMI alone, as central obesity is more closely associated with metabolic syndrome, and cardiovascular disease (Myint et al., 2014).WHR is measured using a standard tape measure, with waist circumference measured at the midpoint between the lowest rib and the iliac crest, and hip circumference at the widest point of the hips, and the ratio is calculated by dividing waist circumference by hip circumference (Huxley et al., 2010). Waist-to-hip ratios above 0.90 for men and 0.85 for women are usually classified as centrally obese. For overweight and obese college students, the inclusion of waist-to-hip ratio in body composition assessments can provide a more complete picture of the health risks and metabolic status of this population. Overall, it is difficult for a single variable to fully reflect the body composition status of college students, so considering BMI, lean body mass, body fat percentage, and waist-to-hip ratio together may provide a more accurate assessment of the health status of college students, the types of obesity, and their potential health risks.

Common methods for measuring body composition include the following:

1. Dual-energy X-ray absorptiometry (DXA) (Andreoli et al., 2016), commonly used for assessing body composition including adiposity and defatted mass. DXA scans are quick with high image resolution (Blake & Fogelman, 1997)

but are most accurate for young, healthy subjects and less so for osteoporotic and obese subjects (Plank, 2005).

2. Hydrostatic Weighing, which calculates body density by comparing underwater and on-land weights but is often impractical for clinical use or mass testing due to its technical requirements (Jackson & Pollock, 1985).

3. Electrical Impedance Analysis (BIA) is another commonly utilized method. BIA relies on variations in electrical conductivity among different body tissues. Various tissues like fat, muscle, bone, and water have different conductivities to electrical currents. BIA devices pass a low-voltage electrical current through the body via electrodes, and the speed at which the current travel through the body is determined by body composition, including muscle, fat, and water content (Kuriyan, 2018). The device then calculates the impedance and employs algorithms, along with user parameters such as height, weight, age, and gender, to estimate body composition metrics such as body fat percentage, muscle mass, and water content (Kyle, 2004).

BIA provides a quick, non-invasive, and convenient method for measuring body composition due to its standardized design and compact nature (Kyle et al., 2004). It is particularly suitable for evaluating body weight, fat percentage, and muscle mass in college students with overweight and obesity. The Tanita BC418-MA is the BIA device used, validated in various studies as a reliable system with good accuracy and consistency (Kelly & Metcalfe, 2012; Aniśko et al., 2024). The Seca stadiometer is utilized to measure the height of college students for BMI calculation, known for its accuracy and widespread use in healthcare settings (Baharudin et al., 2017). A standardized tape measure is employed to determine the waist-to-hip ratio.

2.5 The Effects of Active Video Games on Physical Activity among College Students

To comprehend the current research on the impacts of active video games (AVG) on the physical and mental well-being of college students, this study conducts a systematic review considering the variables mentioned above.

To evaluate the literature on AVG influencing physical activity in college students, the researcher systematically analysed the impact of AVG on physical activity in college students with overweight and obesity. Searches were performed across five prominent international databases (PubMed, SCOPUS, Web of Science, CINAHL Plus, and EBSCOhost) using predefined keywords and their combinations. The systematic reviews adhered to the Preferred Reporting Items for Systematic Assessment and Meta-Analysis (PRISMA) guidelines (Page et al., 2021).

A total of 1023 studies were initially identified, from which eight eligible Randomized Controlled Trials (RCTs) were selected for review. Based on this literature, the researcher authored a systematic review titled "Effects of active video games on physical activity among college students with overweight and obesity: a systematic review," which was published in the February 2024 issue of the Journal Frontiers in Public Health (see Appendix P). The systematic review highlighted gaps in the research on AVG regarding physical activity among college students with overweight and obesity.

2.5.1 Population Gaps

Several noteworthy points concerning the population are as follows:

1. Most existing studies have been conducted in the United States, with none in China, specifically none involving college students with overweight and obesity in China.

2. The majority of studies have focused on a single gender as the study subjects (Rodrigues et al., 2018; De Brito-Gomes et al., 2019; Jacobs et al., 2011; Rahayu et al., 2019; Warburton et al., 2007). However, in Chinese college students, both males and females commonly experience overweight and obesity. There is a marked deficiency in studies that encompass both male and female Chinese college students.

3. The number of subjects in both the experimental and control groups is typically small (less than 20 subjects in each group). Consequently, a larger sample size is essential to better validate the effects of AVG. Given the mentioned aspects, there is a pressing need to investigate physical activity among Chinese college students with overweight and obesity.

2.5.2 Interventions Gaps

The systematic review identified several gaps in the intervention:

(1) The variety of intervention modalities used varied among the studies reviewed.

Four studies utilized the Nintendo Wii (Rodrigues et al., 2018; Jacobs et al., 2011a; Russell et al., 2013; Douris et al., 2012), one study used the Xbox (De Brito-Gomes et al., 2016), and another study employed the PS2 (Warburton et al., 2007). Notably, none of the studies included interventions using the Switch console for enhancing physical activity in college students. However, the Switch console is considerably more popular based on sales figures and its appeal among college students (Tena-Monferrer & Fandos-Roig, 2022; Zheng, 2022).

(2) Regarding the selection of games for active video games (AVGs), most studies focused on games from the Wii series, such as Wii Fit (plus) and Wii Punchout (Jacobs et al., 2011; Rahayu et al., 2019; Douris et al., 2012; Russell et al., 2013). These games, first introduced in 2007, encompass older versions that primarily concentrate on specific exercise types, limiting the diversity and efficacy of the workout. Unlike these older versions, the latest game release in 2019, Nintendo's Ring Fit Adventure (RFA), offers a broader range of whole-body exercises and game modes for a more comprehensive workout experience (Jiang & Tham, 2022). RFA's innovative design and interactive elements make it particularly effective in motivating users to sustain long-term engagement in physical activity (Moreno Carbajal et al., 2024).

(3) The durations of interventions were generally shorter, with only one study running for 12 weeks (Jacobs et al., 2011), while others typically lasted six weeks or less (Rahayu et al., 2019; Rodrigues et al., 2018). Additionally, the sessions were typically limited to 30 minutes each, whereas physical education (PE) sessions in China are typically at least 45 minutes long. Shorter intervention periods and session durations may not yield the desired intervention outcomes. Hence, leveraging the Switch console along with the latest AVG (RFA) is essential for intervening in the physical activity of college students.

2.5.3 Outcome Gaps

In terms of outcomes, the current study focused on the energy expenditure of college students while using AVG and the use of the Borg Scale to assess post-exercise physical activity levels by measuring RPE (De Brito-Gomes et al., 2019; Douris et al., 2012). No studies have focused on measuring college students' physical activity using pedometers. However, the primary activity of Chinese college students currently revolves around walking to classes, thus necessitating continuous monitoring of their physical activity using pedometers—this would yield more valid and accurate measurements.

2.6 The Effects of Active Video Games on Mental Health among College Students

To evaluate the impact of active video games (AVG) on the mental health of college students, the researcher conducted a systematic review of current research on interventions utilizing AVG for this demographic. The search was conducted using keyword combinations in seven international databases (PubMed, SCOPUS, Web of Science, CINAHL Plus, EBSCOhost, Cochrane Library, and CNKI). This search yielded a total of 3,045 references. Following the application of specified inclusion-exclusion criteria, 17 Randomized Controlled Trials (RCTs) were reviewed. Based on this review, the researcher compiled a systematic review titled "Effects of Active Video Games on Mental Health Among College Students: A Systematic Review." This systematic review was published in BMC Public Health in December 2024 (see Appendix P). The systematic review identified gaps in AVG research related to college students' mental health.

2.6.1 Population Gaps

The majority of the studies included in the analysis were conducted in the United States, with the remaining studies concentrated in Europe and North America, including Greece (Nani et al., 2019), Switzerland (Roure et al., 2020), and Canada (Rhodes et al., 2009). Currently, there is no research utilizing AVG to address psychological distress among college students with overweight and obesity in mainland China.

2.6.2 Interventions Gaps

The systematic review revealed the following gaps in interventions:

1. Variety in Intervention Types: The studies predominantly utilized AVGs from three major manufacturers. Microsoft's XBOX was the most used (Huang et al., 2019; Hwang et al., 2023; Nguyen et al., 2016; Yu et al., 2023; Wan Yunus et al., 2020; Huang et al., 2017; Nguyen et al., 2018). The second most popular choice was Nintendo Wii (Russell et al., 2013; Nani et al., 2019; Jacobs et al., 2011; Douris et al., 2012; Wan Yunus et al., 2020). However, when considering AVGs for interventions targeting college students' mental health, most XBOX studies employed Your Shape:

   Fitness Evolved, a title released in 2010 for the Xbox 360 that required use with the Kinect sensor. The game primarily involves a variety of dances, aerobic boxing, and yoga following virtual training instructions (Polechoński et al., 2019).

   Wii games mainly included "Wii Sports," "Free Run," "Punch-out," and "Wii Fit." All these games were released before 2010, with the earliest, Wii Sports, launched in 2006. They allow players to engage in a range of virtual sports activities (Celinder & Peoples, 2012). The game selection is somewhat dated, with releases concentrated around 2010. The gameplay is single mode, limiting the types of exercises available simultaneously to college students, which might impact participant engagement negatively.

2. Session Duration: Most studies reported relatively short session durations, typically lasting between 15 to 50 minutes (Hwang et al., 2023; Nguyen et al., 2018), with none exceeding one hour. A shorter gameplay duration may not provide college students with adequate exposure and completion of the intended training. Hence, selecting newer AVGs and ensuring adequate session durations are essential for interventions targeting college students' mental health.

2.6.3 Outcome Gaps

Among the studies analysed, researchers identified the following gaps in outcome measurement:

(1) Limited studies have utilized Active Video Games (AVG) to address psychological distress among college students. Only three studies have incorporated this intervention (Douris et al., 2012; Wan Yunus et al., 2020; Wu et al., 2022). Out of these, only one study employed the newer AVG known as Remote Fitness Assessment (RFA). However, the primary focus of that study was on assessing physical fitness, with less emphasis on evaluating emotional disorders (Wu et al., 2022). Another study included outcome measures for depression, stress, and anxiety, but the AVG utilized was relatively outdated (Xbox 360 Kinect) (Wan Yunus et al., 2020).

In essence, there is currently a lack of studies employing the latest AVG to simultaneously assess psychological distress among college students, particularly in terms of depression, stress, and anxiety. Given both the increasing popularity of RFA and the prevalent psychological distress related to depression, stress, and anxiety faced mainly by college students with overweight and obesity in China, there is a critical need for studies that combine these two aspects.

(2) Presently, only three studies have explored the impact of AVG on intrinsic motivation, overall motivation, and the intention to participate in other forms of exercise (Hwang et al., 2023; Jacobs et al., 2011; Nguyen et al., 2016).

The remaining studies mainly focused on potential mental health aspects such as sleep quality and attendance (Rhodes et al., 2009; Peng et al., 2012). Changes in exercise motivation are crucial for college students with overweight and obesity in China as it directly influences their future health status. Therefore, there is an urgent need for research in this particular area.

2.7 The Effects of Active Video Games on Body Composition among College Students

In order to assess the impact of active video games (AVGs) on the body composition of college students, the researchers broadened their search to include health-related physical fitness, as defined in the ACSM's measurement manual (Toomey et al., 2015; Medicine, 2013). Subsequently, a systematic review and meta-analysis were undertaken to investigate the effects of AVGs on the health-related physical fitness of college students. The researchers conducted searches across eight globally recognized databases (PubMed, SCOPUS, Web of Science, CINAHL Plus, EBSCOhost (SPORTDiscus), Cochrane Library, and Embase) using a combination of keywords, resulting in the retrieval of 3061 articles. Following the predefined inclusion and exclusion criteria, 14 articles were selected for systematic review, with 10 being subjected to meta-analysis. The researchers authored a systematic review and meta-analysis entitled "Effects of Active Video Games on Physical Fitness Among College Students: A Systematic Review and Meta-Analysis," submitted for review in JMIR Serious Games in January 2025 (see Appendix P). The systematic review and meta-analysis revealed the need for further research on the influence of AVGs on the body composition of college students.

2.7.1 Population Gaps

Among the studies focusing on enhancing the body composition of college students through AVGs, only two studies encompassed college students from Taiwan Province of China, where their body composition saw improvement following AVG interventions (Huang et al., 2017; Wu et al., 2022). Considering the escalating proportion of college students with overweight and obesity in mainland China (Chen et al., 2024), contemplating the use of AVGs to help them enhance their body composition holds promise.

2.7.2 Interventions Gaps

There is a need for a broader range of intervention types and longer session durations. The active video games (AVGs) utilized in the six referenced studies involving body composition assessments were Just Dance 4, Wii Sports, Your Shape: Fitness Evolved, Xbox Kinect (Adventures, Training, Dance Central, Sports), GameBike system combined with Smuggler's Run, and Wii Fit (Roopchand-Martin et al., 2015; Nani et al., 2019; Huang et al., 2017; Zurita-Ortega et al., 2018; Warburton et al., 2007; Jacobs et al., 2011). The most recent games among these are Just Dance 4 and Kinect Training, released in 2012. Kinect Training, which is based on Nike + Kinect Training, primarily offers personalized training programs under virtual coach guidance. Just Dance 4 involves mimicking dance movements as directed on the screen (Eason et al., 2016). Despite having distinctive features, Kinect Training and Just Dance 4 have relatively straightforward game modes. In comparison to the modern AVG called RFA that combines role-playing game elements with various sport types, the older AVGs may not fully meet the requirements of college students, thereby leading to minimal intervention effectiveness. The duration of each session is typically short, around 30 minutes (Nani et al., 2019; Huang et al., 2017; Warburton et al., 2007). With the newer AVGs offering more content and diversified gameplay, the shorter session durations may inadequately facilitate exercise for college students, consequently impacting the intervention outcomes. Hence, it is essential to align the session durations with the class schedules of Chinese universities, gradually increasing them, with a duration of 40 minutes to 1 hour being deemed most suitable.

2.7.3 Outcome Gaps

Of the six profiled studies evaluating body composition among college students (Roopchand-Martin et al., 2015; Nani et al., 2019; Huang et al., 2017; Zurita-Ortega et al., 2018; Warburton et al., 2007; Jacobs et al., 2011), none focused on the waist-to-hip ratio of college students. However, the waist-to-hip ratio offers a more reliable means to observe fat distribution in college students (Rašeta et al., 2017), which is beneficial for evaluating the impact of interventions on their body composition and is a parameter that warrants evaluation. Furthermore, only two studies included body fat percentage as an outcome measure (Roopchand-Martin et al., 2015; Huang et al., 2017). Presently, college students with overweight and obesity in mainland China exhibit poor body composition, notably with high body fat percentages (Peng et al., 2023; Song et al., 2021), necessitating further research on the influence of AVGs on their body fat percentages. Therefore, considering the potential of AVGs in enhancing body composition, there is a need for more extensive research in this area.

2.7.4 Conclusion for Gaps

Building upon preceding studies, the identified gaps in all systematic reviews are outlined as follows:

Intervention gap: The AVGs utilized in current studies to intervene in college students, whether in physical activity, addressing psychological distress, or enhancing body composition, are somewhat dated. These AVGs were typically released in 2010, with their user demographics, gameplay, and configurations aligned with the technology of that era and catered to users' preferences at the time. Nonetheless, these games may struggle to meet contemporary preferences of college students for electronic products, thereby having limited appeal. Therefore, in selecting interventions (AVGs), it is imperative to keep abreast of modern trends and opt for newer AVGs that align with college students' current preferences.

Outcome gap: None of the studies comprehensively assessed college students' physical activity, psychological distress, and body composition through AVGs. Yet, college students with overweight and obesity in China often exhibit reduced physical activity levels and weakened exercise motivation, leading to psychological distress and suboptimal body composition. Careful consideration of these physical and mental health indicators could facilitate a more thorough exploration of the role of AVGs in college students with overweight and obesity.

Population gap: Presently, the experimental subjects predominantly comprise college students from Taiwan Province of China, with a lack of studies on college students with overweight and obesity in mainland China. Hence, there is an urgent need for research to address this gap.

2.8 Theoretical and Conceptual Framework

This section explains the theoretical framework, and conceptual framework.

2.8.1 Theoretical Framework

According to the World Health Organization guidelines on physical activity and sedentary behaviour (Bull et al., 2020), regular physical activity is recommended for all age groups in different countries and regions (Vuori, 2018). Regular physical activity enhances fitness and improves cardiac, vascular, and metabolic health, as well as bone health. Being active also enhances cognitive functioning, including academic performance and mental health, and can reduce symptoms of depression and anxiety (Organization, 2022). However, the relationship between physical activity and health is not always direct or straightforward, involving multiple interrelated physiological and psychological factors (Hardman & Stensel, 2009). This complexity is particularly relevant for the overweight and obese college population, which faces not only physical health issues but also mental health-related challenges. Therefore, it is of great public health importance to examine how to effectively increase physical activity levels in this population while improving their mental health and body composition. To better understand and promote the health of college students with overweight and obesity, several theoretical models and theories need to be utilized to make sense of their relationships.

The Health-Related Fitness Model (HRFM) was proposed in 1994. The model vividly depicts the relationship between physical fitness, physical activity, and health. It suggests that habitual physical activity can directly influence health-related fitness (e.g., cardiorespiratory endurance, muscular strength, flexibility, and body composition) and that these fitness elements determine an individual's health status to some extent. Additionally, improvements in health status can lead to more active individuals, creating a virtuous circle (Bouchard et al., 1994). Particularly among college students with overweight and obesity, increased physical activity may directly improve their body composition (e.g., lower body fat percentage, increased muscle mass) and cardiorespiratory fitness, subsequently enhancing overall health status. The model also underscores how genetic traits and other factors (e.g., lifestyle behaviours, socio-environmental factors, personal attributes) influence the relationship between health-related fitness and health. Genetic traits are genetically transmitted and unchangeable by the individual, while environmental factors and personal habits are influenced by complex social and cultural influences. Therefore, this study focuses on factors amenable to intervention, particularly the relationship between physical activity and psychological distress, exercise motivation, and body composition, as detailed in Figure 2.1.

Several studies are presently integrating the HRFM into instruction. One study indicated that categorizing the HRFM goals into five stages consistent with student development and incorporating its characteristics into instruction effectively enhances high school students' physical fitness (Loviani et al., 2021). There have also been studies applying the HRFM in physical education to assist secondary school students in increasing physical activity, perceived competence, and enjoyment (Fu et al., 2013). However, the model is predominantly applied with middle-aged adults and adolescents, with a scarcity of evidence regarding physical activity among college students with overweight and obesity, underscoring the urgent need to verify its effects on this population.

The Model of Health Outcomes with Active-Play Games proposes that Active-Video Games (AVGs) as an innovative intervention can promote health by increasing physical activity and improving motivation to exercise. The model posits that AVGs can enhance behaviour by influencing four mediators known to improve health behaviours: self-concepts, self-efficacy, physical skills, fitness, and well-being, and communication and social support (Lieberman et al., 2011). For example, self-concepts relate to designing games that boost players' self-concepts, improving self-esteem and reducing social anxiety. Through gradual difficulty progression, self-efficacy can motivate individuals to engage in healthy behaviours more confidently. Physical skills, fitness, and well-being encompass the positive physical and mental effects players experience after participating in AVGs. Communication and social support highlight the benefits of shared gaming experiences, communication, and encouragement in improving health behaviours. The model emphasizes that different game modes of AVGs will impact players cognitively, emotionally, socially, and physically, leading to improved behaviours and outcomes.

Introducing AVGs as an intervention not only augments physical activity but also enhances motivation to exercise and psychological well-being, particularly relevant to college students with overweight and obesity who often face higher levels of psychological distress and lower motivation to exercise. It is crucial to explore how novel AVGs like RFA can enhance their health by increasing physical activity and boosting exercise motivation, as outlined in Figure 2.2.

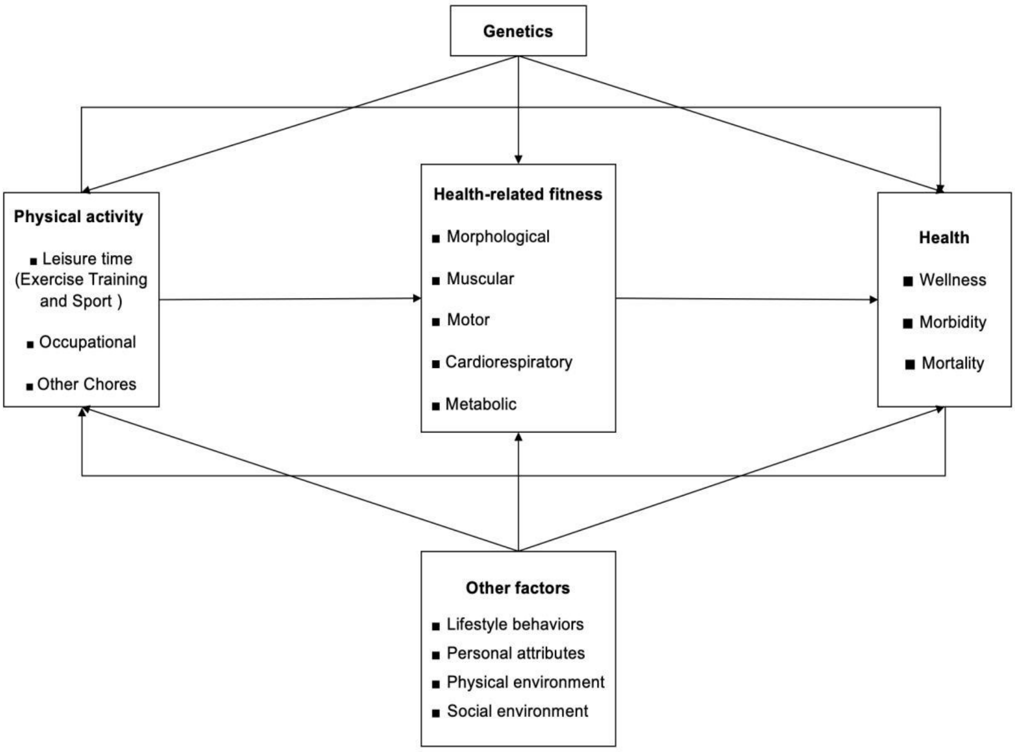

Figure 2.1 : Health-related Fitness Model by Bouchard & Shephard (1994)

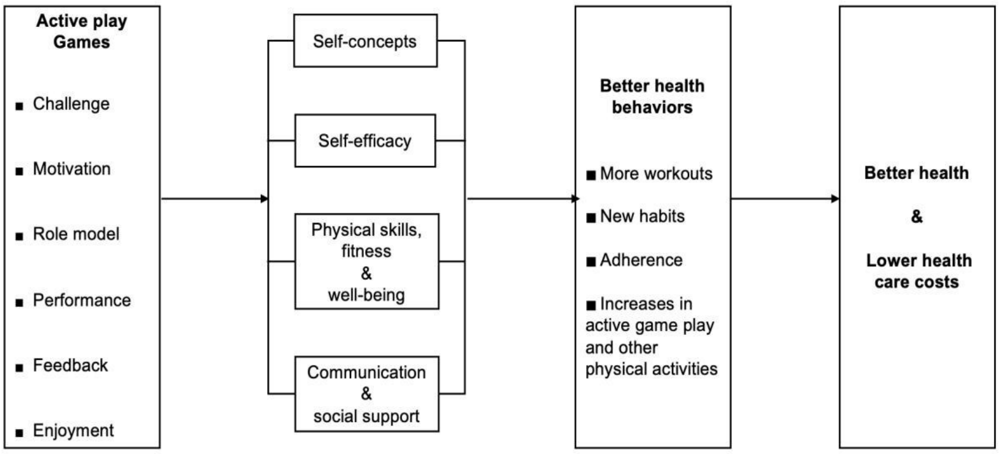

Figure 2.2 : Model of Health Outcomes with Active-Play Games by Debra Lieberman (2000)

2.8.2 Conceptual Framework

Overweight and obesity are associated with an increased risk of chronic diseases, including cardiovascular diseases, musculoskeletal problems, and cancer across all ages and races (Identification et al., 1998). Among overweight and obese populations, who are the least active group, avoidance of exercise is prevalent due to various reasons (Tudor-Locke et al., 2010). Obese individuals may have concerns about their weight and face barriers to participating in physical activity (PA), such as discomfort or embarrassment about exercising in public (Leone & Ward, 2013). They might have had negative past experiences with exercise and find high-intensity workouts challenging. Hence, establishing realistic goals, engaging in moderate-intensity activities, enjoying exercise, and enhancing self-efficacy are crucial for them (Baba et al., 2006). To address these issues, the American College of Sports Medicine (ACSM) has recommended exercise prescriptions for overweight and obese individuals. These recommendations include moderate-to-vigorous intensity exercise for at least 30 minutes continuously or in segments of at least 10 minutes several times a day, incorporating a mix of aerobic and strength training. These recommendations are guided by the FITT principle (frequency, intensity, time, type) (American College of Sports Medicine et al., 2018).

The ACSM recommends following the FITT principle for physical activity among college students with overweight and obesity which underlines the significance of exercise type diversity. The health-related physical fitness model highlights the importance of exercise type choice in promoting health but does not specify which type is superior. Approximately 40%-65% of people initiating traditional physical activity courses drop out within 3 to 6 months (Kyle, 2004; Dishman & Buckworth, 1996). College students with overweight and obesity in China show disinterest in traditional classes and sports, preferring electronic devices and games (Wu & Zhang, 2023; Ma et al., 2023). Hence, this study focuses on using Active Video Games (AVG) as a form of exercise and follows the FITT principle to offer a tailored exercise regimen for health-related physical fitness.

A theoretical framework is presented within the model of health outcomes with active-play games to elucidate how Active Video Games (AVG) can enhance health outcomes by augmenting physical activity levels and boosting exercise motivation. The model integrates psychological and behavioural variables in health promotion. However, the model lacks specific details on improved health behaviours and outcomes due to AVG, as well as the targeted population. College students with overweight and obesity in China often experience elevated psychological distress (depression, anxiety, stress) and lower motivation to engage in physical activity. Taking AVG (RFA) as a type of physical activity in leisure time, by allowing overweight and obese college students to play AVG, they can improve their self-efficacy, self-concept, motor skills and social communication during the game, thereby acquiring better health habits, such as increasing exercise motivation. This healthy habit can be engaging in other types of physical activities or further increasing the use of AVG. Increased physical activity can improve their body composition and bring about a positive psychological state. When mental health and body composition are improved, it will further increase their willingness to engage in physical activity, thus forming a virtuous circle.

In conclusion, this study endeavors to evaluate the impact of Active Video Games (RFA) on physical activity, mental health, exercise motivation, and body composition of college students with overweight and obesity in China. Utilizing AVG, according to the health-related fitness model, can enhance health-related physical fitness. Given that body composition is directly linked to cardiovascular and metabolic diseases, this study specifically concentrates on this aspect, considering the prevalent health issues among overweight college students in China. AVG is believed to bring enjoyment, enhance self-efficacy, and promote well-being in physical activities, fostering better health habits in college life. The analysis focuses on reducing psychological distress and the motivating effect of AVG on exercise, thereby verifying whether AVG (RFA) can enhance these physical and mental health parameters and ultimately promote well-being. Further details are illustrated in Figure 2.3.

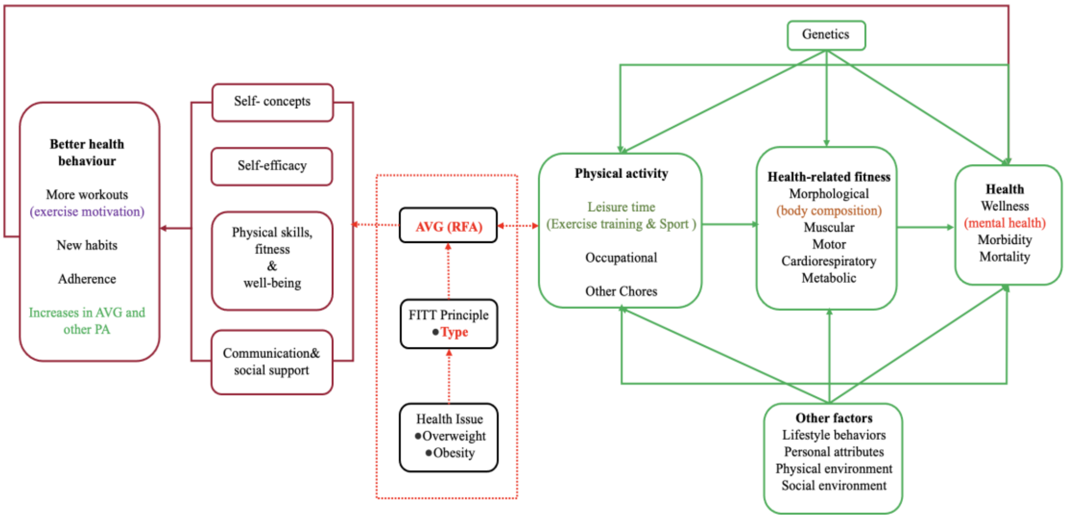

Figure 2.3 : Conceptual Framework

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter focuses on several key areas: research design, cluster selection and randomization, study site, participants and sampling method, sample size determination, research instrument, intervention, pilot study, data collection process, and statistical analysis.

3.2 Research Design

The research design of this study was an experimental, pre-test, and post-test design (Meyers & Grossen, 1974). This study utilized a Cluster Randomized Controlled Trial (CRCT) based on the research purpose and available conditions, and the information was registered on ClinicalTrials.gov before commencement (registration number: NCT06078150). Previous research suggests that a CRCT is most suitable for community health and school-based educational interventions where outcomes may be influenced by the intervention (Torgerson, 2001; Hayes & Moulton, 2017). Delivering interventions in groups helps prevent cross-contamination between intervention and control groups (Campbell et al., 2012). Clustering participants and using this as the randomization unit minimizes the risk of contamination and its impact on study outcomes (Donner et al., 2000).

In this study, clusters (rather than individuals) in Jining City were randomised. Nine major districts in Jining City were considered for cluster selection. Firstly, among the nine main administrative districts in Jining City, the researchers randomly selected two administrative districts using a computer randomisation tool (https://www.randomizer.org/) and further randomly assigned one of them to be the district where the experimental group was located (Qufu district) and the other one to be the district where the control group was located (Yanzhou district). Subsequently, a university within each district was randomly selected as the study site and university students meeting the criteria for overweight or obesity (BMI $\geq$ 25 kg/m²) were recruited on campus as subjects. Subjects were recruited through a combination of campus announcements, online publicity, and health check screening, and those who were eligible signed an informed consent form and received baseline measurements. To reduce bias during the study, the randomisation procedure was performed by different researchers and the physical education teachers and research assistants were not aware of the experimental group to which the subjects belonged, therefore, the study was a single-blind design. The experimental group (EG) received active video game training, while the control group (CG) received standard training. The research framework details are illustrated in Figure 3.1. Following best practices in quantitative research design (Ary et al., 2018), the dependent variable was measured at three points: pre-test (before intervention), post-test 1 (after six weeks of intervention), and post-test 2 (after 12 weeks of intervention). The training intervention protocol was registered and approved on ClinicalTrials.gov (Appendix B).

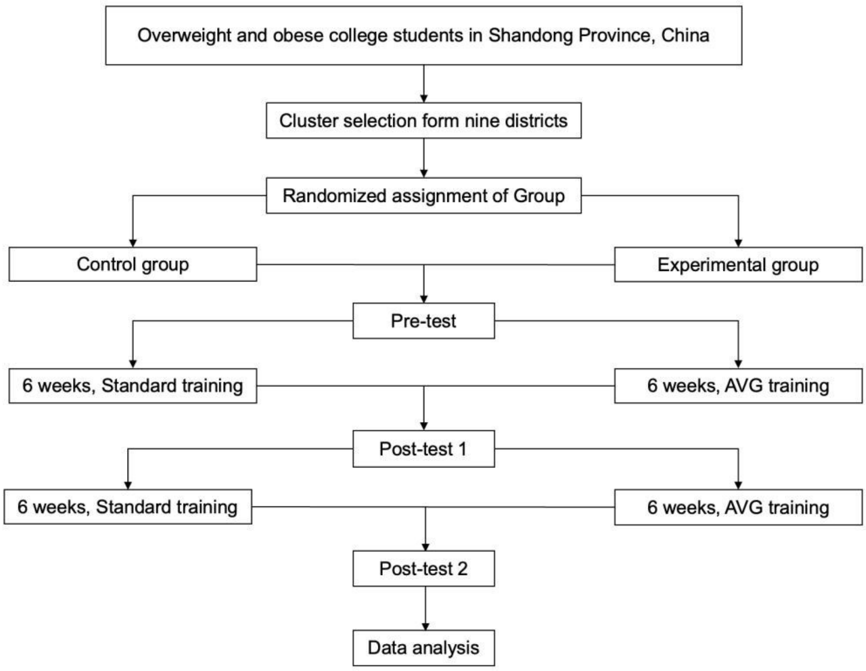

Figure 3.1 : Research Framework

3.3 Study Location

This study was carried out in Jining City, Shandong Province, China, for several reasons. Firstly, Jining City, renowned as the birthplace of Confucius, boasts a rich history and stands as one of the most economically developed cities in Shandong Province. With a large permanent population residing in its nine districts, Jining City hosts six universities, resulting in a significant presence of college students and a wealth of student resources. Secondly, being a northern city in China, Jining City reports a relatively high obesity rate among adults due to geographical factors and cultural practices (Li et al., 2022), making it easier to find suitable samples in areas with high obesity prevalence. Thirdly, drawing on previous research experience and field surveys, it was observed that college students attending universities in Jining City predominantly hail from northern regions such as Hebei Province and Liaoning Province. These students exhibit similar dietary patterns and tend to have higher rates of overweight and obesity, making it advantageous for subject recruitment and selection by conducting research in this location. Lastly, the researchers have prior experience of studying and residing in Jining City, providing them with familiarity with the college environment, its inhabitants, and the available facilities, which facilitates the design and execution of the experiment.

3.4 Population and Sampling Method

This section mainly includes population, sample size determination, participant criteria, and sampling process.

3.4.1 Population and Sampling

The study targeted college students with overweight and obesity in Jining, Shandong Province, China, aged between 18 and 22 years old who met the international criteria for overweight (BMI $>$ 25 and $<$ 30) and obese (BMI $\geq$ 30). Additionally, all participants were non-athletic college students with no prior exposure to active video games. Exclusion criteria encompassed participants with a family history of genetic disorders, psychiatric disorders, sports injuries, or a treatment history. Inclusion and exclusion criteria were enforced to maintain uniformity in the characteristics of the selected target group.

3.4.2 Sample Size

The sample size is closely related to statistical power, and to accurately determine the sample size for this study, the sample size was assessed and calculated using G*Power software (version 3.1), a statistical software that can be run on a wide variety of computer platforms (Erdfelder et al., 1996), and which has a wide range of application scenarios, such as in the fields of sociology, medicine, and behavioural research. Effect size can be defined as the strength of the relationship between the intervention and the variable on which its effect is investigated (Verma & Verma, 2020). The effect size for this study was determined based on previous research, and the minimum effect size for lean body mass was calculated (f=0.208) (Comeras-Chueca et al., 2022) (Table 3.1). The study was divided into two groups, and three replicated tests were conducted, setting the type error I (α err prob) =0.05 and efficacy (1-Berr prob) =0.80. The calculations found an overall sample size of n=40 and a sample size of n=20 for each group. The results of the calculations are shown in the following figure (Figure 3.2).

This study was a cluster random control trial design, which requires a larger sample size due to the statistical inefficiency of CRCTs compared to standard randomised controlled trials (Hemming et al., 2011). A standard solution is to multiply the sample size of a standard randomised controlled trial by a factor of 'Design Effect' (DE) (Ribeiro et al., 2018). According to G*Power's calculations, the sample size for each group is n-20. Typically, in studies involving humans, the intra-class correlation coefficient (ICC) is between 0.01 and 0.02 (Killip, Mahfoud, & Pearce, 2004). In this study, ICC is equivalent to 0.02.

The following equations were used to calculate the sample size:

Equation 1:DE=1+p (m-1), DE=1+0.02 (20-1)

Equation 2: ESS-DE*mk

Where m = number of individuals in each cluster, k indicates the total number of participants in the clustered study, ESS represents the effective sample size, DE defines the design effect, and p means the intracluster correlation coefficient (ICC) (Killip et al., 2004). As a result, the study's overall effective sample size is: ESS=1.38*20*2=56

The dropout rate depends on several factors, such as the type of study, the study population, and the duration of the intervention (Fewtrell et al., 2008), and according to previous studies, it is reasonable to set a dropout rate of 20% for similar interventions (Chan et al., 2024). Therefore, in this study, the dropout rate was set at 20% to avoid excessive subject attrition that would result in compromised sample integrity. By re-calculation, six additional subjects were required in each group. Therefore, this study's subjects were 68, which is 34 for EG and CG, respectively.

Table 3.1 : Effect Size Calculation for Research Variables (Mean, SD)

Variables	Pre-test Mean (SD)	Post-test Mean (SD)	Effect size (f)	Reference
Physical activity	5.23 (3.23)	9.43 (5.81)	0.447	(Peng et al., 2015)
Depression	2.83 (2.73)	3.78 (2.90)	0.315	(Wan Yunus et al., 2020)
Anxiety	2.94 (2.96)	3.67 (2.71)	0.544	(Wan Yunus et al., 2020)
Stress	3.89 (3.39)	5.00 (2.90)	0.357	(Wan Yunus et al., 2020)
Exercise motivation	4.00 (0.71)	4.59 (0.33)	0.436	(Liu, 2021)
Body mass index	23.84 (2.8)	23.33 (2.58)	0.465	(Rica et al., 2020)
Lean body mass	30.7 (4.6)	32.7 (5.0)	0.208	(Comeras-Chueca et al., 2022)
Body fat percentage	43.47 (7.37)	42.66 (7.64)	0.335	(Suire et al., 2022)
Waist-to-hip ratio	0.88 (0.05)	0.77 (0.18)	0.416	(Van Biljon et al., 2021)

Note: SD, standard deviation

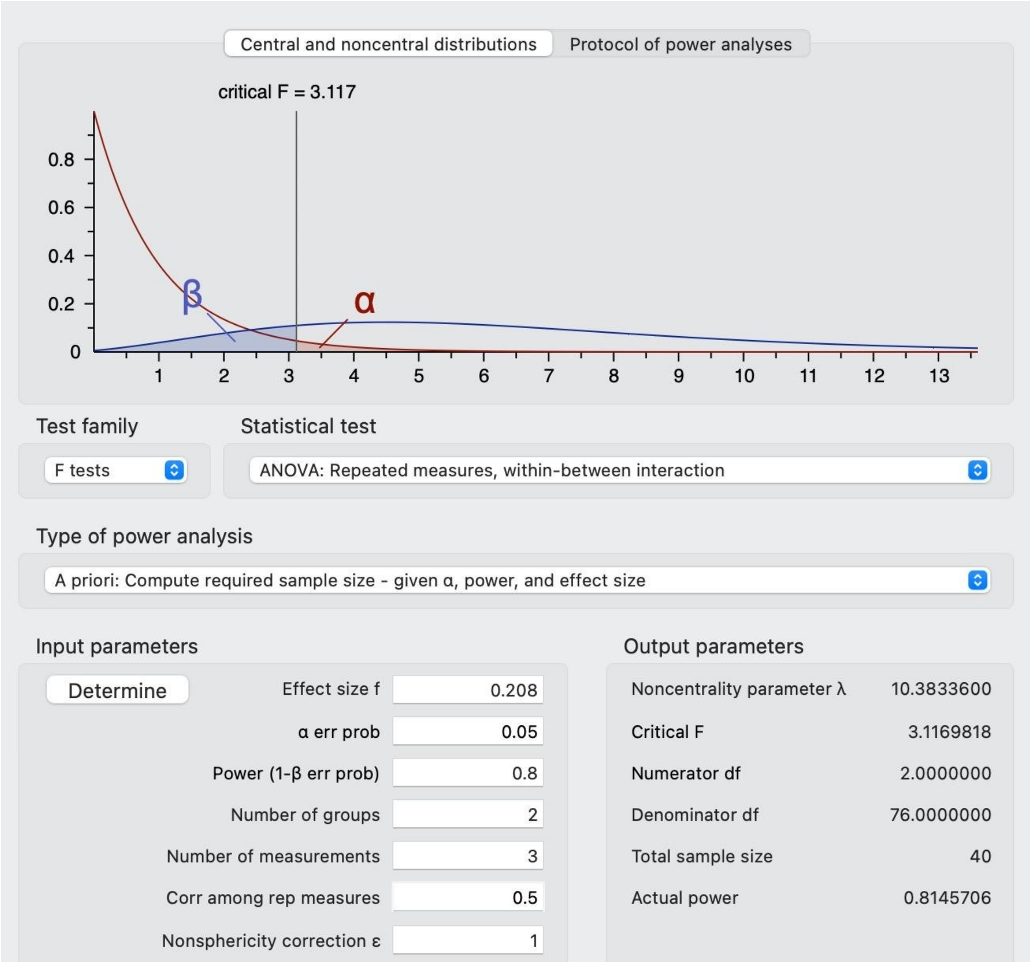

Figure 3.2 : Sample Size Calculation (G* Power)

3.4.3 Criteria for Sampling

The subjects' inclusion and exclusion criteria are established by the researchers according to predetermined standards. The Physical Activity Readiness Questionnaire (PAR-Q) is a pre-exercise questionnaire used to identify if exercise may raise the health risks of participants and serves as the foundation for the participant exclusion criteria (Thomas et al., 1992).

3.4.3.1 Inclusion Criteria

Participants met the inclusion criteria if they fulfilled the following criteria:

(1) Chinese college students ages 18 to 22 (Li, 2023).

(2) Chinese college students who were overweight and obese ($25 \leq BMI \leq 40$).

(3) Absence of previous AVG gaming experience.

(4) Participants who were deemed capable of engaging in healthy exercise based on the Physical Activity Readiness Questionnaire (PAR-Q) (Pei-Tzu Wu et al., 2015).

(5) No ankle or upper or lower extremity injuries that could hinder full-body exercise (Mullins et al., 2012).

3.4.3.2 Exclusion Criteria

Participants were excluded if they met the following exclusion criteria:

1) College students majoring in physical education or professional training (McCarthy et al., 2013; Davoodeh et al., 2020).

2) College students who were pregnant or on a diet.

3) College students with a history of mental illness, metabolic disease, cardiopulmonary or respiratory disease (e.g., asthma), or visual impairment.

4) Severe muscular or skeletal injury within the past three months (Roopchand-Martin et al., 2015).

5) Subjects with contraindications to physical activity as determined by questions on the PAR-Q (Russell et al., 2013).

6) Any other health problems that may affect subject safety during the experiment (Polechoński et al., 2019).

3.4.4 Participants Recruitment Process

All participants were recruited in two waves to control for seasonal effects. The first wave took place in 2023 during the summer holidays at the end of July. Interested potential participants were identified through telephone interviews, and their personal information was recorded. The second wave of recruitment occurred in the field in October 2023, after the start of the autumn school year. All recruitment procedures included informing participants about the importance of maintaining the confidentiality of the intervention, and participants agreed to this condition.

3.4.5 Sampling Method

This study followed the Consolidated Standards of Reporting Trials (CONSORT) guidelines for screening, allocation, and attrition management to ensure transparency and scientific integrity (Campbell et al., 2012). A total of 74 college students were enrolled in the recruitment phase. Initial screening was performed according to the World Health Organisation's BMI classification, and health status was assessed to exclude individuals with serious contraindications to exercise or recent injuries. Ultimately, 72 subjects who met the criteria were allocated to the experimental group (EG, n=35) and control group (CG, n=37) by random allocation and signed an informed consent form prior to allocation.

