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Effects of active video games on mental health among college students: a systematic review

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Abstract

Background Mental health significantly impacts college students' academic performance and overall happiness. Active video games (AVGs) have gained popularity among college students due to their ample entertainment, and there is growing interest in utilizing them to address mental health issues. However, there has not been a comprehensive summary and systematic review of research on the effects of AVGs on college students' mental health.

Methods As of October 18th, 2024, searches were conducted in six internationally renowned databases (PubMed, SCOPUS, Web of Science, CINAHL Plus, EBSCOhost, Cochrane Library). Inclusion and exclusion criteria were developed based on the PICOS principles. A systematic review was conducted following the PRISMA guidelines, and compliant studies using randomised controlled trial design (RCT) were included. The methodological quality of the included studies was evaluated using the PEDro scale.

Results A total of 3471 articles were retrieved, of which 17 met the criteria inclusion. The PEDro scores of the 17 studies ranged from four to nine. The results indicate that AVGs can effectively improve college students' poor mental health, such as stress, anxiety, and depression, as well as increase their happiness and psychological satisfaction. Moreover, AVGs have been shown to increase motivation for exercise, improve college students' attitudes toward other forms of exercise, and promote sustained physical activity. Additionally, AVGs have demonstrated efficacy in improving sleep quality.

Conclusion Overall, AVGs can serve as an effective intervention to reduce dysphoria and promote positive psychological states among college students, thus improving mental health. Using the theory-based design of AVGs will further increase the effect. However, the effects of AVGs vary depending on their type and initial design purpose. Therefore, when using AVGs to improve college students' mental health, it is necessary to carefully consider the students' original state, select AVGs with rich game content that can provide at least moderate-intensity physical activity, and adopt the correct intervention strategy to achieve good results. AVG can potentially become a valuable tool for improving college students' mental health.

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Introduction

Engaging in various forms of exercise is crucial for improving both physical health and mental health [53, 94, 133]. The Coronavirus disease (COVID-19) pandemic has made the importance of basic physical activity [52]. Both the World Health Organisation (WHO) and the American College of Sports Medicine (ACSM) recommend at least 150 min of moderate-intensity or 75 min of vigorous-intensity physical activity per week [102]. However, despite these recommendations, the WHO's Global Physical Activity Report 2022 reveals that more than 1.4 billion adults worldwide remain physically inactive [114]. This inactive trend is prevalent in both developed and developing countries, posing a significant global public health challenge of the twenty-first century [1, 10, 112]. Physical inactivity has reached epidemic levels [120], leading not only to reduced exercise capacity [9] but also adversely affecting core factors of mental health such as the ability to improve emotion and mood, psychological structure and sleep quality. Depression [23, 43], anxiety [153], and stress [21] are commonly associated with physical inactivity. College students, in particular, are disproportionately affected by physical inactivity [119] and warrant special attention [150]. Developing a sedentary lifestyle during university years not only predisposes individuals to various physical ailments but also significantly impacts mental health [17, 179]. The university years are for developing healthy behaviours and mental health [80]. Poor mental health during this period can lead to a decline in academic performance, sleep deprivation [47], depression [63, 172], stress [61], anxiety [5], and even suicidal behaviour [48]. These adverse emotions can have lasting consequences and profoundly affect individuals throughout their lives. Therefore, it is important to prioritize the mental health of college students.

With the continuous development of society, the triggers for mental health problems among college students are becoming increasingly diverse, leading to a rise in both the prevalence and severity of these problems [187]. College students are losing interest in traditional sports and may quit for various reasons [46, 143]. The rapid development of technology and the widespread use of the Internet have changed people's lifestyles [121], particularly impacting college students [18, 44]. The arrival of the Internet and mobile devices on campuses has not only diversified educational approaches [178] but has also enhanced the flexibility of educational venues [163]. Smart devices such as laptops, tablets, and smartphones have become indispensable to college students' lives outside the classroom [85, 129]. With high smartphone ownership [152] and extensive computer usage habits, college students are more susceptible to internet addiction than other demographic groups [70]. The popularity of these mobile internet devices has made it easier for college students to access the Internet, making them more inclined to socialise online (e.g., social media and streaming services) or indulge in various screen-based activities such as gaming [89]. Compared to traditional face-to-face communication, college students often prefer spending time in the virtual world. However, this heavy reliance on the Internet has resulted in a high rate of internet addiction among college students [20]. Internet addiction is widespread [19], it is associated with depression [149], social anxiety, and obsessive–compulsive disorder in this demographic (Othman & Lee, 2017) [151]. It is well known that regular physical activity can produce multiple physiological and psychological changes in the body [26, 42], alleviating poor mood and promoting mental health [55]. Given the multiple benefits physical activity offers to both mind and body [104], it has become imperative to reduce college students' static screen time and encourage them to engage in physical exercise to improve their mental health. The emergence of active video games (AVGs) provides a novel approach to address this issue.