During the 12-week intervention, four participants in the experimental group dropped out (11.43%), two of whom were absent due to academic schedules and two of whom were unable to continue participating due to conflicting course schedules. Five participants in the control group dropped out (13.51%), two of whom were required to participate in a maths competition and three of whom dropped out due to sports injuries (muscle strains). Overall, the subject dropout rate for this study was 12.50% (9/72). Ultimately, 63 subjects (31 in the EG and 32 in the CG) completed the study and were included in the final statistical analyses. Although there was some attrition during the intervention, the dropout rates for the EG and CG were similar (11.43% vs. 13.51%), thus having less of an impact on the between-group comparisons. The complete subject screening and assignment process is shown in Figure 3.3.

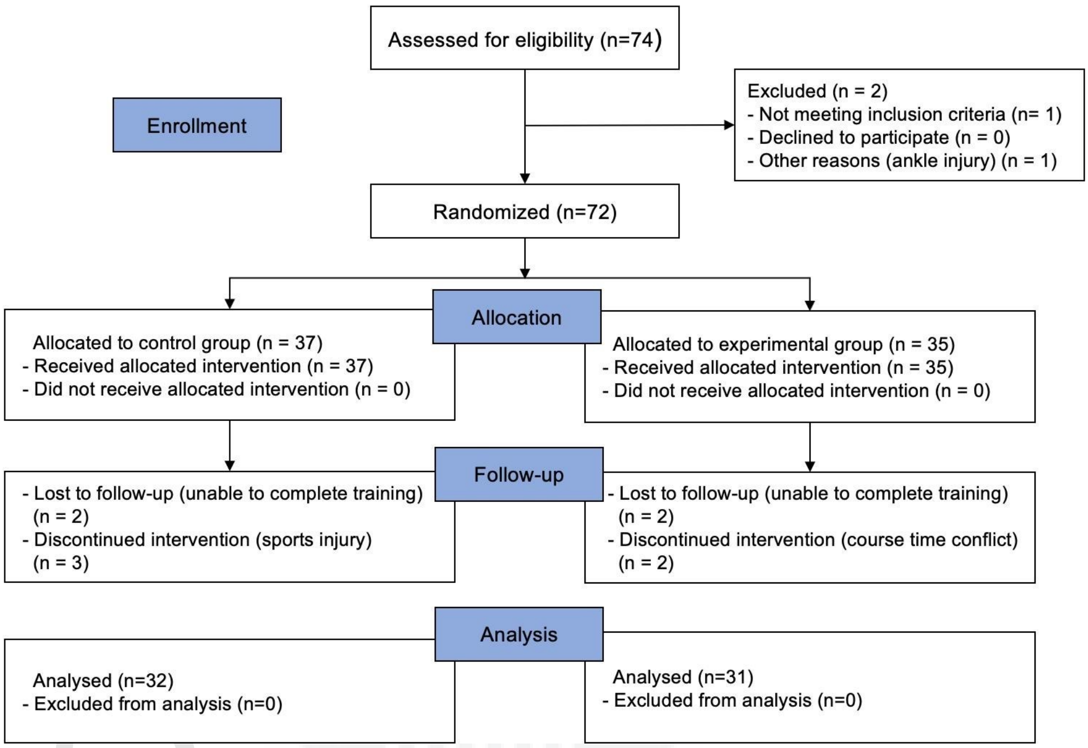

Figure 3.3 : CONSORT Diagram
(Source: Campbell et al., 2012)

3.5 Study Instruments

The instrument of this study comprises two components: a questionnaire and a practical test, each of which is detailed below.

3.5.1 Questionnaires

It includes three main questionnaires: the Physical Activity Readiness Questionnaire (PAR-Q), the Depression Anxiety and Stress Scale (DASS-42), and the Behavioural Regulation in Exercise Questionnaire-2 (BREQ-2). All these questionnaires used in this research were available in both Chinese and English versions and none of them were adapted.

3.5.1.1 Questionnaire for Screening Process

Participants were screened utilizing the Physical Activity Readiness Questionnaire (PAR-Q), which is commonly employed in multiple countries as an independent screening tool for physical activity and exercise programs (Adams, 1999). The PAR-Q serves as a screening mechanism to gauge an individual's suitability for physical activity, aiding in identifying those who may require medical clearance before commencing an exercise regimen, especially if they have underlying health conditions that could be exacerbated by physical activity. Typically, the PAR-Q comprises seven straightforward 'yes' or 'no' queries encompassing diverse aspects of health, focusing on symptoms related to cardiovascular, respiratory, metabolic, and musculoskeletal disorders. If a participant answers 'yes' to any of the seven questions, it is advised that they consult a physician before engaging in physical activities.

The study participants in question were college students with overweight and obesity who generally exhibit poor physical fitness and are at risk of potential health issues from increased exercise intensity. Therefore, in order to ensure the safety of the participants throughout the intervention, this questionnaire was incorporated as part of the screening process. This particular questionnaire was adapted from the guidelines

(Whitfield et al., 2017; Joy & Pescatello, 2016), with specific details located in Appendix D.

3.5.1.2 Questionnaires to Measure Psychological Distress

The Depression Anxiety Stress Scale (DASS) is a psychometric tool intended to offer a simple and valid method for evaluating an individual's levels of depression, anxiety, and stress (S. H. Lovibond & Lovibond, 1996). The DASS is available in two versions, DASS-21 and DASS-42, with the latter comprising 42 items, with 14 items dedicated to each mood state (depression, anxiety, and stress), ranging from 0 (not present) to 3 (highly present). The three subscales measure depression, anxiety, and stress separately, with each subscale having a maximum score of 42. Depression is rated from 0 to 9 as normal, 14-20 as moderate, and above 21 as severe. Anxiety is categorized from normal, which ranges from 0 to 7, to moderate and severe, from 10 to14, and 15-19, respectively. Stress is evaluated on a scale from 0 to 14 as normal, with 26 to 33 indicating significant stress (Lovibond & Lovibond, 1995). The total score of the three subscales reflects the level of psychological distress, with a higher total score showing higher psychological distress levels (Antony et al., 1998).

The DASS has been translated into various languages with good validity (Akin & Çetin, 2007; Makara-Studzińska et al., 2022; Page et al., 2007) and has been widely utilized with college students (Mutalik et al., 2016; Camacho et al., 2016). Thus, to evaluate the impact of AVG on depression, stress, and anxiety in college students, as well as its overall effects on psychological distress, the current study employed the Simplified Chinese version of the DASS, translated by Kelvin Zuo and Alice Chang. This version is tailored for use in mainland China and is accessible through the

Psychology Foundation of Australia. The Simplified Chinese version of DASS has received extensive use and validation in China (Cao et al., 2023; Yu et al., 2022; Wang et al., 2016). Detailed information is provided in Appendix E.

3.5.1.3 Questionnaires to Measure Exercise Motivation

The Behavioural Regulation in Exercise Questionnaire-2 (BREQ-2) is a tool used to evaluate the behavioural regulation that individuals undergo during exercise (Markland & Tobin, 2004). By utilizing the BREQ-2, one can pinpoint an individual's motivation to exercise, grasp the process of motivational transformation, and devise strategies to strengthen intrinsic motivation and foster continued exercise habits (Ghaneapur et al., 2019). Grounded in Self-Determination Theory, the BREQ-2 comprises 19 items rated on a scale from 0 (not at all congruent) to 4 (fully congruent) and encompasses five main subscales: external regulation (4 items), amotivation (4 items), introjected regulation (3 items), identified regulation (4 items), and intrinsic regulation (4 items) (Mahony et al., 2019).

The BREQ-2 questionnaire does not generate a total overall score in the classic sense since it evaluates diverse motivations for exercise, with each dimension of the score being stand-alone. Nevertheless, the scores on the BREQ-2 indicate the intensity of a specific motivation type (Farmanbar et al., 2011). For instance, a high score in the Intrinsic regulation dimension suggests that an individual primarily engages in physical activity due to their enthusiasm and pleasure for the exercise. Conversely, a high score in external regulation implies that an individual participates in the activity more due to external incentives or pressures, with less autonomy in their physical activity engagement (Wilson et al., 2012).

A crucial factor in physical activity is exercise motivation, pivotal for sustained commitment to physical activity (Richard et al., 1997). Examining the impacts of AVG training on exercise motivation becomes essential. The BREQ-2 has undergone translation into multiple languages and validation within a college student demographic (Baghurst et al., 2014). Hence, the BREQ-2 was selected as the tool to assess exercise motivation in this study. The Simplified Chinese version employed in this study has been validated among Chinese college students, showing acceptable reliability and validity indices (Liu et al., 2015). Further details are included in Appendix F.

3.5.2 Practical Test

This section introduces all practical tests used, primarily including three parts: instruments for active video game training, instruments for measuring anthropometric measurements, and instruments for measuring dependent variables. Further details are provided in Appendix G.

3.5.2.1 Instruments Used in Active Video Game Training Programme

In this study, the equipment used for active video game training mainly includes a game console, an active video game, and a video output device. Specifically, the active video game console used in this study was the Nintendo Switch console (OLED version) (Nintendo; Tokyo, Japan). The game selected was Ring Fit Adventure (Jiang & Tham, 2022). The Hewlett-Packard (HP) 19-inch monitor was chosen as the video output device.

Figure 3.4 : Nintendo Console Switch OLED Version

Figure 3.5 : Active Video Game “Ring Fit Adventure”

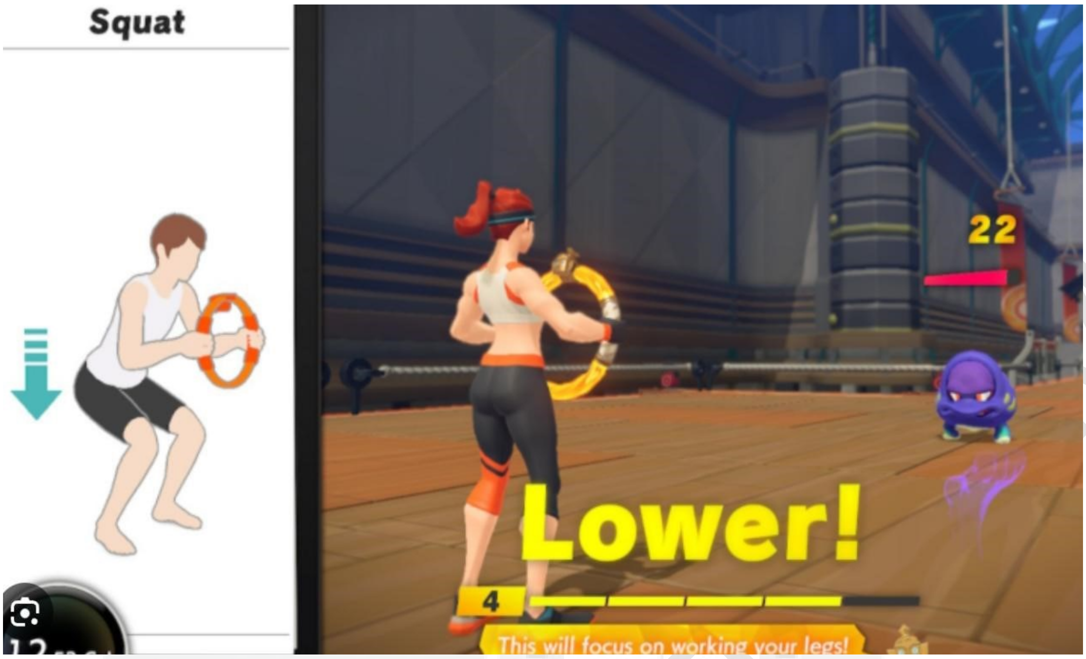

Figure 3.6 : "Ring Fit Adventure" Game Screen

3.5.2.2 Instruments Used to Measure Anthropometric

Height was measured using a portable Seca Stable Stadiometer (Seca; Hamburg, Germany) with an accuracy of 0.1 cm. Weight was measured using a Tanita BC418-MA body composition analyser (Tanita; Tokyo, Japan) with a weighing function to an accuracy of 0.1 kg.

3.5.2.3 Instruments Used to Measure Dependent Variables

The instruments used to measure the dependent variables mainly consist of measures of physical activity and body composition. Table 3.2 discusses the specific test methods and instruments.

(1) Instruments of Physical Activity

Moderate physical activity benefits college students' health and weight loss (Swift et al., 2018). Physical activity can be studied using subjective measurement methods such as various physical activity questionnaires or objective measurement methods involving multiple instruments and equipment. International methods for measuring physical activity typically include criterion methods, objective techniques, and subjective techniques. The equipment used usually involves portable indirect calorimeters (O'Donovan et al., 2012), accelerometers (McDonough et al., 2018), heart rate belts (De Brito-Gomes et al., 2016), and pedometers (Freedson & Miller, 2000; Rowlands et al., 1997). A pedometer is a small, portable, easy-to-use device, making it an ideal tool. Therefore, this study utilized a Yamax Digi-walker CW-700 pedometer (Yamax; Tokyo, Japan) to measure physical activity. Counting the number of steps using a pedometer can provide an objective indication of physical activity, with a higher number of steps indicating increased physical activity levels.

(2) Instruments of Body Composition

This part of the instrument measures four body composition-related variables: body mass index, body fat percentage, lean body mass, and waist-to-hip ratio.

Body mass index serves as the foundation of the prevailing obesity classification system (Prentice & Jebb, 2001). For college students, assessing BMI helps distinguish whether they remain overweight or obese post-intervention. BMI measurement entails measuring height and weight; hence this study used the same two instruments as anthropometry. Height was measured using a Seca stadiometer (Seca; Hamburg, Germany) with an accuracy of 0.1 cm. Weight was measured using a Tanita BC418-MA body composition analyser (Tanita; Tokyo, Japan) with an accuracy of 0.1 kg.

Body fat percentage distinguishes between fat and non-fat components of body weight (such as muscle, bone, and water) and therefore more accurately reflects body fat status (Goonasegaran, 2012). Measuring body fat percentage aids in comprehending the effects of interventions better. Standard methods for measuring body fat percentage include bioelectrical impedance analysis (BIA), dual-energy X-ray absorptiometry (DXA), and underwater weighing (Fosbøl & Zerahn, 2015). BIA is non-invasive and portable, making it suitable for measuring college students in a laboratory. Thus, this study employed the multifunctional body composition analyser Tanita BC418-MA (Tanita; Tokyo, Japan) to measure body fat percentage. The validity of this body composition analyser has been verified and is well-suited for analyzing the body composition of obese individuals (Kelly & Metcalfe, 2012). The subjects should avoid vigorous exercise, alcohol consumption, or excessive drinking for at least 3 hours before the measurement and stand barefoot on the measuring instrument. They should hold the electrode handle with both hands and slightly separate their arms from their body to reduce the influence of resistance. The instrument will automatically analyze and record the body fat percentage data.

Lean body mass is closely linked to bone health, metabolic rate, physical coordination, muscle function, and athletic performance (Duda et al., 2019; Hattori, 1991; Ramírez-Vélez et al., 2017). Increasing lean body mass significantly enhances metabolic health, aids in weight management, and reduces fat deposition (Guimarães et al., 2018). College students with overweight and obesity often exhibit low lean body mass, which is associated with diminished muscle strength and poor muscle quality. Assessing lean body mass assists in understanding an individual's exercise capacity and helps prevent potential muscle damage. Studies have indicated that body composition analysers can effectively measure lean body mass using bioelectrical impedance analysis (BIA) technology (Brunani et al., 2021; Sergi et al., 2017). Therefore, this study employed the Tanita BC418-MA body composition analyser (Tanita; Tokyo, Japan) to measure lean body mass with an accuracy of 0.1 kg. The measurement of lean body mass also uses the BIA method. The subject stands on the electrode plate, holds the handle electrode, and avoids eating, drinking, or vigorous exercise before measurement to reduce the impact of water fluctuations in the body on the measurement results. The body composition analyzer automatically analyzes and records lean body weight data.

Waist to hip ratio (WHR) is widely used to assess body fat distribution and predict health risks associated with fat distribution, particularly cardiovascular disease, and metabolic syndrome (Bigaard et al., 2004; Huxley et al., 2010). In addition, WHR helps evaluate local and overall obesity (Taylor et al., 1998). This ratio is calculated by the ratio of waist circumference (measured at the narrowest point) to hip circumference (measured at the widest point). To ensure measurement accuracy, this study used the soft tape rule measurement method recommended by the World Health Organization (Nishida et al., 2010). Specifically, this study used a 245 centimeter long, 0.1-centimeter precision tape measure to measure waist and hip circumference (Andreacchi et al., 2021). The subject stands, breathes naturally, with feet about 25-30 cm apart, and maintains a relaxed posture. Waist circumference measurement is taken at the narrowest point between the lower edge of the ribs and the top of the ilium, while hip circumference measurement is taken at the widest point of the buttocks. The waist and hip circumference of each measurement site were measured twice, and the average was taken to improve the accuracy and reliability of the measurement.

Table 3.2 : Instruments Used to Measure Dependent Variables

Variables	Component	Instruments	Measurement method
Physical Activity	Count step	Pedometer	Record steps (per week)
Body Composition	Body mass index	Body composition analyser Stable stadiometer	Weight (kg) /height (m)²
	Body fat percentage	Body composition analyser	Bioelectrical impedance analyser
	Lean body mass	Body composition analyser	Bioelectrical impedance analyser
	Waist-to-hip ratio	Tape rule	Waist (cm) / hips (cm)

Note: BIA: Bioelectrical Impedance Analysis; M: meter; KG: kilogram; CM: centimetre.

3.5.3 Validation of Methods

The current literature and recommendations from the expert group support the validity of the questionnaire. The empirical evidence from existing studies, as well as the expert recommendations, indicate that the test is suitable and appropriate for its intended purpose. The judgment of its effectiveness is subjective, with the evaluator relying on observation and intuition to ascertain whether the measurement tool adequately captures the necessary elements (Nunnally & Bernstein, 1994). There are alternative approaches to assessing validity. Content validity, for instance, offers a more robust validation process, involving expert evaluation and rigorous scientific methods to ensure that the measurement tool comprehensively and accurately captures its target construct (Haynes et al., 1995a). In this study, the research instrument's identification involved consultations with experts, which also helped establish its face validity. Conversely, content validity was thoroughly evaluated by a group of scholars and experts. Typically, content validity assessments are conducted by panels comprising 3 to 10 experts (Polit et al., 2007). For this study, six experts in relevant fields were enlisted to evaluate and provide feedback on the intervention and instrument's content validity. Initially, ratings were completed using a 4-point scale (1 = not relevant, 2 = somewhat relevant, 3 = very relevant, 4 = highly relevant), followed by open-ended questions to gather experts' comments and improvement suggestions. Additional information about the experts is provided in Table 3.3.

Table 3.3 : Personal Details of Content Validity of Instrument Experts

Organisation	Title & Degree	Area for Research
Shandong University	Associate Professor	Physical education
Shandong Sport University	Professor	Exercise Training
Shandong Normal University	Associate Professor	Exercise psychology
Wuhan Sports University	Professor	Exercise Training
Hebei Normal University	Professor	Exercise physiology
Linyi University	Associate Professor	Exercise physiology

3.5.3.1 Validation of Questionnaires

The three questionnaires used were PAR-Q, DASS-42, and BREQ-2.

(1) Questionnaire on Physical Activity Readiness

The Chinese version of the PAR-Q employed in this study was translated by the Physical Fitness Development Centre of Wuhan Sports University and verified by the ACSM working group (Medicine, 2013). The PAR-Q is widely utilized among college students. Its primary aim is to safeguard college students from engaging in training that may pose health risks. Its efficacy has been validated (Schwartz et al., 2021; Ghosh, 2024).

(2) Depression Anxiety Stress Scales-42

The Chinese version of DASS-42 used in this research was translated by researchers at the University of Auckland in New Zealand. The questionnaire utilizes a simplified

Chinese character set, and the question order in the questionnaire design aligns with the English version, making it suitable for individuals in mainland China. Numerous studies in China have employed this questionnaire, and its validity has been confirmed (Zhang et al., 2019). Six experts were invited to assess the Chinese version of the questionnaire to enhance its validity.

The content validity index (I-CVI) is a metric used to evaluate the content validity of an individual question in a questionnaire or scale. Content validity primarily assesses whether the scale adequately represents the content domain of the measurement. The criterion employed in this study dictates that when 6 to 10 experts evaluate, the I-CVI should be at least 0.78, which is deemed acceptable (Lynn, 1986). The Kappa coefficient is employed to gauge the consistency among multiple evaluators in assessing the questionnaire items (Cohen, 1960). The criterion adopted in this study is that scores below 0.40 are poor, 0.40-0.75 are good, and scores exceeding 0.75 are excellent (Fleiss et al., 2013). Upon analysis, it was observed that all content validity indices were satisfactory, with the relevancy attributes (I-CVI=0.833-1.000 and Kappa=0.816-1.000) and clarity (I-CVI=0.833-1.000 and Kappa=0.816-1.000) of all items performing well. Further details are provided in Appendix O.

(3) Behavioural Regulation in Exercise Questionnaire-2

A panel of six expert members evaluated the questionnaire. The content validity was statistically assessed using the item content validity index (I-CVI). Previously, an I-CVI of at least 0.78 was deemed the acceptable lower threshold (Vadlin et al., 2015). The Kappa test (Cohen's Kappa) was utilized to ascertain the level of agreement between the I-CVI and its correlation (Polit & Beck, 2006). The standard indicates that values less than 0.40 are poor, those between 0.40 and 0.75 are good, and values exceeding 0.75 are excellent (Fleiss et al., 1981). Post I-CVI analysis, the results demonstrated that the content validity of all items fell within the acceptable range. The correlation attributes of all items (I-CVI=0.833-1.000 and Kappa=0.816-1.000) and clarity (I-CVI=0.833-1.000 and Kappa=0.816-1.000) met the required criteria. Supplementary details are available in Appendix O.

3.5.3.2 Validity of Practical Test Instruments

All six experts in the expert group evaluated the practical test and provided their recommendations based on the established criterion, which required an I-CVI of at least 0.78. The evaluation standard for Kappa is considered excellent starting from 0.75. Based on the I-CVI results, all items were found to have good content validity. The instrument's relevance (I-CVI = 0.833–1.000 and Kappa = 0.816–1.000) and clarity (I-CVI = 0.833–1.000 and Kappa = 0.816–1.000) characteristics met the required criteria. Specific details are provided in Appendix O.

3.6 Intervention

The intervention design and program were developed following a summary of ACSM guidelines and previous research in related fields (Bayles, 2023). Six experts in associated fields reviewed and endorsed the intervention program. This section introduces the principles guiding the intervention, notably the FITT principles (frequency, intensity, time, and type) recommended by ACSM. It outlines the key components of the intervention, including an introduction to AVG and the intervention's process. Finally, it verifies the efficacy of the intervention.

3.6.1 Intervention Program Design and Principles

The study was structured in line with the FITT principles endorsed by ACSM, serving as a framework to direct fitness and exercise programs, where F stands for frequency, I for intensity, T for time, and the second T for type. This principle forms the basis for tailoring exercise programs to achieve fitness goals safely and effectively (Wibisana & Royana, 2023). The FITT principle is particularly useful for sedentary individuals and those infrequently engaging in physical activity to gradually increase their activity levels (Reid et al., 2019; Bülbül, 2020). The specific content design of the FITT principle in this study was derived from a systematic review conducted by the researchers and existing literature. The following details the specific content designs of this study. More information is available in Appendix P.

3.6.1.1 Frequency, Intensity, Time, and Type

(1) Frequency in current AVG-related studies commonly involves interventions twice a week (Vojciechowski et al., 2017; Zurita-Ortega et al., 2018) or three times a week (De Brito-Gomes et al., 2019; Peng et al., 2015; Warburton et al., 2007; Roopchand-Martin et al., 2018). Studies suggest that more frequent exercise sessions lead to increased exercise volume and positively impact the physical activity and body composition of college students with overweight and obesity. Hence, this study opted for a training frequency of three times a week, consistent with the standard exercise frequency for interventions utilizing the Nintendo Wii series and RFA among college students (McCarthy et al., 2013; Nani et al., 2019; Wu et al., 2022).

(2) Regarding exercise intensity, refer to the physical activity guidelines developed by ACSM. The guidelines recommend that adults perform at least 75 minutes of high-intensity aerobic exercise or 150 minutes of moderate-intensity aerobic exercise per week to burn 1,000 kcal for optimal health (Bushman, 2019). Therefore, college students with overweight and obesity

must achieve at least moderate-intensity physical activity levels to achieve good results. The perceived exertion (RPE) scale was used in this study to determine the intensity of the exercise. The Borg RPE Scale with a 6–20 scale was used and validated (Leuciuc, 2020; Medicine, 2010; Ritchie, 2012) (Appendix Q). There is a correlation between RPE and heart rate (Borg, 1982; Mackinnon, 2003). When the RPE score is 12 to 14, moderate-intensity physical activity can be performed, with a maximum heart rate range of 60% to 75%. A score of 15-20 can achieve high-intensity physical activity with a maximum heart rate greater than 75% (Liguori & Medicine, 2020). Therefore, this study chose an intensity of 60%–75% of the maximum heart rate (RPE 12-14). It is worth noting that RFA automatically determines the user's state and gives the appropriate exercise intensity at the first use. Over time, the game's difficulty will increase, and the exercise intensity will also increase. However, to ensure the exercise intensity of EG and CG each time, both EG and CG will use a smartwatch (heart rate monitor) in the middle of each session to initially monitor the exercise intensity. The RPE was then used after each session to judge exercise intensity.

(3) Concerning duration, both ACSM and WHO recommend a minimum of 30 minutes of moderate-intensity aerobic exercise in a singular session (Bull et al., 2020). For instance, exercising five times a week for 30 minutes meets the ACSM recommended level (150 minutes per week) (Liguori & Medicine, 2020). In current studies utilizing AVG to address the mental health of college students, sessions lasting 30 minutes or more are commonly chosen (Douris et al., 2012; Huang et al., 2019; Hwang et al., 2023; Nguyen et al., 2016; Yu et al., 2023). In the context of physical activity, it is likewise advised to maintain each session for at least 30 minutes (Douris et al., 2012; Rahayu et al., 2019). Therefore, this study designated the session duration at 40 to 60 minutes to enhance the physical activity of college students with overweight and obesity, while also considering the typical class duration of Chinese college students. For the intervention period, a total cycle of 12 weeks was selected as it is standard practice (Vojciechowski et al., 2017; Huang et al., 2017), aligning with the duration of this study.

(4) Concerning the type of AVG, there are various manufacturers and types available with Xbox, PS, and Nintendo being popular choices. Many investigations have favoured Nintendo's AVG for interventions with college students, showing superior outcomes (Byrne et al., 2012; Davoodeh et al., 2020; Gioftsidou et al., 2013; Vernadakis et al., 2012). As such, this study selected Nintendo's Switch console paired with the latest AVG (Ring Fit Adventure) as the intervention tool. This AVG offers diverse gameplay options and is well-received among Chinese college students (refer to Chapter 2 for additional insights).

3.6.2 Intervention Training Programme

The intervention in this study lasted for 12 weeks, with 40 minutes to 1 hour of moderate-intensity exercise (60-75% HRmax, RPE 12-14) three times a week (Monday, Wednesday, and Friday), which was arranged during college physical education classes. Physical education courses in Chinese universities usually arrange 2 to 3 physical activities per week, each lasting 45 to 90 minutes, with the main goal of improving students' physical fitness and sports skills. The intervention program in this study is specifically aimed at college students with overweight and obesity. Therefore, during physical education classes, these students followed the training program designed in the study instead of participating in regular physical education classes. To ensure the effectiveness and adaptability of the training, the intervention was divided into three stages, and a 3-hour familiarization course was arranged before the formal intervention. The familiarization courses for EG and CG were instructed by two different groups of professional coaches. The content included an introduction to the intervention process, explanation of the training mode, and basic sports skills drills. EG students were required to create an RFA game account and enter basic information to ensure personalized training records. CG students learned basic sports movements in the familiarization course.

EG's training content is all delivered through RFA's own functions. It mainly consists of a 5-minute warm-up and cool-down (guided by the RFA virtual coach) as well as the main training session. The training is carried out according to the principle of stage progression: weeks 1-4, including a 30-minute adventure mode. This is the main mode of the RFA, in which the participant's physical activity can be sensed using a combination of Ring-Con and Joy-Con, and various motor skills (e.g., running, squatting, push-ups, and open-jumping) can be used to defeat the monsters and take adventures in the virtual world; Weeks 5-8 consisted of a 20-minute adventure mode and 20-minute training in the combination mode. The combination mode is where participants can freely combine different workouts offered by RFA, such as back stretches combined with planks. The addition of this new game mode in Phase 2 will help participants to choose their favourite exercises for free combinations after completing the adventure mode breakout game to further enhance the training effect. In weeks 9-12, a 10-minute mini-game mode is added to the previous phase, bringing the total training time to 50 minutes. Mini-game mode is a series of short, high-intensity games specially designed by RFA to exercise different parts of the muscles while adding fun. For example, 'Squat Goals' is a game where players control a character throwing a Frisbee through squats to strengthen the lower body and core muscles. The addition of this new game mode in the third phase can improve the overall fun of the training and increase the participants' participation and enthusiasm for exercise. CG used standardised brisk walking training to match the frequency and duration of EG exercise. The training consisted of a 5-minute warm-up and a 5-minute cool-down, both of which were completed in an indoor sports field under the guidance of a professional sports coach. The main training consisted of 30-50 minutes of brisk walking (30 minutes in weeks 1-4, 40 minutes in weeks 5-8, and 50 minutes in weeks 9-12). All students are free to form brisk walking groups with their classmates and are allowed to communicate with each other to ensure the completion of the training.

All training sessions for EG and CG were supervised by two different groups of trained physical education teachers and research assistants, respectively, to ensure safety and standardisation of exercise execution. The research equipment (including AVG equipment and measurement instruments) was centrally managed by the research team and was checked and calibrated before and after each training session to ensure the reliability of the data. In addition, to control for non-exercise factors that might affect the study results, all participants were asked to maintain their normal diet and lifestyle habits during the intervention period without additional physical activity. During the study period, subjects were required to download the mobile phone app KEEP on their mobile phones to record their daily diet and total calorie intake, and to fill in a dietary record form at the end of each week's training. At the end of the intervention, the physical indicators of EG and CG were measured by the same instrument to ensure consistency and comparability of data. Details are provided in Appendix H.

3.6.3 Validation for Intervention Training Programme

Content validity ensures that the data collection instrument accurately represents the content being studied. High content validity denotes that the measurement tool effectively captures the actual circumstances of the research subjects, providing reliable and meaningful data. This is critical for the research's validity and the accurate interpretation of its results (Haynes et al., 1995; Rubio et al., 2003). In this study, a panel of six experts, all professors or associate professors, was invited to evaluate the effectiveness of the intervention training program. Table 3.4 provides information about this expert group. Detailed information about the questionnaire is available in Appendix I.

The six experts assessed the intervention content. One expert recommended fixing the playing time of the adventure mode to ensure participants have time for training in other game modes since they are drawn to it by the plot. Another expert suggested maintaining the training combination mode time in the third stage unchanged due to the potential for RFA (Ring Fit Adventure) to involve more intense sports, such as trail running, considering the participants are overweight or obese college students. Furthermore, assigning a dedicated person to prevent sports injuries during the intervention was also advised.

Analysis revealed that the content validity of all items fell within an acceptable range. Specifically, the content validity of all items concerning relevance ranged between 0.833 and 1.000 for I-CVI and 0.816 to 1.000 for Kappa. Similarly, all items met acceptable clarity standards, ranging from 0.833 to 1.000 for I-CVI and 0.816 to 1.000 for Kappa. Hence, the intervention training program in this study demonstrated good content validity. Detailed information on the intervention items can be found in Appendix O.

Table 3.4 : Personal Details of Intervention Training Programme Experts

Organisation	Title & Degree	Area for Research
Ohio University	Associate Professor	Exercise physiology
Tianjin University of Sport	Professor	Exercise psychology
Beijing Sport University	Associate Professor	Exercise Training
Shandong Sport University	Professor	Exercise physiology
Jining University	Associate Professor	Physical Education
Yantai University	Associate Professor	Exercise Training

3.6.4 Control of Extraneous Variables

If extraneous variables are not controlled, they may confound the experimental results and compromise the accuracy of the findings (Campbell & Stanley, 2011). Hence, it is imperative to control for extraneous variables (Street, 1995). The intervention training program and measurements for this study were developed based on field testing. The sports venue and surroundings will significantly influence the study. Attaining sound experimental outcomes and guaranteeing their accuracy necessitate thoughtful consideration and meticulous oversight of every facet of the experiment, thus effectively managing these extraneous variables.

3.6.4.1 Control of Intervening Factors

(1) Training Location and Environment

For more effective training, the EG training sessions are held in a dedicated classroom with a specially controlled environment. The classroom is equipped with temperature and humidity meters to monitor these factors during experiments. Additionally, the AVG is connected to a monitor screen via an HDMI cable to ensure consistent display.

To maintain stable lighting conditions, room lights are kept on during all interventions. Sound-absorbing cotton is installed on doors and windows to reduce external noise and ensure sound insulation.

(2) Training Time and Content

To standardize the training sessions and minimize the impact of time on results, training sessions are scheduled from 9:00 - 12:00 every Monday, Wednesday, and Friday. Each session spans four weeks, with an incremental increase in duration: 40, 50, and 60 minutes, respectively. The total intervention period lasts 12 weeks. The training content includes warm-up, relaxation, primary training, as well as additional content introduced at different stages based on previous research (Gao et al., 2021; Chan et al., 2024).

(3) Training Instructors

The experimental group is supported by two physical education teachers and two research assistants who are well-versed in AVG technology. The physical education teachers have over 10 years of experience, while the assistants have more than three years of experience with AVG. They oversee training implementation, safety, and participants' comprehension of the training. The assistants assist in setting up accounts, demonstrating equipment, explaining game operations, and addressing participant queries. CG also has two physical education teachers with 10 years of teaching experience who are responsible for guiding CG in standardized training.

(4) Training Instruments

To minimize equipment interference, all training equipment is consistent in model. This includes using the Nintendo Switch console (OLED version), ring-fit adventure (RFA) game, and a 19-inch HP LED monitor for display. A Bluetooth speaker is provided for audio output. Standardizing equipment aims to maintain uniformity across training sessions.

(5) Training Participation Control

Training participation and attendance are monitored through training logs maintained by the PE teacher and attendance forms managed by the research assistant. Regular checks on training logs and attendance records enable researchers to track participants' progress and ensure the experiment's integrity (Appendix R).

(6) Dietary Factors Control

Dietary intake control is a significant aspect of the study. Participants are required to record their daily diet using a designated app called Keep. A professional nutritionist lecture emphasizes the importance of a balanced diet. Participants eat at the school cafeteria, and their dietary intake is recorded weekly by researchers and assistants for monitoring and analysis (Appendix S).

(7) Other Factors Control

Participants are encouraged to maintain their usual lifestyle habits and refrain from acquiring new motor skills or engaging in additional exercises during the intervention to prevent interference with the study's outcomes.

3.6.4.2 Control for Test Protocol

The implementation of the intervention plan directly affected the results of the experiment. Therefore, the researchers provided the PE teachers and research assistants with a detailed manual that clearly described the implementation steps and precautions for the AVG training. The manual served as a reference for the experimenters during the implementation of the intervention, ensuring consistency. During the intervention, the experimenters were regularly supervised and provided feedback. Based on the results of the supervision, timely feedback was provided to the experimenters to help them improve the quality of intervention implementation. Finally, the experimenters were required to strictly follow the predetermined intervention plan and not modify the content or implementation method of the intervention at will. Details are provided in Appendix N.

3.7 Pilot Study

There are three primary purposes for conducting a two-week pilot study before the formal CRCT. Firstly, the pilot study allows researchers to evaluate the reliability and validity of the data collection tool. Secondly, it enables researchers to assess the feasibility of the intervention procedure and to identify any potential issues. Thirdly, the pilot study aids researchers in becoming acquainted with the research process, enhancing the accuracy and consistency of the operations, and preparing for the seamless implementation of the formal intervention.

In this pilot study, sixteen Chinese college students with overweight and obesity were recruited and randomly assigned to either an experimental group (n = 8) or a control group (n = 8). The intervention and testing procedures for the ten-point experiment are identical to those of the formal intervention, ensuring alignment of the experimental protocol with the practicality of working with college students with overweight and obesity (Van Teijlingen & Hundley, 2001; Thabane et al., 2010).

3.7.1 Reliability of the Methods

Reliability refers to the ability of a measuring instrument to consistently produce the same results when measurements are repeated (Bolarinwa, 2015). The higher the reliability, the greater the accuracy and consistency of the measurements (Hopkins, 2000). Typically, there are three methods to assess the reliability of social science surveys: test-retest, alternative form, and internal consistency (Drost, 2011). This study employed Cronbach's Alpha to examine the internal consistency of the DASS-42 and BREQ-2. Additionally, this research evaluated the test-retest reliability as a practical option to assess instruments used for measuring physical activity and body composition. By conducting multiple measurements on the same subject at different time points, the study aimed to gauge the consistency and stability of the instrument's results.

3.7.1.1 Reliability for Questionnaires

The criterion adopted in this study for Cronbach's Alpha is that an alpha value greater than or equal to 0.7 is deemed acceptable. A range between 0.8 and 0.9 signifies good reliability, while a value exceeding 0.9 indicates excellent internal consistency of the scale (Taber, 2018). Subsequent analysis revealed that the Cronbach's Alpha value for DASS-42 exceeded 0.8, indicating excellent reliability (Table 3.5); detailed information is available in Appendix N.

Table 3.5 : Cronbach's Alpha Value of the Depression Anxiety Stress Scales-42 (n=16)

Questionnaire	Domain	Number of items	CITC	Cronbach's Alpha
DASS-42	Depression	14	0.321 - 0.812	0.891
	Anxiety	14	0.209 - 0.849	0.910
	Stress	14	0.223 - 0.721	0.803

CITC: Corrected Item-Total Correlation

After testing, the Cronbach's Alpha for BREQ-2 ranged from 0.745 to 0.860. Since the Cronbach's Alpha for the questionnaire is over 0.7, the scale's reliability is acceptable (Table 3.6).

Table 3.6 : Cronbach's Alpha Value of the Behavioural Regulation in Exercise Questionnaire-2 (n=16)

Questionnaire	Domain	Number of items	CITC	Cronbach's Alpha
BREQ-2	External regulation	4	0.529 - 0.794	0.860
	Amotivation	4	0.348 - 0.842	0.798
	Introjected regulation	3	0.626 - 0.777	0.807
	Identified regulation	4	0.450 - 0.653	0.745
	Intrinsic regulation	4	0.404 - 0.831	0.788

CITC: Corrected Item-Total Correlation

3.7.1.2 Reliability for Practical Test

This study utilized the retesting method to evaluate the reliability of the instruments employed for assessing physical activity and body composition. The Intraclass Correlation Coefficient (ICC) is a common metric in retest reliability investigations to gauge the consistency of measurements across repeated tests. It is a well-established index for reliability assessment (Mehta et al., 2018). Following established guidelines, the criteria for interpreting ICC values in this study include: ICC < 0.5 indicating poor reliability, ICC between 0.5 and 0.75 signifying moderate reliability, ICC between

0.75 and 0.9 indicating good reliability, and ICC > 0.9 indicating very good reliability (Koo & Li, 2016). A thorough examination of the measurement instruments in the pilot study revealed that all outcomes fell within an acceptable range (see Table 3.7). Further details are available in Appendix N.

Table 3.7 : Test-retest Reliability of Instruments

Variables	Indicators	ICC	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Physical activity	Step counts	0.981	0.945	0.993
Body composition	Body mass index	0.987	0.963	0.995
	Body fat percentage	0.999	0.999	1.000
	Lean body mass	0.960	0.885	0.986
	Waist-to-hip ratio	0.996	0.988	0.999

3.8 Data Collection Procedures

The data collection process mainly consists of obtaining approval from participants and actual data collection.

3.8.1 Request for Permission

Prior to the experiment, approval was secured from the Biomedical Ethics Committee of Qufu Normal University, confirming the alignment of the research content with ethical standards, and authorizing the study to proceed. This research was assigned the ethical number 2023124 (see Appendix A). All questionnaires and instruments used in this study were granted approval.

3.8.2 Data Collection

The data collection process was structured into two phases: a preparatory phase before the formal intervention and the intervention phase itself. All experimental data for this study were gathered in two settings under the direct supervision of physical education teachers and research assistants.

3.8.2.1 Pre-intervention Phase

All participants were required to carefully read and sign an informed consent form before the intervention (refer to Appendix C). A month prior to the official commencement of the experiment, the researchers executed the following preparatory tasks:

(1) Setup and configuration of the equipment in a designated room, which involved connecting the monitor to the Switch Dock, installing the RFA cartridge, and pairing the Bluetooth headset with the Switch host.

(2) Physical education teachers and research assistants were invited to the experimental site to become acquainted with the environment.

(3) Introduction of RFA to the physical education teachers and research assistants, covering aspects such as an overview of the Switch host, installation and removal of the Ring-Con, creation of an RFA account, entering participant information into the RFA system, warm-up exercises guided by the RFA, all game modes within the RFA, and the relaxation activities provided by the RFA.

(4) Training of physical education teachers and research assistants on how to complete the research log and attendance sheet, as well as distribution of the game manual to assist them in guiding subjects during training sessions and answering any queries.

(5) Detailed explanation provided by the researchers to the physical education teachers and research assistants regarding the intervention's precautions, requirements, and safety measures to be implemented.

(6) A two-week pilot study was carried out to assess the feasibility of all experimental procedures, verify the reliability and validity of the experimental questionnaire and instruments.

3.8.2.2 Intervention Implementation Phase

The formal intervention phase spanned 12 weeks and consisted of a structured training and testing protocol. Data collection occurred over three distinct periods: baseline data at the onset of week 0, post-test 1 following six weeks of training, and post-test 2 after completion of the full 12-week training period. Test data for the EG and CG were gathered simultaneously on the same day and at the same time. Physical activity and body composition data were recorded between 10:00 and 12:00, while questionnaire data were obtained between 14:00 and 16:00. Further detailed information is available in Appendix K.

3.9 Data Analysis

The experimental data were analysed using the social science statistical software SPSS 27.0 (IBM Company, Chicago, IL, US). The significance level for the results was set to $p < 0.05$. The main content consists of two parts: descriptive analysis and statistical analysis. Initially, data cleaning and preparation were conducted, involving data entry, identification of missing data, and outlier detection. Subsequently, descriptive statistics were conducted, including demographic information (e.g., height, weight, age, gender) and all variables. Descriptive statistics are presented as means and standard deviations (SD) for continuous variables and frequencies and percentages for categorical variables, based on their distribution. Statistical tests such as Shapiro-Wilk normality tests were used to evaluate the normality of the data distribution. If the normality test conditions were satisfied, parametric tests were employed for further analysis; otherwise, non-parametric tests were utilized. The homogeneity of variance (Levene's) test was used to examine the variance homogeneity of all variables.

Generalized estimating equation (GEE) analysis is commonly applied in cluster-randomized controlled trial studies (Jamshidi-Naeini et al., 2022; Friedel et al., 2019; Barker et al., 2016). Therefore, this study adopted the generalized estimating equation model to assess the impact of the intervention plan on the dependent variable. Additionally, Cohen's d was used as a statistic to gauge the effect size (Larner, 2014), and the effect size was automatically computed by SPSS 27.0. The effect size in this study was interpreted based on the standards outlined by Cohen (2013): an effect size of 0.2 is considered small, 0.5 is moderate, and 0.8 is large (Cohen, 2013). Refer to Table 3.8 for more details.

Table 3.8 : Research Hypotheses and Statistical Analysis

Objective	Hypotheses and Research Question	Analysis
H_o1	There are no significant differences among EG and CG at baseline, week-6, and week-12 on physical activity among college students with overweight and obesity in China.	GEE
H_o2	There are no significant differences among EG and CG at baseline, week-6, and week-12 on depression among college students with overweight and obesity in China.	GEE
H_o3	There are no significant differences among EG and CG at baseline, week-6, and week-12 on anxiety among college students with overweight and obesity in China.	GEE
H_o4	There are no significant differences among EG and CG at baseline, week-6, and week-12 on stress among college students with overweight and obesity in China.	GEE
H_o5	There are no significant differences among EG and CG at baseline, week-6, and week-12 on psychological distress among college students with overweight and obesity in China.	GEE
H_o6	There are no significant differences among EG and CG at baseline, week-6, and week-12 on external regulation among college students with overweight and obesity in China.	GEE
H_o7	There are no significant differences among EG and CG at baseline, week-6, and week-12 on amotivation among college students with overweight and obesity in China.	GEE
H_o8	There are no significant differences among EG and CG at baseline, week-6, and week-12 on introjected regulation among college students with overweight and obesity in China.	GEE
H_o9	There are no significant differences among EG and CG at baseline, week-6, and week-12 on identified regulation among college students with overweight and obesity in China.	GEE
H_o10	There are no significant differences among EG and CG at baseline, week-6, and week-12 on intrinsic regulation among college students with overweight and obesity in China.	GEE
H_o11	There are no significant differences among EG and CG at baseline, week-6, and week-12 on body mass index among college students with overweight and obesity in China.	GEE
H_o12	There are no significant differences among EG and CG at baseline, week-6, and week-12 on body fat percentage among college students with overweight and obesity in China.	GEE
H_o13	There are no significant differences among EG and CG at baseline, week-6, and week-12 on lean body mass among college students with overweight and obesity in China.	GEE
H_o14	There are no significant differences among EG and CG at baseline, week-6, and week-12 on waist-to-hip ratio among college students with overweight and obesity in China.	GEE

CHAPTER 4

RESULTS

4.1 Introduction

This chapter presents the findings of the data analysis based on the objectives. Initially, it outlines the demographic data of the participants through frequency, percentage, mean, and standard deviation of the variables. The analysis was conducted using both descriptive and inferential methods. Moreover, during the pre-test, an independent t-test and a Mann-Whitney U test were performed to compare the research variables in both groups. In this context, all statistical assumptions, including normality tests and homogeneity of variances, were examined before the inferential analysis. Subsequently, Generalized Estimating Equations (GEE) were employed to assess the effects of active video games on each outcome variable.

4.2 Test of Normality

Normality is a crucial assumption for many statistical tests as it indicates the distribution of data. Tests examining the normality of data include Kurtosis, Skewness, as well as the Kolmogorov-Smirnov and Shapiro-Wilk tests, among others. In this study, data distribution was assessed using skewness and kurtosis to determine normality. The results of the skewness and kurtosis tests for the research variables ranged from -0.882 to 2.003 and -1.372 to 7.102, respectively. Moreover, based on the outcomes of the Kolmogorov-Smirnov and Shapiro-Wilk tests, it was found that certain variables including stress, external regulation, amotivation, introjected regulation, identified regulation, intrinsic regulation, BMI, body fat percentage, and lean body mass, were not normally distributed, while other variables exhibited normal distribution (see Appendix L).

4.3 Homogeneity Test of Variance

One of the main assumptions for statistical analysis when comparing groups is the homogeneity of variance, which implies equality of variances across different groups. This assumption is commonly verified using Levene's test, which assesses whether variances among groups differ significantly. The results of Levene's test, as shown in Table 4.1, indicated that the error variances for both the experimental and control groups were equal for all research variables at the pre-test ($p>0.05$). Therefore, it can be concluded that the assumption of variance homogeneity has been satisfied, ensuring that any differences observed between group means are solely attributable to the experimental manipulation itself and not due to variability in variances. Failing to meet this assumption could introduce bias in the estimates of treatment effects, underscoring the importance of this step in ensuring the validity of the analysis. The findings from Levene’s test confirmed that the groups exhibited similar error variances at baseline, aligning with the assumption of variance homogeneity (Appendix M).

Table 4.1 : Results of Levene's Test for Equality of Error Variances

Variable	Levene Statistic	df1	df2	p value
Age	0.28	1	61	0.599
Heigh	1.655	1	61	0.203
Weight	0.492	1	61	0.486
Physical activity	0.052	1	61	0.82
Depression	0.084	1	61	0.772
Anxiety	0.006	1	61	0.939
Stress	0.545	1	61	0.463
Psychological distress	0.086	1	61	0.771
External Regulation	1.094	1	61	0.300
Amotivation	0.297	1	61	0.588
Introjected Regulation	0.026	1	61	0.871
Identified Regulation	0.138	1	61	0.711
Intrinsic Regulation	1.919	1	61	0.171
BMI	2.572	1	61	0.114
Lean body mass	3.103	1	61	0.083
Body fat percentage	0.454	1	61	0.503
Waist-to-hip ratio	0.422	1	61	0.518

* Significant at 0.05 level

4.4 Sociodemographic Characteristics

Before proceeding with data analysis for all research hypotheses, the homogeneity between groups concerning background variables such as age, height, and weight was assessed. As age did not follow a normal distribution, the Mann-Whitney U test was utilized, while the independent t-test was employed for height and weight, which exhibited normal distributions. The age (years) of the college students was 19 ± 2 in AVG group and 19 ± 1 in CG. The height (cm) was 171.7 ± 10.19 in AVG group and 172.8 ± 8.68 in CG group.The weight (kg) was 88.14 ± 13.90 in AVG group and 89.56 ± 14.03 in CG group. The results presented in Table 4.2 indicated no significant differences between the AVG and control groups for age (Z= 0.662, p=0.508), height (t= 0.499, p=0.655), and weight (t= 0.404, p=0.688). These findings suggest that these variables displayed a similar pattern in both groups.

Table 4.2 : Baseline Characteristics of Participants between AVG and CG

	Groups	Mean	SD	t/z value	p value
Age [b]	CG	19	1	0.662	0.508
	AVG	19	2		
Height [a]	CG	172.8	8.68	0.499	0.656
	AVG	171.7	10.19		
Weight [a]	CG	89.56	14.03	0.404	0.688
	AVG	88.14	13.90		

a: Independent t test (Mean and SD), b: U Mann Whitney test (median and IQR)

4.5 Baseline Research Variables Comparison between Control 123 and Intervention Groups

Before proceeding with data analysis to test hypotheses, it is advisable to first evaluate the assumption of homogeneity among the groups in terms of all research variables at the baseline. An independent sample t-test was conducted to examine the differences in research variables between the AVG and control groups at baseline for physical activity, depression, anxiety, psychological distress, body fat percentage, and waist-to-hip ratio, as these variables displayed a normal distribution. Conversely, the Mann-Whitney U test was utilized to evaluate differences in stress, external regulation, amotivation, introjected regulation, identified regulation, intrinsic regulation, BMI, and lean body mass. The total number of steps per week in the CG and AVG groups was 49778.5 ± 10460.1 vs. 49325.4 ± 10497.0. The scores for psychological distress were 8.84 ± 2.29 vs. 9 ± 2.32 for depression, 9.78 ± 2.35 vs. 9.74 ± 2.24 for anxiety and 18.5 ± 4 vs. 17 ± 4 for stress for the AVG and CG groups, respectively. The overall psychological distress score for AVG was 36.81 ± 6.08 vs. 36.71 ± 5.54. In external motivation, both CG and AVG had baseline scores of 2 ± 1. In amotivation both CG and AVG also had scores of 2 ± 1. In introjected motivation, CG and AVG had scores of 3 ± 2 vs. 3 ± 1, respectively. in identified motivation, both CG and AVG had scores of 4 ± 2. Intrinsic motivation varied slightly, with CG having scores of 4 ± 2 and AVG having scores of 4 ± 1. In body composition, BMI was 29.5 ± 5.6 vs. 29.4 ± 3.3 for CG and AVG, respectively. Lean body mass at baseline was 58.85 ± 11 vs. 59.8 ± 6.4 for CG and AVG. Body fat percentage was approximately the same, 33.09 ± 3.20 vs. 33.60 ± 3.92 for CG compared to AVG. Waist-to-hip ratios for both CG and AVG were 0.92 ± 0.04. The outcomes (refer to Table 4.3) indicated no statistically significant variances between the AVG and control groups concerning all research variables at the pre-test, reflecting similar characteristics in both groups at the pre-test stage for all dependent variables.

Table 4.3 : Comparison between AVG and CG at Pre-test for All Research

Variable	CG (n = 32)	AVG (n = 31)	t/z value	p value
	Mean (SD)	Mean (SD)		
Physical activity [a]	49778.5(10460.1)	49325.4(10497.0)	0.172	0.864
Depression [a]	8.84(2.29)	9(2.32)	-0.269	0.789
Anxiety [a]	9.78(2.35)	9.74(2.24)	0.068	0.946
Stress [b]	18.5(4)	17(4)	-1.248	0.212
Psychological distress [a]	36.81(6.08)	36.71(5.54)	0.072	0.943
External Regulation [b]	2(1)	2(1)	-0.734	0.463
Amotivation [b]	2(1)	2(1)	-1.178	0.239
Introjected Regulation [b]	3(2)	3(1)	-0.086	0.931
Identified Regulation[b]	4(2)	4(2)	0.021	0.983
Intrinsic Regulation [b]	4(2)	4(1)	0.087	0.93
BMI [b]	29.5(5.6)	29.4(3.3)	-0.028	0.978
Lean body mass [b]	58.85(11)	59.8(6.4)	0.309	0.757
Body fat percentage [a]	33.09(3.20)	33.60(3.92)	-0.562	0.576
Waist-to-hip ratio [a]	0.92(0.04)	0.92(0.04)	0.173	0.864

a: Independent t-test (Mean and SD), b: U Mann Whitney test (median and IQR)

4.6 Inferential Statistics

A Generalized Estimating Equation was employed to investigate the research objectives and evaluate the effects of an active video game intervention on physical activity, psychological distress (specifically depression, anxiety, and stress), exercise motivation (including external motivation, lack of motivation, internal motivation, identification motivation, and intrinsic regulation), and body composition (comprising BMI, lean body mass, body fat percentage, and waist-to-hip ratio) among college students with overweight and obesity in China. The subsequent sections present the outcomes of the analysis for all dependent variables.

4.6.1 Effect of AVG on Physical Activity

To evaluate the first research objective on the effect of the active video games intervention on physical activity and compare both within and between groups on average physical activity across three time points (pre-test, week 6, and week 12) among the groups, Generalized Estimating Equations (GEE) were utilized. Table 4.5 shows the descriptive data, specifically the mean and standard error, for both groups at each time point.

As shown in Table 4.4, the control group (CG) and the active video games group (AVG) had different mean values across the three time points. The table shows increased physical activity for both groups over time, with a more pronounced increase observed in the AVG group. The standard errors (SE) indicate the variability in the means for each group at the three time points.

Table 4.4 : Descriptive Statistics (Mean and SE) of Physical Activity

Groups	Time	Mean	SE
CG	**Pre-test**	49778.6	1820.0
	Week6	52913.1	2224.9
	Week12	54475.2	1956.5
AVG	**Pre-test**	49325.4	1854.7
	Week6	56153.9	1689.7
	Week12	64664.6	1922.8

The Generalized Estimating Equations (GEE) analysis in Table 4.5 indicated that the main effect of the group on physical activity was not statistically significant (χ^2=2.843, p=0.092). This suggests that there was no statistically significant overall difference in physical activity levels between the two groups. The analysis also revealed a statistically significant main effect of time on physical activity (χ^2=196.381, p<0.001), indicating substantial variations in physical activity levels at different time points. Additionally, there was a significant interaction effect between time and group (χ^2=53.924, p<0.001), demonstrating that the pattern of physical activity differed significantly across the three time points.

Table 4.5 : Results of GEE for Physical Activity

Source	Wald Chi-Square	df	p-value
Groups	2.843	1	0.092
Time	196.381*	2	<.001
Time * Group	53.924*	2	<.001

*: Significant at 0.05 level

Table 4.6 presents the mean comparison of physical activity between the AVG and control groups at various time points (pre-test, week 6, and week 12). The table provides data on the mean difference, standard error (SE), p-value, 95% confidence interval (CI) for the difference, and effect size (d). The results indicate that there was no significant difference between the AVG and control groups at the pre-test (p=1) and week 6 (p=1). However, a significant difference in physical activity between the AVG and control groups was observed at week 12 (p<0.001). The effect sizes suggest a substantial impact of the intervention, with a large effect observed at week 12 (d=0.94).

Table 4.6 : Pairwise Mean Comparison of Physical Activity between AVG and CG across the Time (between Groups)

Group	Time	Mean Difference	SE	P value	95%CI for Difference		Effect Sized
					LB	UB	
Pre-test	CG Vs AVG	453.17	2598.48	1.00	-4803.44	5709.79	0.04
Week6	CG Vs AVG	-3240.81	2793.80	1.00	-10234.67	3753.05	0.29
Week12	CG Vs AVG	-10189.42	2743.23	<0.001	-17796.18	-2582.67	0.94

* The mean difference is significant at the .05 level Adjustment for multiple comparisons: Bonferroni.

Table 4.7 displays the mean comparison of physical activity across three time intervals (pre-test, week 6, and week 12) in both the AVG and control groups. The table provides data on the mean difference, standard error (SE), p-value, 95% confidence interval (CI) for the difference, and effect size (d).

The findings indicated a notable increase in physical activity within the control group from the pre-test to week 6 ($p < 0.001$) and from the pre-test to week 12 ($p < 0.001$). The difference between week 6 and week 12 ($p = 1.00$) was not significant. The effect sizes for time within the control group suggest a small effect ($d = 0.40$).

In contrast, the AVG group demonstrated significant enhancement in physical activity from the pre-test to week 6 ($p < 0.001$), pre-test to week 12 ($p < 0.001$), and week 6 to week 12 ($p < 0.001$). However, the effect sizes for this group indicated a substantial impact compared to the control group. A large effect size was observed for the influence of time in the AVG group (d = 1.5).

Table 4.7 : Pairwise Mean Comparison for Physical Activity across the Time in both Groups (within Groups)

Group	test	Mean Difference	SE	P value	95%CI for Difference		Effact Sized
					LB	UB	
CG	Pre vs week6	-3134.5	1076.4	<0.001	-6077.9	-191.1	0.4
	Pre vs week12	-4696.5	665.6	<0.001	-6620.5	-2772.6	
	week6 vs week12	-1562.1	1260.6	1.0	-4809.1	1685.0	
AVG	Pre vs week6	-6828.4	979.3	<0.001	-9634.3	-4022.6	1.5
	Pre vs week12	-15339.2	1287.5	<0.001	-19118.1	-11560.2	
	week6 vs week12	-8510.7	1095.2	<0.001	-11701.9	-5319.5	

* The mean difference is significant at the .05 level Adjustment for multiple comparisons: Bonferroni.

Based on the data depicted in Figure 4.1, illustrating the mean physical activity scores over time, it is evident that the AVG group experienced a higher level of physical activity after 12 weeks compared to the control group.

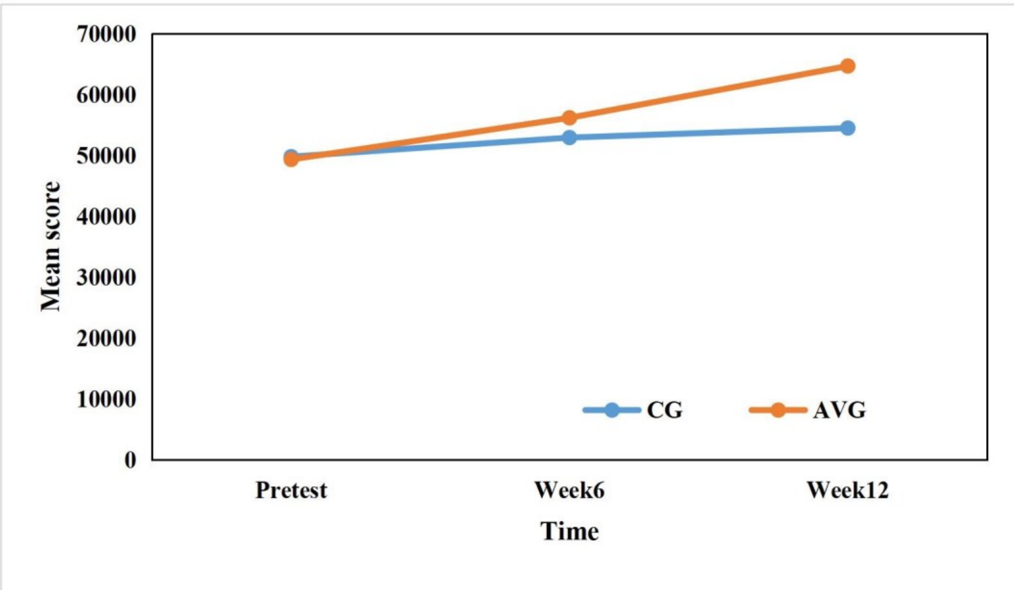

Figure 4.1 : Mean of Physical Activity for AVG and CG across the Time

4.6.2 Effect of AVG on Psychological Distress

The second objective of this study was to assess the effect of active video games on psychological distress among Chinese college students with overweight and obesity. To evaluate the impact of the intervention on psychological distress and its three components (depression, anxiety, stress) and to analyse any differences in the mean score of these variables across three time points (pre-test, week 6, and Week 12), Generalized Estimating Equations (GEE) were applied. Table 4.8 presents the descriptive statistics, specifically the mean and standard error, for both groups at each time point for psychological distress and its three components (depression, anxiety, stress). As shown in Table 4.8, the mean values for CG and AVG varied over time with respect to depression, anxiety, and stress. Additionally, the mean scores at each time point differed between the two groups in terms of psychological distress and its components.

While the CG only displayed minimal decreases in the levels of depression, anxiety, and stress across the three measured time points, as depicted in Table 4.8, the intervention group, AVG, experienced a significant reduction in all three components, particularly in stress levels, which exhibited a notable drop at the end of the study. Psychological distress decreased more over time in the intervention group compared to the control group.

Table 4.8 : Descriptive Statistics (Mean and SE) of Psychological Distress for Both Groups across the Time

Variable	Groups	Time	Mean	SE
Depression	CG	**Pre-test**	8.84	0.40 0.42
		Week6	8.22	0.30
		Week12	8.25	
	AVG	**Pre-test**	9.00	0.41
		Week6	8.39	0.28
		Week12	6.87	0.27
Anxiety	CG	**Pre-test**	9.78	0.41 0.44
		Week6	9.50	0.39
		Week12	9.41	
	AVG	**Pre-test**	9.74	0.40
		Week6	9.03	0.27
		Week12	7.81	0.31
Stress	CG	**Pre-test**	18.19	0.53 0.48
		Week6	18.06	0.48
		Week12	17.94	
	AVG	**Pre-test**	17.97	0.68
		Week6	16.19	0.67
		Week12	13.84	0.41
Total PD	CG	**Pre-test**	36.81	1.05
		Week6	35.78	1.00
		Week12	35.59	0.91
	AVG	**Pre-test**	36.71	0.95
		Week6	33.61	0.90
		Week12	28.52	0.68

PD: psychological distress

The Generalized Estimating Equations (GEE) results for psychological distress and its three components (depression, anxiety, stress) are presented in Table 4.9. The analysis indicated that the main effect of the group was not statistically significant for depression (χ+=0.69, p=0.408). Conversely, the main effect of time on depression was statistically significant (χ^2=33.73, p<0.001), suggesting notable variations in depression at different time points. Furthermore, the analysis revealed a significant interaction effect between time and group (χ^2=16.00, p<0.001), indicating significant differences in depression levels between groups at different time points.

For anxiety, the results indicated that the main effect of the group was not statistically significant (χ^2=1.99, p=0.158), whereas the main effect of time on anxiety was statistically significant (χ^2=70.31, p<0.001). There was a significant interaction effect between time and group (χ^2=33.53, p<0.001), showing significant differences in anxiety levels between groups at different time points.

In the analysis of stress, the main effect of the group was statistically significant (χ^2=8.56, p=0.009). Furthermore, there were significant differences in stress levels at different time points, which was statistically significant (χ^2=97.79, p<0.001). The interaction effect between time and group was also significant (χ^2=76.93, p<0.001), indicating significant differences in stress levels between the AVG and control groups at different time points.

GEE analysis of psychological distress showed that the main effect of group was significant (χ^2=6.83, p=0.009). The main effect of time on overall psychological distress is statistically significant (χ^2=198.69, p<0.001). Furthermore, it was shown that there was a significant difference in psychological distress between the AVG group and the control group across time, which was reflected in a significant interaction between time and group (χ^2=116.76, p<0.001).

Table 4.9 : Results of GEE for Psychological Distress

Variable	Source	Wald Chi-Square	df	p-value
Depression	Groups	0.69	1	0.408
	Time	33.73*	2	<.001
	Time * Group	16.00*	2	<.001
Anxiety	Groups	1.99	1	0.158
	Time	70.31*	2	<.001
	Time * Group	33.53*	2	<.001
Stress	Groups	8.56*	1	0.003
	Time	97.79*	2	<.001
	Time * Group	76.93*	2	<.001
Total PD	Groups	6.83*	1	0.009
	Time	198.69*	2	<.001
	Time * Group	116.76*	2	<.001

*: Significant at 0.05 level; PD: psychological distress

Table 4.10 presents the results of the post-hoc test utilizing the Bonferroni method for between-group comparisons (AVG vs. control) at three time points for the level of depression (pre-test, week 6, and week 12). The findings indicated that there were no statistically significant differences between the AVG and control groups at the pre-test (p=1.00) and also at week 6 (p=1.00). However, there was a significant difference in the level of depression between the AVG and control groups at week 12 (p=0.010). The effect sizes indicate that at the pre-test and week 6, there was a small effect, while after 12 weeks, there was a large effect size (d=0.87).

The outcomes of the between-group comparison for anxiety also revealed no significant difference between the AVG and control groups at the pre-test (p=1.00) and week 6 (p=1.00). However, there was a difference in the level of anxiety between the AVG and control groups at week 12 (p=0.020), which was statistically significant.

The effect sizes demonstrate a substantial impact, with a large effect observed in week 12 (d=0.81).

Regarding the mean comparison for the level of stress between the AVG and control groups, the results showed no statistically significant difference between the groups at the pre-test ($p=1.00$) and also at week 6 ($p=0.18$). However, there was a significant difference in the level of stress between the AVG and control groups at week 12 ($p<0.001$). The effect sizes for the pre-test were small ($d=0.22$), while the results showed a medium effect size in week 6 ($d=0.58$) and a large effect size in week 12 ($d=1.64$).

These results for total psychological distress indicated that there were no significant differences between the AVG and control groups at the pre-test ($p=1.00$) and also at week 6 ($p=0.64$). Nevertheless, there was a significant difference in the level of total psychological distress between the AVG and control groups at week 12 ($p<0.001$). The effect sizes show that at the pre-test and week 6, there was a small effect, whereas after 12 weeks, there was a large effect size ($d=1.57$).

Table 4.10 : Pairwise Mean Comparison of Psychological Distress across the Time in Both AVG and CG (between Groups)

Variable	Group	Time	Mean Difference	SE	P value	95%CI for Difference LB	95%CI for Difference UB	Effect Sized
Depression	Pre-test	CG Vs AVG	-0.16	0.57	1.00	-1.34	1.02	0.07
	Week6	CG Vs AVG	-0.17	0.51	1.00	-1.22	0.89	0.08
	Week12	CG Vs AVG	1.38*	0.40	0.01	0.24	2.52	0.87
Anxiety	Pre-test	CG Vs AVG	0.04	0.57	1.00	-1.09	1.17	0.02
	Week6	CG Vs AVG	0.47	0.52	1.00	-0.90	1.84	0.23
	Week12	CG Vs AVG	1.60*	0.50	0.02	0.18	3.02	0.81
Stress	Pre-test	CG Vs AVG	0.22	0.86	1.00	-1.55	1.99	0.06
	Week6	CG Vs AVG	1.87	0.82	0.18	-0.37	4.11	0.58
	Week12	CG Vs AVG	4.10*	0.63	<0.001	2.29	5.90	1.64
Total PD	Pre-test	CG Vs AVG	0.10	1.41	1.00	-2.70	2.91	0.02
	Week6	CG Vs AVG	2.17	1.34	0.64	-1.37	5.71	0.41
	Week12	CG Vs AVG	7.08*	1.13	<0.001	3.83	10.33	1.57

* The mean difference is significant at the .05 level Adjustment for multiple comparisons: Bonferroni.

The Bonferroni test was utilized to evaluate within-group comparisons. Table 4.11 depicts the mean comparison of psychological distress and its components across three time points (pre-test, week 6, and week 12) in both the AVG and control groups.

It displays the mean difference, standard error (SE), p-value, 95% confidence interval (CI) for the difference, and effect size (d).

The results indicated that there was no significant difference between the pre-test and week 6 ($p=0.70$). However, there was a significant reduction in the level of depression in the AVG group from the pre-test to week 12 ($p<0.001$) and also from week 6 to week 12 ($p<0.001$). The effect size for time was large ($d=1.11$). Conversely, in the control group, there were no significant differences between the pre-test and week 6

($p=0.18$), pre-test and week 12 ($p=0.34$), and week 6 and week 12 ($p=1.00$). The effect size in the control group indicated a small impact compared to the AVG group across time points ($d=0.30$).

Further analysis on the level of anxiety revealed no significant difference between the pre-test and week 6 ($p=0.11$) in the AVG group. However, a significant reduction was observed from the pre-test to week 12 ($p<0.001$) and week 6 to week 12 ($p<0.001$). The effect sizes indicated a large effect for time in the AVG group ($d=0.98$). In the control group, there were no significant differences in anxiety levels between the pre-test and week 6 ($p=0.64$), pre-test and week 12 ($p=0.29$), and week 6 and week 12 ($p=1.00$) with a small effect size ($d=0.16$).

The findings demonstrated a significant reduction in stress levels in the AVG group at different intervals: from pre-test to week 6 ($p=0.03$), pre-test to week 12 ($p<0.001$), and week 6 to week 12 ($p<0.001$). The effect size for time was large with significant impact ($d=1.32$). In contrast, the control group showed no significant changes in stress levels across all three time points ($p=1.00$) with an effect size of $d=0.09$.

Regarding the total score of psychological distress, no significant difference was found between the pre-test and week 6 ($p=0.16$). However, there was a significant reduction in psychological distress levels in the AVG group from the pre-test to week 12 ($p<0.001$) but not between week 6 to week 12 ($p=0.17$). The effect size for time was large ($d=1.78$). Conversely, in the control group, no significant differences were observed between the pre-test and week 6 ($p=0.17$), pre-test and week 12 ($p=0.05$), and week 6 and week 12 (p=1.00), with a small effect size compared to the AV group across the time points (d=0.22).

Table 4.11 : Pairwise Mean Comparison for Psychological Distress across the Time in Both Groups (within Groups)

Variable	Group	test	Mean Difference	SE	P value	95%C1 for Difference LB	95%C1 for Difference UB	Effect Sized
Depression	CG	Pre vs week6	0.63	0.26	0.18	-0.12	1.37	0.30
		Pre vs week12	0.59	0.29	0.34	-0.20	1.39	
		week6 vs week12	-0.03	0.28	1.00	-0.59	0.53	
	AVG	Pre vs week6	0.61	0.36	0.70	-0.37	1.59	1.11
		Pre vs week12	2.13*	0.38	<0.001	1.03	3.23	
		week6 vs week12	1.52*	0.32	<0.001	0.60	2.44	
Anxiety	CG	Pre vs week6	0.28	0.16	0.64	-0.16	0.72	0.16
		Pre vs week12	0.38	0.18	0.29	-0.11	0.86	
		week6 vs week12	0.09	0.21	1.00	-0.35	0.54	
	AVG	Pre vs week6	0.71	0.28	0.11	-0.07	1.49	0.98
		Pre vs week12	1.94*	0.21	<0.001	1.31	2.56	
		week6 vs week12	1.23*	0.24	<0.001	0.53	1.93	
Stress	CG	Pre vs week6	0.13	0.25	1.00	-0.41	0.66	0.09
		Pre vs week12	0.25	0.25	1.00	-0.42	0.92	
		week6 vs week12	0.13	0.25	1.00	-0.41	0.66	
	AVG	Pre vs week6	1.77*	0.59	0.03	0.12	3.43	1.32
		Pre vs week12	4.13*	0.37	<0.001	3.04	5.22	
		week6 vs week12	2.35*	0.53	<0.001	0.85	3.86	
Total PD	CG	Pre vs week6	1.03	0.46	0.17	-0.20	2.26	0.22
		Pre vs week12	1.22*	0.44	0.05	0.01	2.42	
		week6 vs week12	0.19	0.42	1.00	-0.71	1.09	
	AVG	Pre vs week6	3.10*	0.96	0.16	0.41	5.78	1.78
		Pre vs week12	8.19*	0.54	<0.001	6.60	9.79	
		week6 vs week12	5.10*	0.80	0.17	2.78	7.42	

* The mean difference is significant at the .05 level. Adjustment for multiple comparisons: Bonferroni. PD is psychological distress.

Based on Figure 4.2, illustrating the mean depression scores over time, it is evident that the AVG group experienced a decrease in depression levels after 12 weeks compared to the control group. Figure 4.3 indicates a reduction in mean anxiety scores in the AVG group over time compared to the control group. In Figure 4.4, the reduction in stress levels was more pronounced in the AVG group compared to the control group within the same 12-week period. Finally, Figure 4.5 demonstrates that the overall psychological distress score decreased within 12 weeks for the AVG group, whereas in the control group, the mean psychological distress score decreased slightly.

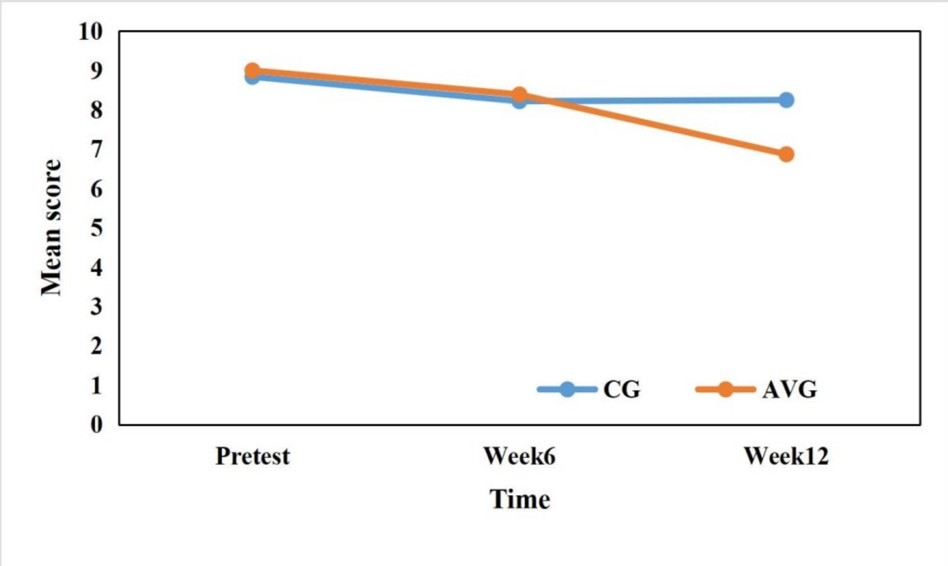

Figure 4.2 : Mean of Depression for AVG and CG across the Time

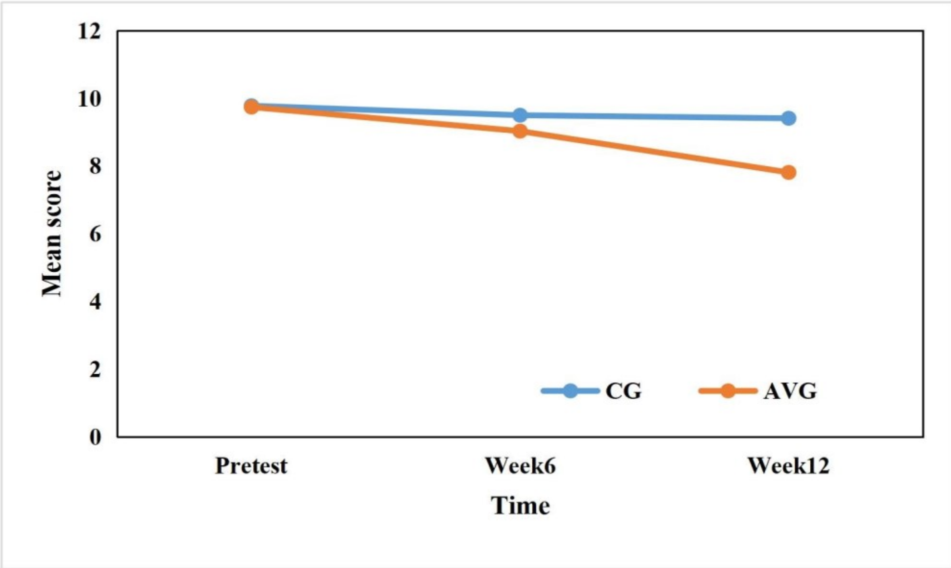

Figure 4.3 : Mean of Anxiety for AVG and CG across the Time

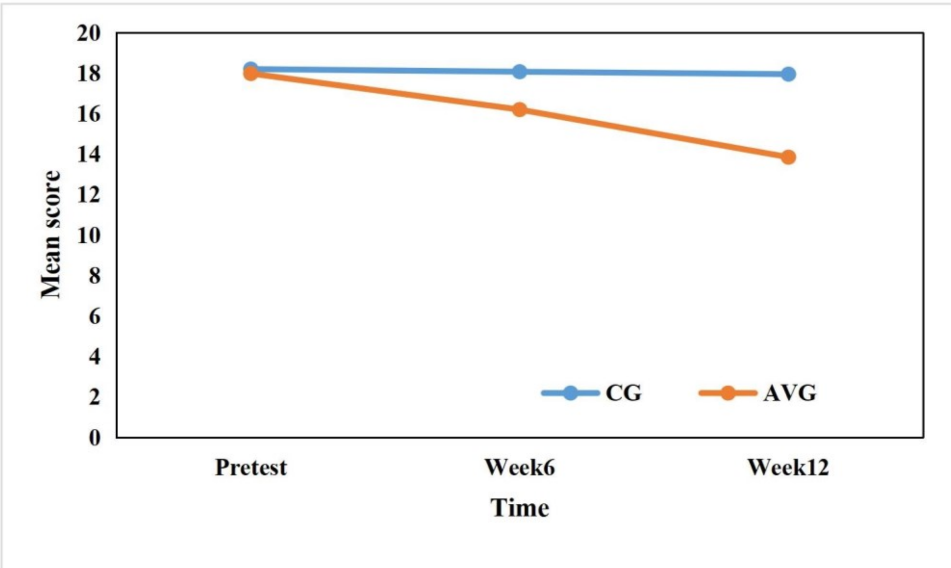

Figure 4.4 : Mean of Stress for AVG and CG across the Time

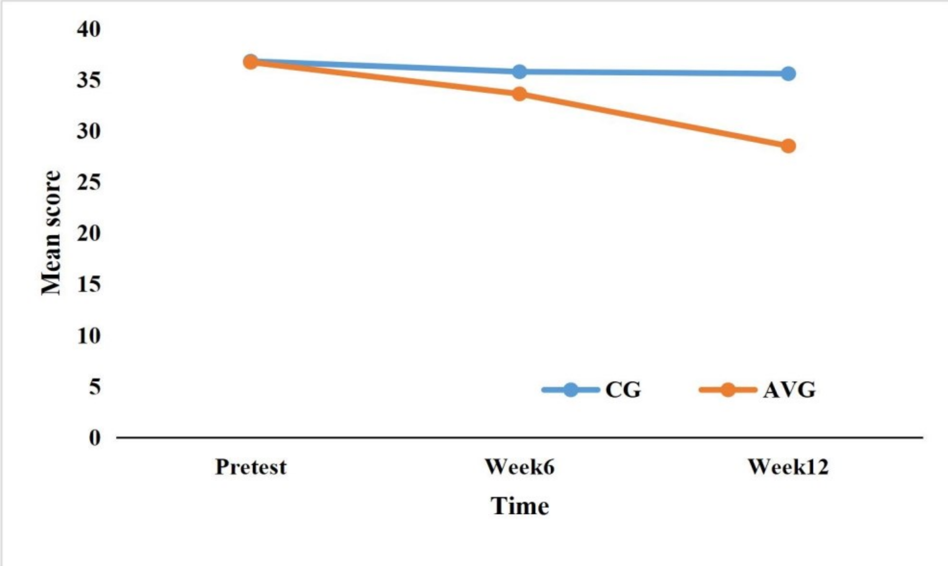

Figure 4.5 : Mean of Total PD for AVG and CG across the Time

4.6.3 Effect of AVG on Exercise Motivation

The third research objective of this study was to assess the effect of active video games on exercise motivation among Chinese college students with overweight and obesity. In order to evaluate the impact of the intervention on exercise motivation and its five components (external regulation, amotivation, introjected regulation, identified regulation, and intrinsic regulation) and to analyse any differences in the mean scores of these variables across three time points (pre-test, week 6, and week 12), Generalized Estimating Equations (GEE) were used. Table 4.12 presents the descriptive statistics, specifying the mean and standard error, for both groups at each time point for the components of exercise motivation (external regulation, amotivation, introjected regulation, identified regulation, and intrinsic regulation).

As shown in Table 4.12, the mean scores of the Control Group (CG) and the Active Video Games Group (AVG) vary over time in terms of external regulation, amotivation, introjected regulation, identified regulation, and intrinsic regulation.

Additionally, the mean scores at each time point differ between the two groups. The CG demonstrated minimal reductions in external regulation and amotivation throughout the three time points, while showing stable or slight increases in introjected regulation, identified regulation, and intrinsic regulation. On the other hand, the AVG exhibited a significant decrease in external regulation and amotivation during the research period, with amotivation notably reduced after 12 weeks, while introjected regulation, identified regulation, and intrinsic regulation increased over time. In summary, subjects in the intervention group showed greater improvement in exercise motivation compared to those in the control group.

Table 4.12 : Descriptive Statistics (Mean and SE) of Exercise Motivation for Both Groups across the Time

Variable	Groups	Time	Mean	SE
External Regulation	CG	Pre-test	2.44 2.25	0.19
		Week6	2.09	0.16
		Week12		0.16
	AVG	Pre-test	2.23	0.17
		Week6	2.00	0.14
		Week12	1.77	0.14
Amotivation	CG	Pre-test	2.22 2.09	0.14
		Week6	1.91	0.14
		Week12		0.12
	AVG	Pre-test	2.00	0.14
		Week6	1.68	0.14
		Week12	1.23	0.14
Introjected Regulation	CG	Pre-test	3.28 3.41	0.18
		Week6	3.50	0.18
		Week12		0.17
	AVG	Pre-test	3.32	0.20
		Week6	3.65	0.22
		Week12	3.97	0.20
Identified Regulation	CG	Pre-test	4.25 4.34	0.23
	AVG	Week6	4.41	0.20
		Week12		0.21
		Pre-test	4.26	0.25
		Week6	4.84	0.18
		Week12	5.71	0.18
Intrinsic Regulation	CG	Pre-test	3.84 4.09	0.19
		Week6	3.97	0.19
		Week12		0.23
	AVG	Pre-test	3.90	0.14
		Week6	4.03	0.14
		Week12	4.74	0.11

The results of the Generalized Estimating Equations (GEE) analysis for the five components of exercise motivation—external regulation, amotivation, introjected regulation, identified regulation, and intrinsic regulation—are presented in Table 4.13.

The analysis indicated that the group's main effect was not statistically significant for external regulation (χ^2=1.54, p=0.215); however, the main effect of time on external regulation was statistically significant (χ^2=18.98, p<0.001), highlighting variations in external regulation at different time points. Additionally, there was no significant interaction effect between time and group (χ^2=0.34, p=0.84), suggesting that the level of external regulation did not significantly differ between groups at different time points.

For amotivation, the results indicated a statistically significant main effect of the group (χ^2=6.40, p<0.011) and a significant main effect of time on amotivation (χ^2=57.46, p<0.001). Moreover, a significant interaction effect between time and group was observed (χ^2=10.41, p=0.005), demonstrating differences in amotivation levels between the groups at different time points.

In the analysis of introjected regulation, the main effect of the group was not statistically significant (χ2=0.97, p=0.326), while there were significant differences at different time intervals in the level of introjected regulation (χ2=34.88, p<0.001). Additionally, a significant interaction effect between time and group was found (χ2=8.28, p=0.016), indicating differences in the level of introjected regulation between the AVG and control groups at different time intervals.

The GEE results for identified regulation revealed a statistically significant main effect of the group (χ2=5.45, p=0.020) and a significant main effect of time on identified regulation (χ2=40.85, p<0.001), showing variations at different time points. Furthermore, a significant interaction effect between time and group was observed (χ2=26.83, p<0.001), indicating differences in the level of identified regulation between groups at different time points.

Regarding intrinsic regulation, the main effect of the group was not statistically significant (χ^2=1.41, p=0.236), whereas the main effect of time on intrinsic regulation was statistically significant (χ^2=27.13, p<0.001). An interaction effect between time and group was also significant (χ^2=19.35, p<0.001), revealing distinct patterns in intrinsic regulation levels between the groups at different time points.

Table 4.13 : Results of GEE for Exercise Motivation

Variable	Source	Wald Chi-Square	df	p-value
External Regulation	Groups	1.54	1	0.215
	Time	18.982*	2	<.001
	Time * Group	0.339	2	0.844
Amotivation	Groups	6.397	1	0.011
	Time	57.463*	2	<.001
	Time * Group	10.408*	2	0.005
Introjected Regulation	Groups	0.967	1	0.326
	Time	34.878*	2	<.001
	Time * Group	8.277*	2	0.016
Identified Regulation	Groups	5.445	1	0.02
	Time	40.855*	2	<.001
	Time * Group	26.834*	2	<.001
Intrinsic Regulation	Groups	1.407	1	0.236
	Time	27.134*	2	<.001
	Time * Group	19.348*	2	<.001

*: Significant at 0.05 level

Table 4.14 presents the results of the post hoc test using the Bonferroni method for between-group comparison (AVG vs control) at three points for the level of external regulation (pre-test, week 6, and week 12). The results indicated no statistically significant differences between the AVG and control groups at the pre-test (p=1.00), week 6 (p=1.00), and week 12 (p=0.78). The effect sizes indicated a small effect size at all three time points, ranging between d= 0.21 and 0.38.

The comparison for amotivation showed no significant differences between the AVG and control groups at the pre-test (p=0.86) and week 6 (p=0.23). However, a difference in the level of amotivation was observed between the AVG and control groups at week 12 (p<0.001), which was statistically significant, with the effect sizes demonstrating a substantial impact, showing a large effect observed in week 12 (d=0.92).

The comparison of mean levels of introjected regulation between the AVG and control group indicated no statistically significant differences at the pre-test (p=1.00), week 6 (p=1.00), and week 12 (p=0.61). The effect sizes showed small effects at all three time points, ranging between d= 0.04 and 0.45.

The results for identified regulation indicated no significant differences between the AVG and control groups at the pre-test (p=1.00) and week 6 (p=0.55). However, a significant difference in the level of total identified regulation between the AVG and control groups at week 12 (p<0.001) was observed. The effect sizes indicated a small effect size at pre-test and week 6, while after 12 weeks, a large effect size was observed (d=1.17).

Regarding intrinsic regulation, no significant differences were found between the AVG and control groups at the pre-test (p=1.00) and week 6 (p=1.00). However, a significant difference in the level of total intrinsic regulation between the AVG and control groups at week 12 (p=0.040) was observed. The effect sizes indicated a small effect size at pre-test and week 6, while after 12 weeks, a medium effect size was observed (d=0.75).