AVGs, also known as exergames, is a new generation of video games that require full-body movement to play, integrating physical activity with gameplay (Staiano et al., 2017; Yang et al., 2005) [82]. Currently, the more popular and common AVGs include Xbox, PlayStation, and Wii. These games utilize somatosensory control technology [156], which entails the use of various sensors and devices, such as cameras, motion detectors, and somatosensory controllers, to capture the player's body movements. These movements are then translated into in-game actions or manipulations, allowing players to interact with the game characters on screen [66]. For instance, as the player runs and jumps, the on-screen character replicates these movements, providing intuitive feedback that enhances player participation and engagement [86]. Unlike traditional sports activities that require specialised venues, AVGs offer flexibility in terms of where they can be played. Players can engage in these games anytime and anywhere, whether at home, in the office, or their dormitories [131, 142, 165]. This convenience greatly broadens the venues where college students can engage in physical activity, thereby increasing the likelihood of exercising. AVGs have gained immense popularity worldwide across all age groups. Studies have shown that 36% of 8- to 18-year-olds own and play games on platforms such as Nintendo's Wii [128], and 86% have played games on Xbox, PlayStation, and Wii [84]. Among college students, AVGs are particularly popular due to their user-friendly interfaces, diverse game content, and high entertainment value [118, 183]. These games not only satisfy students' love for electronics and video games but also transform their static sedentary screen time into

dynamic screen time by combining gaming with physical exercise [8]. This transformation helps reduce sedentary behaviours while simultaneously improving mental health through physical activity.

AVGs have a wide range of application scenarios and are utilized across various fields and by different groups of people, serving as more than just entertainment. These games have been shown to elicit varying levels of physical activity, offering a fun alternative to traditional exercise. For instance, research has demonstrated that numerous games on platforms like Wii Fit Plus and Wii Sports can provide mild (3 MET) to moderate-intensity physical activity, with some games reaching up to 6 METs [105]. Similarly, interventions using Xbox 360 Kinect games, such as Adventure, Dance, and Boxing, have been found to achieve moderate-intensity physical activity among children aged 8 – 13 years, as measured by indirect calorimetry [16]. Furthermore, studies have shown that young people can achieve moderate to vigorous physical activity with AVGs, meeting the recommended intensity of exercise and often resulting in a more positive mood compared to traditional exercise [107]. Research involving children and adolescents has shown promising results regarding the effectiveness of AVGs in promoting physical activity and improving mental health. For instance, a nine-month intervention with primary school students in the United States showed that children in the experimental group had significantly higher levels of physical activity than the control group, with positive effects on physical activity participation and attitudes [45].

Similarly, a study involving urban ethnic minority adolescents using "Just Dance" found a reduction in sedentary time, an increase in moderate to vigorous physical activity (MVPA), and increased enjoyment [99]. The use of AVGs can help overweight and obese college students achieve internationally recommended physical activity levels (PAL) [185]. AVGs also offer benefits for specific populations and rehabilitation [124]. For example, AVG interventions have been shown to improve rumination and subjective cognition in patients with depression [79], treat Parkinson's syndrome [184], improve balance in patients with multiple sclerosis [25] and alleviate skeletal muscle pain in the elderly [32]. Moreover, AVGs have been associated with mental health benefits. Children and adolescents using AVGs 1 – 3 times per week have shown improvements in self-esteem [144], while older women in the community playing AVGs have experienced positive effects on psychological happiness and self-perception [176], as well as reduced loneliness and increased positive emotions. Furthermore, several studies have focussed on the use of AVGs to improve physical strength and energy expenditure, and their beneficial effects have been demonstrated [157]. Additionally, AVGs have been found to improve loneliness [40] and mental disorders [134]. Considering college students as an important user group of AVGs, it is essential to focus on their mental health. However, the current systematic reviews and research studies have primarily focused on children, adolescents, older adults, and special populations, with an emphasis on promoting physical activity. There is a significant lack of focus on college students, particularly regarding their mental health. Therefore, this systematic review aims to assess the impact of using AVGs on college student's mental health and clarify the role of AVGs in promoting mental happiness through evidence provided by existing randomised controlled trials.

Materials and methods

Protocol and registration

Our systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) reporting guidelines [115], as well as the ethical standards in sports and exercise science research [51]. The systematic review was registered in the international database of systematic reviews (https://www.crd.york.ac.uk/PROSPERO/; registration number CRD42024510488).

Data sources and search strategy

We conducted searches in six internationally recognised databases for relevant published articles. The databases included PubMed, Web of Science, EBSCOhost (SPORTDiscus), CINAHL Plus, Scopus, and Cochrane Library. When searching for literature in these databases, the article's publication date is not restricted. Therefore, the search time range was from the inception of each database to October 18th, 2024. The search was conducted using a combination of negotiated keywords and search algorithms. The research team negotiated the keywords and algorithms for the search, using the following negotiated keywords, combinations of keywords, and Boolean operators: "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 "happiness" 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*." To ensure a

comprehensive search and avoid missing important literature, we employed two additional search methods. Firstly, we screened the reference lists of previous relevant studies or systematic reviews for appropriate literature. Secondly, we manually searched Google Scholar using the specified keywords and screened the results.

Eligibility criteria

Selection of literature for eligibility was conducted using the PICOS framework [100]. Only studies that met the criteria specified in PICOS were included. The acronym PICOS stands for Population, Intervention, Comparison, Outcome, and Study Type, respectively. The review included Chinese or English literature with no restriction on the time of publication. The inclusion and exclusion criteria for systematic reviews are demonstrated as follows.

Studies that met the following inclusion criteria were included:

i. Study participants were college students (including overweight and obese college students).
ii. AVG was the only intervention, and there were no restrictions on where or when AVG could be used.
iii. At least one experimental group and one control group were included.
iv. The study outcomes include at least one assessment of the impact of AVG on mental health.
v. The experimental design was a randomised controlled trial.

Studies that met the following exclusion criteria were excluded:

i. Study participants were not college students, or the participants were college students but had a serious medical condition (e.g., heart disease, asthma, malignancy, etc.).
ii. AVGs were not used as an intervention; instead, other electronic devices (e.g., arcade games or computer games) were used. The use of AVGs in conjunction with other training modalities was also excluded to avoid contamination of the effects of AVGs by other training modalities.
iii. The effect of AVGs was measured in the absence of a control group.
iv. The results of the study did not include any factors related to mental health.
v. The experimental design was a non-randomised controlled trial, cross-sectional study, or case study.
vi. The article was not published in English or Chinese.

Study selection

The studies retrieved from the six international databases and additional sources were imported into the literature management software Zotero (version 6.0.37), and duplicates were removed using the software's built-in function. The screening process adhered to pre-established inclusion and exclusion criteria. In the title screening stage, 2 independent reviewers YZ and WCR reviewed the article titles to exclude articles that were not relevant to the study. The inter-rater agreement reached 88%. In the abstract screening stage, 2 independent reviewers CL and XZW reviewed the abstract of each article, and the agreement between the two authors was 92%. In the full-text screening stage, 2 independent reviewers YZ and WCR independently re-evaluated the full text. The reasons for exclusion were recorded for articles that did not meet the criteria. The inter-rater agreement was 95%, showing excellent consistency. At any stage, if there was a disagreement on an article, a third independent reviewer (KGS) was consulted to re-evaluate and make the final decision.