Table 4.14 : Pairwise Mean Comparison of Exercise Motivation between AVG and CG across the Time (Between Groups)

Variable	Group	*Time*	Mean Difference	SE	P value	95%CI for Difference		Effect Sized
						LB	UB	
External Regulation	Pre-test	CG Vs AVG	0.21	0.26	1.00	-0.38	0.81	0.21
	Week6	CG Vs AVG	0.25	0.21	1.00	-0.29	0.79	0.30
	Week12	CG Vs AVG	0.32	0.21	0.78	-0.24	0.88	0.38
Amotivation	Pre-test	CG Vs AVG	0.22	0.19	0.86	-0.25	0.69	0.29
	Week6	CG Vs AVG	0.42	0.19	0.23	-0.11	0.94	0.53
	Week12	CG Vs AVG	0.68*	0.19	<0.001	0.16	1.20	0.92
Introjected Regulation	Pre-test	CG Vs AVG	-0.04	0.27	1.00	-0.57	0.49	0.04
	Week6	CG Vs AVG	-0.24	0.28	1.00	-0.90	0.42	0.21
	Week12	CG Vs AVG	-0.47	0.26	0.61	-1.19	0.25	0.45
Identified Regulation	Pre-test	CG Vs AVG	-0.01	0.34	1.00	-0.67	0.65	0.01
	Week6	CG Vs AVG	-0.49	0.27	0.55	-1.24	0.25	0.46
	Week12	CG Vs AVG	-1.30*	0.28	<0.001	-2.11	-0.50	1.17
Intrinsic regulation	Pre-test	CG Vs AVG	-0.06	0.23	1.00	-0.75	0.63	0.06
	Week6	CG Vs AVG	0.06	0.24	1.00	-0.64	0.77	0.06
	Week12	CG Vs AVG	-0.77*	0.26	0.04	-1.53	-0.02	0.75

* The mean difference is significant at the .05 level. Adjustment for multiple comparisons: Bonferroni.

The Bonferroni test was utilized to evaluate within-group comparisons. Table 4.15 illustrates the average comparison of exercise motivation components across three time points (pre-test, week 6, and week 12) within both the AVG and control groups.

The table displays the mean difference, standard error (SE), p-value, 95% confidence interval (CI) for the difference, and effect size (d).

The findings revealed a significant difference between the pre-test and week 6 ($p = 0.040$). Additionally, there was a notable reduction in external regulation levels in the AVG group from the pre-test to week 12 ($p = 0.010$). However, no significant difference was observed between weeks six and 12 ($p = 0.35$). The effect size for time was moderate in the AVG group ($d = 0.53$). Conversely, in the control group, no significant differences were observed between the pre-test and week 6 ($p = 0.24$), pre-test and week 12 ($p = 0.10$), and week 6 and week 12 ($p = 0.36$). Nonetheless, the effect size in the control group indicated a small impact compared to the AVG group over time ($d = 0.35$).

The results of the within-group comparison for the level of amotivation demonstrated a significant difference between the pre-test and week 6 ($p = 0.01$) in the AVG group. Moreover, there was a substantial reduction from the pre-test to week 12 ($p < 0.001$) and from week 6 to week 12 ($p < 0.001$). The effect sizes showed a large effect for the impact of time in the AVG group ($d = 0.99$). Conversely, in the control group, there were no significant differences in the level of amotivation from pre-test to week 6 ($p = 0.72$), with a significant difference between pre-test and week 12 ($p < 0.001$), but no significant difference from week 6 to week 12 ($p = 0.41$) with a small effect size ($d = 0.42$).

The results for introjected regulation indicated no significant difference between the pre-test and week 6 ($p = 0.25$) in the AVG group. There was a significant improvement in the level of introjected regulation from the pre-test to week 12 ($p < 0.001$), while no significant difference was observed between week six and week 12 ($p = 0.40$). The effect size for time was moderate, with a value of $d = 0.59$. In contrast, results in the control group showed no significant changes in introjected regulation at pre-test ($p = 0.36$), week 6 ($p = 0.15$), and week 12 ($p = 1.00$) with an effect size of $d = 0.22$, indicating a small effect size.

The results for identified regulation indicated no significant difference between the pre-test and week 6 ($p = 0.18$). However, there was a significant reduction in the level of identified regulation in the AVG group from the pre-test to week 12 ($p < 0.001$) and between week 6 to week 12 ($p = 0.010$). The effect size for time was large ($d = 1.20$). In contrast, in the control group, results showed no significant differences between the pre-test and week 6 ($p = 1.00$), pre-test and week 12 ($p = 0.57$), and week 6 and week 12 ($p = 1.00$) with a small effect size compared to the AVG group over time ($d = 0.13$).

The findings for intrinsic regulation showed no significant difference between the pre-test and week 6 ($p = 1.00$) in the AVG group. Conversely, there was a significant improvement in intrinsic regulation levels from the pre-test to week 12 ($p < 0.001$) and between week six and week 12 ($p < 0.001$). The effect size for time was large, with a value of $d = 1.19$. In contrast, results in the control group showed no significant changes in intrinsic regulation at pre-test ($p = 0.68$), week 6 ($p = 1.00$), and week 12 ($p = 1.00$) with an effect size of $d = 0.11$, indicating a small effect size.

Table 4.15 : Pairwise Mean Comparison for Exercise Motivation across the Time in Both Groups (within Groups)

Variable	Group	test	Mean Difference	SE	P value	95%CI for Difference LB	95%CI for Difference UB	Effect Sized
External Regulation	CG	Pre vs week6	0.19	0.08	0.24	-0.05	0.42	0.35
		Pre vs week12	0.34	0.13	0.10	-0.03	0.72	
		week6 vs week12	0.16	0.08	0.36	-0.06	0.37	
	AVG	Pre vs week6	0.23*	0.08	0.04	0.01	0.44	0.53
		Pre vs week12	0.45*	0.14	0.01	0.05	0.85	
		week6 vs week12	0.23	0.11	0.35	-0.08	0.53	
Amotivation	CG	Pre vs week6	0.13	0.09	0.72	-0.10	0.35	0.42
		Pre vs week12	0.31*	0.08	<0.001	0.08	0.55	
		week6 vs week12	0.19	0.10	0.41	-0.08	0.46	
	AVG	Pre vs week6	0.32*	0.10	0.01	0.06	0.59	0.99
		Pre vs week12	0.77*	0.12	<0.001	0.43	1.12	
		week6 vs week12	0.45*	0.11	<0.001	0.14	0.77	
Introjected Regulation	CG	Pre vs week6	-0.13	0.06	0.36	-0.29	0.04	0.22
		Pre vs week12	-0.22	0.09	0.15	-0.47	0.03	
		week6 vs week12	-0.09	0.09	1.00	-0.32	0.13	
	AVG	Pre vs week6	-0.32	0.14	0.25	-0.72	0.08	0.59
		Pre vs week12	-0.65*	0.13	<0.001	-1.01	-0.28	
		week6 vs week12	-0.32	0.16	0.40	-0.77	0.12	
Identified Regulation	CG	Pre vs week6	-0.09	0.08	1.00	-0.30	0.11	0.13
		Pre vs week12	-0.16	0.09	0.57	-0.40	0.08	
		week6 vs week12	-0.06	0.06	1.00	-0.21	0.09	
	AVG	Pre vs week6	-0.58	0.25	0.18	-1.27	0.11	1.20
		Pre vs week12	-1.45*	0.24	<0.001	-2.15	-0.76	
		week6 vs week12	-0.87*	0.25	0.01	-1.58	-0.16	
Intrinsic Regulation	CG	Pre vs week6	-0.25	0.13	0.68	-0.62	0.12	0.11
		Pre vs week12	-0.13	0.11	1.00	-0.44	0.19	
		week6 vs week12	0.13	0.13	1.00	-0.26	0.51	
	AVG	Pre vs week6	-0.13	0.14	1.00	-0.52	0.27	1.19
		Pre vs week12	-0.84*	0.15	<0.001	-1.28	-0.39	
		week6 vs week12	-0.71*	0.17	<0.001	-1.20	-0.22	

* The mean difference is significant at the .05 level. Adjustment for multiple comparisons: Bonferroni

Figure 4.6 illustrates the mean score of external regulation over time. It indicates that both groups experienced a similar decrease in external regulation after 12 weeks. In Figure 4.7, the mean motivation score decreased in the AVG group over time compared to the control group. Figure 4.8 indicates that the introjected regulation level increased more in the AVG group than in the control group within 12 weeks.

Figure 4.9 demonstrates an increase in the identified regulation score within 12 weeks in the AVG group, while in the control group, the mean identified regulation score slightly improved. As shown in Figure 4.10, which presents the mean score of intrinsic regulation over time, both groups had similar levels until week 6; however, after 12 weeks, the identified regulation level increased in the AVG group.

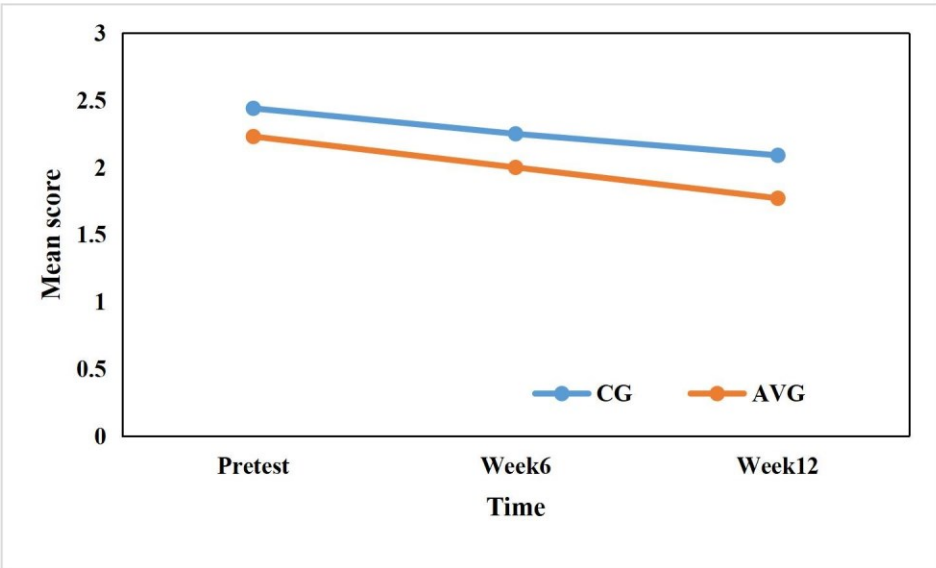

Figure 4.6 : Mean of External Regulation for AVG and CG across the Time

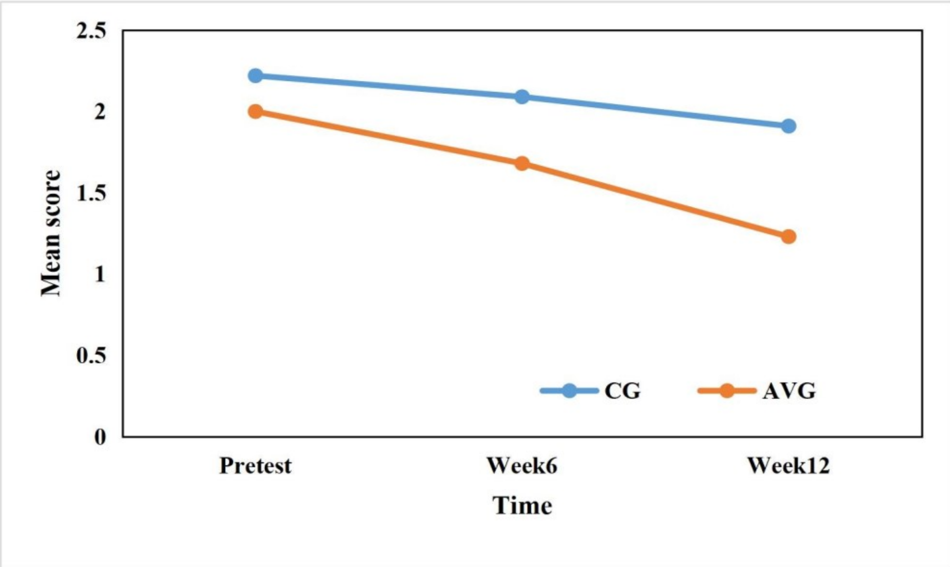

Figure 4.7 : Mean of Amotivation for AVG and CG across the Time

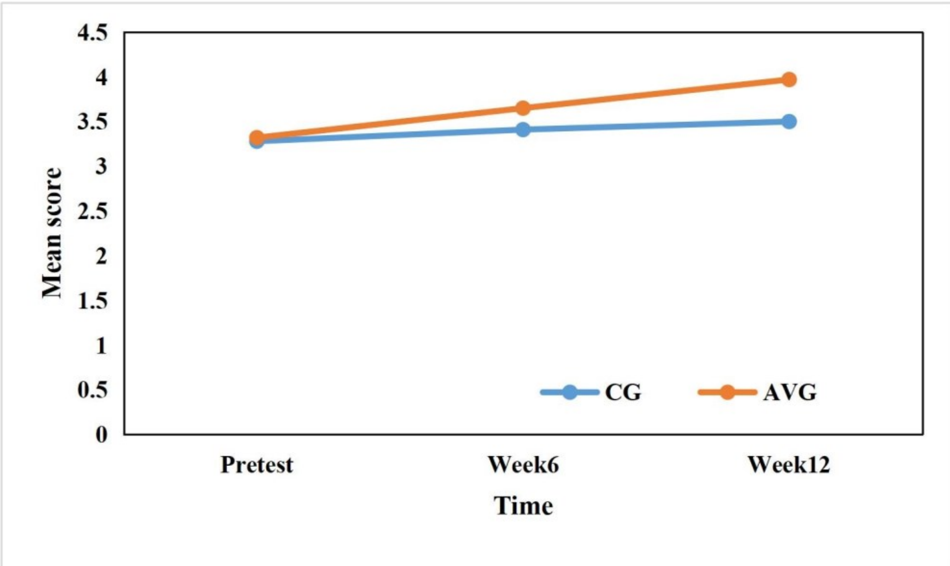

Figure 4.8 : Mean of Introjected Regulation for AVG and CG across the Time

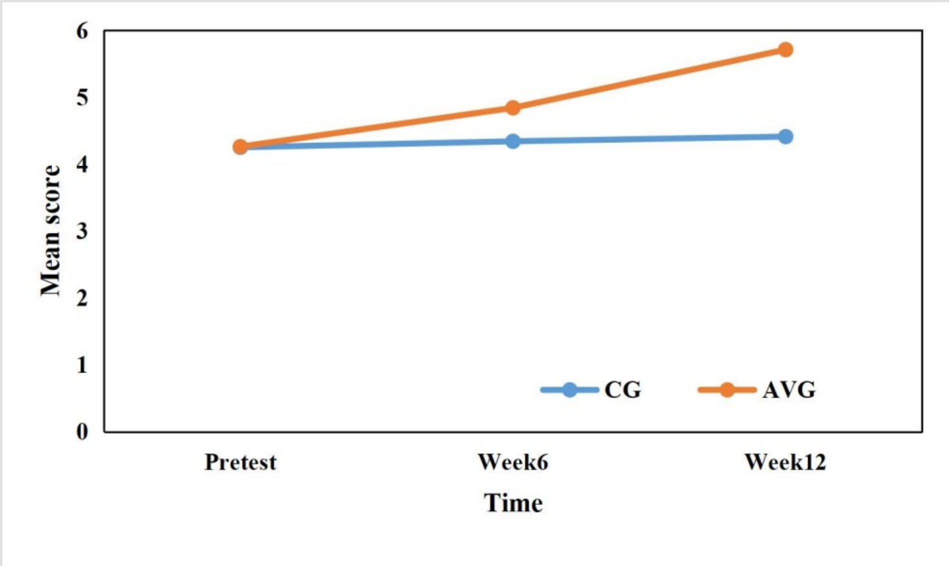

Figure 4.9 : Mean of Identified Regulation for AVG and CG across the Time

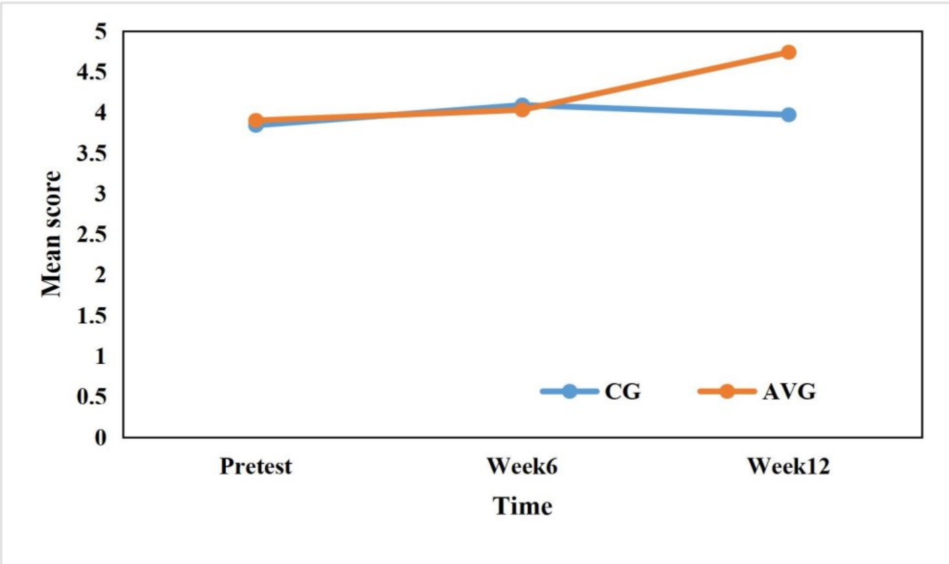

Figure 4.10 : Mean of Intrinsic Regulation for AVG and CG across the Time

4.6.4 Effect of AVG on Body Composition

The fourth objective of this study was to evaluate the impact of active video games on body composition among Chinese college students with overweight and obesity. Generalized Estimating Equations (GEE) were employed to analyse the effect of the intervention on body composition components (BMI, lean body mass, body fat percentage, and waist-to-hip ratio) across three time points (pre-test, week 6, and week 12). Table 4.16 presents the descriptive statistics, encompassing the mean and standard error, for both groups at each time point for body composition components and its four constituents (BMI, lean body mass, body fat percentage, and waist-to-hip ratio).

As depicted in Table 4.16, the control group demonstrated slight changes in BMI, lean body mass, body fat, and waist-to-hip ratio over the three time points. Conversely, the most noticeable change in the AVG group was a reduction in BMI and body fat percentage towards the conclusion of the study. The intervention group also exhibited a decrease in lean body mass and waist-to-hip ratio during the study duration. In summary, the intervention group displayed more significant changes in body composition compared to the control group.

Table 4.16 : Descriptive Statistics (Mean and SE) of Body Composition for Both Groups across the Time

Variable	Groups	Time	Mean	SE
BMI	CG	**Pre-test**	29.85	0.51
		Week6	29.82	0.46
		Week12	30.12	0.48
	AVG	**Pre-test**	29.75	0.46
		Week6	29.58	0.43
		Week12	28.20	0.43
Lean body mass	CG	**Pre-test**	60.51	1.45
		Week6	60.50	1.32
		Week12	60.55	1.38
	AVG	**Pre-test**	59.98	1.05
		Week6	59.63	0.98
		Week12	58.47	1.02
Body fat percentage	CG	**Pre-test**	33.09	0.56
		Week6	33.16	0.68
		Week12	33.60	0.52
	AVG	**Pre-test**	33.60	0.69
		Week6	32.02	0.52
		Week12	30.80	0.71
Waist-to-hip ratio	CG	**Pre-test**	0.92	0.01
	AVG	**Week6**	0.92	0.01
		Week12	0.92	0.01
		Pre-test	0.92	0.01
		Week6	0.91	0.01
		Week12	0.89	0.01

The Generalized Estimating Equations (GEE) results for body composition components (BMI, lean body mass, body fat percentage, and waist-to-hip ratio) presented in Table 4.17 indicated that the main effect of the group was not statistically significant for BMI (χ^2=1.38, p=0.239), whereas the main effect of time on BMI was statistically significant (χ^2=38.90, p<0.001), demonstrating notable variations in BMI at different time intervals. Moreover, the statistical analysis revealed a significant interaction effect between time and group (χ^2=89.81, p<0.001), indicating that the BMI levels differed significantly between the groups at different time points.

The findings for lean body mass demonstrated that the main effect of the group was not statistically significant (χ^2=0.47, p=0.491), while the main effect of time on lean body mass was statistically significant (χ^2=6.49, p=0.039). These results suggested a significant interaction effect between time and group (χ^2=7.46, p=0.024), indicating that lean body mass differed significantly between the groups at different time points.

Regarding body fat percentage, the results of the GEE analysis showed that the main effect of the group was statistically significant (χ^2=2.239, p=0.140). There were significant variations at different time intervals, as statistically evidenced for body fat percentage (χ^2=14.41, p<0.001). Furthermore, the statistical evaluation demonstrated a significant interaction effect between time and group (χ^2=31.59, p<0.001), suggesting significant differences in body fat percentage between the AVG and control groups at different time intervals.

For the waist-to-hip ratio, the main effect of the group was not statistically significant (χ^2=3.04, p=0.081). In contrast, the main effect of time on the waist-to-hip ratio was statistically significant (χ^2=18.77, p<0.001). These results indicated a significant interaction effect between time and group (χ^2=16.03, p<0.001), demonstrating significant differences in the waist-to-hip ratio between the groups at different time points.

Table 4.17 : Results of GEE for Body Composition

Variable	Source	Wald Chi-Square	df	p-value
BMI	Groups	1.386	1	0.239
	Time	38.899*	2	<0.001
	Time * Group	89.808*	2	<0.001
Lean body mass	Groups	0.474	1	0.491
	Time	6.491*	2	0.039
	Time * Group	7.456*	2	0.024
Body fat percentage	Groups	2.239	1	0.14
	Time	14.406*	2	<0.001
	Time * Group	31.59*	2	<0.001
Waist-to-hip ratio	Groups	3.035	1	0.081
	Time	18.767*	2	<0.001
	Time * Group	16.034*	2	<0.001

*: Significant at 0.05 level

Table 4.18 presents the results of the post hoc test using the Bonferroni method for between-group comparisons (AVG vs control) at three time points (pre-test, week 6, and week 12) for body composition components (BMI, lean body mass, body fat percentage, and waist-to-hip ratio). The results indicated that there were no statistically significant differences in BMI between the AVG and control groups at the pre-test ($p = 1.00$) and also at week 6 ($p = 1.00$). However, there was a significant difference in BMI between the AVG and control groups at week 12 ($p = 0.040$). The effect sizes show that at the pre-test and week 6, there was a small effect, while after 12 weeks, there was almost a large effect size ($d = 0.75$).

The results of the between-group comparison for lean body mass indicate that there was also no significant difference between the AVG and control groups at the pre-test ($p = 1.00$), week 6 ($p = 1.00$), and week 12 ($p = 1.00$), and the effect sizes demonstrate a small effect (ranging between 0.07 and 0.30).

Results of the mean comparison for the body fat percentage between the AVG and control group showed that there was no statistically significant difference between the groups at the pre-test ($p = 1.00$) and also at week 6 ($p = 1.00$). There was a significant difference in the body fat percentage between the AVG and control groups at week 12 ($p = 0.02$). The effect sizes for the pre-test ($d = 0.14$) and week 6 ($d = 0.33$) were small, while the results showed a large effect size at week 12 ($d = 0.80$).

These results for the waist-to-hip ratio indicated no significant difference between the AVG and control groups at the pre-test ($p = 1.00$) and week 6 ($p = 1.00$). However, there was a significant difference in waist-to-hip ratio between the AVG and control groups at week 12 ($p = 0.02$). The effect sizes show that at the pre-test and week 6, there was a small effect, while after 12 weeks, there was a large effect size ($d = 0.81$).

Table 4.18 : Pairwise Mean Comparison of Body Composition between AVG and CG across the Time (between Groups)

Variable	Group	Time	Mean Difference	SE	P value	95%C1 for Difference LB	95%C1 for Difference UB	Effect Sized
BMI	Pre-test	CG Vs AVG	0.10	0.69	1.00	-1.28	1.48	0.04
	Week6	CG Vs AVG	0.24	0.63	1.00	-1.09	1.57	0.10
	Week12	CG Vs AVG	1.922*	0.65	0.04	0.06	3.79	0.75
Lean body mass	Pre-test	CG Vs AVG	0.53	1.79	1.00	-3.18	4.23	0.07
	Week6	CG Vs AVG	0.87	1.65	1.00	-2.71	4.45	0.13
	Week12	CG Vs AVG	2.08	1.72	1.00	-2.27	6.44	0.30
Body fat percentage	Pre-test	CG Vs AVG	-0.51	0.89	1.00	-2.45	1.44	0.14
	Week6	CG Vs AVG	1.13	0.85	1.00	-1.09	3.36	0.33
	Week12	CG Vs AVG	2.80*	0.88	0.02	0.22	5.37	0.80
Waist-to- hip ratio	Pre-test	CG Vs AVG	0.01	0.01	1.00	-0.02	0.02	0.04
	Week6	CG Vs AVG	0.01	0.01	1.00	-0.01	0.04	0.34
	Week12	CG Vs AVG	0.03*	0.01	0.02	0.00	0.06	0.81

* The mean difference is significant at the .05 level Adjustment for multiple comparisons: Bonferroni.

The Bonferroni test was utilized to evaluate within-group comparisons. Table 4.19 illustrates the mean comparison of body composition components (BMI, lean body mass, body fat percentage, and waist-to-hip ratio) across three time points (pre-test, week 6, and week 12) in both the AVG and control groups. The table presents the mean difference, standard error (SE), p-value, 95% confidence interval (CI) for the difference, and effect size (d).

The BMI findings revealed no significant difference between the pre-test and week six (p=1.00). However, a significant reduction in BMI was observed in the AVG group from the pre-test to week 12 (p<0.001), and also from week six to week 12 (p<0.001).

The effect size of time was moderate ($d = 0.63$). Conversely, the control group results indicated no significant differences between the pre-test and week 6 ($p=1.00$), between the pre-test and week 12 ($p=1.00$), and also from week six to week 12 ($p = 0.14$). Nevertheless, the effect size in the control group demonstrated a small impact compared to the AVG group across time ($d=0.10$).

Regarding body fat percentage, no significant difference was observed in the AVG group from pre-test to week 6 ($p = 0.39$). However, there was a significant reduction in body fat percentage from the pre-test to week 12 ($p<0.001$), but not from week 6 to week 12 ($p=0.39$). The effect size of time was moderate, indicating a significant impact, with a value of $d=0.71$. In the control group, results indicated no significant changes in body fat percentage across all three-time points ($p=1.00$), which had a small effect size of $d=0.17$.

For the waist-to-hip ratio, there was no significant difference between the pre-test and week 6 ($p=0.20$). Nevertheless, a significant reduction in the waist-to-hip ratio was observed in the AVG group from the pre-test to week 12 ($p<0.001$), but no significant difference between week 6 to week 12 ($p = 0.39$). The effect size of time was approaching large ($d=0.77$). In contrast, the control group results showed no significant differences between the pre-test and week 6 ($p=0.64$), between the pre-test and week 12 ($p=1.00$), and from week 6 to week 12 ($p=1.00$) with a small effect size compared to the AVG group across time ($d=0.01$).

Table 4.19 : Pairwise Mean Comparison for Body Composition across the Time in Both Groups (within Groups)

Variable	Group	test	Mean Difference	SE	P value	LB	UB	Effect Sized
BMI	CG	Pre vs week6	0.03	0.16	1.00	-0.30	0.36	0.10
		Pre vs week12	-0.27	0.18	1.00	-0.76	0.22	
		week6 vs week12	-0.30	0.12	0.14	-0.64	0.04	
	AVG	Pre vs week6	0.17	0.19	1.00	-0.27	0.61	0.63
		Pre vs week12	1.55*	0.21	<0.001	0.95	2.16	
		week6 vs week12	1.38*	0.14	<0.001	0.97	1.79	
Lan body mass	CG	Pre vs week6	0.01	0.41	1.00	-0.80	0.82	0.01
		Pre vs week12	-0.04	0.25	1.00	-0.56	0.47	
		week6 vs week12	-0.05	0.32	1.00	-0.70	0.60	
	AVG	Pre vs week6	0.36	0.43	1.00	-0.64	1.35	0.26
		Pre vs week12	1.51	0.58	0.13	-0.18	3.21	
		week6 vs week12	1.16	0.43	0.10	-0.09	2.41	
Body-fat percentage	CG	Pre vs week6	-0.07	0.38	1.00	-0.83	0.70	0.17
		Pre vs week12	-0.51	0.20	0.15	-1.09	0.08	
		week6 vs week12	-0.44	0.42	1.00	-1.47	0.58	
	AVG	Pre vs week6	1.57	0.78	0.39	-0.59	3.74	0.71
		Pre vs week12	2.79*	0.57	<0.001	1.12	4.47	
		week6 vs week12	1.22	0.60	0.39	-0.46	2.90	
Waist-to-hip ratio	CG	Pre vs week6	0.002	0.001	0.64	-0.001	0.006	0.01
		Pre vs week12	0.000	0.002	1.00	-0.004	0.004	
		week6 vs week12	-0.002	0.002	1.00	-0.008	0.003	
	AVG	Pre vs week6	0.013	0.005	0.20	-0.003	0.027	0.77
		Pre vs week12	0.029*	0.007	<0.001	0.008	0.049	
		week6 vs week12	0.016	0.008	0.39	-0.006	0.038	

* The mean difference is significant at the .05 level. Adjustment for multiple comparisons: Bonferroni.

Based on Figure 4.11, which illustrates the mean BMI scores over time, it is evident that both groups did not exhibit any changes until week 6. However, after 12 weeks, the AVG group displayed a decrease in BMI. Figure 4.12 indicates that the mean lean body mass scores remained stable in both groups until week six, but after 12 weeks, the AVG group exhibited a decrease in lean body mass compared to the control group. Figure 4.13 illustrates a greater reduction in body fat percentage in the AVG group compared to the control group within 12 weeks. Lastly, according to Figure 4.14, the waist-to-hip ratio decreased within 12 weeks in the AVG group, while there was no change in the mean waist-to-hip ratio score in the control group.

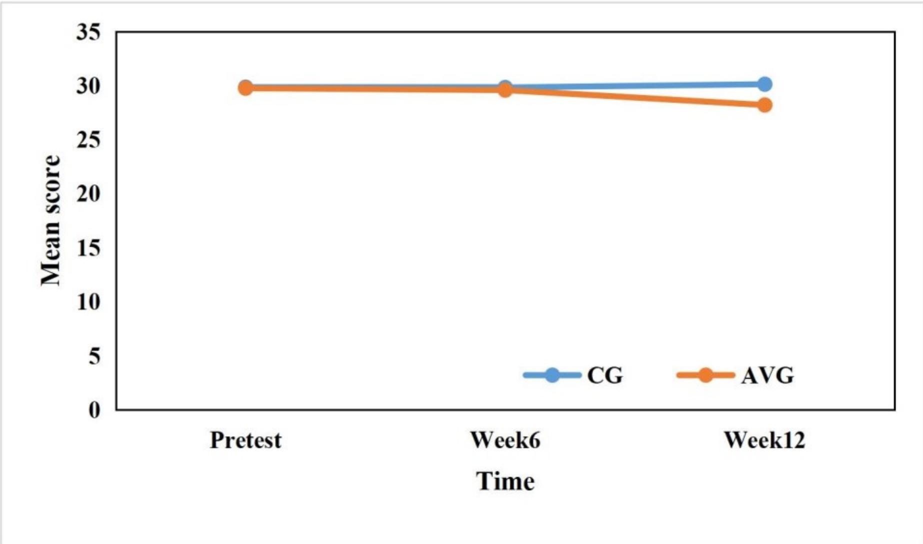

Figure 4.11 : Mean of BMI for AVG and CG across the Time

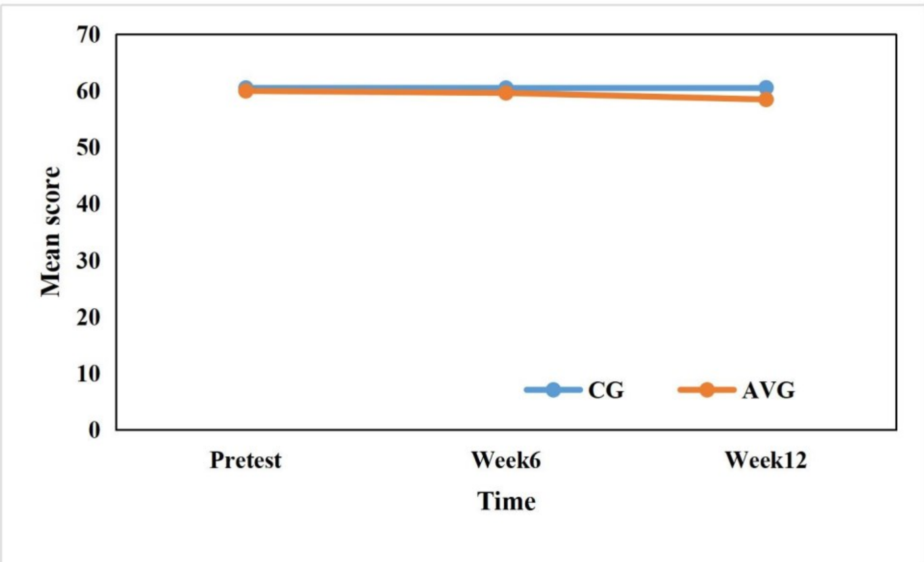

Figure 4.12 : Mean of Lean Body Mass for AVG and CG across the Time

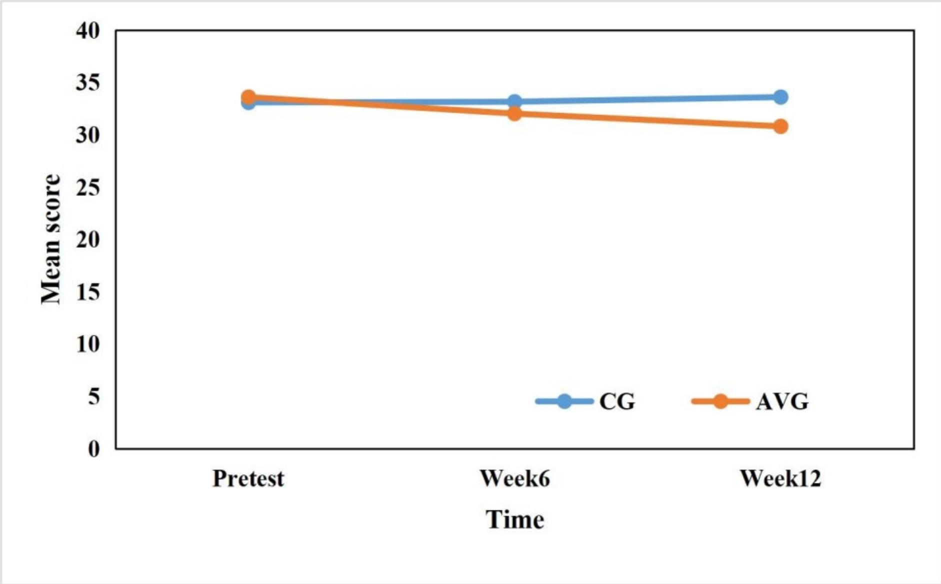

Figure 4.13 : Mean of Body Fat Percentage for AVG and CG across the Time

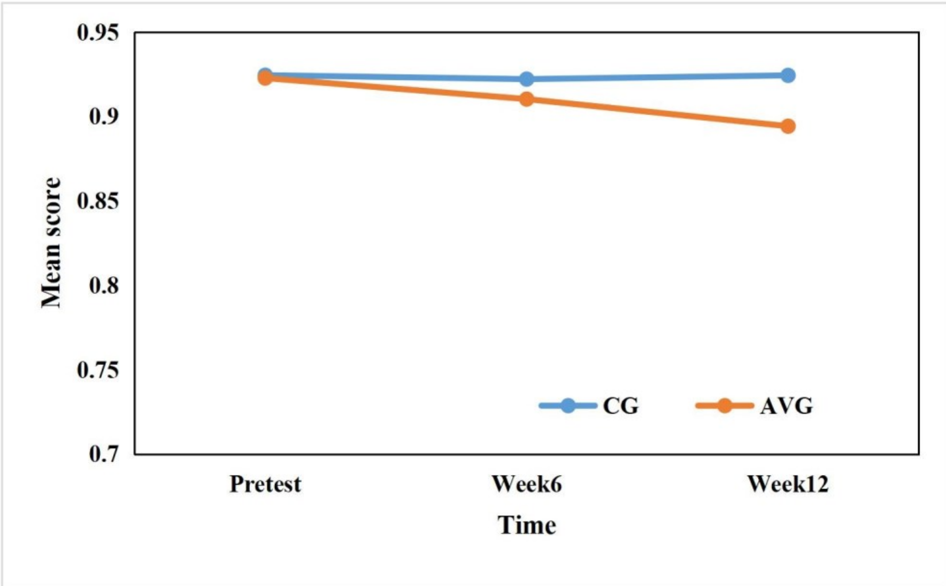

Figure 4.14 : Mean of Waist-to-Hip Ratio for AVG and VG across the Time

CHAPTER 5

DISCUSSION, CONCLUSION, IMPLICATION, AND RECOMMENDATION

5.1 Introduction

This chapter explores the impact of exercise on physical activity, psychological distress, exercise motivation, and body composition, along with conclusions, research implications, and suggestions for future research.

5.2 Discussion of the Effects of Active Video Games on Physical Activity

The results of the study indicate that six weeks of Active Video Game (AVG) training can effectively boost the physical activity levels of Chinese college students with overweight and obesity. A notable increase in physical activity was observed after 12 weeks, in contrast to the Control Group (CG), supporting the hypothesis that AVG training can improve physical activity among Chinese college students with overweight and obesity.

Influencing energy expenditure and physical well-being, physical activity plays a crucial role for college students with overweight and obesity (Herbert, 2022). This study employed pedometers to evaluate post-training physical activity, demonstrating a positive impact of active video games on the physical activity (step count) of Chinese college students with overweight and obesity. By utilizing three different game modes of Ring Fit Adventure for training, this study suggests that such training could be instrumental in elevating the physical activity levels among college students with overweight and obesity.

Prior studies focusing on college students with overweight and obesity have advocated for the integration of AVGs to advance their physical activity levels. For instance, Peng et al. (2015) used a third-person AVG based on self-determination theory to train college students over four weeks, resulting in higher moderate to vigorous physical activity (MVPA), increased MVPA duration, and greater game engagement compared to the control group. Douris et al. (2012) observed that college students with overweight and obesity engaging in Wii Fit 'Free Run' exhibited higher average maximum heart rates and Ratings of Perceived Exertion (RPE) compared to those on a treadmill, suggesting that AVGs can provide a more intense physical activity option compared to traditional moderate-intensity aerobic exercise. Similarly, Jacobs et al. (2011) conducted group training sessions using Nintendo Wii Fit with overweight and obese female college students over 12 weeks, showing a significant increase in the number of steps taken, measured by pedometers, underscoring the effectiveness of AVG in enhancing physical activity levels.

AVGs not only boost physical activity by increasing step count but also offer additional advantages, such as improved energy expenditure and heightened physical activity levels. One study noted that structured AVG training resulted in greater energy expenditure and a robust energy response after six weeks of training (De Brito-Gomes et al., 2019). Noah et al. (2011) found that adults engaging in an AVG such as Dance Dance Revolution achieved vigorous intensity physical activity levels, substantially escalating energy expenditure during gameplay. Another study by Canabrava et al. (2018) highlighted that playing AVGs like adventure, boxing, and dance on Xbox corresponded to the energy expenditure of walking at 5 km/h, providing a moderate-intensity physical activity option. Research by Comeras-Chueca et al. (2020)

compared the energy expenditure between Ring Fit Adventure and BKOOL (indoor cycling), indicating that Ring Fit Adventure could offer energy expenditure levels similar to cycling. These findings emphasize the potential of AVGs to promote energy expenditure and physical activity, particularly among overweight or obese individuals. Additionally, a review by Dutta and Pereira (2015) recommended AVGs as an alternative to sedentary or traditional games for young people.

Research evaluating oxygen uptake and RPE levels following engagements with various AVGs on Xbox One reported that these games could facilitate moderate to vigorous intensity physical activity, enabling young individuals to fulfill recommended physical activity levels (Aygün & Çakır-Atabek, 2023). The use of three game modes in Wii Fit for training sessions illustrated that aerobic exercise and strength training could lead to moderate-intensity physical activity, as assessed using Metabolic Equivalents (METs). Wii Fit was recognized as having the potential to aid college students in enhancing their physical activity levels (Grieser et al., 2012). Similarly, a study examining six sessions of AVG using Xbox 360 Kinect among college students found that AVG provided moderate to vigorous intensity physical activity based on maximum oxygen uptake, indicating that AVG could serve as a viable alternative to conventional exercise (Wu et al., 2015). Furthermore, Perron et al. (2011) determined that AVGs like Wii Fit and EA Sports Active could achieve moderate-intensity physical activity levels based on heart rate data, making them suitable for meeting physical activity guidelines. A school-based AVG intervention program spanning 12 weeks notably increased children's physical activity levels and aerobic fitness (Lau et al., 2016). A meta-analysis by Moller et al. (2023) concluded that AVGs have a positive impact on enhancing overall physical activity levels.

The effectiveness of AVGs on physical activity is influenced by the specific types of AVGs used, as different developers design games to target distinct fitness aspects. For example, utilizing aerobic exercise games in Wii Fit can simulate a treadmill experience by engaging in virtual combat and achieving moderate-intensity physical activity, thereby enhancing overall muscle strength and health. Regular use of Wii Fit for 30 minutes weekly can meet recommended weekly energy expenditure targets (Xian et al., 2014). Dance-type AVGs like Dance Dance Revolution (DDR) and Just Dance (JD) require players to follow dance moves displayed on the screen (arrows) to complete a song, focusing on lower body workouts. Maloney et al. (2012) reported a notable increase in MVPA frequency among overweight and obese children and adolescents following 12 weeks of DDR training. Similarly, 12 weeks of JD training were found to encourage overweight and obese adolescent girls to engage in exercise more frequently and raise their physical activity levels (Staiano, Beyl, et al., 2017).

Another study by Yang et al. (2014) demonstrated that using 'Your Shape Fitness Evolved' (where participants follow a virtual trainer) with sedentary college students led to improved enjoyment during training, better adherence to movements, and increased MVPA time.

The latest type of AVG, Ring Fit Adventure (RFA), is distinctive from single-type AVGs due to its unique game modes and equipment, creating diverse physical activity scenarios (Chen et al., 2023). The combination of Joy-Con and Ring-Con as advanced motion sensing devices can effectively capture and reflect the movements of college students with overweight and obesity on the game screen, fostering player engagement (Takei et al., 2024). Each game type in RFA can cater to the specific physical activities of college students with overweight and obesity. The adventure mode's engaging storyline motivates participants to achieve physical activity goals to defeat virtual monsters, while the free combination training mode offers flexibility in choosing preferred workout routines, promoting running habits. The mini-game mode provides relaxation, aiding college students with overweight and obesity in unwinding during training. By integrating these three game modes, Chinese college students with overweight and obesity naturally enhance their physical activity levels, incorporating this habit into their daily routines and boosting step counts. To date, no studies have explored the effects of AVG (RFA) training on physical activity among Chinese college students with overweight and obesity. The data from this study reiterate the efficacy of AVG training in enhancing the physical activity levels of college students with overweight and obesity, contributing to the existing body of AVG research.

5.3 Discussion of the Effects of Active Video Games on 165 Physical Activity

The primary aim of this section is to discuss the impact of active video games on psychological distress, specifically depression, anxiety, and stress, in Chinese college students with overweight and obesity in line with the second objective. The results are segmented into four subsections. These subsections compare the effects of active video game training with those of past research regarding depression, anxiety, and stress, as well as explore the overall impact of active video games on psychological distress. Additionally, this section offers potential rationales and examines how the intervention can ameliorate psychological distress in Chinese college students with overweight and obesity.