Data extraction and quality assessment

Following the literature search, data were extracted from the eligible literature using a pre-established format in a Microsoft Excel spreadsheet (version 16.72). The extracted data included the following main features: 1. Author name, publication year, and country; 2. Participant characteristics; 3. Intervention characteristics (type of AVGs, frequency of intervention, time per session, and intervention period); 4. Measurement method; 5. Main indicators and study results; and 6. Main findings. The methodological quality of randomized controlled trials was assessed using the Physiotherapy Evidence Database (PEDro, www.pedro.org.au). PEDro has been validated by multiple sources and is considered sufficiently reliable [37, 92, 108]. The scale consists of 11 items that evaluate the literature in terms of randomization, blinding, group comparison, and data analysis. Each item was scored as Yes (1 point) if the requirement was met or No (0 points) if it was not met. Higher total scores indicate a higher quality of research methodology. Consistent with existing systematic reviews in fields related to AVGs [30], quality assessment scores were categorised as follows: a total score of ≤ 3 was considered low quality, 4 –5 was considered moderate quality, and 6 – 10 was considered high quality. Two independent reviewers (YZ and WCR) rated the methodological quality independently. In cases of disagreement, a third independent reviewer (KGS) evaluated and finalized the assessment.

Results

Study selection

Figure 1 illustrates the search process. A total of 3471 possible documents were retrieved from all databases. There are 149 from PubMed, 265 from SCOPUS, 404 from Web of Science, 14 from Cochrane Library, 1141 from CINAHL Plus, and 1487 from EBSCOhost (SPORT Discus), totalling 3460 articles. Additionally, 11 additional documents were added, including seven references from other articles and four articles from Google Scholar. After removing 257 duplicates using literature management software, 3214 articles remained for initial screening and evaluation. Following a review of the titles and abstracts, 3022 articles were removed, leaving 192 for full-text analysis. After carefully evaluating these articles based on the defined exclusion criteria, 175 mismatched articles were removed. Finally, 17 matching randomised controlled trial studies were identified for systematic review.

Study quality assessment

Table 1 illustrates the details of the quality assessment using the PEDro scale for the included studies. The PEDro scores of the seventeen included articles ranged from four to nine. Specifically, one study scored four [111], 11 studies scored 5 [34, 65, 109, 117, 126, 132, 135, 137, 169, 180, 181], two studies scored six [62, 118], two studies scored eight [58, 110], and one study scored nine [59, 60]. According to PEDro's rating criteria, 12 studies were rated as medium quality, and five studies were rated as high quality. Only one study was fully blinded to participants, assessors, and treaters [59, 60]. The remaining studies lost points primarily because the intervention involved AVGs, which required on-site participation and exercise.

Population characteristics

Detailed information on the characteristics of the populations included in the studies is shown in Table 2 and includes the following main aspects. (1) Sample size: a total of 2048 participants were collected from seventeen studies. Among them, the samples ranged from 5 to 337 [58–60, 65, 111]. The mean sample size was 120.47. (2) Gender: three of the included studies did not specify the gender and only distinguished between experimental and control groups [59, 60, 110, 181]. Of the remaining