5.3.1 Effects of Active Video Game on Depression

The results of this study demonstrated that 6 to 12 weeks of AVG training are effective in improving depression in Chinese college students with overweight and obesity. A significant difference in depression among college students with overweight and obesity was observed between the Experimental Group (EG) and Control Group (CG) following 12 weeks of AVG training. This outcome supports the hypothesis that AVG training can significantly enhance depression symptoms in this population.

Negative emotions, particularly depression, play a crucial role in determining the psychological well-being of college students during their academic years, ultimately influencing their ability to positively navigate college life (Lail et al., 2021; Hossain et al., 2022). This study utilized the Depression, Anxiety, and Stress Scale (DASS-42) to assess depression levels in college students post AVG training. The findings indicated that utilizing AVG as an intervention effectively mitigated depressive symptoms in college students with overweight and obesity in China. These training modalities, incorporating various game formats, were found to be efficacious in ameliorating negative emotions.

Prior studies utilizing AVG for mental health interventions among college students have reinforced the effectiveness of this approach in alleviating depression (reference).

One study employed games from Xbox 360 Kinect for a 6-week intervention with college students, leading to a decrease in depression levels among participants in the experimental group based on DASS-21 assessments (Wan Yunus et al., 2020). Xu et al. (2021) implemented an intervention using an exergame with college students, resulting in significant reductions in depression scores after six weeks of training, with high satisfaction levels reported by most participants.

Studies conducted on various populations have provided evidence supporting the effectiveness of Active Video Games (AVG) in enhancing depression symptoms. Research indicates that children can significantly reduce depressive mood after just 30 minutes of AVG sessions, emphasizing the acute positive impact of AVG on mood (Lee et al., 2017). Additionally, community residents have shown significant improvement in depression after four weeks of Wii Fit training (Chao et al., 2015). In a study involving elderly individuals with depression, a six-week intervention with Wii games demonstrated a significant reduction in depression levels (Li et al., 2016). AVG has proven to be more effective than traditional exercises as shown in a study where weekly Wii training for six weeks increased positive emotions significantly and improved depression among community-dwelling older adults with depression (Li et al., 2018). Furthermore, Rosenberg et al. (2010) successfully enhanced the depression and cognitive abilities of elderly individuals with subsyndromal depression through a 12-week AVG (Wii sport) program. A study by Zheng et al. (2022) using Xbox 360 Kinect with dementia patients revealed a significant reduction in depressive symptoms post-training, suggesting that AVG can effectively improve the quality of life of patients with dementia. Baghaei et al. (2021) highlighted in their review that virtual reality (VR) can be an effective tool in treating depression in clinical settings as it offers fully immersive AVG experiences allowing engagement in various sports and action games in a virtual environment through a head-mounted display. Li et al. (2016) conducted a meta-analysis suggesting that AVG could be a valuable tool for healthcare professionals in treating depression effectively.

Depression, an emotional disorder leading to persistent feelings of sadness and loss of interest, is prevalent among college students with overweight and obesity (Nag et al., 2024). College students with overweight and obesity often face negative social and environmental evaluations, leading to weight-related social stigma, negative self-image, and subsequent onset or exacerbation of depression (Abdel Wahed & Hassan, 2017; Puhl & Heuer, 2009). Depression can further decrease enthusiasm for social interactions and physical activities among college students with overweight and obesity, further exacerbating isolation and obesity. This study implemented RFA to alleviate depression among college students with overweight and obesity in China, showing promising results possibly due to the following factors.

Moderate physical activity (PA) is known to significantly reduce depressive symptoms (Rebar et al., 2015). The diverse game modes of RFA utilized in this study provided ample PA for college students with overweight and obesity. PA helps alleviate depression by balancing neurotransmitters, affecting the endocrine system, and influencing brain areas responsible for emotion regulation like the hippocampus (Kandola et al., 2019; Gold, 2021). Moderate PA can also enhance sleep quality among this population, which is essential for reducing depression (Dinis & Bragança, 2018). The game mode of RFA is pivotal as the mini-games included in the training phase enable college students with overweight and obesity to find common interests, communicate with peers, and collaborate to overcome various game challenges. The social environment facilitated by AVG can aid these students in enhancing their sense of community, reducing loneliness, and subsequently alleviating depressive symptoms.

While college students, especially those who are overweight and obese, are at high risk for mental health issues, including depression (Rith-Najarian et al., 2019; Voelker, 2003), there is limited research utilizing AVG for improving depression in college students facing mental distress. The outcomes of this research further validate the utility of AVG training in ameliorating depression among college students with overweight and obesity in China, expanding the application domains of AVG for enhancing mental well-being.

5.3.2 Effects of Active Video Game on Anxiety

The study findings indicated that 6 to 12 weeks of AVG training effectively improved anxiety in Chinese college students with overweight and obesity. A significant difference in anxiety between the Experimental Group (EG) and Control Group (CG) of college students with overweight and obesity was observed after 12 weeks of AVG training. This outcome supported the hypothesis that AVG training significantly reduced anxiety levels in this demographic.

Anxiety is a prevalent concern among college students, particularly those who are overweight and obese (Wang et al., 2022). Anxiety often arises due to an imbalance between academic demands and personal life among students (Sprung & Rogers, 2021). High levels of anxiety can adversely affect the physical and mental well-being and overall quality of life of college students (Bamber & Morpeth, 2019). In this study, anxiety in college students was assessed using the DASS-42 after systematic AVG training. The results highlighted that utilizing RFA in training sessions effectively improved anxiety levels in Chinese college students with overweight and obesity, contributing to a more positive psychological state.

The study findings are consistent with prior research suggesting the efficacy of AVG in reducing anxiety among college students. For instance, undergraduate students participating in a 6-week AVG training using Kinect Sports showed a significant improvement in anxiety compared to the control group (Wan Yunus et al., 2020). Immersive AVG tools, such as Virtual Reality, have also been effective in alleviating anxiety. Interventions using VR devices like Oculus Quest resulted in notable reductions in anxiety levels among undergraduate students (Shchory et al., 2024). VR has emerged as a promising tool for managing self-anxiety in college students (Bennett & Christensen, 2024), with regular VR use aiding in anxiety reduction (Camara & Hicks, 2019; Browning et al., 2023).

Beyond college students, AVGs have demonstrated efficacy in alleviating various types of anxiety in different populations. For instance, adult women experienced reduced state anxiety after playing an AVG like Zumba Fitness once, with suggestions for long-term use to address trait anxiety (Viana et al., 2017). Older adults engaging with AVGs saw reductions in social anxiety and improvements in social competence (Xu et al., 2016). Patients with systemic lupus erythematosus participating in AVG sessions with Wii Fit reported decreased fatigue and anxiety levels (Yuen et al., 2011).

The immersive and entertaining nature of AVGs has been recognized in medical contexts as well, with AVG and VR technologies noted for effectively reducing anxiety among nursing staff (Sajeev et al., 2021). Additionally, meta-analyses confirm the positive impact of AVG training on anxiety across diverse populations (Viana et al., 2020).

Low physical activity level is associated with increased anxiety prevalence. Regular physical activity not only enhances physical health but also boosts positive emotions while reducing the risk of psychological issues like anxiety (Singh et al., 2023; Wanjau et al., 2023). This underpins the rationale for employing AVG to address anxiety among college students with overweight and obesity. The RFA incorporated in this study's training sessions enabled students to engage in at least moderate-intensity physical activity, leading to improved anxiety levels. Moreover, overweight and obese students may possess trait anxiety tendencies, which could be alleviated by participating in physical activities like RFA. The structured and progressive nature of RFA sessions ensures student engagement and completion of the program. Exercise participation has been known to reduce anxiety (Smits et al., 2008), and RFA provides a conducive environment for participation, enhancing social opportunities for students and aiding in anxiety reduction.

Previous studies have primarily overlooked college students with overweight and obesity as a specific demographic, even though they require particular attention. The study findings suggest that implementing AVG training can effectively reduce anxiety levels in this group, warranting the integration of AVG into college programs to alleviate the stress experienced by overweight and obese students in China.

5.3.3 Effects of Active Video Game on Stress

The results of this study showed that six weeks of AVG training can reduce the stress of Chinese college students with overweight and obesity. Compared with the CG, there was a significant difference in the stress levels of college students with overweight and obesity after 12 weeks of AVG training. This finding provides evidence to support the hypothesis that AVG training can significantly reduce the stress of Chinese college students with overweight and obesity.

Chinese college students often experience excessive stress due to heavy academic workloads and poor lifestyle habits (Chen et al., 2020). Excessive stress can affect eating behaviour, leading to irregular eating or overeating, which can cause overweight and obesity (Dallman, 2010). In this study, college students with overweight and obesity were trained using AVG and measured using the DASS-42. The results showed that intervention using RFA can significantly reduce the stress of Chinese college students with overweight and obesity and enable this group to achieve a more positive psychological state.

The results of current studies on the use of AVG interventions for college students support the results of this study, showing that AVG is an effective tool for relieving stress in college students. Huang et al. (2019) found that playing AVG (Your Shape Fitness Evolved) for 30 minutes can have a relaxing effect on college students. Yunus et al. (2020) found that academic tasks are a significant source of stress for college students and that a six-week training program using the Xbox 360 Kinect can help college students reduce their stress. Huang et al. (2017) conducted a two-week AVG (Your Shape: Fitness Evolved) event for college students and staff. It was found that 30 minutes of training per week for two consecutive weeks reduced stress levels and improved their sense of well-being.

AVG also plays an important role in reducing stress in other areas. Young people playing AVG can improve their endocrine system, thereby relieving stress and negative emotions (Mitsuishi & Ogi, 2022). Cutter et al. (2014) recruited methadone-maintained patients to participate in an 8-week, 5-times-per-week AVG (Wii Fit Plus) training program. After 8 weeks, the patients not only perceived stress reduction but also an improvement in optimism. A recent systematic review on the effects of AVG on emotional experience indicated that physical activity through AVG can increase positive emotions and help reduce stress (Marques et al., 2023).

Regular exercise is associated with reduced stress and improved mood (Hamer et al., 2012). The results of this study support the evidence that physical activity through RFA can have a stress-reducing effect on Chinese college students with overweight and obesity. This is closely associated with the game mode and RFA training plan. Chinese college students with overweight and obesity face heavy academic workloads and high levels of life and social stress (Guo et al., 2023). Prolonged high stress can lead to a lack of motivation and a sense of accomplishment from exercise. The adventure mode of RFA used in the AVG training process provides a good scenario for releasing stress. In the adventure mode, college students with overweight and obesity must defeat monsters and pass levels through various movements. In this process, they not only engage in physical activity but also release stress and gain a sense of relief. During the game, due to the immersive game plot of the adventure mode, college students with overweight and obesity may enter the flow state by focusing on the game content (Nakamura & Csikszentmihalyi, 2009). Individuals in the flow state are completely immersed in the current task. This high concentration level can inhibit negative self-reflection and promote an internal sense of satisfaction and accomplishment (Csikszentmihalyi, 1990; Csikszentmihalyi, 2020), thereby reducing stress. RFA also provides college students with overweight and obesity with an alternative to traditional sports. They do not need to study too much to quickly master the game method (motor skills), and they can make new friends through sports and gain a sense of accomplishment, thereby reducing stress.

Although college students, especially college students with overweight and obesity, are under a lot of pressure, there has been little research on the use of AVG to address this situation. The results of this study further expand on previous research findings, demonstrating that AVG not only relieves stress in college students but also has a significant stress-reducing effect on college students with overweight and obesity. When college students with overweight and obesity are reluctant to participate in traditional sports or need to release stress, using AVG is a wise choice.

5.3.4 Effects of Active Video Games on Psychological Distress

The results of this study showed that AVG training lasting 6 to 12 weeks was effective in improving the psychological distress of Chinese college students with overweight and obesity. There was no significant change in the psychological distress of the CG at any time point. Compared with the CG, there was a substantial difference in the psychological distress of Chinese college students with overweight and obesity after 12 weeks of AVG training. This finding provides evidence to support the hypothesis that AVG training can significantly improve the psychological distress of Chinese college students with overweight and obesity.

College students, particularly college students with overweight and obesity, are more likely to suffer from psychological distress than the general population (Nho & Chae, 2021; Nerdrum et al., 2006). These psychological distresses include adverse emotional states such as depression, anxiety, stress, and low self-esteem. The causes of these psychological problems are often related to food addiction and lack of exercise (Luo et al., 2022). This study used the total score of the DASS-42 to assess the overall psychological distress of Chinese college students after 12 weeks of training using AVG. The results showed that the overall psychological distress of Chinese college students with overweight and obesity was significantly improved through systematic training with RFA.

Current research on AVG intervention for the mental health of college students involves various aspects of psychology. In addition to its ameliorative effects on depression, anxiety, and stress, AVG can also improve psychological distress by regulating emotions and increasing happiness. Russell & Newton (2008) found that compared to sedentary behaviour, college students who only played AVG (bike games) for 30 minutes could improve positive mood, meaning that AVG can bring direct emotional benefits and achieve good results in the short-term impact on mood. Nguyen et al. (2018) found that college students playing AVG regularly can maintain a sense of happiness through two weeks of Xbox 360 game training. This situation is even more effective for college students who want to control their weight. Nani et al. (2019) used Nintendo Wii Sports for the intervention. After training three times a week for 10 weeks, the students significantly improved their subjective vitality and felt more hopeful about life. Yu et al. (2023) found that college students improved their overall mental health after 12 weeks of training (30 minutes three times a week). Overall, AVG has a special role in increasing positive emotions and enhancing well-being. It can be used to indirectly improve psychological distress in college students.

The benefits of AVG on mental health have also been confirmed in studies of other groups. Both young and middle-aged people, after five weeks of training (three times a week for 45 minutes) using three Kinect-based AVGs, felt happier while playing AVGs, and as a result, their mental health and subjective well-being improved significantly (Hastürk & Akyıldız Munusturlar, 2022). AVGs are also often used to improve the poor psychological state of the elderly. Compared to traditional exercise, older adults had significantly higher levels of enjoyment and were happier during a six-week AVG training programme (Li et al., 2017). Older adults with mental illness can effectively improve their depression and negative symptoms after 10 weeks (three times a week for 50 minutes) of AVG activities (Heinbach et al., 2021). A systematic review stated that AVG is a safe and cost-effective tool for improving psychological distress. AVG can provide mental health treatment for adults and improve psychological distress (Byrne & Kim, 2019). Other systematic reviews also expressed the same view, that AVG can not only increase physical activity but also improve the healthy psychology (self-esteem) of children and adolescents (Santos et al., 2021).

Psychological distress is a chronic problem affecting the mental health of college students (Sharp & Theiler, 2018). This study assessed psychological distress by depression, stress, and anxiety scores. Overall, compared to the CG, the EG showed significant improvements in depression, anxiety, and stress after 12 weeks of training. This is consistent with the overall improvement in psychological distress. The reduction of negative thinking and the increase of positive emotions are the keys to improving the psychological distress of college students with overweight and obesity in China. The possible reasons are as follows.

First, Chinese college students with overweight and obesity are usually accompanied by three different degrees of negative emotions: depression, anxiety, and stress (Fan & Che, 2023). They often do not participate in traditional sports regularly and avoid socialising (Chen et al., 2020). RFA provides them with regular physical activity. Adequate physical activity enhances their sense of movement, promotes the secretion of dopamine in the body, and helps reduce anxiety and depression (Ruiz-Tejada et al., 2022). Second, RFA's Adventure Mode has a very coherent gameplay storyline and a range of difficulty levels, making it possible for college students to give their full attention to each campaign. Twelve consecutive weeks of training allowed them to complete all the storyline missions. Their self-efficacy, self-esteem, and optimism were enhanced by defeating the game's monsters in each scenario. These positive mental states can reduce psychological distress (Winefield et al., 2012). Finally, in other game modes of the RFA, college students with overweight and obesity can communicate and cooperate to earn game medals or coins by completing various mini-games, which provides them with a social environment and helps establish more social connections. Good social connections can reduce isolation and psychological burden (Holt-Lunstad, 2021). In conclusion, AVG is an effective strategy to improve psychological distress among college students with overweight and obesity in China.

5.4 Discussion of the Effects of Active Video Games on Exercise Motivation

The main objective of this section is to discuss the impact of active video games on the five components of exercise motivation in Chinese college students with overweight and obesity in the context of the third objective. The results are divided into five subsections, which compare active video game training with previous research on exercise motivation. The impact of active video games on different types of exercise motivation is discussed to better illustrate the overall effect of active video games on exercise motivation. In addition, this section provides potential reasons and discusses how the intervention can affect the improvement of exercise motivation in Chinese college students with overweight and obesity.

5.4.1 Effects of Active Video Games on External Regulation

Current results show that EG training at both 6 and 12 weeks can reduce external regulation in Chinese college students with overweight and obesity. CG training at any time has no significant effect on this variable. However, compared with CG, 12 weeks of training does not significantly reduce external regulation in EG. This finding provides evidence that AVG intervention does not significantly reduce external regulation in Chinese college students with overweight and obesity.

Higher exercise motivation among college students can predict more physical activity, and physical activity can stimulate and improve self-efficacy, promoting physical and mental health (Li et al., 2024). Understanding the changes in the type of motivation among college students after active video game training can more intuitively reflect the effect of AVG on exercise motivation. In this study, the exercise motivation of college students with overweight and obesity in China was assessed using the BREQ-2 after 12 weeks of AVG training, and it was found that AVG training did not significantly reduce external regulation in this group.

It is worth noting that there are various types of motivation. This study is based on the classification of motivation according to self-determination theory and combined with a dedicated measurement tool, allowing for a more accurate assessment of changes in specific motivation types. According to self-determination theory, an individual's motivation is mainly judged by the degree of self-determination. Motivation can be ranked from high to low as intrinsic, extrinsic, and motivation (Deci & Ryan, 2013). Extrinsic motivation can be further subdivided based on the degree to which individuals internalise these external motivations. They are mainly divided into integrated regulation, identified regulation, introjected regulation, and external regulation. External regulation is the lowest level of regulation in extrinsic motivation, where individuals exercise entirely due to external rewards or punishments (Vlachopoulos & Karageorghis, 2007).

Few studies have directly explored the impact of AVG on external regulation. Peng et al. (2012) used an internally developed AVG that can meet the three basic needs of people (competence, autonomy, and relatedness) in SDT. After the intervention, it was found that AVG can improve college students' enjoyment of exercise and motivation to play in the future. Zhao et al. (2022) combined SDT with an active video game intervention, in which older adults completed three phases of training over 12 weeks (50–55 minutes each) with step-by-step guidance from the researchers. AVG can increase older adults' exercise motivation even with less external monitoring. Although these two studies did not directly measure participants' external regulation, they both suggest that participants have sufficient intrinsic motivation to train with AVG without much supervision. One study assessed college students' external regulation after a 4-week intervention using VR games. The results showed that VR games can reduce college students' external regulation, but there was no significant difference compared to the control group (Liu, 2021). Our findings are similar to this study. That is, although AVG can reduce external regulation, it does not seem to be the best way to reduce external regulation.

Although there was no significant difference between EG and CG in terms of changes in external regulation, this phenomenon can be better explained by combining the different training components of EG and CG. On the one hand, assessments from before the intervention found relatively low levels of external regulation in extrinsic motivation at the beginning of both EG and CG. That is, external regulation may not initially be a major driver of exercise behaviour among college students with overweight and obesity in China, and thus there is limited scope for further reductions to reach significant levels. On the other hand, RFA is new to Chinese college students with overweight and obesity in terms of game content. Playing video games helps improve emotion regulation (Villani et al., 2018). Participating in game training to gain pleasure led to a decrease in external regulation of EG after training. However, CG wore a pedometer throughout the trial. It may have prompted the CG to increase physical activity through self-monitoring. Self-monitoring can increase physical activity (Kanejima et al., 2019). This was verified by the fact that CG showed an upward trend in the number of steps during the trial. CG's external regulation was also decreased, causing no significant difference between EG and CG at the end of training. Overall, AVG may help college students with overweight and obesity reduce external regulation in extrinsic motivation, but it is also important to consider the influence of other motivational interventions (e.g., step count monitoring).

5.4.2 Effects of Active Video Game on Amotivation

The results of this study showed that EG could reduce amotivation after six weeks of AVG training. In addition, after 12 weeks, there was a significant difference in amotivation between EG and CG. This finding provides evidence to support the hypothesis that AVG practice can significantly reduce the amotivation of Chinese college students with overweight and obesity.

In SDT, amotivation refers to the state in which an individual lacks the intention or desire to engage in a particular behaviour (Perlman, 2015). This happens because the individual may not value the activity, not believe it will lead to the desired outcome, or not feel capable of performing the activity themselves. It is common for college students to lack motivation to engage in physical education (Shen et al., 2010). College students with overweight and obesity chronically experience amotivation, which is very detrimental to their physical activity and physical and mental health. This study measured the changes in amotivation of Chinese college students with overweight and obesity after 12 weeks of AVG training using the BREQ-2. The results showed that AVG training can significantly reduce the amotivation of Chinese college students with overweight and obesity and promote physical activity.

There is limited research on the use of AVG training to target amotivation in college students, but the impact on amotivation can be inferred by observing changes in attendance and game participation. Pasco et al. (2017) conducted a 15-minute test with undergraduate students using an AVG like a fitness bike. The results found that the overall interest, immediate enjoyment, and exploratory intention of college students participating in AVGs were higher and that AVGs can promote physical activity in college students by enhancing situational interest. Although the intervention period in this study was relatively short, the acute effects of AVG can generate sufficient interest and enjoyment in college students, transforming amotivation into other forms of motivation. Peng et al. (2015) used an adventure-based AVG with SDT features to conduct a 5-week intervention with college students. The study found that college students who played AVG with SDT features had higher game engagement, game time, game enjoyment, attendance, and psychological need satisfaction. These characteristics resulted in more MVPA. Kimhy et al. (2016) conducted a 12-week AVG (Xbox 360) intervention with physically inactive clinical patients (schizophrenic patients). The results showed that the patients who played AVG had the highest completion rate and attendance and enjoyed it to a greater extent. Higher participation and engagement led to lower amotivation.

The present study used RFA as an intervention to significantly reduce the amotivation of college students with overweight and obesity in China, and the emergence of this result can be explained by combining the basic needs described in SDT with the AVG (RFA) chosen in this study (Wang et al., 2019). First, the different game modes of RFA can satisfy the three basic human needs in SDT. Adventure mode provides explicit feedback, challenges, and rewards (achievement markers and breakthrough records) for college students who complete tasks, which helps participants gain competence and satisfaction over time. Competence and satisfaction can increase motivation (Xi & Hamari, 2019). Secondly, in the training combination model, one can develop their own exclusive sport. When college students' need for autonomy is satisfied, they are more likely to internalise the reasons for their behaviour, thus reducing lack of motivation (Gagne, 2003). Finally, the mini-game mode provides college students the opportunity to share their progress with friends and compete on leaderboards. More socialisation fosters their sense of connectedness and social support. When college students with overweight and obesity' need for relatedness is met, it helps reduce feelings of isolation or apathy, which increases motivation (Van Roy & Zaman, 2019). Overall, AVG (RFA) reduces amotivation and promotes physical activity in college students, and it is recommended that the use of AVG be increased in college classrooms to promote motivation in students.

5.4.3 Effects of Active Video Games on Introjected Regulation

Based on the current data, the results indicate that the introjected regulation of EG was significantly improved after 12 weeks. However, there was no significant difference in introjected regulation between the two groups after 12 weeks of active video game training. This finding provides corresponding evidence: the AVG intervention did not significantly improve the introjected regulation of college students with overweight and obesity in China.

In SDT, introjected regulation is a type of extrinsic motivation, where individuals engage in behaviour to avoid guilt or anxiety or to enhance self-worth (Ryan & Patrick, 2009). This behaviour is somewhat internalised but not entirely autonomous, as it is driven by internal pressure rather than genuine enjoyment or value (Linley & Joseph, 2004). In terms of physical activity, this may mean exercising to meet expectations or avoid feelings of shame. This study assessed changes in introjected regulation using the BREQ-2 after 12 weeks of AVG training, and AVG did not significantly change the introjected regulation of Chinese college students with overweight and obesity.

The effect of AVG on introjected regulation can be understood from another perspective through its improvement of sedentary behaviour and its impact on physical activity compliance. Yang et al. (2014) found that college students with sedentary habits spent more time in MVPA and enjoyed playing AVG after participating in two Xbox Kinect games. In other words, AVG can transform the exercise motivation of sedentary college students. Bock et al. (2015) evaluated the physical activity and fitness results of adults after playing Wii Heart Fitness for 12 weeks and measured motivation using the BREQ-2. They found that AVG stimulated participants' enthusiasm by presenting physical activity as a game, enhancing intrinsic motivation to play. As a result, the AVG group spent more time in MVPA (attendance mediated). This is similar to the results of the current study, which showed that AVG can promote physical activity. However, the difference in this study is that college students' introjected regulation (internal pressure) also increased during the intervention period.

In general, introjected regulation is less internalised than fully internalised motivation (e.g., intrinsic regulation). However, an increase in introjected regulation may imply that individuals are beginning to internalise external motivation to some extent (Deci et al., 1994). Several factors may explain the increased but not significant differences in introjected regulation found in both EG and CG in the present study. Firstly, RFA focuses on immediate rewards and structured gameplay, which may increase motivation by elevating internal pressures (e.g., guilt or feelings of self-worth) to some extent (Deckers, 2018). Physical activity also increases in CG, where social comparison or tracking tools (e.g., pedometers) can motivate users to keep up with or surpass others or meet their own predetermined physical activity standards, which may similarly increase introjected regulation. Secondly, the rise in introjected regulation may be closely related to the emphasis on rule-following and social expectations in traditional Chinese culture (Yin, 2003). The combination of the game's incentives and the normativity in traditional culture when using AVG for exercise may have prompted students to be more actively involved, thus facilitating an increase in introjected regulation.

The use of AVG for exercise with Chinese college students with overweight and obesity does not entirely avoid the presence of endogenous stress. Timely care should be given when using AVG to intervene with college students to alleviate the internal stress caused by the need to follow rules and to fully realise the potential of AVG.

5.4.4 Effects of Active Video Games on Identified Regulation

Current results showed that 6 to 12 weeks of active video game training could help EG increase identified regulation. In contrast, CG did not show significant changes in identified regulation at any time. In addition, there was a significant difference in identified regulation between EG and CG after 12 weeks. This finding provides evidence to support the hypothesis that active video game training can significantly improve the identified regulation of Chinese college students with overweight and obesity.

Identified regulation is an internalised form of extrinsic motivation, where individuals perceive a behaviour as essential and worthwhile and choose to engage in it (Deci & Ryan, 2012). Although the motivation comes from an external source (e.g. health, weight management), individuals recognise that these behaviours are consistent with their values or goals. College students with overweight and obesity often have a low sense of identity with physical activity, do not think they should be involved in sports, and do not agree with the benefits of physical exercise (Lopez, 2016). Changing their identified regulation is key to addressing this problem. After 12 weeks of AVG training, college students with overweight and obesity in China were found to have significantly improved identified regulation as measured by BREQ-2.

Previous studies have also confirmed the role of AVG in improving the identified regulation of college students. For example, some studies used AVG (virtual reality exercise game) to train college students for four weeks. After the experiment, it was found that AVG not only improved the physical activity of college students but also significantly improved their identified regulation (Liu, 2021). Physical activity interventions based on self-determination theory suggest that better-identified regulation and intrinsic regulation (higher levels of self-determination) can better promote continuous physical activity (Teixeira et al., 2012). This supports the results of this study, which state that an increase in identified regulation promotes more physical activity. Soltani et al. (2021) evaluated the acute response of healthy college students playing AVG and their intention to participate in PA in the future. It was found that the novel game elements and entertaining features of AVGs increased college students' intention to engage in PA in the future. Zhao et al.'s (2024) systematic review on AVGs for physical activity in college students with overweight and obesity supports the results of this study, stating that AVGs can increase the motivation of college students with overweight and obesity to exercise and make them more willing to exercise.

AVGs have also been shown to improve exercise motivation in studies with other populations. Glen et al. (2017) found that adults who participated in an AVG game reported feeling good, enjoying themselves more, and experiencing a greater sense of accomplishment despite exercising at a higher intensity. AVGs can help adults improve their exercise motivation. In addition, Meekes & Stanmore (2017) pointed out that after six weeks of AVG-assisted training, older adults were more motivated to participate in AVG because they found it fun and felt that their health had improved.

Students' motivation to participate in physical activity varies (Furia et al., 2009). However, when college students perceive that their regulation has improved, that they approve of the physical activity they are engaged in, and that they feel the benefits of physical activity, they are more inclined to continue participating (Samendinger & Hill, 2021). Chinese college students with overweight and obesity showed significant improvements in their identified regulation after RFA training, indicating that they gradually came to recognise the benefits of exercise and the value of AVG. There are three possible reasons for this result.

First, RFA differs from other AVGs that directly engage in exercise training. This game requires the creation of a virtual character, whose level continuously improves during subsequent training sessions. Various player-preferred equipment and accessories are purchased for the virtual character. College students with overweight and obesity will have a stronger sense of identification during the game and will be more willing to exercise with their virtual partners. Therefore, college students will gradually identify with the AVG training method and increase their motivation to participate in physical activity. Recent retrospective studies have found that virtual characters in games can affect people's motivation during exercise, and enjoyment and other factors confirm this view (Mouatt et al., 2020). Second, positive feedback is an effective strategy for promoting physical activity (Mouratidis et al., 2008). The adventure mode of RFA gives rewards and badges after defeating monsters and displays the energy consumption at the end of each session. This game feedback mechanism enables college students with overweight and obesity to see their progress and the benefits of exercise more intuitively, enhancing their sense of identity with fitness. Third, college students with overweight and obesity continuously improve their physical function during repeated AVG training. This training process effectively links AVG with exercise and personal goals (such as weight loss and health). This continuously internalises external motivation, thereby enhancing identified regulation. It is recommended that college students who lack interest in traditional sports use AVG (RFA) to increase their sense of identification with physical activity.

5.4.5 Effects of Active Video Games on Intrinsic Regulation

The current experimental results show that 6 to 12 weeks of active video game training can help EG increase intrinsic regulation. At the same time, there was no significant change in CG's intrinsic regulation during the 12-week training period. In addition, a significant difference in intrinsic regulation between EG and CG was found after 12 weeks of training. This finding provides evidence to support the hypothesis that active video game training can significantly improve the intrinsic regulation of college students with overweight and obesity in China.

Intrinsic regulation refers to an individual's participation in an activity because of their interest, enjoyment, or sense of satisfaction in the activity itself. Here, motivation comes entirely from the intrinsic value of the activity, rather than external factors or pressure (Ryan & Deci, 2020). In SDT, intrinsic motivation is considered the most desirable form of motivation because it is closely related to an individual's psychological satisfaction (Walker et al., 2020). Using the BREQ-2 to test the effect of 12 weeks of AVG training on Chinese college students with overweight and obesity, it was found that AVG training can significantly improve their intrinsic regulation.

AVG has been validated as a tool to improve the exercise motivation of college students. For example, Hwang et al. (2023) showed that using Xbox One Kinect can improve intrinsic motivation and psychological satisfaction in college students in the short and long term compared to traditional aerobic exercise. Intrinsic motivations, enjoyment, and happiness are crucial to long-term engagement (Waterman et al., 2008). Huang et al. (2019) found that a two-week AVG intervention can improve college students' happiness and perceived energy, so AVG can be used to encourage positive attitudes and behaviours towards exercise. Nguyen et al. (2016) had college students play AVG for 12 weeks and found that AVG can improve college students' attitudes and intentions towards other sports. Another study by Nguyen et al. (2016) found that AVG can maintain happiness, which is more prominent for college students who want to maintain their weight. This also shows that when college students play AVG, maintaining happiness is conducive to transforming external and internal motivation. Rhodes et al. (2009) found that using stationary bicycles combined with AVG can improve exercise adherence and increase college students' exercise participation and attitudes.

The ability of AVG to improve exercise motivation has been demonstrated in other groups. One study that put children with chronic ankle instability through a 4-week home AVG training programme found that AVG not only improved balance, but also increased intrinsic motivation through increased interest and enjoyment (Chuadthong et al., 2023). Ramírez-Granizo et al.'s (2020) systematic review indicated that children and adolescents can improve their health and exercise motivation when using AVG. A meta-analysis by Andrade et al. (2019) expressed the same view that participating in AVG can improve self-esteem and self-efficacy and generate greater intrinsic motivation for children and adolescents. These studies further verify that AVG can be used as a potential tool to improve exercise motivation.

Focusing on changes in intrinsic regulation is the most effective way to assess the impact of AVG on the exercise motivation of college students with overweight and obesity. When intrinsic regulation significantly improves, college students' attitudes towards exercise change from within, and they begin to enjoy physical activities (Lauderdale et al., 2015). The game mode of RFA and the training method used in this study are key to the significant improvement in intrinsic regulation. First, in terms of the game content of RFA, the adventure mode involves facing different game monsters in each chapter, ensuring the richness of the training content each time (Jiang & Tham, 2022).

College students with overweight and obesity experience fun and enjoyment while playing AVG. Enjoying AVG can increase physical activity and exercise motivation (Gu et al., 2023; Garn et al., 2012). Second, different game modes require unique exercise skills to obtain rewards. College students may feel satisfied by the challenge and sense of achievement the game offers, which in turn enhances intrinsic regulation.

Finally, regarding training methods, this research plan is divided into three stages. New game modes are introduced at each stage so that college students can always maintain enthusiasm and anticipation for AVG training. Each AVG training phase includes setting new challenges and goals based on the game content, encouraging college students to constantly surpass themselves and enhancing their sense of competence. Competence promotes intrinsic motivation (Elliot et al., 2000). This integrated experience allows college students to engage in physical activity not just for external rewards, but because they truly enjoy the process. Overall, RFA, as the newest AVG, can safely and efficiently increase exercise motivation in college students with overweight and obesity.

5.5 Discussion of the Effects of Active Video Games on Body

The main objective of this section is to discuss the effects of active video games on the four components of body composition in Chinese college students with overweight and obesity, in line with the fourth objective. The results are divided into four subsections, comparing the effects of active video game training on body composition with findings from other studies involving physical activity. The impact of active video games on body mass index, body fat percentage, lean body mass, and waist-to-hip ratio in Chinese college students with overweight and obesity is examined in detail. Additionally, this section explains the research results in connection with the specific features of the game and outlines how active video games (RFA) influence the body composition of Chinese college students with overweight and obesity.

5.5.1 Effects of Active Video Games on Body Mass Index

This study showed that 6 to 12 weeks of active video game training can help EG reduce BMI, while CG did not show significant changes in BMI throughout the 12-week trial period. In addition, compared with CG, there was a significant difference in BMI in EG after the 12th week. This finding provides evidence to support the hypothesis that AVG training can significantly improve the BMI of Chinese college students with overweight and obesity.

The harm of overweight and obesity to college students is closely related to BMI. A high BMI usually indicates higher health risks, such as metabolic diseases and mental health problems (Oluwasanu et al., 2023; Mu et al., 2021). This study evaluated the changes in BMI of Chinese college students with overweight and obesity after AVG training. The results showed that training with AVG (RFA) can effectively reduce the BMI of Chinese college students with overweight and obesity.

Currently, the results of studies attempting to use AVG to control college students' weight are inconsistent. One study had female college students train on the Xbox 360 for six weeks with Just Dance 4, and the results showed no significant change in the BMI of the participants (Roopchand-Martin et al., 2015). Another study conducted a 10-week Wii Sports intervention and found that although playing AVG led to a decrease in the BMI of the experimental group, there was no significant difference compared to the control group (Nani et al., 2019). However, Jacobs et al. (2011) found that overweight and obese female college students experienced a significant reduction in weight and BMI after 12 weeks of Wii Fit intervention. Reviewing these studies suggests that differences in participants' original weight and the types of AVG games used may be the most important factors influencing BMI outcomes.

AVG has also been shown to yield excellent results in terms of weight control in children and adolescents. Christison and Khan (2012) found that AVG can be an effective weight management intervention for overweight or obese children in the community, significantly reducing BMI. Similarly, Trost et al. (2014) asked overweight and obese children to participate in an AVG training programme using an Xbox game for 16 weeks. After the intervention, the children's physical activity significantly increased, and their BMI z score decreased. Staiano et al. (2013) studied overweight and obese adolescents who participated in different modes of Wii Active game training after school. The results showed that cooperative participation in AVG training can significantly reduce their weight. The study concluded that AVG is a promising tool for combating adolescent obesity. A systematic review by Valeriani et al. (2021) stated that AVG training can have a positive effect on weight-related outcomes for overweight and obese children and adolescents.

Increasing physical activity (PA) can effectively control the weight of college students with overweight and obesity, thereby improving BMI (Mustelin et al., 2009). The significant reduction in BMI in this study may be due to several factors. First, the basal metabolic rate of obese individuals is generally higher (Merghani et al., 2015), making them more likely to lose weight when they start exercising. College students with overweight and Obesity tend to burn more energy when performing moderate-to-vigorous physical activity (MVPA) due to their higher body fat, which can lead to a more significant reduction in BMI. Second, as young people, college students are generally highly interested in games. Exercising through AVG can shift their focus from simply exercising to enjoying the game, reducing feelings of fatigue and boredom (Lyons et al., 2014). More active engagement in exercise increases physical activity levels and calorie consumption, ultimately improving BMI. Third, RFA provides a variety of exercise forms through multiple game modes, such as running, squats, and push-ups (Tuan et al., 2024). These different modes simulate various exercise scenarios, offering well-rounded training that can provide sufficient PA over a long training cycle, making it more effective in improving BMI. As the latest AVG, RFA can be implemented in universities to help control the weight of college students with overweight and obesity.

5.5.2 Effects of Active Video Games on Body Fat Percentage

According to the current experimental data, a 12-week active video game intervention can help EG reduce body fat percentage. There was no significant change in CG body fat percentage over 12 weeks. Regarding the group differences between EG and CG, there was a significant difference in body fat percentage after 12 weeks of AVG training among college students with overweight and obesity. This finding provides evidence to support the hypothesis that AVG training can significantly reduce body fat percentage among Chinese college students with overweight and obesity.

The generally high body fat percentage of college students with overweight and obesity poses various health risks (Zaccagni et al., 2014). Excess body fat affects appearance and has long-term adverse effects on health (Kim et al., 2013). This study used bioelectrical impedance analysis devices to assess the body fat percentage of Chinese college students with overweight and obesity. The results showed that intervention using AVG can effectively reduce the body fat percentage of Chinese college students with overweight and obesity.

In a study with college students, Huang et al. (2017) had students do AVG training for 12 weeks. The results showed that AVG can improve physical fitness (upper limb muscle strength, abdominal muscle strength, etc.), but body fat percentage increased. Roopchand-Martin et al. (2015) showed that six weeks of Xbox 360 training did not improve body fat percentage in female college students. It is worth noting that the participants in these two studies were not all college students with overweight and obesity, which differs from the population in this study. The differences in body fat percentage among the participants may have led to different results.

For children and adolescents, Maddison et al. (2011) evaluated the effect of long-term (six months) use of AVG on body composition in overweight and obese children. They found that body fat percentage was reduced after 12 weeks, and body fat percentage was significantly reduced after the intervention. AVG has a clear effect on body composition in overweight and obese children. Staiano et al. (2017) had overweight and obese female adolescents use Xbox to play dance games. After 12 weeks of intervention, these girls had significantly lower body fat and higher bone mineral density. Adamo et al. (2010) found that overweight or obese adolescents who participated in AVG training on a stationary bike twice a week for 60 minutes for ten weeks had a lower body fat percentage. Gao & Zeng's (2016) systematic review stated that AVG has proven benefits for physical activity, and long-term use of AVG is feasible for promoting weight loss in overweight and obese children and adolescents.

The summary of findings suggests that using AVG to improve body composition (body fat percentage) seems to be more effective in overweight and obese groups.

AVG has been introduced into communities and families to promote PA, prevent obesity, and assist with rehabilitation training (Maillot et al., 2012; Zeng et al., 2017). The results of this study demonstrate that AVG (RFA) is an effective way to address the high body fat percentage of college students. The following reasons may account for the positive results.

RFA can improve fat distribution and enhance metabolic health through whole-body functional exercise. The movements in this game involve compound exercises that engage multiple large muscle groups, such as pushing, pulling, and squatting. These exercises effectively activate the core muscle group and coordinate full-body movements, thereby increasing overall energy expenditure (Yoshioka et al., 2001). Consistent participation in physical activity enhances the metabolic capacity of college students, resulting in significant reductions in body fat accumulation, especially visceral fat, which has notable health benefits (Goris & Westerterp, 2008; Després, 2001). Additionally, this recreational mode of exercise reduces psychological stress and anxiety, indirectly ameliorating stress-induced fat storage problems (Epel et al., 2000). Thus, RFA not only reduces body fat through direct physical training but also contributes to lowering body fat percentage on multiple levels by improving psychological well-being and encouraging long-term adherence to exercise. Furthermore, in this study, college students were asked to use an app to record their daily dietary status and report it during weekly training. Such measures may help college students develop sensible dietary habits, which may also influence body fat percentage. Given the role of AVG (RFA) in reducing body fat percentage, AVG could be implemented in college or home settings to improve the health of college students with overweight and obesity in China.

5.5.3 Effects of Active Video Games on Lean Body Mass

According to the current experimental results, 12 weeks of active video game training did not improve the lean body mass of EG and CG. In addition, there was no significant difference in lean body mass between EG and CG during the 12-week training period. This finding provides evidence that the AVG intervention did not significantly increase the lean body mass of overweight and obese Chinese college students.

Lean body mass is crucial for college students with overweight and obesity because it not only affects the body's metabolic functions but also has a significant impact on overall health (Hasan et al., 2022). An increase in lean body mass enhances muscle strength, which improves daily exercise performance (Stephenson et al., 2015). The lean body mass of Chinese college students with overweight and obesity was assessed using bioelectrical impedance analysis devices. However, the results showed that 12 weeks of AVG training was not effective in increasing the lean body mass of Chinese college students with overweight and obesity.

Different types of AVG have varying effects on lean body mass. Comeras-Chueca et al. (2022) conducted a 5-month intervention with overweight and obese children using a variety of AVG devices (Xbox, Wii, etc.). The results showed that AVGs can promote increased light physical activity and improve lean body mass in overweight and obese children. A long-term intervention and a combination of different types of AVGs are ideal ways to increase lean body mass. Zurita-Ortega et al. (2018) used the Xbox to train healthy college students for 12 weeks. After the trial, it was shown that AVG training can increase lean body mass in college students. Suire et al. (2022) used RFA to train adult women for 8 weeks (2 times a week, 45 minutes each time). The results showed that RFA can effectively increase lean body mass and bone density.

There was no significant increase in the lean body mass of college students with overweight and obesity in this study. The main reasons for this may be due to the following three factors. First, although the RFA game model included some strength training, it was primarily aerobic in nature. Thus, while it may improve BMI and body fat percentage, seeing a significant increase in lean body mass may require longer periods of strength training or a dedicated resistance training programme (Thomas & Burns, 2016; Aravena-Sagardia et al., 2021). Second, the population in this study consisted of college students with overweight and obesity, a group that tends to have a higher body fat percentage and more complex body composition, making it more difficult to increase lean body mass (Ribeiro et al., 2022). Third, muscle growth requires adequate protein and total calorie intake (Ten Haaf et al., 2018). During this study, the level of PA may have reduced the appetite of the college students, affecting their energy intake. Additionally, because the participants had to keep track of their diets daily, some college students with overweight and obesity who were eager to control their weight may have eaten as little as possible. The lack of adequate nutritional support could have resulted in muscle mass remaining the same or even decreasing slightly.

5.5.4 Effects of Active Video Game on Waist-to-Hip Ratio

The results of this study showed that 12 weeks of active video game training was effective in improving the waist-to-hip ratio of EG. The waist-to-hip ratio of the control group did not change significantly during the 12-week intervention period. In addition, after 12 weeks of active video game training, there was a significant difference in waist-to-hip ratio between EG and CG. This finding provides evidence to support the hypothesis that AVG training can significantly improve the waist-to-hip ratio of Chinese college students with overweight and obesity.

The waist-to-hip ratio can provide important information about fat distribution and is used to assess abdominal obesity, cardiovascular disease risk, and metabolic syndrome (You et al., 2022; Vazquez et al., 2007). Therefore, a healthy waist-to-hip ratio is crucial for college students with overweight and obesity. This study used a tape measure to assess the waist-to-hip ratio of Chinese college students with overweight and obesity. The results showed that the waist-to-hip ratio of these students was significantly reduced after 12 weeks of AVG training.

Previous studies focusing on the waist-to-hip ratio have mainly involved children and adolescents. Irandoust et al. (2020) found that AVG had similar effects to water sports in improving waist-to-hip ratio by having obese male primary school students participate in AVG training for 12 weeks (60 minutes, three times a week). Van Biljon et al. (2021) involved overweight and obese primary school children in a 6-week AVG training intervention and found that the waist-to-hip ratio of these children was significantly reduced after the intervention. These studies show that AVG can induce changes in body composition, making it a viable alternative to traditional sports.

This study used RFA to conduct AVG training for overweight and obese Chinese college students, significantly reducing their waist-to-hip ratio. This finding fills a gap in AVG research on waist-to-hip ratio in college students. There are two main reasons for this result. First, a decrease in waist-to-hip ratio generally indicates a reduction in abdominal fat, which suggests a decrease in visceral fat (Gadekar et al., 2020). Proper physical activity reduces fat accumulation (Dionne et al., 2000), and RFA's unique game mechanics provide college students with overweight and obesity with whole-body and targeted exercises, helping to reduce waist circumference and thus lower the waist-to-hip ratio.

Second, RFA includes a primary game mode that combines various forms of exercise, such as aerobic, strength, and core muscle training (Siriphorn et al., 2024). These exercises promote fat burning and strengthen core muscles, particularly the abdominal muscles, thereby reducing abdominal fat (Okuneye et al., 2010; Vispute et al., 2011). This highly effective exercise method further reduces participants' waist circumference by increasing metabolic rate and promoting fat breakdown, thereby improving the waist-to-hip ratio. It is recommended that RFA be promoted as a tool to improve the unhealthy waist-to-hip ratio of college students with overweight and obesity in China.

5.6 Conclusion

This study investigated the effects of 12 weeks of active video game training on physical activity, psychological distress, exercise motivation, and body composition in Chinese college students with overweight and obesity. Based on the research objectives and results, the following conclusions were drawn:

(1) Compared with the control group, 12 weeks of active video game training significantly increased physical activity. The results of this study support the hypothesis that active video game training can be an effective strategy to increase physical activity in Chinese college students with overweight and obesity.

(2) Compared with the control group, 12 weeks of active video game training showed significant improvements in depression, anxiety, stress, and psychological distress. The results of this study support the hypothesis that active video game training can be an effective tool for improving depression, anxiety, stress, and psychological distress in Chinese college students with overweight and obesity.

(3) Compared with the control group, 12 weeks of active video game training showed significant improvement in motivation, identification, and intrinsic regulation. The results of this study support the hypothesis that active video game training can be a potential tool for improving the exercise motivation of Chinese college students who are overweight or obese. However, the results for external regulation and introjected regulation did not reach statistical significance.

(4) Compared with the control group, 12 weeks of active video game training showed significant improvements in BMI, body fat percentage, and waist-to-hip ratio. The results of this study support the hypothesis that active video game training can be a potential tool for improving the body composition of Chinese college students with overweight and obesity. However, the results for lean body mass did not reach statistical significance.

5.7 Study Implications

5.7.1 Theoretical Implications

Active video game training is characterised by the integration of video games and exercise. Its unique game modes and content guide individuals to increase physical activity while improving physical and mental health (Street et al., 2017). As the latest AVG, Adventure on the Fitness Ring offers a wealth of gameplay and game mechanics that better meet human needs, thereby promoting physical activity and delivering numerous benefits (Sato et al., 2021; Chan et al., 2024). Traditional sports may focus more on enhancing a specific skill or physical function, whereas AVG training uniquely combines the interactive and recreational aspects of physical movement and play. This combination helps to increase enjoyment and sustain exercise, which not only leads to similar physical benefits but also improves mental health and body composition, ultimately contributing to holistic physical and psychological health (Yusoff et al., 2021; Mullins et al., 2012; Mackintosh et al., 2016). This comprehensive benefit is particularly important for college students with overweight and obesity.

This study utilises the health-related physical fitness model and the model of health outcomes with active-play games as theoretical support, focusing on the physical and mental health benefits brought by this type of exercise (Bouchard et al., 1994; Lieberman et al., 2011). Together, these two models depict the process by which AVG promotes physical and mental health. Primarily, physical activity can foster positive psychological factors such as self-efficacy and happiness, thereby improving exercise motivation. Enhanced exercise motivation, in turn, can improve body composition. The main findings of this study show that AVG training effectively improves the physical activity and exercise motivation of Chinese college students with overweight and obesity, while also alleviating psychological distress and improving body composition. Limited studies have been published on the practical application of these two models. Hence, this study extends the role of these models in promoting physical and mental health in the overweight and obese college student population. Moreover, this study reinforces the application of SDT, demonstrating how RFA can meet the psychological needs of college students to enhance intrinsic motivation and sustain behaviour change.

5.7.2 Practical Implications

The results of the study are intended to be valuable to college administrators, physical education teachers, researchers, and Chinese college students with overweight and obesity. This study demonstrates the advantages of incorporating active video game training into the training programs for Chinese college students with overweight and obesity. Specifically, the study shows that a 12-week active video game (Ring Fit Adventure) training program (three times per week, each session lasting 40–60 minutes) can positively improve the physical activity, psychological distress, exercise motivation, and body composition of Chinese college students with overweight and obesity. These findings can be used to develop training programs that meet the specific needs of this population, offering new ways to address their physical and mental health issues while providing a potentially more effective tool.

From a practical perspective, increasing physical activity is fundamental to improving physical and mental health. The unique game modes and gameplay of the active video game (Ring Fit Adventure) differ from traditional sports, appealing to college students' interest in electronic games while encouraging physical activity. This approach more effectively improves physical and mental health indicators.

Additionally, active video game training is generally more cost-effective than traditional sports training methods. Unlike traditional sports, which require dedicated venues and sports equipment, the portability of active video games allows Chinese college students with overweight and obesity to exercise in small spaces and more easily integrate exercise into their daily lives. The diverse training modes in active video games can help these students master basic sports skills and foster greater participation in other physical activities. Therefore, it is recommended that active video game training be incorporated into Chinese college physical education classes and training programs.

5.8 Recommendations for Future Research

Based on the research results, several recommendations for future research are listed:

(1) According to the results of this study, there were no significant differences in external and introjected regulation between the two groups regarding specific exercise motivation. Both gender and training duration may influence changes in motivation type. Therefore, future research could classify college students with overweight and obesity in more detail and explore more deeply the mechanisms that improve extrinsic and introjected regulation in this population.

(2) Active video game (Ring Fit Adventure) training brought positive improvements to the body composition of Chinese college students with overweight and obesity. However, there was no significant difference in lean body mass between the two groups. Usually, an increase in lean body mass requires more strength training and energy intake. Therefore, future studies could investigate the dose-response relationship of active video game training on lean body mass in overweight and obese Chinese college students.

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APPENDICES

Appendix A

Ethical Approval

曲阜师范大学生物医学伦理审批件

编号(No)：2023124

李兆进课题组（李兆进、李思民、赵越） 申请的 学术论文 项目（论文）《视频互动体感游戏对超重和肥胖大学生身体活动，心理健康和身体组成的影响》，经过生物医学伦理委员会的审核，符合伦理原则，同意开展。

曲阜师范大学生物医学伦理委员会

伦理委员会主任（副主任）委员签章

2023年10月30日

公　证　书

（2024）鲁枣庄鲁南证外字第 1451 号

申请人：赵越，男，1992 年 6 月 6 日出生，公民身份号码：370402199206067710。

公证事项：审批件

兹证明曲阜师范大学生物医学伦理委员会于 2023 年 10 月 30 为赵越出具的《曲阜师范大学生物医学伦理审批件》的原件与前面的复印件相符，原件属实。

中华人民共和国山东省枣庄市鲁南公证处

公证员 朱新伟

2024 年 9 月 26 日

NOTARIAL CERTIFICATE

(2024)Lu Zaozhuang Lunan Zheng Wai Zi, No.1451

Applicant: Zhao Yue，male，was born on June 6, 1992，ID Card No.: 370402199206067710.

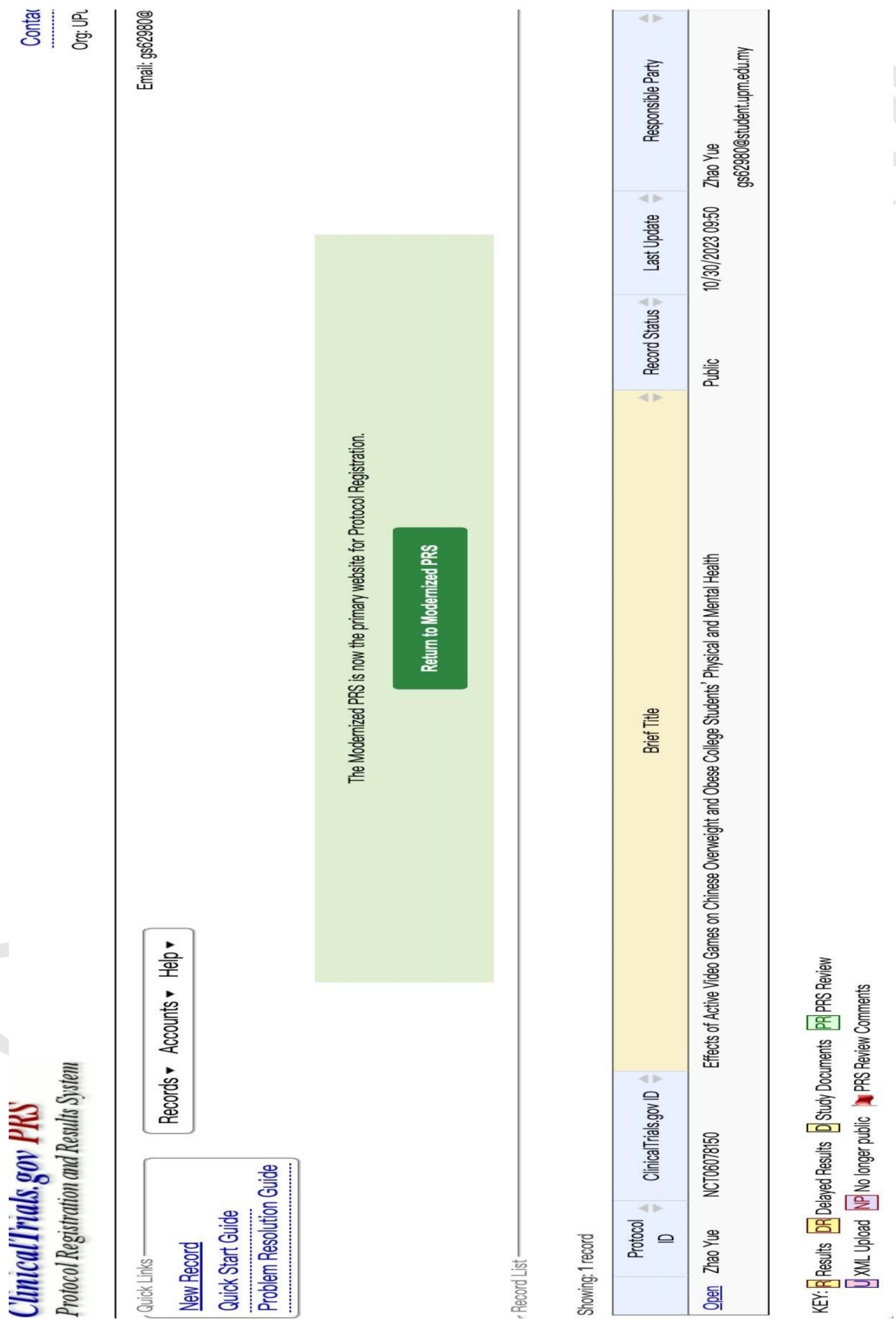
Issue under notarization: Biomedical Ethics Approval

This is to certify that the foregoing photocopy of the "Biomedical Ethics Approval from Qufu Normal University" issued to Zhao Yue by Biomedical Ethics Committee of Qufu Normal University on October 30, 2023 conforms to the original, and that the original document is genuine and authentic.

Zaozhuang Lunan Notary Public Office
Shandong Province
The People's Republic of China
Notary Public: Zhu Xinwei
September 26, 2024

Appendix B

Registration of Trial Protocol



ClinicalTrials.gov PRS
Protocol Registration and Results System

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Email: gs62980@

Quick Links
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Quick Start Guide
Problem Resolution Guide

Records ▾ Accounts ▾ Help ▾

The Modernized PRS is now the primary website for Protocol Registration.

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	Protocol ID	ClinicalTrials.gov ID	Brief Title	Record Status	Last Update	Responsible Party
Open	Zhao Yue	NCT06078150	Effects of Active Video Games on Chinese Overweight and Obese College Students' Physical and Mental Health	Public	10/30/2023 09:50	Zhao Yue gs62980@student.upm.edu.my

KEY: R Results DR Delayed Results D Study Documents PR PRS Review
U XML Upload NP No longer public PRS Review Comments

Appendix C

Respondent's Information Sheet and Informed Consent Form (English Version)

JAWATANKUASA ETIKA UNIVERSITI UNTUK PENYELIDIKAN MELIBATKAN MANUSIA (JKEUPM)

FORM 2.4: RESPONDENT'S INFORMATION SHEET AND INFORMED CONSENT FORM

Please read the following information carefully and do not hesitate to discuss any questions you may have with the researcher.

1. STUDY TITLE :

EFFECTS OF ACTIVE VIDEO GAMES ON PHYSICAL ACTIVITY, PSYCHOLOGICAL DISTRESS, EXERCISE MOTIVATION, AND BODY COMPOSITION AMONG COLLEGE STUDENTS WITH OVERWEIGHT AND OBESITY IN CHINA

2. INTRODUCTION:

With the advancement of the times and the development of science and technology, world economic integration and trade globalization have become a trend, and global economic exchanges continue to expand. Although the COVID-19 epidemic has caused a huge blow and far-reaching impact on the global economy, overall, the world economy is still developing in a more stable and prosperous direction. Economic development has brought about comprehensive improvements in material life, education, and medical care and significantly improved people's quality of life. However, as the quality of life improves, Chinese people's eating habits and entertainment methods are also undergoing tremendous changes. The most intuitive and far-reaching problem brought about by these changes is the problem of obesity.

Among all obese groups, college students are of particular concern. As a typical group of young people, college students will face various pressures during their college years, which will affect their physical and mental health. In recent years, modern technology has developed at an alarming rate. Various electronic products have profoundly changed people's lifestyles. The popularization of the Internet and digital technology have had a profound impact on life. As the most representative young group, college students' use of the Internet and electronic devices has long become a common phenomenon. Currently, there is a kind of game that is very popular among college students and allows them to exercise in the game. This type of game is called active video game (AVG). Active Video Games combine physical activities with interactive video games, capturing the player's movements through somatosensory devices and converting them into in-game actions. These games can create virtual sports scenes and simulate physical activities, which can improve their physical and mental health. With the continuous advancement of technology and the expansion of application fields, AVG will continue to play an important role among college students, especially as an alternative to traditional exercise, helping college students with overweight and obesity improve their physical and mental health, and promoting people's pursuit of healthier and more active lifestyle.

3. WHAT WILL YOU HAVE TO DO?

Using active video games to increase physical activity, improve psychological distress, increase exercise motivation, and improve body composition in college students with overweight and obesity in China. The study lasted 12 weeks, with 3 training sessions per week for 40 minutes to 1 hour.
There were three tests in total, namely pre-test, post-test 1, and post-test 2.

4. WHO SHOULD NOT PARTICIPATE IN THE STUDY?

The exclusion criteria of this study include the following six aspects:
(1) College students majoring in sports or engaging in professional training.
(2) College students who are pregnant or dieting.
(3) College students with a history of mental illness, metabolic disease, cardiopulmonary or respiratory disease (such as asthma) or visual impairment.
(4) Severe muscle or bone injuries in the past 3 months.
(5) Subjects with contraindications to physical activity as determined by questions on the PAR-Q.
(6) Other health problems that may affect the safety of the subjects during the experiment.

5. WHAT WILL BE THE BENEFITS OF THE STUDY:

(a) TO YOU AS THE SUBJECT?

Participants in this experiment will help improve physical activity, psychological distress, exercise motivation, and body composition among college students with overweight and obesity in China, making them healthier.

(b) TO THE INVESTIGATOR?

To examine the effects of an active video game (Ring Fit Adventure) on the physical and mental health of college students with overweight and obesity in China, which may help to identify potential alternatives to traditional exercise.

6. WHAT ARE THE POSSIBLE RISKS?

Due to the use of an active video game, participants need to hold a somatosensory device and interact with the characters in the computer to perform various exercises, such as stretching or jumping. There may be muscle soreness and exercise fatigue. However, there will be warm-up activities before each training session and relaxation activities after the exercise. Professional physical education teachers and research assistants are on hand to help participants through the training and provide safety at all times. Therefore, there is no need to worry about adverse reactions during training.

7. WILL THE INFORMATION THAT YOU PROVIDE AND YOUR IDENTITY REMAIN CONFIDENTIAL?

All your personal and health information will be kept at Universiti Putra Malaysia. Researchers, research organisations and ethics committees will be granted access to your health records. All of your information will be used for research purposes only and will not be used for any other purposes, and no public reports will contain your personal information. By signing this informed consent form, you agree to the use of your personal and health information as described above.

8. WHO SHOULD YOU CONTACT IF YOU HAVE ADDITIONAL QUESTIONS DURING THE COURSE OF THE RESEARCH?

If you have various questions about this study, please contact the researcher immediately
Researcher's name: Zhao Yue Tel: 60177271149 Email: yuezhao0606@gmail.com
If you have any questions about your rights as a participant in this study, please contact:
The Secretariat, JKEUPM, at email address **jkeupm@upm.edu.my**

*Please initial here if you have read and understood the contents of this page*______

9. CONSENT

I …………………………………… Identity Card No. …………………………… address………………………………………………………………………………
……….. ……………………………………………………. hereby voluntarily agree to take part in the research stated above *(clinical /drug trial/video recording/ focus group/interview-based/ questionnaire-based).

I have been informed about the nature of the research in terms of methodology, possible adverse effects and complications (as written in the Respondent's Information Sheet). I understand that
I have the right to withdraw from this research at any time without giving any reason whatsoever.
I also understand that this study is confidential and all information provided with regard to my identity will remain private and confidential.
I* wish / do not wish to know the results related to my participation in the research
I agree/do not agree that the images/photos/video recordings/voice recordings related to me be used in any form of publication or presentation (if applicable)

* delete where necessary

Signature ……..………………………… Signature ……..………………………….
(Respondent) (Witness)
Date :……………………………………..…
Name :…………………………………
I/C No. :………………………………….

confirm that I have explained to the respondent the nature and purpose of the above-mentioned research.

Date ……..………………………… Signature ……..………………………….
(Researcher)

Appendix D

Physical Activity Readiness Questionnaire (PAR-Q) (English Version)

Physical Activity Readiness Questionnaire (PAR-Q) and You

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly:

YES	NO		
☐	☐	1.	Has your doctor ever said that you have a heart condition <u>and</u> that you should only do physical activity recommended by a doctor?
☐	☐	2.	Do you feel pain in your chest when you do physical activity?
☐	☐	3.	In the past month, have you had chest pain when you were not doing physical activity?
☐	☐	4.	Do you lose your balance because of dizziness or do you ever lose consciousness?
☐	☐	5.	Do you have a bone or joint problem that could be made worse by a change in your physical activity?
☐	☐	6.	Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
☐	☐	7.	Do you know of <u>any other reason</u> why you should not do physical activity?

If you answered:

YES to one or more questions

Talk to your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want – as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to <u>all</u> PAR-Q questions, you can be reasonably sure that you can:

- Start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- Take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively.

Delay becoming much more active:

- If you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- If you are or may be pregnant – talk to your doctor before you start becoming more active.

Please note: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed use of the PAR-Q: Reprinted from ACSM's Health/Fitness Facility Standards and Guidelines, 1997 by American College of Sports Medicine

Physical Activity Readiness Questionnaire (PAR-Q) (Chinese Version)

体力活动准备问卷

PAR－Q（2002年修订）

PAR－Q & 你

（适用于15～69岁）

规律的体力活动可以促进健康并令人愉悦，越来越多的人参与到运动中。对于大多数人来说，运动是安全的。而对某些人来说，在明显增加体力活动前应先征求医生的意见。

如果你计划参加更多的体力活动，请先回答下表中的7个问题。如果你的年龄在15～69岁之间，PAR－Q会告诉你运动前是否需要咨询医生。如果你超过了69岁，且没有体力活动习惯，那么请咨询医生。

回答问题时最好依据你的一般感觉。请仔细阅读并诚实回答每一个问题：选择是或否。

是	否	
□	□	1. 医生是否曾经告诉过你患有心脏病并且只能参加医生推荐的体力活动？
□	□	2. 当你参加体力活动时，是否感觉胸痛？
□	□	3. 自上个月以来，你是否在没有参加体力活动时发生过胸痛？
□	□	4. 你是否曾因头晕跌倒或曾失去知觉？
□	□	5. 你是否有因体力活动变化而加重的骨或关节疾病（如腰背部、膝关节或髋部）？
□	□	6. 最近医生是否因为你的血压或心脏问题给你开药（如水剂或片剂）？
□	□	7. 你是否知道一些你不能进行体力活动的其他原因？

对一个或更多问题，如果你回答了“是”

在你进行体适能评价前应咨询医生。告诉医生PAR－Q和你回答了“是”的问题。

只要你遵守循序渐进的原则，就能参加你想参加的体力活动。只是你需要控制体力活动在安全的范围内，告诉医生你希望参加的体力活动，听从他（她）的建议。参与一个安全而有益的社区运动计划。

如果全部问题回答“否”

如果你对所有PAR－Q问题都回答了“否”，那么，你有理由相信你能：

参加更多的体力活动，但要缓慢开始并循序渐进，这是最安全、最容易的方法。

进行体适能评价，这是确定你的基础体适能的良好方法，并使你能够确定实现积极生活方式的最佳途径。强烈推荐你测量血压。如果你的血压高于144/94 mmHg，请在参加更多的体力活动前咨询医生。

→ 下列情况应推迟参加体力活动：

如果你由于暂时的疾病，如感冒或发热，感到身体不适，请等到疾病康复后再锻炼；

如果你怀孕了或可能怀孕了，在参加更多的体力活动前，请咨询医生。

请注意：如果你的健康状况改变了，对以上任何一个问题回答了“是”，请告诉体适能或健康专家，询问是否需要调整体力活动计划。

PAR－Q使用时注意：加拿大运动生理协会、健康加拿大人和他们的代理人声明：对参加体力活动的人不承担责任。如果在完成问卷后有疑问，请在参加体力活动前咨询医生。

你可以影印PAR－Q，但是请使用完整形式，不允许改动。

注：如果某人在参加体力活动或体适能评价前得到了PAR－Q问卷筛查，可以用于法律或管理目的。

“我已经阅读、理解并完成了这份问卷，对于我的所有疑问都得到了令我满意的回答。”

姓　名________________

签　字________________　日　期________________

父母签字________________　证明人________________

或监护人（未成年的运动参加者）

注：这个调查表的有效期是从完成问卷开始12个月以内。如果你的身体状况改变了，你回答的7个问题中任何一个回答了“是”，之前的问卷就无效了。

continued on other side...

（经许可，引自：Canada's Physical Activity Guide to Healthy Active Living [Internet]. Ontario (Canada): Public Health Agency of Canada; [cited 2007 Jun 15]. Available from: http: //www. phac－aspc. gc. ca/pau－uap/paguide/index. html。

经加拿大运动生理协会允许由加拿大公共健康机构再版。http: //www. csep. ca. @2002）

Appendix E

Depression Anxiety Stress Scale-42 (English Version)

DASS *Name:* *Date:*

Please read each statement and circle a number 0, 1, 2 or 3 which indicates how much the statement applied to you *over the past week*. There are no right or wrong answers. Do not spend too much time on any statement.

The rating scale is as follows:

0 Did not apply to me at all
1 Applied to me to some degree, or some of the time
2 Applied to me to a considerable degree, or a good part of time
3 Applied to me very much, or most of the time

1	I found myself getting upset by quite trivial things	0	1	2	3
2	I was aware of dryness of my mouth	0	1	2	3
3	I couldn't seem to experience any positive feeling at all	0	1	2	3
4	I experienced breathing difficulty (eg, excessively rapid breathing, breathlessness in the absence of physical exertion)	0	1	2	3
5	I just couldn't seem to get going	0	1	2	3
6	I tended to over-react to situations	0	1	2	3
7	I had a feeling of shakiness (eg, legs going to give way)	0	1	2	3
8	I found it difficult to relax	0	1	2	3
9	I found myself in situations that made me so anxious I was most relieved when they ended	0	1	2	3
10	I felt that I had nothing to look forward to	0	1	2	3
11	I found myself getting upset rather easily	0	1	2	3
12	I felt that I was using a lot of nervous energy	0	1	2	3
13	I felt sad and depressed	0	1	2	3
14	I found myself getting impatient when I was delayed in any way (eg, elevators, traffic lights, being kept waiting)	0	1	2	3
15	I had a feeling of faintness	0	1	2	3
16	I felt that I had lost interest in just about everything	0	1	2	3
17	I felt I wasn't worth much as a person	0	1	2	3
18	I felt that I was rather touchy	0	1	2	3
19	I perspired noticeably (eg, hands sweaty) in the absence of high temperatures or physical exertion	0	1	2	3
20	I felt scared without any good reason	0	1	2	3
21	I felt that life wasn't worthwhile	0	1	2	3

Please turn the page ☞

Reminder of rating scale:

0 Did not apply to me at all
1 Applied to me to some degree, or some of the time
2 Applied to me to a considerable degree, or a good part of time
3 Applied to me very much, or most of the time

22	I found it hard to wind down	0	1	2	3
23	I had difficulty in swallowing	0	1	2	3
24	I couldn't seem to get any enjoyment out of the things I did	0	1	2	3
25	I was aware of the action of my heart in the absence of physical exertion (eg, sense of heart rate increase, heart missing a beat)	0	1	2	3
26	I felt down-hearted and blue	0	1	2	3
27	I found that I was very irritable	0	1	2	3
28	I felt I was close to panic	0	1	2	3
29	I found it hard to calm down after something upset me	0	1	2	3
30	I feared that I would be "thrown" by some trivial but unfamiliar task	0	1	2	3
31	I was unable to become enthusiastic about anything	0	1	2	3
32	I found it difficult to tolerate interruptions to what I was doing	0	1	2	3
33	I was in a state of nervous tension	0	1	2	3
34	I felt I was pretty worthless	0	1	2	3
35	I was intolerant of anything that kept me from getting on with what I was doing	0	1	2	3
36	I felt terrified	0	1	2	3
37	I could see nothing in the future to be hopeful about	0	1	2	3
38	I felt that life was meaningless	0	1	2	3
39	I found myself getting agitated	0	1	2	3
40	I was worried about situations in which I might panic and make a fool of myself	0	1	2	3
41	I experienced trembling (eg, in the hands)	0	1	2	3
42	I found it difficult to work up the initiative to do things	0	1	2	3

Depression Anxiety Stress Scale-42 (Chinese Version)

DASS 姓名: 性别: 男 / 女 年龄: 日期:

请阅读以下各项，然后根据过去一周之内符合您的实际情况，在相应的数字（*0*，*1*，*2* 或 *3*）上打勾。您的回答没有对错之分，所以请不要在以下任何一项上花太多时间。

打分等级介绍如下：

0 表示此项根本不符合我的情况；

1 表示此项在某种程度上或是某些时候与我的实际情况相符；

2 表示此项在很大程度上或是大部分情况下与我的实际情况相符；

3 表示此项与我的实际情况非常相符。

1	我发现我自己被一些琐碎的事情弄得很不开心	0	1	2	3
2	我感到嘴巴很干	0	1	2	3
3	我似乎完全不能积极乐观起来	0	1	2	3
4	我感到过呼吸困难（例如： 在没有体力透支的情况下而感到呼吸急促， 喘不过气来）	0	1	2	3
5	我似乎没法提起劲来做事情	0	1	2	3
6	我对于所处的环境（情况）易于反应过度	0	1	2	3
7	我曾有发抖的感觉（例如：腿都站不稳）	0	1	2	3
8	我发现很难放松下来	0	1	2	3
9	我发现我曾处于非常焦虑的情况下，极想立刻离开这种环境松一口气	0	1	2	3
10	我感到我没什么可期待的	0	1	2	3
11	我发现我极其容易不开心	0	1	2	3
12	我感到时常神经紧张	0	1	2	3
13	我感到伤心和郁闷	0	1	2	3
14	我发现当我因为某种原因而耽误时间的时候，我变得没有耐性（例如：等电梯，在十字路口等红绿灯或其他处于等待的状态）	0	1	2	3
15	我曾有眩晕的感觉	0	1	2	3
16	我一度感到我对几乎任何事情都失去了兴趣	0	1	2	3
17	我感到自己曾不具备作为人而存在的价值	0	1	2	3
18	我感到我曾极容易因为小事而生气	0	1	2	3
19	在不是高温或体力透支的情况下，我明显容易出汗（例如：汗手）	0	1	2	3

DASS

20	没有什么特殊原因的情况下，我感到害怕	0	1	2	3
21	我感到生命没有价值	0	1	2	3

打分等级介绍如下：

0 表示此项根本不符合我的情况；

1 表示此项在某种程度上或是某些时候与我的实际情况相符；

2 表示此项在很大程度上或是大部分情况下与我的实际情况相符；

3 表示此项与我的实际情况非常相符。

22	我发现很难让自己安静下来休息	0	1	2	3
23	我曾有过吞咽困难的感觉	0	1	2	3
24	我似乎没法从我做过的事情中找到乐趣	0	1	2	3
25	在没有体力透支的情况下我也能感觉到自己的心跳或心律不正常（例如：感到心跳过快或心律不齐）	0	1	2	3
26	我感到消沉和沮丧	0	1	2	3
27	我发现我容易烦躁	0	1	2	3
28	我感到我曾接近恐慌	0	1	2	3
29	我发现当某件事情使我不开心之后，我很难平静下来	0	1	2	3
30	我担心我会因为某些琐碎和不熟悉的工作而感到筋疲力竭	0	1	2	3
31	我对任何事情都没法充满热情	0	1	2	3
32	我发现我很难忍受我做事的时候受到任何干扰	0	1	2	3
33	我曾处于神经紧张的状态	0	1	2	3
34	我一度感到我很没价值	0	1	2	3
35	我曾对阻碍我正在进行的工作的事情感到无法容忍	0	1	2	3
36	我曾感到恐惧	0	1	2	3
37	对于未来我看不到任何希望	0	1	2	3
38	我曾感到生活没有意义	0	1	2	3
39	我发现自己变得焦虑不安	0	1	2	3
40	我担心自己可能因为惊慌而干蠢事出洋相	0	1	2	3
41	我曾感到发抖（例如：手打哆嗦）	0	1	2	3
42	我发现很难发挥主动性去做事情	0	1	2	3

Appendix F

Behavioral Regulation in Exercise Questionnaire-2 (English Version)

EXERCISE REGULATIONS QUESTIONNAIRE (BREQ-2)

Age: __________ years Sex: male female (please circle)

WHY DO YOU ENGAGE IN EXERCISE?

We are interested in the reasons underlying peoples' decisions to engage, or not engage in physical exercise. Using the scale below, please indicate to what extent each of the following items is true for you. Please note that there are no right or wrong answers and no trick questions. We simply want to know how you personally feel about exercise. Your responses will be held in confidence and only used for our research purposes.

		Not true for me		Sometimes true for me		Very true for me
1	I exercise because other people say I should	0	1	2	3	4
2	I feel guilty when I don't exercise	0	1	2	3	4
3	I value the benefits of exercise	0	1	2	3	4
4	I exercise because it's fun	0	1	2	3	4
5	I don't see why I should have to exercise	0	1	2	3	4
6	I take part in exercise because my friends/family/partner say I should	0	1	2	3	4
7	I feel ashamed when I miss an exercise session	0	1	2	3	4
8	It's important to me to exercise regularly	0	1	2	3	4
9	I can't see why I should bother exercising	0	1	2	3	4
10	I enjoy my exercise sessions	0	1	2	3	4
11	I exercise because others will not be pleased with me if I don't	0	1	2	3	4
12	I don't see the point in exercising	0	1	2	3	4
13	I feel like a failure when I haven't exercised in a while	0	1	2	3	4
14	I think it is important to make the effort to exercise regularly	0	1	2	3	4
15	I find exercise a pleasurable activity	0	1	2	3	4
16	I feel under pressure from my friends/family to exercise	0	1	2	3	4
17	I get restless if I don't exercise regularly	0	1	2	3	4
18	I get pleasure and satisfaction from participating in exercise	0	1	2	3	4
19	I think exercising is a waste of time	0	1	2	3	4

Thank you for taking part in our research

Behavioral Regulation in Exercise Questionnaire-2 (Chinese version)

中文版运动行为调节问卷

年龄: 岁

性别：男性/女性（请圈选）

为什么你要从事运动呢?

对于民众决定从事或不从事运动这件事情，其原因令我们感到非常有兴趣。藉由下面的量表，请在每一个选项中，选出最适合你的描述。本问卷并没有标准答案，因此每个选项并没有对错，也没有陷井题存在。我们只是单纯的想了解您对于运动的个人观感。本份问卷的内容将会被保密，且仅会应用在我们研究目的上。

		完全不适合我		有时适合我		非常适合我
1	我会运动，是因为别人认为我应该运动	0	1	2	3	4
2	我不运动时会有罪恶感					
3	我重视运动带来的益处					
4	我运动是因为运动很有趣					
5	我不认为我应该要运动					
6	我去运动，是因为我的朋友/家人/伴侣说我应该要运动					
7	当我缺席了一次运动，我会感到羞愧					
8	对我而言规律运动是很重要的					
9	我实在不认为为什么要运动					
10	我非常喜欢我的运动					
11	我去运动是因为如果我不运动，别人会感到不高兴					
12	我不觉得运动有什么重要性					
13	当一段时间没运动，我会觉得自己像个失败的人					
14	我认为努力地维持规律运动是很重要的					
15	我觉得运动是个充满乐趣的事情					
16	我感受到来自朋友或家人的压力，促使我去运动					
17	我如果不规律运动会感到烦躁不安					
18	我从参与运动中，获得快乐和满足					
19	我认为运动是浪费时间的行为					

Appendix G

Physical Activity and Body Composition Test Program Protocol

1. Preparation for the actual test

Preparation before the actual test is intended to ensure that accurate and effective data can be obtained, and the safety of the subjects can be guaranteed. To this end, the researcher makes the following preparations:

(1) Inform the subjects of all measurement content and precautions, and make
(3) All subjects should avoid spicy foods, alcohol, caffeine or smoking at least 3 hours before the test.
(4) On the day of the test, all subjects should wear loose-fitting and appropriate sportswear and sports shoes. They should not wear tight clothing, slippers or other clothing.
(5) After the test, the subjects should avoid fatigue and pay attention to rest to avoid physical discomfort.

The researcher, physical education teacher and research assistant jointly inspected the equipment to ensure that it was placed correctly and calibrated according to the equipment instructions. This mainly included checking the Switch console, ring fit adventure (3) AVG introductory brochure and user manual. (4) Confidentiality undertaking (undertaking to keep the content of the experiment confidential).

2. Practical test instruments and procedures

All participants were Chinese college students with overweight and obesity. To better complete the field test, the operational procedures of this study refer to the guidelines and standards formulated by the General Administration of Sport of China. They are the 'National Physical Fitness Measurement Standards (revised in 2023)' and the 'National Fitness Guidelines' (Wang Bihan et al., 2024; Zheng Jiakun, 2021).

2.1 Anthropometric instruments and procedures

(1) Height
Instrument: Seca stadiometer
Aim: To measure the height of the participant **Procedure:**

1. Place the Seca stadiometer on a firm, level surface to ensure that the device is stable and does not wobble.
2. Ask the subject to remove shoes, thick socks and any accessories that may add height (e.g. hair accessories).
3. Ensure that the subject's back, buttocks and heels are as close as possible to the stadiometer. The shoulders should be relaxed, and the arms should hang naturally at the sides of the body. Gently move the measuring rod (stylus) downwards until it makes smooth contact with the subject's head, ensuring that the measuring rod is parallel to the ground. Check the height scale displayed on the measuring rod.

Height is measured in centimetres (cm) to the nearest 0.1 cm. The subject's height is measured twice and the average of the two measurements is taken.

(2) Weight
Instrument: Body Composition Analyser Tanita BC418-MA
Aim: To measure the participant's weight **Procedure:**

1. Place the body composition analyser on a flat, stable surface, ensuring that the surface of the device is clean and free from obstructions.
2. The subject must take off their shoes and socks and place their feet (barefoot) on the left and right electrode plates. Hold the electrode plates with both hands to ensure good contact between the measuring electrodes and the skin and an even distribution of body weight.
3. The device will automatically measure and display the weight on the screen. The weight is displayed in kilograms (kg) and measured to 0.1kg. The participant will be weighed twice and the average of the two measurements will be taken.

2.2 Physical activity variables

Instrument: Yamax Digi-Walker® CW-700 pedometer
Aim: To measure the number of steps taken by the participants **Procedure:**

1. This pedometer is small, lightweight, and easy to wear, weighing only 45.36 grams, so it does not interfere with the students' lives. We asked the participants to clip the pedometer to the waistband of their trousers close to the centre of their body and fix it a second time with a clip to ensure that it accurately senses the pace of walking.
2. Participants were asked to start wearing the pedometers after waking up and to continue wearing them until going to bed. They were also asked to ensure that the pedometers were worn during any form of physical activity (e.g., walking, running, etc.). The pedometers displayed the accumulated step count in real time, and all data (step count) could be saved for up to two weeks.
3. The pedometers are specially treated to ensure that participants cannot open them. The researchers ask participants to hand in their pedometers every Sunday in a fixed classroom, where they are opened and the number of steps for the week recorded using a special tool. After recording, the pedometers are checked and calibrated on site.

2.3 Body composition variables

(1) Body mass index
Instruments: Seca stadiomete and Tanita BC418-MA
Aim: To measure the height and weight of participants and calculate BMI using the formula **Procedure:**

1. After obtaining height and weight through anthropometric measurement, BMI is calculated using the formula Weight (kg) /height (m)^2.

(2) Body fat percentage
Instrument: Body composition analyser Tanita BC418-MA

Aim: To measure the body fat percentage of the participants **Procedure:**

1. All subjects were asked to maintain a regular diet and drink moderately for 24 hours before the body composition test.
2. On the day of the test, the subjects first entered their gender, age and height. Then the subjects removed any items that could interfere with the weight and body composition measurements, such as heavy accessories, heavy clothing, etc. Then the subjects stood barefoot on two electrodes while holding the handle electrodes.
3. The device measures the electrical resistance of different parts of the body by applying a weak electric current and calculates the body fat percentage based on the subject's gender, age and height. The subject is required to remain still throughout the process, and the results are displayed on the screen once the measurement is complete. The researcher takes notes.

(3) Lean body mass

Instrument: Body composition analyser Tanita BC418-MA
Aim: To measure the lean body mass of the participants
Procedure:

1. The participants were asked to maintain a regular diet and drink moderately for 24 hours.
2. During the test, the gender, age and height of the participants were entered into the device. The participants stood barefoot on the electrodes of the body composition analyser wearing loose clothing and holding the two electrodes. The participants were asked not to move or speak until the device displayed the specific data information.
3. The researcher records the measurement data to the nearest 0.1 kg.

(4) Waist-to-hip ratio

Instrument: 245 cm long measuring tape
Aim: To measure the waist-to-hip ratio of the participants **Procedure:**
Measurement procedure:

1. Participants are asked to wear light, tight-fitting clothing to ensure that the measuring tape fits snugly against the body during the measurement. The subject stands with feet shoulder-width apart, relaxed and in a natural posture.
2. Measure the waist circumference. Find the narrowest part of the waist, usually halfway between the lower edge of the ribs and the top of the iliac bone. Place the tape measure horizontally around the narrowest part of the waist, ensuring that it is parallel to the floor and pressed against the skin without compressing it too much. Ask the subject to breathe normally, without holding their breath or hunching their back, and the researcher records the measurement to the nearest 0.1 cm.
3. Measure hip circumference. Locate the widest part of the hips, usually at the most prominent part of the buttocks, where the thighs meet, and the buttocks are at their widest. Wrap the tape measure horizontally around the widest part of the hips, pressing it against the skin to measure and record the measurement to the nearest 0.1 cm. Waist and hip circumferences are measured in centimetres, and two measurements are taken and averaged. Calculate using the formula (WHR= waist (cm) / hips (cm)). Researchers ensured that the same measuring tape, method, and location were used to ensure consistency and comparability of data.

Appendix H

Training Protocol

Overview of Training Protocol

1. AVG Training Protocol (experimental group)

Week	Duration& Frequency	Exercises& Order	Contents
Week 1-4	3 times/week 40 minutes	5-minute warm-up + 30-minute game + 5-minute cool down	RFA guided warm-up (5min) + Adventure mode (30min) (60-75% HRmax) + RFA guided cool down (5min)
Week 5-8	3 times/week 50 minutes	5-minute warm-up + 40-minute game + 5-minute cool down	RFA guided warm-up (5min) + Adventure mode (20min) (60-75% HRmax) + Training combination mode (20min) (60-75% HRmax) + RFA guided cool down (5min)
Week 9-12	3 times/week 1hour	5-minute warm-up + 50-minute game + 5-minute cool down	RFA guided warm-up (5min) + Adventure mode(20min) (60-75% HRmax) + Training combination mode (20min) (60-75% HRmax) + Mini game mode (10min) (60-75% HRmax) + RFA guided cool down (5min)

2. Standard Training Protocol (control group)

Week	Duration& Frequency	Exercises& Order	Contents
Week 1-4	3 times/week 40 minutes	5-minute warm-up + 30-minute sports activities + 5-minute cool down	5 minutes dynamic stretching + 30 minutes brisk walking (60-75% HRmax) + 5 minutes static stretches
Week 5-8	3 times/week 50 minutes	5-minute warm-up + 40-minute sports activities + 5-minute cool down	5 minutes dynamic stretching + 40 minutes brisk walking (60-75% HRmax) + 5 minutes static stretches
Week 9-12	3 times/week 1hour	5-minute warm-up + 50-minute sports activities + 5-minute cool down	5 minutes dynamic stretching + 50 minutes brisk walking (60-75% HRmax) + 5 minutes static stretches

2. Detailed Training Protocol (experimental group)

(1) Experimental Group Phase1 (Week 1- 4)

Training Purpose	Week	Duration& Frequency	Exercises& Order	AVG Intervention
Familiarisation games	Week 1	3 times/week 40 minutes	RFA guided warm-up(5min) + 30-minute game + RFA guided cool-down (5min)	5-minute RFA warm-up (1) 30-minute adventure mode (Level 1 - 2) 5-minute RFA cool-down
	Week 2	3 times/week 40 minutes		5-minute RFA warm-up (1) 30-minute adventure mode (Level 3 - 4) 5-minute RFA cool-down
	Week 3	3 times/week 40 minutes		10-minute RFA warm-up (1) 30-minute adventure mode (Level 5 - 6) 5-minute RFA cool-down
	Week 4	3 times/week 40 minutes		5-minute RFA warm-up (1) 30-minute adventure mode (Level 7 - 8) 5-minute RFA cool-down

Phase 1 (weeks 1-4): 5 minutes warm-up and 5 minutes cool-down. Adventure mode (30 minutes) to give subjects ample time to adapt to the game mode (Adventure mode) so that they can play the game accurately and unlock other game modes.

RFA-guided warm-up and cool-down are various warm-up and relaxation manoeuvres performed by the participants according to the instructions of the virtual coach in the game.

(2) Experimental Group Phase2 (Week 5 - 8)

Training Purpose	Week	Duration& Frequency	Exercises& Order	AVG Intervention
New Modes & Enhance Autonomy	Week 5	3 times/week 50 minutes	RFA guided warm-up(5min) + 40-minute game + RFA guided cool-down (5min)	5-minute RFA warm-up (1) 20-minute adventure mode (Level 9 - 10) + (2) 20-minute self-selected combination training mode 5-minute RFA cool-down
	Week 6	3 times/week 50 minutes		5-minute RFA warm-up (1)20-minute adventure mode (Level 11 - 12) + (2) 20-minute self-selected combination training mode 5-minute RFA cool-down
	Week 7	3 times/week 50 minutes		5-minute RFA warm-up (1) 20-minute adventure mode (Level 13 - 14) + (2) 20-minute self-selected combination training mode 5-minute RFA cool-down
	Week 8	3 times/week 50 minutes		5-minute RFA warm-up (1) 20-minute adventure mode (Level 15 - 16) + (2) 20-minute self-selected combination training mode 5-minute RFA cool-down

Phase 2 (5-8 weeks): 5 minutes of warm-up and 5 minutes of cool-down. The adventure mode is adjusted to 20 minutes, and a new 20-minute optional combination training mode is added. The subjects can freely combine it into a suitable personalized training to improve autonomy.

(3) Experimental Group Phase3 (Week 9 - 12)

Training Purpose	Week	Duration& Frequency	Exercises& Order	AVG Intervention
New Modes & Enhance Fun	Week 9	3 times/week 1 hour	RFA guided warm-up(5min) + 50-minute game + RFA guided cool-down (5min)	5-minute RFA warm-up (1) 20-minute adventure mode (Level 17 - 18) + (2) 20-minute self-selected combination training mode + (3) 10-minute mini-game mode 5-minute RFA cool-down
	Week 10	3 times/week 1 hour		5-minute RFA warm-up (1)20-minute adventure mode (Level 19 - 20) + (2) 20-minute self-selected combination training mode + (3) 10-minute mini-game mode 5-minute RFA cool-down
	Week 11	3 times/week 1 hour		5-minute RFA warm-up (1) 20-minute adventure mode (Level 21 - 22) + (2) 20-minute self-selected combination training mode + (3) 10-minute mini-game mode 5-minute RFA cool-down
	Week 12	3 times/week 1 hour		5-minute RFA warm-up (1) 20-minute adventure mode (Level 23) + (2) 20-minute self-selected combination training mode + (3) 10-minute mini-game mode 5-minute RFA cool-down

Phase 3 (weeks 9-12): 5 minutes warm-up and 5 minutes cool-down. 20 minutes of adventure mode and 20 minutes of optional combination training mode. Added mini-game mode to increase the subject's interest in physical activities.

3. Detailed Training Protocol (control group)

Control Group Phase1 (Week 1- 4)

Training Purpose	Week	Duration& Frequency	Exercises& Order	AVG Intervention
Standard Physical Education Class	Week 1	3 times/week 40 minutes	warm-up(5min) + 30-minute sports activities + cool-down (5min)	5 minutes dynamic stretching (lateral lunges + leg swings) + 30 minutes brisk walking (60-75% HRmax) + 5 minutes static stretches (neck stretch + shoulder stretch)
	Week 2	3 times/week 40 minutes		5 minutes dynamic stretching (lateral lunges + leg swings) + 30 minutes brisk walking (60-75% HRmax) + 5 minutes static stretches (neck stretch + shoulder stretch)
	Week 3	3 times/week 40 minutes		5 minutes dynamic stretching (lateral lunges + leg swings) + 30 minutes brisk walking (60-75% HRmax) + 5 minutes static stretches (neck stretch + shoulder stretch)
	Week 4	3 times/week 40 minutes		5 minutes dynamic stretching (lateral lunges + leg swings) + 30 minutes brisk walking (60-75% HRmax) + 5 minutes static stretches (neck stretch + shoulder stretch)

Control Group Phase2 (Week 5- 8)

Training Purpose	Week	Duration& Frequency	Exercises& Order	AVG Intervention
Standard Physical Education Class	Week 5	3 times/week 50 minutes	warm-up(5min) + 40-minute sports activities + cool-down (5min)	5 minutes dynamic stretching (arm circles + ankle hops) + 40 minutes brisk walking (60-75% HRmax) + 5 minutes static stretches (calf stretch + chest stretch)
	Week 6	3 times/week 50 minutes		5 minutes dynamic stretching (arm circles + ankle hops) + 40 minutes brisk walking (60-75% HRmax) + 5 minutes static stretches (calf stretch + chest stretch)
	Week 7	3 times/week 50 minutes		5 minutes dynamic stretching (arm circles + ankle hops) + 40 minutes brisk walking (60-75% HRmax) + 5 minutes static stretches (calf stretch + chest stretch)
	Week 8	3 times/week 50 minutes		5 minutes dynamic stretching (arm circles + ankle hops) + 40 minutes brisk walking (60-75% HRmax) + 5 minutes static stretches (calf stretch + chest stretch)

Control Group Phase3 (Week 9- 12)

Training Purpose	Week	Duration& Frequency	Exercises& Order	AVG Intervention
Standard Physical Education Class	Week 9	3 times/week 60 minutes	warm-up(5min) + 50-minute sports activities + cool-down(5min)	5 minutes dynamic stretching (arm swings + walking lunges) + 50 minutes brisk walking (60-75% HRmax) + 5 minutes static stretches (back stretch + thigh stretch)
	Week 10	3 times/week 60 minutes		5 minutes dynamic stretching (arm swings + walking lunges) + 50 minutes brisk walking (60-75% HRmax) + 5 minutes static stretches (back stretch + thigh stretch)
	Week 11	3 times/week 60 minutes		5 minutes dynamic stretching (arm swings + walking lunges) + 50 minutes brisk walking (60-75% HRmax) + 5 minutes static stretches (back stretch + thigh stretch)
	Week 12	3 times/week 60 minutes		5 minutes dynamic stretching (arm swings + walking lunges) + 50 minutes brisk walking (60-75% HRmax) + 5 minutes static stretches (back stretch + thigh stretch)

Appendix I

Validation of Experts for Intervention Program

Dear Experts

I am a PhD student in Physical Education at Universiti Putra Malaysia. My research title is " Effects of active video games on physical activity, psychological distress, exercise motivation and body composition among college students with overweight and obesity in China". As you have good theoretical and practical experience in your professional field, I would like to invite you to participate in my research. Therefore, I sincerely invite you as an expert to give your opinions and suggestions for my research. All the information you fill in will be used for this study and will not be used for any other purpose, and everything you fill in will be kept confidential. Please fill it out carefully.

Thank you for your help.

University Putra Malaysia
Supervisor committee: Prof. Dr. Soh Kim Geok
Dr. Hazizi Abu Saad

1. Expert information

Name:	
Title:	
Research Area:	
Work unit:	

2. Questionnaire information

The questionnaires are scored on a 4-point scale where 1 = not relevant, 2 = somewhat relevant, 3 = relevant and 4 = highly relevant. Please rate the instrument for all variables on the appropriate scale and mark "√". If you have any further comments or suggestions, please make notes, and indicate them.

Table 1 : Evaluation of the Effectiveness of Intervention Program

Contents									Comments
	4	3	2	1	4	3	2	1	
Frequency									
Intensity									
Time									
Duration									
Type (AVG selection)									
Warm-up content									
Main intervention content									
Cool-down content									
Risk									
Overall evaluation of the program									

Active Video Game Training intervention information

This protocol summarises previous research and literature in related fields and incorporates the characteristics of active video game (RFA) to design a unique active video game training programme. According to the relevant literature, 30 minutes to 1 hour per session three times a week for 6 to 12 weeks has shown improvement in the physical and mental health of college students (Zhao et al., 2024; Wu et al., 2022; Peng et al., 2015; Jacobs et al., 2011). Therefore, to better improve the overall health of college students with overweight and obesity, it was also combined with the usual classroom time in China. The frequency of training in this experiment was three times per week, 40-60 minutes per session, and the duration of training was 12 weeks. The characteristics of the AVG (RFA) used in this experiment were divided into three phases. The first phase was 1-4 weeks. The second phase was 5-8 weeks, and the third phase was 9-12 weeks. Exercise duration was 40 minutes in the first phase, 50 minutes in the second phase and 1 hour in the third phase. Exercise intensity was controlled by maximum heart rate. Exercise intensity was ensured after each training session with measurements using the Ring-Con that comes with the AVG, combined with a secondary assessment on a standard Borg scale (6-20 points).

It should be noted that the AVG used in this study is Nintendo's Fitness Ring Adventure. Before the intervention, participants were instructed on how to play the game and create a personal account. RFA comes with a leg strap and a fitness ring (Ring-Con) that needs to be controlled by the hand and needs to be used in conjunction with the controller (Joy-Con) of the Switch console. After the corresponding Joy-Con is inserted into the leg strap and the fitness ring, all the movements of the participants can be reflected in the game character. RFA mainly includes three game modes.

(1) Adventure Mode: This mode has a total of 23 worlds, each of which requires the participant to engage in levelling activities. Participants run, jump, squat, push-ups,

and other movements to control the character to defeat various monsters and win the game.

(2) Easy Mode (Mini-Game Mode): Participants can play a variety of fun mini-games, such as dodgeball, balance beam, and more. By playing these games directly to get scores and rewards

(3) Training Combination Mode: Participants can freely mix and match from more than 60 combinations of movements to choose the exercise mode that suits them. Players can choose from the combination mode and train directly according to their goals, such as improving shoulder pain, slimming the waist, lifting the buttocks, and so on.

Adding new game modes at each stage increases participants' enjoyment of the game and stimulates their interest in exercise and exercise autonomy. The details are as follows:

In Phase 1 (1-4 weeks): it consists mainly of a 5-minute warm-up and a 5-minute relaxation. 30-minute adventure mode

In Phase 2 (5-8 weeks): 5 minutes of warm-up and 5 minutes of relaxation. 20 minutes of adventure mode plus 20 minutes of training combination mode.

In Phase 3 (9-12 weeks): 5 minutes of warm-up and 5 minutes of relaxation. 20 minutes of Adventure Mode plus 20 minutes of Training Combo Mode plus 10 minutes of Mini-Games Mode.

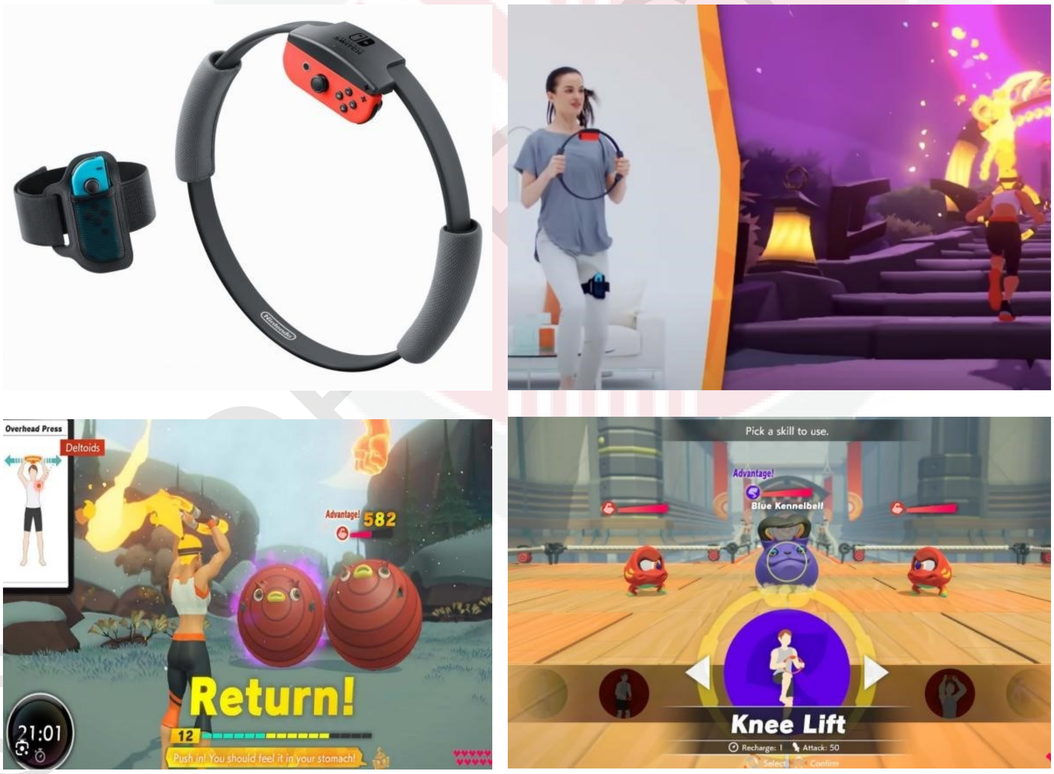

Table 2 : AVG Training Protocol (Experimental Group)

Week	Duration& Frequency	Exercises& Order	Contents
Week 1-4	3 times/week 40 minutes	5-minute warm-up + 30-minute game + 5-minute cool down	RFA guided warm-up (5min) + Adventure mode (30min) (60-75% HRmax) + RFA guided cool down (5min)
Week 5-8	3 times/week 50 minutes	5-minute warm-up + 40-minute game + 5-minute cool down	RFA guided warm-up (5min) + Adventure mode (20min) (60-75% HRmax) + Training combination mode (20min) (60-75% HRmax) + RFA guided cool down (5min)
Week 9-12	3 times/week 1hour	5-minute warm-up + 50-minute game + 5-minute cool down	RFA guided warm-up (5min) + Adventure mode(20min) (60-75% HRmax) + Training combination mode (20min) (60-75% HRmax) + Mini game mode (10min) (60-75% HRmax) + RFA guided cool down (5min)

Appendix J

Validation of Experts for Instrument Contents

Dear Experts

I am a PhD student in Physical Education at Universiti Putra Malaysia. My research title is " Effects of active video games on physical activity, psychological distress, exercise motivation and body composition among college students with overweight and obesity in China". As you have good theoretical and practical experience in your professional field, I would like to invite you to participate in my research. Therefore, I sincerely invite you as an expert to give your opinions and suggestions for my research. All the information you fill in will be used for this study and will not be used for any other purpose, and everything you fill in will be kept confidential. Please fill it out carefully.

Thank you for your help.

University Putra Malaysia
Supervisor committee: Prof. Dr. Soh Kim Geok
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3. Expert information

Name:		
Title:		
Research Area:		
Work unit:		

4. Questionnaire information

The questionnaires are scored on a 4-point scale where 1 = not relevant, 2 = somewhat relevant, 3 = relevant and 4 = highly relevant. Please rate the instrument for all variables on the appropriate scale and mark "√". If you have any further comments or suggestions, please make notes, and indicate them.

Table 1 : Evaluation of the Effectiveness of Instrument Contents

Type	Sub-type	Relevance				Clarity				Suggestions
		4	3	2	1	4	3	2	1	
	1. I found myself getting upset by quite trivial things									
	2. I was aware of dryness of my mouth									
	3. I couldn't seem to experience any positive feeling at all									
	4. I experience difficulty (eg. Excessively rapid breathing breathlessness in the absence									
	5. I just couldn't seem to get going									
	6. I tended to over-react to situations									
	7. I had a feeling of shakiness (eg. Legs going to give way)									
	8. I found it difficult to relax									
	9. I found myself in situations that made so anxious I was most relieved when they ended									
	10. I felt that I had nothing to look forword to									
	11. I found myself getting upset rather easily									
	12. I felt that I was using a lot of nervous energy									
Depression Anxiety and Stress Scale-42 (DASS-42)	13. I felt sad and depressed									
	14. I found myself getting impatient when I was delayed in any way (eg, elevators, traffic lights, being kept waiting)									
	15. I had a feeling of faintness									
	16. I felt that I had lost interest in just about everything									
	17. I felt I wasn't worth much as a person									
	18. I felt that I was rather touchy									
	19. I perspired noticeably (eg, hands sweaty) in the absence of high temperatures or physical exertion									
	20. I felt scared without any good reason									
	21. I felt that life wasn't worthwhile									
	22. I found it hard to wind down									
	23. I had difficulty in swallowing									
	24. I couldn't seem to get any enjoyment out of the things I did									
	25. I was aware of the action of my heart in the absence of physical exertion (eg, sense of heart rate increase, heart missing a beat)									
	26. I felt down-hearted and blue									
	27. I found that I was very irritable									
	28. I felt I was close to panic									
	29. I found it hard to calm down after something upset me									
	30. I feared that I would be "thrown" by some trivial but unfamiliar task									

	31. I was unable to become enthusiastic about anything									
	32. I found it difficult to tolerate interruptions to what I was doing									
	33. I was in a state of nervous tension									
	34. I felt I was pretty worthless									
	35. I was intolerant of anything that kept me from getting on with what I was doing									
	36. I felt terrified									
	37. I could see nothing in the future to be hopeful about									
	38. I felt that life was meaningless									
	39. I found myself getting agitated									
	40. I was worried about situations in which I might panic and make a fool of myself									
	41. I experienced trembling (eg. In the hands)									
	42. I found it difficult to work up the initiative to do things									

Table 2 : Evaluation of the Effectiveness of Instrument Contents

Type	Sub-type	Relevance				Clarity				Suggestions
		4	3	2	1	4	3	2	1	
Behavioral Regulation in Exercise Questionnaire-2 (BREQ-2)	1. I exercise because other people say I should									
	2. I feel guilty when I don't exercise									
	3. I value the benefits of exercise									
	4. I exercise because it's fun									
	5. I don't see why I should have to exercise									
	6. I take part in exercise because my friends/family/partner say I should									
	7. I feel ashamed when I miss an exercise session									
	8. It's important to me to exercise regularly									
	9. I can't see why I should bother exercising									
	10. I enjoy my exercise sessions									
	11. I exercise because others will not be pleased with me if I don't									
	12. I don't see the point in exercising									
	13. I feel like a failure when I haven't exercised in a while									
	14. I think it is important to make the effort to exercise regularly									
	15. I find exercise a pleasurable activity									
	16. I feel under pressure from my friends/family to exercise									
	17. I get restless if I don't exercise regularly									
	18. I get pleasure and satisfaction from participating in exercise									
	19. I think exercising is a waste of time									

Table 3 : Evaluation of the Effectiveness of Instrument Contents

Variables	Sub variables	Measurement Method	Relevance				Clarity				Comments
Physical activity	Step counts	Pedometer (record steps)	4	3	2	1	4	3	2	1	
Body Composition	Body mass index	Body composition analyzer (BIA) stable stadiometer + Tape ruler									
	Body fat percentage	Body composition analyzer (BIA)									
	Lean body Mass	Body composition analyzer (BIA)									
	Waist to hip ratio	Tape ruler Waist (cm) / hips (cm)									

4. Instruments Information

The dependent variables in this study were physical activity, psychological distress, exercise motivation and body composition. Based on internationally recommended instruments. Physical activity (steps) was measured using a pedometer. Psychological distress was measured using the DASS-42. Exercise motivation was measured using the BREQ-2. Body composition was measured using Body Composition Analyser (BIA) and tape measure.

Appendix K

Data Collection Process

Phase1: Pre-intervention Phase	
Recruiting participants	★ Inclusion and exclusion criteria
	★ Physical activity readiness questionnaire (PAR-Q)
Cluster randomization	★ Experimental group
	★ Control group
Preliminary preparation	★ Equipment installation
	★ Familiarity with specialised classrooms
	★ Introduction to RFA
	★ Distribute training logs, attendance sheets and game instruction manuals
	★ Introduction notes
	★ Pilot study
Pre-test (0^{th} week)	★ Anthropometric assessments (height weight)
	★ Physical activity
	★ Psychological distress
	★ Exercise motivation
	★ Body composition
Phase2: Intervention Implementation Phase	
EG: RFA training	RFA warm-up, basic training, cool-down
CG: ST training	Activity of daily living + Record diet
Post-test 1 (6^{th} week)	★ Physical activity
	★ Psychological distress
	★ Exercise motivation
	★ Body composition
EG: RFA training	RFA warm-up, basic training, cool-down
EG: ST training	Activity of daily living + Record diet
Pre-test 2 (12^{th} week)	★ Physical activity
	★ Psychological distress
	★ Exercise motivation
	★ Body composition

Basic Information Name: Date of birth: Height (cm): Weight(kg) Test Content: (baseline/ week 6/ week 12)

Variable	Components	Test	Score		
			Week 0	Week 6	Week 12
Physical activity	Step counts	Pedometer			
Body composition	Body mass index	Body Composition Analyser			
	Body fat percentage	Body Composition Analyser			
	Lean body mass	Body Composition Analyser			
	Waist-to-hip ratio	Tape rule			

Appendix L

Normality Test for Variables

Table 1 : Results of Kolmogorov-Smirnov and Shapiro-Wilk test for normality

Time		Group	Kolmogorov-Smirnov[a]	df	Sig.	Shapiro-Wilk	df	Sig.
Pre-test	Age	CG	.242	32	<.001	.803	32	<.001
		EG	.210	31	.001	.849	31	<.001
	Height	CG	.129	32	.188	.942	32	.085
		EG	.134	31	.168	.949	31	.149
	Weight	CG	.133	32	.161	.936	32	.057
		EG	.145	31	.095	.886	31	.003
	Physical activity	CG	0.095	32	.200*	0.956	32	0.218
		EG	0.067	31	.200*	0.984	31	0.901
	Psychological distress	CG	0.075	32	.200*	0.987	32	0.962
		EG	0.137	31	0.142	0.953	31	0.188
	Depression	CG	0.113	32	.200*	0.962	32	0.318
		EG	0.118	31	.200*	0.973	31	0.602
	Anxiety	CG	0.15	32	0.063	0.963	32	0.336
		EG	0.178	31	0.013	0.97	31	0.525
	Stress	CG	0.163	32	0.031	0.972	32	0.568
		EG	0.239	31	<.001	0.826	31	<.001
	External regulation	CG	0.216	32	<.001	0.9	32	0.006
		EG	0.239	31	<.001	0.866	31	0.001
	Amotivation	CG	0.234	32	<.001	0.856	32	<.001
		EG	0.274	31	<.001	0.841	31	<.001
	Introjected Regulation	CG	0.172	32	0.017	0.924	32	0.027
		EG	0.154	31	0.058	0.94	31	0.084
	Identified Regulation	CG	0.228	32	<.001	0.903	32	0.007
		EG	0.26	31	<.001	0.914	31	0.016
	Intrinsic Regulation	CG	0.214	32	<.001	0.917	32	0.017
		EG	0.258	31	<.001	0.854	31	<.001
	Body mass index	CG	0.154	32	0.05	0.929	32	0.037
		EG	0.128	31	.200*	0.851	31	<.001

Week6	Body fat percentage	CG	0.101	32	.200*	0.938	32	0.066
		EG	0.122	31	.200*	0.927	31	0.037
	Lean body mass	CG	0.154	32	0.051	0.898	32	0.005
		EG	0.167	31	0.028	0.908	31	0.012
	Waist-to-hip ratio	CG	0.129	32	0.194	0.934	32	0.051
		EG	0.08	31	.200*	0.969	31	0.488
	Physical activity	CG	0.126	32	.200*	0.915	32	0.015
		EG	0.147	31	0.084	0.949	31	0.147
	Psychological distress	CG	0.094	32	.200*	0.979	32	0.759
		EG	0.115	31	.200*	0.968	31	0.473
	Depression	CG	0.151	32	0.06	0.951	32	0.158
		EG	0.188	31	0.007	0.937	31	0.07
	Anxiety	CG	0.203	32	0.002	0.937	32	0.06
		EG	0.186	31	0.008	0.95	31	0.159
	Stress	CG	0.136	32	0.142	0.96	32	0.281
		EG	0.198	31	0.003	0.933	31	0.053
	External regulation	CG	0.233	32	<.001	0.876	32	0.002
		EG	0.274	31	<.001	0.841	31	<.001
	Amotivation	CG	0.222	32	<.001	0.806	32	<.001
		EG	0.256	31	<.001	0.846	31	<.001
	Introjected Regulation	CG	0.211	32	<.001	0.885	32	0.003
		EG	0.239	31	<.001	0.903	31	0.008
	Identified Regulation	CG	0.184	32	0.007	0.912	32	0.013
		EG	0.203	31	0.002	0.894	31	0.005
	Intrinsic Regulation	CG	0.283	32	<.001	0.838	32	<.001
		EG	0.258	31	<.001	0.843	31	<.001
Week12	Body mass index	CG	0.142	32	0.097	0.947	32	0.116
		EG	0.096	31	.200*	0.908	31	0.011
	Body fat percentage	CG	0.102	32	.200*	0.935	32	0.054
		EG	0.101	31	.200*	0.923	31	0.028
	Lean body mass	CG	0.156	32	0.045	0.907	32	0.01
		EG	0.119	31	.200*	0.915	31	0.018
	Waist-to-hip ratio	CG	0.154	32	0.051	0.945	32	0.101
		EG	0.121	31	.200*	0.952	31	0.179
	Physical activity	CG	0.133	32	0.158	0.961	32	0.285
		EG	0.136	31	0.152	0.969	31	0.484
	Psychological distress	CG	0.128	32	0.199	0.96	32	0.27
		EG	0.131	31	0.191	0.96	31	0.293

	Depression	CG	0.236	32	<.001	0.807	32	<.001
		EG	0.175	31	0.016	0.943	31	0.097
	Anxiety	CG	0.166	32	0.025	0.956	32	0.219
		EG	0.165	31	0.03	0.949	31	0.142
	Stress	CG	0.134	32	0.156	0.957	32	0.227
		EG	0.14	31	0.124	0.93	31	0.045
	External regulation	CG	0.292	32	<.001	0.839	32	<.001
		EG	0.251	31	<.001	0.806	31	<.001
Amotivation		CG	0.273	32	<.001	0.803	32	<.001
		EG	0.288	31	<.001	0.856	31	<.001
	Introjected Regulation	CG	0.225	32	<.001	0.872	32	0.001
		EG	0.191	31	0.006	0.885	31	0.003
	Identified Regulation	CG	0.194	32	0.003	0.9	32	0.006
		EG	0.221	31	<.001	0.885	31	0.003
	Intrinsic Regulation	CG	0.197	32	0.003	0.947	32	0.122
		EG	0.304	31	<.001	0.772	31	<.001
	Body mass index	CG	0.175	32	0.014	0.928	32	0.034
		EG	0.145	31	0.097	0.872	31	0.002
	Body fat percentage	CG	0.132	32	0.165	0.927	32	0.032
		EG	0.116	31	.200*	0.949	31	0.145
	Lean body mass	CG	0.18	32	0.01	0.905	32	0.008
		EG	0.148	31	0.083	0.908	31	0.012
	Waist-to-hip ratio	CG	0.152	32	0.059	0.922	32	0.024
		EG	0.11	31	.200*	0.974	31	0.646

EG: experimental group; CG: control group; a: Lilliefors Significance Correction.

Appendix M

Levene's Test of Equality of Error Variance at Baseline

Table 1 : Levene's Test of Equality of Error Variance at Baseline (Basic Information)

Variable	Levene Statistic	df 1	df 2	p-value
Age	0.28	1	61	0.599
Heigh	1.655	1	61	0.203
Weigh	0.492	1	61	0.486

Table 2 : Levene's Test of Equality of Error Variances at Baseline

Variable	Test	Levene Statistic	df 1	df 2	p-value
Physical activity	Pedometer	0.052	1	61	0.82
Depression	DASS-42	0.084	1	61	0.772
Anxiety	DASS-42	0.006	1	61	0.939
Stress	DASS-42	0.545	1	61	0.463
Psychological distress	DASS-42	0.086	1	61	0.771
External Regulation	BREQ-2	1.094	1	61	0.300
Amotivation	BREQ-2	0.297	1	61	0.588
Introjected Regulation	BREQ-2	0.026	1	61	0.871
Identified Regulation	BREQ-2	0.138	1	61	0.711
Intrinsic Regulation	BREQ-2	1.919	1	61	0.171
Body mass index	Body omposition analyser (BIA) +Tape measure	2.572	1	61	0.114
Lean body mass	Body omposition analyser (BIA)	3.103	1	61	0.083
Body fat percentage	Body omposition analyser (BIA)	0.454	1	61	0.503
Waist-to-hip ratio	Tape measure	0.422	1	61	0.518

* Significant at 0.05 level

Appendix N

Reliability Test Results

1. Reliability Test Results of the Questionnaire

1.1 Depression Anxiety and Stress Scale-42

(1) Depression

Reliability Statistics for Depression

Cronbach's Alpha	Number of Items
.891	14

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
D3	9.25	27.533	.490	.887
D5	9.31	28.496	.515	.886
D10	9.69	29.429	.321	.893
D13	9.25	27.533	.603	.882
D16	9.44	25.729	.765	.874
D17	9.38	28.383	.384	.892
D21	9.63	25.583	.732	.875
D24	9.38	28.250	.510	.886
D26	9.38	28.250	.510	.886
D31	9.44	28.796	.382	.891
D34	9.69	25.029	.812	.871
D37	9.63	27.717	.511	.886
D38	9.75	25.133	.800	.871
D42	9.25	27.533	.603	.882

(2) Anxiety

Reliability Statistics for Anxiety

Cronbach's Alpha	Number of Items
.910	14

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
A2	8.31	28.763	.570	.906
A4	8.50	25.600	.752	.899
A7	8.31	29.429	.450	.910
A9	8.25	29.267	.530	.907
A15	8.94	27.663	.773	.899
A19	8.63	30.917	.209	.917
A20	8.75	29.933	.402	.911
A23	8.94	27.263	.849	.896
A25	8.38	28.650	.550	.907
A28	8.81	27.229	.763	.898
A30	8.38	24.783	.805	.896
A36	8.56	27.729	.643	.903
A40	8.00	26.667	.834	.895
A41	7.88	29.717	.506	.908

(3) Stress

Reliability Statistics for Stress

Cronbach's Alpha	Number of Items
.803	14

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
S1	14.63	17.850	.259	.804
S6	15.50	17.333	.453	.789
S8	14.69	17.296	.396	.793
S11	14.44	14.396	.721	.759
S12	15.50	16.533	.656	.775
S14	14.06	17.662	.223	.810
S18	14.38	16.383	.540	.781
S22	14.50	16.533	.508	.784
S27	15.00	17.867	.275	.802
S29	14.56	17.729	.368	.795
S32	14.94	16.729	.464	.787
S33	15.19	17.496	.352	.796
S35	14.94	17.662	.369	.795
S39	14.88	17.850	.397	.794

1.2 Behavioral Regulation in Exercise Questionnaire-2

(1) External Regulation

Reliability Statistics for External Regulation

Cronbach's Alpha	Number of Items
.860	4

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
ER1	3.06	3.529	.766	.797
ER6	2.94	3.396	.794	.784
ER11	2.81	4.296	.529	.887
ER16	2.81	3.496	.748	.805

(2) Amotivation

Reliability Statistics for Amotivation

Cronbach's Alpha	Number of Items
.798	4

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
AM5	1.63	2.650	.348	.854
AM9	1.63	1.717	.842	.619
AM12	1.31	2.096	.578	.763
AM19	1.44	1.863	.704	.698

(3) Introjected Regulation

Reliability Statistics for Introjected Regulation

Cronbach's Alpha	Number of Items
.807	3

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
INR2	2.06	1.796	.657	.761
INR7	1.94	.996	.777	.636
INR13	1.75	1.667	.626	.770

(4) Identified Regulation

Reliability Statistics for Identified Regulation

Cronbach's Alpha	Number of Items
.745	4

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
IDR	3.94	1.396	.613	.645
IDR8	4.13	1.583	.450	.734
IDR14	4.13	1.583	.450	.734
IDR17	4.31	1.296	.653	.617

(5) Intrinsic Regulation

Reliability Statistics for Intrinsic Regulation

Cronbach's Alpha	Number of Items
.788	4

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
ISR4	2.50	1.867	.404	.830
ISR10	2.94	1.663	.780	.662
ISR15	2.81	1.629	.475	.813
ISR18	2.81	1.496	.831	.618

2. Test-retest Reliability of Physical Activity Instruments and Body Composition Instruments

Variables	Indicators	ICC	95% Confidence Interval	
			Lower Bound	Upper Bound
Physical activity	Step counts	0.981	0.945	0.993
	Body mass index	0.987	0.963	0.995
Body composition	Body fat percentage	0.999	0.999	1.000
	Lean body mass	0.960	0.885	0.986
	Waist-to-hip ratio	0.996	0.988	0.999

Appendix O

Content Validity of Intervention and Instruments

Table 1 : Relevancy and Clarity Agreement of the Intervention Items

Contents	Relevance			Clarity		
	Number of Agreement	I-CVI	KAPPA	Number of Agreement	I-CVI	KAPPA
Frequency	6	1.00	1.00	6	1.00	1.00
Intensity	5	0.833	0.816	6	1.00	1.00
Time	6	1.00	1.00	6	1.00	1.00
Duration	5	0.833	0.816	5	0.833	0.816
Type (AVG selection)	6	1.00	1.00	6	1.00	1.00
warm-up	6	1.00	1.00	6	1.00	1.00
Main intervention content	6	1.00	1.00	6	1.00	1.00
cool-down	6	1.00	1.00	6	1.00	1.00
Risk	6	1.00	1.00	5	0.833	0.816
Overall evaluation of the program	6	1.00	1.00	6	1.00	1.00

Table 2 : Relevancy and Clarity Agreement of the Instruments Items (DASS-42)

Type	Sub type	Number of experts	Agreement	Relevance		Clarity	
				I-CVI	KAPPA	I-CVI	KAPPA
	Q1	6	6	1	1	1	1
	Q2	6	6	1	1	1	1
	Q3	6	6	1	1	1	1
	Q4	6	6	1	1	1	1
	Q5	6	6	1	1	1	1
	Q6	6	6	1	1	1	1
	Q7	6	6	1	1	1	1
	Q8	6	6	1	1	1	1
	Q9	6	6	1	1	1	1

Depression Anxiety and Stress Scale (DASS-42)	Q10	6	6	1	1	1	1
	Q11	6	6	1	1	1	1
	Q12	6	6	1	1	1	1
	Q13	6	6	1	1	1	1
	Q14	6	6	1	1	1	1
	Q15	6	6	1	1	1	1
	Q16	6	6	1	1	1	1
	Q17	6	6	1	1	1	1
	Q18	6	6	1	1	1	1
	Q19	6	6	1	1	1	1
	Q20	6	6	1	1	1	1
	Q21	6	6	1	1	1	1
	Q22	6	5	0.833	0.816	1	1
	Q23	6	6	1	1	1	1
	Q24	6	6	1	1	1	1
	Q25	6	6	1	1	1	1
	Q26	6	5	0.833	0.816	1	1
	Q27	6	6	1	1	1	1
	Q28	6	6	1	1	1	1
	Q29	6	6	1	1	1	1
	Q30	6	5	1	1	0.833	0.816
	Q31	6	6	1	1	1	1
	Q32	6	6	1	1	1	1
	Q33	6	6	1	1	1	1
	Q34	6	5	1	1	0.833	0.816
	Q35	6	6	1	1	1	1
	Q36	6	6	1	1	1	1
	Q37	6	6	1	1	1	1
	Q38	6	6	1	1	1	1
	Q39	6	5	1	1	0.833	0.816
	Q40	6	6	1	1	1	1
	Q41	6	6	1	1	1	1
	Q42	6	6	1	1	1	1

Table 3 : Relevancy and Clarity Agreement of the Instruments Items (BREQ-2)

Type	Sub type	Number of experts	Agreement	Relevance		Clarity	
				I-CVI	KAPPA	I-CVI	KAPPA
Behavioral Regulation in Exercise Questionnaire-2 (BREQ-2)	Q1	6	6	1	1	1	1
	Q2	6	6	1	1	1	1
	Q3	6	6	1	1	1	1
	Q4	6	6	1	1	1	1
	Q5	6	6	1	1	1	1
	Q6	6	6	1	1	1	1
	Q7	6	6	1	1	1	1
	Q8	6	6	1	1	1	1
	Q9	6	6	1	1	1	1
	Q10	6	5	0.833	0.816	1	1
	Q11	6	6	1	1	1	1
	Q12	6	5	1	1	0.833	0.816
	Q13	6	6	1	1	1	1
	Q14	6	6	1	1	1	1
	Q15		6	1	1	1	1
	Q16	6	6	1	1	1	1
	Q17	6	6	1	1	1	1
	Q18	6	6	1	1	1	1
	Q19	6	6	1	1	1	1

Table 4 : Relevancy and Clarity Agreement of the Instruments Items

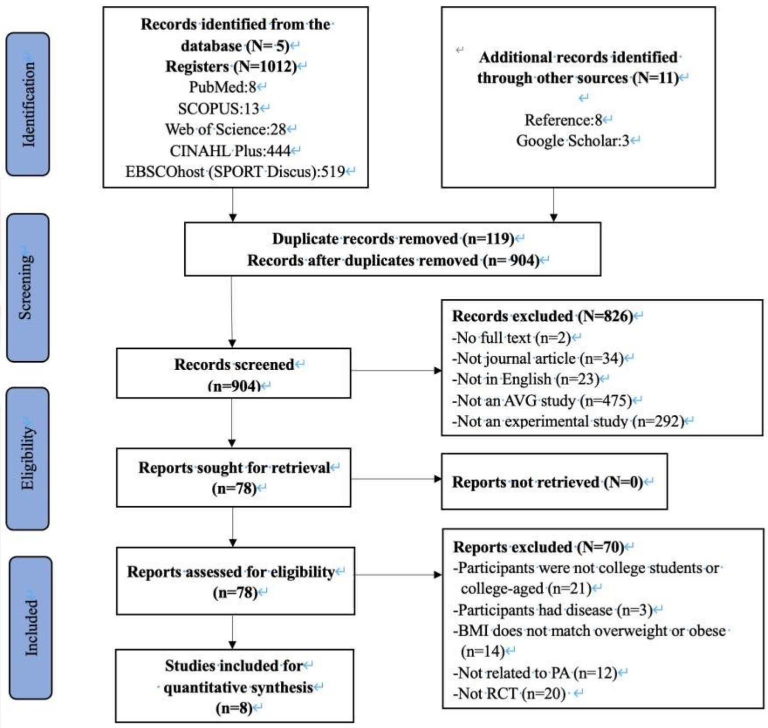
Type	Sub type	Measurement Method	Number of experts	Agreement	Relevance		Clarity	
					I-CVI	KAPPA	I-CVI	KAPPA
PA BC	Step counts	Pedometer (record steps)	6	5	0.833	0.816	0.833	0.816
	Body mass index	Body composition analyzer (BIA) Stable stadiometer [Weight (kg)/Height (m)^2]	6	6	1	1	1	1
	Body fat percentage	Body composition analyzer (BIA)	6	6	1	1	1	1
	Lean body mass	Body composition analyzer (BIA)	6	6	1	1	1	1
	Waist to hip ratio	Tape ruler [Waist (cm) / hips (cm)]	6	6	1	1	1	1

Note: PA: physical activity; BC: body composition; BIA: Bioelectrical Impedance Analysis; M: meter; KG: kilogram; CM: centimetre.

Appendix P

Systematic Review and Meta-Analysis of AVG

1. Effects of active video games on physical activity among college students with overweight and obesity: a systematic review 1.1 PRISMA Table



1.2 Keywords and Search Strategies

Keyword	Search Strategy	Database
Exergame, moderate-to-vigorous physical activity, energy expenditure, obesity, young adult	"video gam*" OR "videogam*" OR "active video gam*" OR "exergam*" OR "interactive gam*" OR "interactive video gam*" OR "exercise video gam*" OR "fitness gam*" OR "Playstation" OR "Nintendo" OR "Wii" OR "Xbox" OR "Kinect" OR "EyeToy" AND "physical activity" OR "energy expenditure" OR "exercise" OR "energy metabolism" OR "bodily movement" OR "heart rate" OR "metabolic equivalent" OR "oxygen consumption" OR "activity count*" AND "obes*" OR "overweight" AND "college student*" OR "university student*" OR "undergraduate student*" OR "graduate student*."	PubMed Web of Science EBSCOhost (SPORTDiscus) CINAHL Plus Scopus

1.3 Characteristics of the Studies

Authors (Year) Country	Study Description	Population	Frequency & Duration	AVGs	Instrument	Measurement & Main outcome	Key Findings
Jacobs, K et al. (2011)	To determine the feasibility of Nintendo Wii Fit to encourage undergraduate students to lose weight through a 12-week intervention program.	F=5 Age≥ 18 BMI≥18 Race: Asian(n=2,40%). White (n=2, 40%). Mexican (n=1, 20%).	Experimental group: 45 minutes each time, 4 times a week. Control group: walking to class. Duration is 12 weeks.	Nintendo Wii Wii Fit	1. Pedometer 2. Standard bathroom scale or Wii Fit balance board 3. Activity Level Test Questionnaire 4. BREQ-2 5. PAR-Q	1. Body weight and BMI. 2. Participants' current activity level, personal exercise motivation, and physical health. 3. Measure RPE every Wii session. 4. Record steps, activity and self-reported daily food every day BMI↓, weight↓ sports motivation↑, PAL ↔	Using Wii Fit for exercise can increase exercise motivation and be used as a tool for college students to control their weight individually.
Peng, W et al. (2015)	To assess the potential of active video games informed by theoretical guidance to enhance both MVPA and game involvement among college students, while also decreasing their sedentary behavior.	F=56; M=65 (Invalid number, n=31) Age: 18-25 Race: Asian (n=11, 9.1%). White(n=90,74.4%). African American (n=12, 9.9%). Other (n=8, 6.6%).	Experimental group: Three times a week for four weeks. Control group: no treatment.	A third person, fantasy role-playing game	1. ACTi Graph GT3X accelerometers 2. PACES 3. Active inputs (Wii mote, Nunchuk, and dance pad) 4. Controller input (Xbox 360 controller)	1. Baseline measurement in week 0 2. Physical activity was objectively measured at week 0 (baseline), and week 1 and 5. 3. Calculate the attendance rate 4. Measure the players' enjoyment, perceived need satisfaction of competence, and future play motivation in the first and fourth weeks. MVPA↑, attendance↑, psychological need satisfaction↑	An AVG designed with the motivation theory has a positive impact on attendance and MVPA, and can improve the effectiveness of AVG.
Warburton, D. E et al. (2007)	To assess the efficacy of AVGs (combined with stationary cycling) in enhancing exercise adherence relative and physical fitness when compared to cycling	M=14 Age: 18-25 BMI: Intervention group =27±6. Control group=28±6.	30 minutes each time, three times a week. Duration is 6 weeks.	Sony PlayStation Game Bike	1. Polar s-510 2. Bioelectrical impedance 3. Television monitor 4. Electronically braked cycle ergometer	1. Attendance rates were monitored. 2. Physical fitness (VO2max, body composition, muscle strength, muscle burst, and flexibility) and	Compared to traditional bicycle training, AVG combined with fixed bicycles can lead to greater health improvements, and

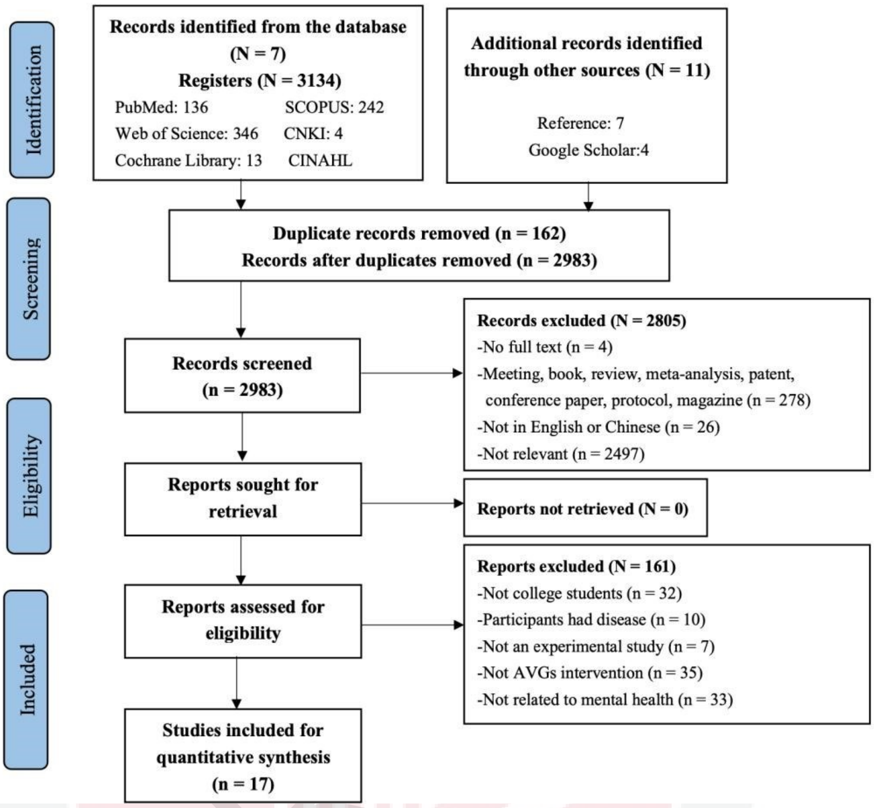
	training.				5. Metabolic cart 6. CPALFA 7. Vertec device 8. Flexometer 9. Pulse Wave	resting blood pressure. VO_2max↑, BM↔, BMI↔, FM↔, LBM↔, RSP↓, SBP↓	higher attendance leads to more physical activity.
Rodrigues, G. A et al. (2018)	To compare metabolic and cardiovascular responses when using the AVG with and without the Mini trampoline.	M=19 Age: 20.6 ± 2.01	Eight minutes each time, two times in total (with an interval of 2 days). Duration is 1week.	Nintendo Wii Fit Plus Free Run	1. Bioelectrical Impedance Analyzer 2. VO2000 portable automated system, treadmill, and prevent Pneumotach 3. Polar	Day 1: measure height, weight, body composition, VO_2 max and HR max Day 4: VO_2, HR, and METs were measured in both MT-PT and EXG-PT groups. Day 7: experimental and control groups exchange game conditions. PAL↑, %VO_2max↑, %HRmax↑, METs↑	Playing AVG on MT has greater physiological needs than playing AVG in traditional ways and can achieve moderate to intense physical activity. MT is an additional tool to enhance the physiological response when playing AVG.
Rahayu, T et al. (2019)	To determine the effect of playing AVG (only use the upper and lower limbs) on BG, HR, and SpO2.	M=24 Age: ±20 BMI: upperEx =24.6 ± 2.93. lowerEx =23.4 ± 2.47. control =24.6 ± 3.15.	Play avg of 30 minutes. Lasts 120 minutes.	XBOX or Nintendo Wii	1. Accucheck Performa glucometer 2. OxyOne Finger Pulse Oximeter	1. Measure fasting BG, HR, SpO2 2. A sweet drink was given to all participants. Measure BG, HR, SpO2 at 30, 60, 90, 120 minutes 3. AVG groups played AVG within 30 to 60 minutes, while the control group did not exercise. SpO2↔, HR↔,BG↓	Only the upper and lower AVGs effect BG and HR, but will not affect the SpO+ of college students. Playing with upper and lower limb AVG is beneficial for health.
Russell, W. D et al. (2013)	To examine AVG's physiological and affective responses across user experience and social conditions (paired vs. solo).	F=19; M=29 Age: F=21.4 ± 5.6. M=22.4 ± 5.7.	30 minutes each time, two times total (Paired mode and solo mode).	Nintendo Wii Punchout	1. PAR-Q 2. Polar 3. Body fat analyzer 4. StepWatch 3 pedometers 5. Borg's modified 10-point scale 6. POMS	1. Physical Measures: in solo and paired mode, record heart rate every minute, and measure RPE every five minutes. Measure RecHR and SeRPE for 15 minutes after exercise. 2. Mood: Use the POMS scale five minutes before exercise, five minutes and 15 minutes after exercise	Physical and emotional responses are not influenced by experience or social conditions when playing Wii punchout. Using AVG as a potential alternative to traditional sports activities requires consideration.

						to measure mood changes. resting HR↔, Steps↔, mood↔	
Douris, P. C et al. (2012)	To contrast the physiological and psychological reactions between college students engaging in Nintendo Wii Fit games and those participating in moderate-intensity brisk walking for an equivalent duration.	F=12; M=9 Age: 23.2 ±1.8 BMI:23.7±3.7	30 minutes per day for two days. (One week apart).	Nintendo Wii Fit Free Run	1. PAR-Q 2. Standing blood pressure cuff 3. Stethoscope 4. Digital body weight scale, stopwatch, and measuring tape. 5. SEES 6. Treadmill	1. Every session was measured at 5-minute intervals for HR, RR, BP, and RPE. 2. After each exercise condition, measurements of HR, BP, RPP, RPE, and SEES were recorded. HRmax↑, RPP↑, RPE↑, positive well-being↓	Wii Fit Free Run could serve as a viable alternative to conventional moderate-intensity aerobic exercise.
De Brito-Gomes, J. L et al. (2016)	To examine and contrast the effects of structured and unstructured AVG on physical activity and motivation. Use indirect measure analysis (heart rate) to verify the effect of AVG on physical activity.	M=13 Age: 19.4 ± 1.6 BMI: structured AVG=23.6 ± 3.3. unstructured AVG=22.6 ± 2.0	30 minutes each time, three times a week. Duration is 6 weeks (18 lessons).	XBOX 360 Kinect 1. Kinect Sports: Boxing 2. Nike Kinect: Training	1. PAR-Q 2. Polar FT1 2. Automated blood pressure machine 3. Metabolic gas analyzer 4. Borg Scale (6–20 points) 5. Multimedia projector	1. Baseline assessments of height, BW, resting HR, BP, AE (VO2max), and peak workload. 2. Hemodynamic and inotropic measures SBP and DBP 3. In each session, measure maximum HR and average HR, RPE, EE, and MET through mathematical formulas. AE↔, pkHR↔,RPE↔, motivation↔, averge HR↑, MET↑, EE↑	The indirect measurements can analyze physical effort intensity. Structured AVG shows better HR and EE response than unstructured AVG.

BREQ-2, the Behavioral Regulation in Exercise Questionnaire-2; PAR-Q, Physical Activity Readiness Questionnaire; F, female; M, male; RPE, ratings of perceived exertion; SDT, self-determination theory; PACES, The Physical Activity Enjoyment Scale; CPAFLA, Canadian Physical Activity Fitness and Lifestyle Approach; MT, mini-trampoline; MT-PT, play AVG on mini-trampoline; EXG-PT, play AVG on wooden surface; BG, blood glucose; HR, heart rate; OSL, oxygen saturation levels; SpO_2, the percentage of oxygen saturation; upperEx, upper only extremities exergaming; lowerEx, only extremities exergaming; HRR, heart rate reserve; THR, target heart rate; pkHR, peak heart rate; RecHR, recovery heart rate; SeRPE, post exercise session rating of perceived exertion; POMS, The Profile of Mood States; RPP, rate pressure product; BP, blood pressure; BW, body weight; RSP, resting blood pressure; RR, respiratory rate; SEES, Subjective Exercise Experience Scale; SBP, systolic blood pressure; DBP, diastolic blood pressure; EE, energy expenditure; MET, metabolic equivalent; BM,body mass; BMI, body mass index; FM, fat mass; LBM, lean body mass;↑, significant improvement; ↓, significant decrease; ↔, no significant difference.

2. Effects of Active Video Games on Mental Health Among College Students: A Systematic Review

2.1 PRISMA Table



2.2 Keywords and Search Strategies

Keyword	Search Strategy	Database
Exergame, depression, anxiety, stress, well-being, enjoyment, young adult	"video gam*" OR "videogam*" OR "active video gam*" OR "exergam*" OR "interactive gam*" OR "interactive video gam*" OR "exercise video gam*" OR" fitness gam*" OR "Playstation" OR "Nintendo" OR "Wii" OR "Xbox" OR "Kinect" OR "EyeToy" AND "mental health" OR "depression*" OR "anxiety" OR "stress" OR "psychological" OR "psychological health" OR "self-esteem" OR "well-being" OR "wellbeing" OR "psychosocial" OR "mental disorder" OR "mental illness" OR "mental disease" OR "mental distress "OR "mental problem*" OR "emotional problem*" OR "psychiatric problem*" OR "mental illness" OR "mental disease" OR "mental distress "OR "psychiatric problem*" OR "psychiatric disorder" OR "psychological disorder" OR "psychotic disorder" AND "college student*" OR "university student*" OR" undergraduate student*" OR "graduate student*.	PubMed SCOPUS Web of Science CINAHL Plus EBSCOhost Cochrane Library CNKI

2.3 Characteristics of the Studies

Authors (Year)	Study purpose	Population characteristics			AVGs	Frequency & duration	Comparison	Measurement	Main Index & outcomes	Key findings
		N	Sex	Age						
Wei, P et al. (2015) USA	To assess the impact of an AVG based on SDT design on MVPA and psychological factors in college students.	121	Mixed F = 56 M = 65	18–25	Third-person role-playing game based on SDT design	Freq: 3 times/week Time: NR Length: 4 weeks	EG1: SDT off AVG EG2: SDT on AVG EG3: Passive CG: Control group	Week 0, 1, and 5: 1. Physical activity was measured (use accelerometer). Week 1 and 4: 2. Perceived need satisfaction of competence and relatedness was measured (use perceived need satisfaction of autonomy scale). 3. Enjoyment was measured (use PACES). 4. Future gaming motivation was measured (using an adapted scale).	EG: PA (LPA, MPA, VPA)↑, attendance↑, time spent on the game↑, game enjoyment↑, future gameplay motivation↑, perceived need satisfaction↑	Intervention using an AVG based on SDT functionality improves psychological need satisfaction in college students, bringing higher attendance and greater MVPA
Huang, H et al. (2019) Taiwan, China	To assess whether playing AVG makes college students feel more energetic and relaxed and the moderating effect of exercise enthusiasm.	337	Mixed F = 194 M = 143	> 18	Xbox 360: Your Shape: Fitness Evolved	Freq: 1times/week Time: 30mins Length: 2 weeks	EG: Your Shape: Fitness Evolved CG: Maintain a normal routine (not playing AVG)	Baseline and Week 2. 1. Measure happiness, perceived energy, and relaxation using an adapted questionnaire. 2. Self-evaluation of enthusiasm for exercise.	EG: happiness↑ perceived energy↑ relaxation↑	Playing AVG can have a positive impact on the happiness, perceived energy, and relaxation of college students, especially those who are enthusiastic about exercising.
Nani, S et al. (2018) Greece	To access the effects of playing Wii Nintendo Sports on physiological	20	Mixed F = 13 M = 7	20 –25	Nintendo Wii Sports (baseball, golf, boxing, tennis, and bowling)	Freq: 3 times/week Time: 30 min Length: 10 weeks	EG: Wii Nintendo Sports (Choose two games) CG: Not join in training programs	Week 1 and 10: 1. BMI is calculated using a formula. 2. Portable gas analyser of VIASYS measures VO_2 max.	EG and CG: BW↔, BMI↔, VO_2 max ↔, HRmax↔ EG: SV↑	Exergames can improve college students' subjective vitality, making them feel more

	parameters and subjective vitality among college students.				Choose 2 out of 5			3. Heart rate monitor (Polar) measures HRmax. 4. Subjective Vitality Scale measures SV		energetic and well-being.
Douris, P.C et al. (2012)	To compare the physiological and psychological	21	Mixed F = 12 M = 9	18–25	Nintendo Wii Fit Free Run	Freq: 2 times/9days (One week apart) Time: 30 min Length: 9 days	EG: Wii Fit Free Run CG: brisk walking on a treadmill	Baseline and Day 9: 1. Measure positive well-being, psychological distress,	HRmax↑, RPP↑, RPE↑, positive well-being↓, Psychological	When sedentary college students played Wii Fit, their positive well-being
USA	responses of college students playing Nintendo Wii F with moderate-intens ity brisk walking on a treadmill.							and fatigue using SEES. 2. Brog scale to measure RPE. 3. Use a standing blood pressure cuff, stethoscope, and stopwatch to measure HR, RPP, and VR.	distress↓ Feelings of fatigue↑	and psychological distress decreased, and their fatigue increased. Wii Fit meets ACSM's recommended levels of moderate-intensity physical activity.
Nguyen, H et al. (2016) Taiwan, China	To assess the impact of playing sports games on college students' attitudes and intentions to engage in other sports and the intervening role of prior exercise frequency.	117	NR EG = 55 CG = 62	21–31	Xbox 360 Your Shape: Fitness Evolved	Freq: 3 times/week Time: 30 min Length: 12 weeks	EG: Your Shape: Fitness Evolved CG: Not join in training programs	Baseline and Weeks 4,8,12： 1. EG completed an adapted questionnaire assessing attitudes and intentions toward other forms of exercise. Baseline and Weeks 12: 2. CG completed an Adapted questionnaire.	EG: attitudes towards other forms of sports↑ Intention towards other forms of sports↔	Playing AVG can increase the attitude of college students who exercise regularly to participate in other forms of exercise, especially for students who exercise regularly. However, there will be no impact on other forms of exercise intentions.
Wu, Y et al. (2021) Taiwan,	To assess the effects of playing RFA on college students'	80	Mixed F = 34 M = 46	20–36	Nintendo Ring Fit Adventure	Freq: 3 times/week Time: 30 min Length: 4 weeks	EG: Ring Fit Adventure (in adventure mode) CG: maintained	Baseline and Week 4: 1. CPSQI to measure sleep quality. 2. BSRS-5 to measure	EG: Sleep quality↔, mood disorders↑, 1600-meter run	RFA maintains the health and fitness of college students and provides a reliable
China	1600-meter running times, heart						their regular habits (no intervention)	mood disorders.	time↓, CFI peak acceleration↔	tool for those who don't have time to exercise.

	performance indices, and psychological factors							3.CFI to measure cardiac status during exercise. 4. Zephyr BioPatch to measure physiological parameters.		
Yu, J et al. (2022) Taiwan, China	To assess whether playing exergame improves college students' quality of life and to explore potential moderators.	117	NR EG = 55 CG = 62	20–24	Xbox 360 Your Shape: Fitness Evolved	Freq: 3 times/week Time: 30 min Length: 12 weeks	EG: Your Shape: Fitness Evolved CG: maintained their regular habits (no intervention)	Baseline and Week 12: 1. SF-36 scale measures psychological and physical health status	EG: Physical functioning↑, role-physical↑, general health↑, social functioning↑, bodily pain↔, vitality↔, role-emotional↔, mental health↔	Playing AVGs helps improve the physical and mental health and quality of life of college students.
Russell, W. D et al. (2013) USA	To assess the emotional and physiological responses of college students when playing AVGs at experience levels (experienced or inexperienced) and under social conditions (single or paired mode).	48	Mixed F = 19 M = 29	F: 21.4 ±5.6 M: 22.4 ±5.7	Nintendo Wii Punch-out	Freq: NR Time: 30 min (solo and paired modes) Length: NR	EG: 1. experienced + single mode 2. experienced + paired mode CG: 3. inexperienced + single mode 4. inexperiencepaired moded +	POMS measures emotional states: 1. 10 min before the experiment (pre-1) 2. 5 min after the experiment (post-1) 3. 15 min after the experiment (post-2) 4. Polar, Step Watch 3 pedometers, Brog scales measure HR, SC, RPE	EG vs. CG peak HR↔, RecHR HR↔,Mean HR↔, RPE↔, SC↔ mood↔ Paired vs. Solo peak HR↑ (paired model)	The physiological and emotional states of college students playing Wii Punch are unaffected by experience and game mode, and this game requires careful consideration as an alternative to traditional exercise.
Roure, C et al. (2019) Switzerland	To assess the impact of AVG (Greedy Rabbit) on situational interest and physical activity of	60	Mixed F = 29 M = 31	18–25	Greedy Rabbit (design-based bike AVG)	Freq: 2 times/2week Time: NR Length: 2 weeks	EG: Greedy Rabbit CG: a placebo version of Greedy Rabbit	1. French 19-item situational interest scale to measure situational interest (5 min after test) 2. Indicators of physical activity (HR, VO2, and cadence)	EG: SI (instant enjoyment and attention demand) ↑, %HRmax↑, %VO2 max↑	Playing design-based cycling AVGs is a good tool to enhance situational interest (instant enjoyment and attention demand) and physical activity

	college students.							using a calibrated metabolic cart and heart rate detector.		among college students
Huang, H et al. (2017) Taiwan, China	To assess how playing AVGs affects the emotional state of college students and staff and whether this effect is related to gender and time spent exercising	337	NR EG = 168 CG = 167	> 20	Xbox 360 Your Shape: Fitness Evolved	Freq: 1 times/week Time: 30 min Length: 2 weeks	EG: Your Shape: Fitness Evolved CG: No intervention. Only fill out the questionnaire	1. Baseline and Week 2: Measurement of vigour, well-being, and perceived stress using adapted scales	happiness↑, vigour↑, perceived stress↔	AVG improves mood states (including increased vitality and well-being and reduced perceived stress) in college students and does not change by gender, occupation, or time spent exercising.
Yunus, F. W et al. (2020) Malaysia	To access the impact of using Xbox 360 Kinect on sleep quality and depression, stress, and anxiety among undergraduate students	36	Mixed F = 31 M = 5	EG: 22.67 ± 1.138 CG: 23.11 ± 0.963	Xbox 360 Kinect game	Freq: 3 times/week Time: 30 min Length: 6 weeks	EG: Xbox 360 Kinect game CG: continue with normal daily routine	At baseline and week 6: 1. Emotional states were measured using the DASS-21 2. Sleep was measured using the FOSQ-30	EG: Sleep quality↑, mental health↑(depression, stress anxiety)	Using AVG to intervene in sleep and mood in undergraduate college students is feasible and has shown promising results for both mood improvement and sleep quality.
Nguyen, H et al. (2018) Taiwan, China	SCT was used to assess the effects of AVG on college students' well-being and the moderating effects of being optimistic or attempting to control weight	337	Mixed F = 143 M = 192	20–40	Xbox 360 Your Shape: Fitness Evolved	Freq: 1 times/week Time: 30 min Length: 2 weeks	EG: Your Shape: Fitness Evolved CG: No intervention	1. Using the adapted scale to measure happiness, optimism, and willingness to control weight.	EG: Happiness↑ (Optimism weight control)	Playing AVG among college students helps maintain a sense of happiness, and this effect is most effective among college students who are trying to control their weight.

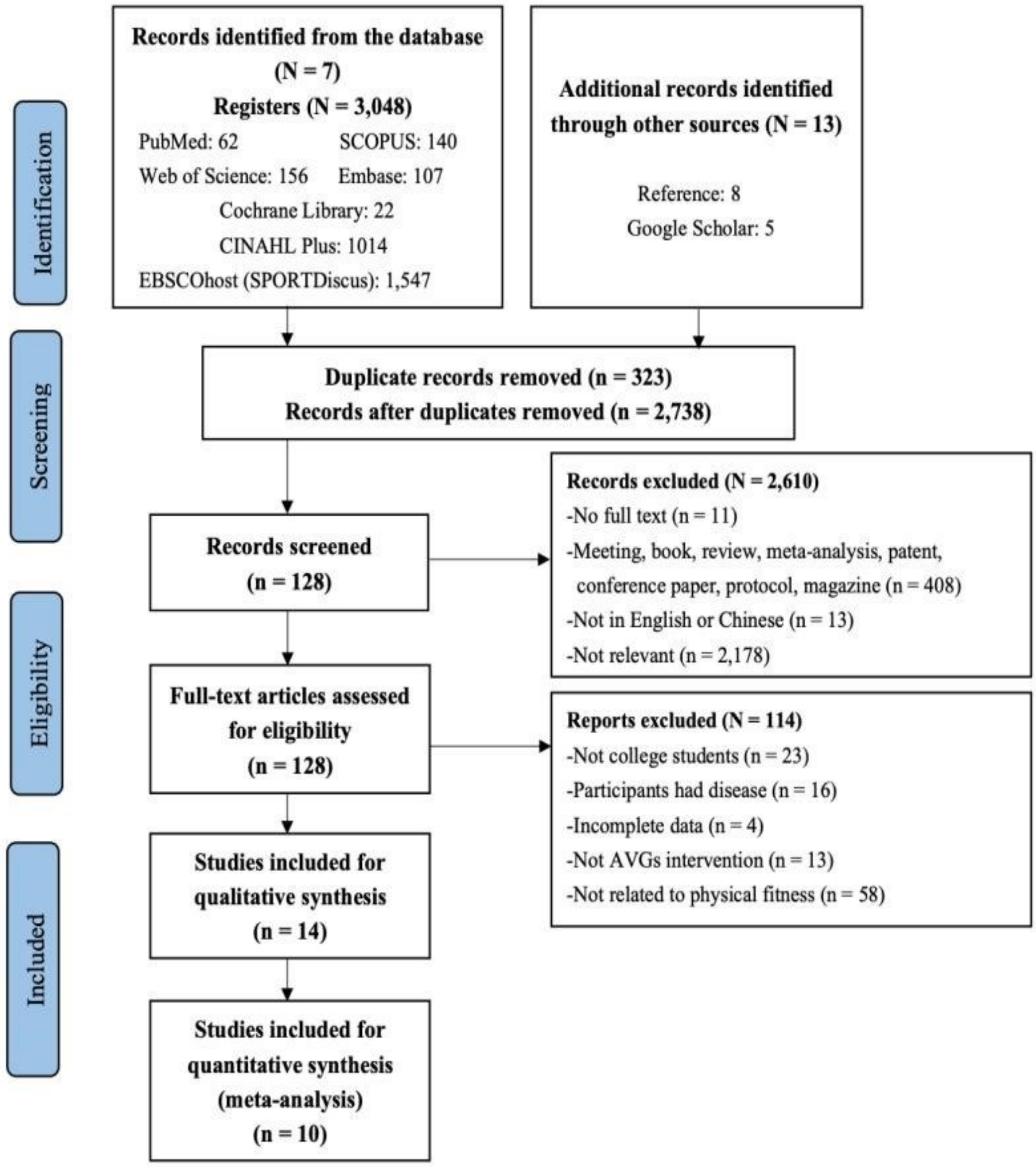
Wei, P et al.	To access how SDT-enabled	160	Mixed F = 49	Mean 21	Olympus (Third-person	Freq: 1 time Time: 15 min	EG1: autonomy on+ competence on	Before and after the game: Use the modified	EG1: Game enjoyment↑	AVG with SDT function support can
(2012) USA	AVG affects young people's need satisfaction and gaming experience		M = 111		adventure game with SDT functionality)		EG2: autonomy on+ competence off EG3: autonomy off+ competence on CG: autonomy off + competence off	questionnaire to measure all four groups, including Game enjoyment, effort for gameplay, motivation for future play, self-efficacy for exercise, game recommendation	Effort for gameplay↑ Motivation for future play↑ self-efficacy for exercise↑ game recommendation↑	bring greater fun, motivation, and participation to college students
Rhodes, R. E et al. (2009) Canada	To assess the effects of using AVG and stationary bicycles (optional music) on college students' attendance, emotional attitudes	29	M = 29	Mean: 22.7	Sony PlayStation 2+Game Bike	Freq: 3 times/week Time: 30 min Length: 6 weeks	EG: Game Bike + (Smuggler's Run、ATV Offroad Fury、Gran Turismo 3、Nascar Heat and Need for Speed) CG: Standard stationary bike + music	At baseline and week six: 1. Exercise attitude was measured using 7-point semantic differential scales. Each session: 2. Record attendance 3. Polar monitoring HR	EG: Attendance↑ affective attitudes↑ intentions↑	Compared to traditional bicycle training, college students using AVG can generate higher emotional attitudes, thereby improving compliance
Hwang, Y et al. (2021) USA	To assess and compare the short- and long-term effects of using EX-GAME and TRAD on the psychological structure and physical activity of college students.	55	Mixed F = 33 M = 22	18–24	Xbox One Kinect (Just Dance 2015, Shape Up, Kinect Sports, Zumba Fitness World Party, and Just Dance 2016 and 2017)	Freq: 3 times/week Time: 50 min Length: 6 weeks	EG: Xbox One Kinect (Just Dance 2015、Shape Up、Kinect Sports、Zumba FitnessWorld Party、Just Dance 2016-2017) CG: instructor-led traditional aerobic exercise	1. Pre-test (8 – 10 days before intervention) 2. Post-test (1 – 3 days after intervention) 3. Follow-up test (6 weeks after intervention) 4.ActiGraph measures PA, Polar measures, and Brog scale measures RPE 5.SCQ-2 measures exercise enjoyment 6. BREQ-2 measures self-determined exercise motivation	EG: autonomy satisfaction↑, intrinsic motivation↑ CG: exercise exertion↑, enjoyment↑, relatedness↑	The long-term persistence and transformation of autonomous and rational movements into intrinsic motivation. The use of AVG by college students is beneficial for improving their autonomy and intrinsic motivation, but traditional training can lead to greater physical exertion.

								7. BPNES measures psychological need support. 8. PESS measurement self-determination support		
Russell, W. D & Newton, M (2008) USA	To assess the short-term psychological effects of using AVG on college students and whether it can lead to mood improvements as traditional training	168	Mixed F = 90 M = 78	21.51 ± 5.31	Sony PlayStation Smuggler's Run	Freq: 1 time Time: 30 min	EG1: regular bicycle Eg2: video game interactive bicycle CG: video game-only	Before training, after training, 10 min after training: 1. Measuring emotions using PANAS 2. MC-SDS measures social desirability or defensiveness. 3. TAG measures attention. 4. Measuring RPE using PES 5. Record RPE every five minutes	EG1,EG2:PA↑, CG: NA↑	Although playing AVG for college students may bring emotional benefits, it is necessary to examine the situations where these benefits are most likely to occur
Jacobs, K et al. (2011) USA	To evaluate the feasibility of using Wii Fit for weight loss among undergraduate students.	5	F = 5	>18	Nintendo Wii Fit (Aerobic+ yoga, balance, and strength)	Freq: 4 times/week Time: 45min Length: 12 weeks	EG1; Wii Solo group1 +group2. EG2; Wii paired group1+group2. CG: walking to classes.	1. Measure weight and BMI in week 1, week 6 and week 12 2. Using ALTQ and BREQ-2 to measure PAL and exercise motivation. 3. Measure RPE every Wii session.	BMI↓, weight↓ sports motivation↑, PAL ↔	Undergraduate students using Wii Fit can increase their motivation to exercise and lose weight.

Freq, frequency; NR, Not reported; AVGs, active video games; SDT, self-determination theory; MVPA, moderate-to-vigorous physical activity; SV, subjective vitality; BW, body weight; BMI, body mass index; VO2 max, maximum oxygen uptake; HRmax, maximum heart rate; VR, ventilation rate; RPP, rate pressure product; RPE, rate of perceived exertion; SEES, Subjective Exercise Experience Scale; HR, heart rate; RFA, Ring Fit Adventure; CPSQI , Chinese Version of the Pittsburgh Sleep Quality Index; BSRS-5, Five-item Brief Symptom Rating Scale; CFI, cardiac force index; SF-36, the short-form 36-item version scale; POMS, The Profile of Mood States; SI, situational interest; PANAS, Positive and Negative Affect Schedule; RER, respiratory exchange ratio; SAM, Self-Assessment Manikin; PA, positive affect; NA, negative affect; DASS-21, Depression, Anxiety, and Stress Scale-21;FOQS, Functional Outcome Sleep Questionnaire; SCT, Social Cognitive Theory; MC-SDS, Marlowe-Crowne Social Desirability Scale; TAG, The Attentional Grid; PES, Perceived Exertion Scale; EX-GAME, exergame; TRAD, traditional group aerobic training; SCQ-2, Sport Commitment Questionnaire 2; BPNES, Basic Psychological Needs in Exercise Scale; BREQ-2, The Behavioural Regulation in Exercise Questionnaire 2 scale; PESS, Perceived Environmental Supportiveness Scale for Exercise Settings; PAL, physical activity level; ALTQ, Activity Level Test Questionnaire

3. Effects of Active Video Games on Physical Fitness Among College Students: A Systematic Review and Meta-Analysis

3.1 PRISMA Table



3.2 Keywords and Search Strategies

Keyword	Search Strategy	Database
Exergames, body composition, cardiorespiratory fitness, muscular strength, flexibility, balance, university students	(‘video gam*’ OR ‘videogam*’ OR ‘active video gam*’ OR ‘exergam*’ OR ‘interactive gam*’ OR ‘interactive video gam*’ OR ‘exercise video gam*’ OR ‘fitness gam*’ OR ‘serious gam*’ OR ‘PlayStation’ OR ‘Nintendo’ OR ‘Wii’ OR ‘Xbox’ OR ‘X-box’ OR ‘Kinect’ OR ‘EyeToy’ OR ‘Dance dance revolution’ OR ‘balance board’ AND ‘physical fitness’ OR ‘physical endurance’ OR ‘physical conditioning’ OR ‘skill-related fitness’ OR ‘skill related fitness’ OR ‘skill-related physical’ OR ‘skill related physical’ OR ‘skill-related physical fitness’ OR ‘skill related physical fitness’ OR ‘speed’ OR ‘power’ OR ‘reaction time’ OR ‘agility’ OR ‘balance’ OR ‘coordination’ OR ‘health related physical fitness’ OR ‘health related physical’ OR ‘health related fitness’ OR ‘health-related physical’ OR ‘health-related fitness’ OR ‘health-related physical fitness’ OR ‘cardiorespiratory fitness’ OR ‘cardiorespiratory endurance’ OR ‘aerobic endurance’ OR ‘muscular fitness’ OR ‘musculoskeletal fitness’ OR ‘muscle strength’ OR ‘muscular endurance’ OR ‘flexibility’ OR ‘body composition’ OR ‘weight’ OR ‘body mass index’ OR ‘BMI’ OR ‘body fat’ OR ‘body fat percentage’ AND ‘college student*’ OR ‘university student*’ OR ‘undergraduate student*’ OR ‘graduate student*’	PubMed SCOPUS Web of Science CINAHL Plus EBSCOhost (SPORTDiscus) Cochrane Library Embase

3.3 Characteristics of the Studies

Authors (Year)	Study design	Population characteristics		Intervention characteristics		Comparison		Main Index & Outcomes
		Sex	Age	AVGs	Length/ Frequency/ Time	EG	CG	
Martinet, S et al. (2015) Jamaica	non-RCT	N = 28 ND	18–25	Xbox 360	Length: 6 weeks Freq: 5 times/week(1-2week) Time: 30mins Freq: 4 times/week(3-4week) Time: 45mins Freq: 3 times/week(5-6week) Session time: 60mins	Just Dance 4	No control group	Body composition (BMI↔, BF% ↔) Cardiorespiratory fitness (VO2max↑) Cardiorespiratory response (RHR↓, DBP↓) Flexibility↑
Nani, S et al. (2018) Greece	RCT	N = 20 F = 13 M = 7	20-25	Nintendo Wii	Length: 10 weeks Freq: 3times/week Session time: 30mins	Wii Sports	No training program	Body composition (weight↔, BMI↔) Cardiorespiratory fitness (VO2max↔) Cardiorespiratory response (HRmax↔) SV↑
Huang, H et al. (2016) Taiwan, China	RCT	N = 117 F = 67 M = 50	20 –24	Xbox 360	Length: 12 weeks Freq: 3 times/week Session time: 30 min	Your Shape: Fitness Evolved	No need to use AVGs (only record other exercise time)	Body composition (%BF↑) Cardiorespiratory fitness (3-min step test↑) Cardiorespiratory response (DBP↓) Muscular endurance↑
Zurita-Ortega et al. (2018) Spain	non-RCT	N = 47 F = 18 M = 29	20-28	Xbox 360	Length: 12 weeks Freq: 2 times/week Session time: 2h	Block 1: Kinect Adventures Block 2: Kinect Training Block 3: Kinect Dance Central Block4: Kinect Sports	No control group	Body composition (lean fat↑) Cardiorespiratory fitness (VO2max↑) Flexibility↔
Wu, H et al. (2022) Taiwan, China	RCT	N = 80 F = 34 M = 46	23.20 ±2.96	Nintendo Wii	Length: 4 weeks Freq: 3 times/week Session time: 30 min	Ring Fit Adventure	Maintained their regular habits	Cardiorespiratory fitness (1600-meter outdoor run↑) Cardiorespiratory response (CFIPA_walk↔, CFIPA_run↔)
Vojciechowski et al.(2017) Brazil	non-RCT	N = 40 F = 26 M = 14	AVG: 21.85 ± 0.62 CG: 23.10 ± 0.61	Xbox 360	Length: 12 weeks Freq: 2 times/week Session time: 30 min	1.Kinect Sports 2.Kinect Adventures	No control group	Muscular strength↑ Muscular endurance↑ Flexibility↑, Agility↑, Speed↑
Martin, S et al. (2018) Jamaica	RCT	N = 27 F = 15 M = 12	AVG: 24.36±5.66 Ladder drills: 23.54 ±5.27	Xbox 360	Length: 6 weeks Freq: 3 times/week Session time: 45 min	Just Dance 2014	Traditional agility ladder drills	Agility↑

Byrne, M et al. (2012) Canada	non-RCT	N = 19 ND	21.6 ±1.1	Nintendo Wii	Length: 3 weeks Freq: 8 times/3week Session time: 15 min	Wii Fit 1.Soccer heading 2. Ski Salom 3. Ski Jump 4. Balance Bubble 5.Tightrope Walk	No control group	Balance (dynamic balance↑)
Davoodeh, S et al. (2020) Iran	RCT	N = 40 F = 40	18-20	Nintendo Wii	Length: 6 weeks Freq: 2 times/week Session time: 35 min	Wii Fit 1.Balance Games 2.Yoga Games 3.Muscle Workouts Games 4.Aerobic exercises Games	Engage in common daily physical activities	Balance (static balance↑) Motor competence↑
Warburton, E.R. et al. (2007) Canada	RCT	N = 14 M = 14	18-25	Sony PlayStation 2	Length: 6 weeks Freq: 3 times/week Session time: 30 min	GameBike system+ 1. Smuggler's Run 2. ATV Offroad Fury 3. Gran Turismo 3 4. NASCAR Heat 5. Need for Speed	Exercise on a standard bicycle (at their desired intensity and duration)	Body composition (weight I↔, BMI↔, Fat mass ↔, Lean mass↔) Cardiorespiratory fitness (VO2 max↑) Cardiorespiratory response (RSBP↓, DBP↔, POmax↑, HRmax↓) Muscular strength↔, Flexibility↔, Power↑
Vernadakis, N et al. (2012) Greece	RCT	N= 32 F = 14 M = 18	20-22	Nintendo Wii	Length: 8 weeks Freq: 2 times/week Session time: 24 min	Wii Fit Plus 1.Yoga exercises 2. Balance games	Train using mini trampolines and inflatable discs	Balance (static balance↑)
McCarthy, H et al. (2013) Canada	RCT	N= 32 F = 1 M = 166	18-22	Nintendo Wii	Length: 4 weeks Freq: 3 times/week Session time: 20 min	Wii Fit Yoga exercises	Continue their regular activities	Flexibility↑
Gioftsidou, A et al. (2013) Greece	RCT	N= 40 F = 18 M = 22	20-22	Nintendo Wii	Length: 8 weeks Freq: 2 times/week Session time: 24 min	Wii Fit Plus 1. Yoga exercises 2. Balance games	Mini trampoline and inflatable disc exercise plan	Balance (static balance↑)
Jacobs, K et al. (2011)	RCT	N= 5 F = 5	>18	Nintendo Wii	Length: 12 weeks Freq: 4 times/week Session time: 45 min	Wii Fit 1. Yoga games 2. Balance games 3. Strength games 4. Aerobic games	moderate intensity physical activity (walking to classes)	Body composition (weight ↓, BMI ↓)

RCT, randomised control trial; non-RCT, non-randomised control trial; EG, experimental group; CG, control group; ND, no description; F, female; M, male; Min, minute; H, hour; ↑, improvement; ↓, decrease; ↔ , no significant difference; SAR, sit and reach test; BMI, body mass index; BF%, body fat percentage; VO2max, maximal oxygen consumption; RHR, resting heart rate; DPB, diastolic blood pressure; HRmax, maximum heart rate; SV, Subjective vitality; CFIPA, cardiac force index peak acceleration; RSBP, resting systolic blood pressure; POmax, maximal power output; HRmax, maximal heart rate.

Appendix Q

Rating of Perceived Exertion Scale and Permission

1.Borg RPE Scale (English version)

Borg RPE Scale®

Use this scale to tell how strenuous and tiring the work feels to you. The exertion is mainly felt as fatigue in your muscles and as breathlessness or possibly aches. When the exercise is hard it also becomes difficult to talk. It is your own feeling of exertion that is important. Don't underestimate it, but don't overestimate it either. For common exercise, such as cycling, running or walking, 11-15 is a good level. For strength and high-intensity interval training (HIIT), 15-19 is good. If you are sick follow your doctor's advice. Look at the scale and the descriptions and then choose a number. Use whatever numbers you want, even numbers between the descriptions.

6	**No exertion at all**	No muscle fatigue, breathlessness or difficulty in breathing.
7	**Extremely light**	Very, very light.
8		
9	**Very light**	Like walking slowly for a short while. Very easy to talk.
10		
11	**Light**	Like a light exercise at your own pace.
12	**Moderate**	
13	**Somewhat hard**	Fairly strenuous and breathless. Not so easy to talk.
14		
15	**Hard**	Heavy and strenuous. An upper limit for fitness training, as when running or walking fast.
16		
17	**Very hard**	Very strenuous. You are very tired and breathless. Very difficult to talk.
18		
19	**Extremely hard**	The most strenuous effort you have ever experienced.
20	**Maximal exertion**	Maximal heaviness.

Borg RPE Scale®
Ratings (R) of Perceived (P) Exertion (E).

English

2. Borg RPE Scale (Chinese version)

博格 RPE 量表®

使用此量表来表示你因体力活动而感受的辛苦和疲劳程度。这种用力的感觉主要是肌肉疲劳、呼吸困难或可能疼痛。当动作强度高时，说话也会变得困难。最重要的是你自己的用力感觉。不要低估它，但也不要高估它。对于骑自行车、跑步或步行等普通运动，11-15 是一个良好水平。对于力量和高强度间歇训练（HIIT）来说，15-19 是良好状态。如果你生病了，请听从医生的建议。请看量表和说明，然后选择一个数字。使用任何你想要的数字，甚至是两个说明之间的数字。

6	完全不用力	无肌肉疲劳、喘不上气或呼吸困难。
7	极轻	非常非常轻。
8		
9	很轻	如同慢慢地走了片刻。非常容易说话。
10		
11	轻	就像按自己的节奏而进行的轻量运动。
12	适度	
13	有些困难	相当吃力，气喘吁吁。没那么好说话
14		
15	困难	沉重而费力。健身训练的上限，如快跑或快走。
16		
17	很困难	非常吃力。你非常疲惫，上气不接下气。很难开口说话。
18		
19	极困难	你所经历过的最费劲的用力。
20	最大用力	最为沉重。

博格 RPE 量表®
感知(P)运动量(E)的评级(R)。

中文

3.Borg RPE Scale Permission

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License Agreement #DL9VJZ#

Summary

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Usage specification / study name: My thesis- Effects of Active Video Games on Physical Activity, Psychological Distress, Exercise Motivation and Body Composition Among Overweight and Obese College Students in China

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Licensee details

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Licensee address:

UPM Serdang Selangor Darul Ehsan Malaysia

43300

Serdang Selangor

Malaysia

Appendix R

Training logs and Training Attendance Sheets

1. Training Log
(1) Physical Education Teacher Name: __________ Telephone Number: __________
(2) Physical Education Teacher Name: __________ Telephone Number: __________

If the participant has completed the prescribed training content, please tick “√” in the form; if not, please tick “x” in the form and record the reason.

Table1 : Training Log

Number	Name	Week 1			Week 2			Week 3			Week 4			Week 5			Week 6			Week 7			Week 8			Week 9			Week 10			Week 11			Week 12		
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1																																					
2																																					
3																																					
4																																					
5																																					
6																																					

2. Training Attendance Sheets
(1) Research Assistant Name: __________ Telephone Number: __________
(2) Research Assistant Name: __________ Telephone Number: __________

If the participant has completed the prescribed training content, please tick "√" in the form; if not, please tick "x" in the form and record the reason.

Table2 : Training Attendance Sheets

Number	Name	Week 1			Week 2			Week 3			Week 4			Week 5			Week 6			Week 7			Week 8			Week 9			Week 10			Week 11			Week 12		
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1																																					
2																																					
3																																					
4																																					
5																																					
6																																					

Appendix S

Dietary Record Sheet

1. Dietary Information Record Form

(1) Research Assistant Name: ________________________ Telephone Number: _______________

(2) Research Assistant Name: _________________________ Telephone Number: _______________

Record participants' weekly energy intake (Kcal).

Number	Name	Week1	Week2	Week3	Week4	Week5	Week6	Week7	Week8	Week9	Week10	Week11	Week12
1													
2													
3													
4													
5													
6													

BIODATA OF STUDENT

Zhao Yue, born on 6 June 1992 in Zaozhuang City, Shandong Province, graduated from high school in 2012 and was admitted to Shandong Institute of Commerce and Industry, majoring in accounting. During his undergraduate studies, he learnt a lot about finance. As he likes sports, especially basketball, he learnt a lot about physical education and participated in many school basketball matches. He loves learning, actively participates in group activities, and has strong affinity and leadership ability. He was admitted to Bank of Communications Qingdao branch after graduating from undergraduate in 2017. He resigned in 2018 and successfully enrolled in Qufu

Normal University for postgraduate studies, specialising in social sports instruction. During his postgraduate studies he actively communicated with different teachers, learnt a lot of professional knowledge about sports and focused on the field of e-sports.

Zhao Yue graduated from Qufu Normal University in 2019 and successfully entered Universiti Putra Malaysia. During his study in Malaysia, he actively communicated with his teachers and cooperated with his classmates to study. He mastered the knowledge of different fields of sports and further delved into e-sports. As a PhD student, he has demonstrated his dedication and passion for sports. His open mind and unique exploratory spirit allow him to make valuable creations in the field he loves.

LIST OF PUBLICATIONS

Publication - Published

Zhao, Y., Soh, K. G., Saad, H. A., Liu, C., & Ding, C. (2024). Effects of active video games on physical activity among college students with overweight and obesity: a systematic review. Frontiers in Public Health, 12, 1320112.

Y Zhao，KG Soh，HBA Saad， W Rong，C Liu，X Wang（2024） Effects of Active Video Games on Mental Health Among College Students: A Systematic Review. BMC Public Health 24:3482.

Publication – Under review

Zhao, Y et al (2024). Effects of Active Video Games on Physical Fitness Among College Students: A Systematic Review and Meta-Analysis. JMIR Serious Game. Since March 2025