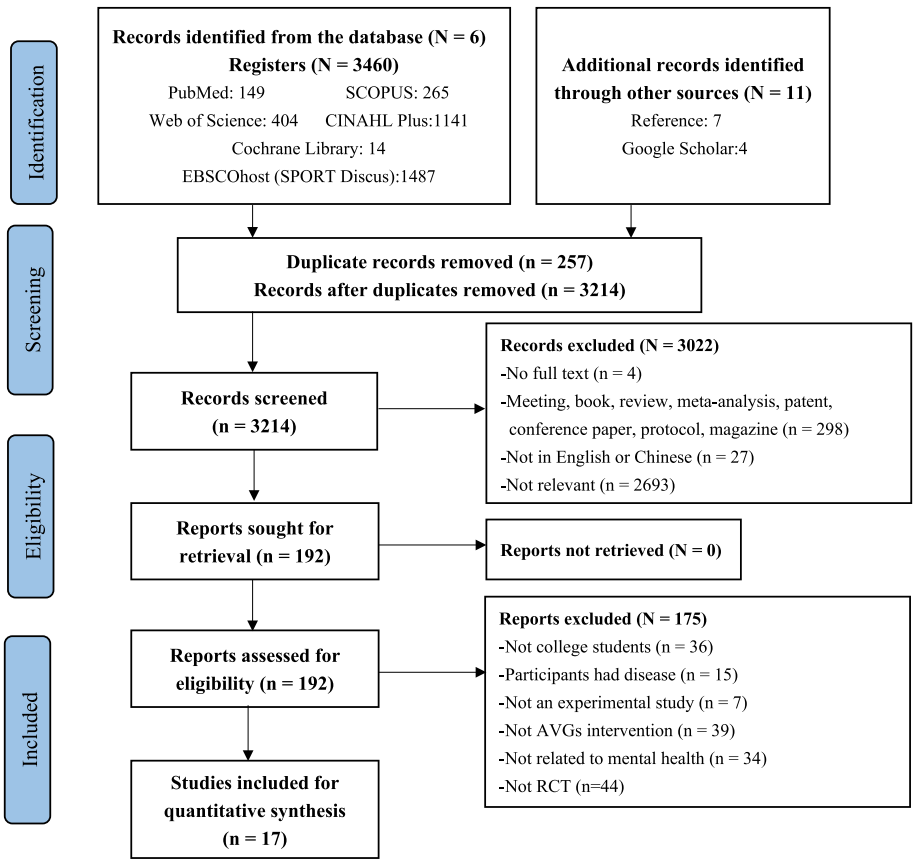

Fig. 1 Flow diagram of the study selection

Table 1 Scores of the methodological quality assessment

References	Eligibility criteria	Random allocation	Allocation concealment	Baseline comparability	Blind participants	Blind therapist	Blind assessor	Follow-up	Intention to treat analysis	Between-group comparisons	Point measure and variability	Total PEDro score
Wei, P et al (2015) [118]	1	1	0	1	0	0	1	0	0	1	1	6
Huang, H et al (2019) [58]	1	1	1	0	1	1	1	0	0	1	1	8
Nani, S et al (2019) [109]	1	1	0	1	0	0	0	0	0	1	1	5
Douris, P. C et al (2012) [34]	1	1	0	1	0	0	0	0	0	1	1	5
Nguyen, H et al (2016) [110]	1	1	1	0	1	1	1	0	0	1	1	8
Wu, Y et al (2022) [180]	1	1	0	1	0	0	0	0	0	1	1	5
Yu, J et al (2023) [181]	1	1	0	1	0	0	0	0	0	1	1	5
Russell, W. D et al (2013) [135]	1	1	0	1	0	0	0	0	0	1	1	5
Roure, C et al (2020) [132]	1	1	0	1	0	0	0	0	0	1	1	5
Huang, H et al (2017) [59, 60]	1	1	1	1	1	1	1	0	0	1	1	9
Yunus, F. W et al (2020) [169]	1	1	0	1	0	0	1	0	0	1	1	5
Nguyen, H et al (2020)	1	1	0	0	0	0	0	0	0	1	1	4
Wei, P et al (2012) [117]	1	1	0	1	0	0	0	0	0	1	1	5
Rhodes, R. E et al (2009) [126]	1	1	0	1	0	0	0	0	0	1	1	5

Table 1 (continued)

References	Eligibility criteria	Random allocation	Allocation concealment	Baseline comparability	Blind participants	Blind therapist	Blind assessor	Follow-up	Intention to treat analysis	Between-group comparisons	Point measure and variability	Total PEDro score
Hwang, Y et al (2023) [62]	1	1	0	1	0	0	0	1	0	1	1	6
Russell, W. D & Newton, M (2008) [136]	1	1	0	1	0	0	0	0	0	1	1	5
Jacobs, K et al (2011) [65]	1	1	0	1	0	0	0	0	0	1	1	5

Table 2 Characteristics of included studies

Authors (Year)	Study purpose	Population characteristics			AVGs & Gameplay	Frequency & duration	Comparison	Measurement	Main Index & outcomes	Key findings
		N	Sex	Age						
Wei, P et al (2015) [118] 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 Gameplay: Players need control their whole body through WiiMote and Dance pad to learn skills and kill monsters in the mythic world	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) [58] 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 Gameplay: Detect player movements with Kinect. Follow a virtual fitness trainer for aerobic exercises, strength training and more	Freq: 1times/week Time: 30min 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 (2019) [109] Greece	To access the effects of playing Wii Nintendo Sports on physiological parameters and subjective vitality among college students	20	Mixed F = 13 M = 7	20 –25	Nintendo Wii Sports Gameplay: Player holds the Wii Remote (with built-in motion sensor) to control the sports equipment for virtual sports	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 3. Heart rate monitor (Polar) measures HRmax 4. Subjective Vitality Scale measures SV	EG and CG: BW↔, BMI↔, VO_2 max↔, HRmax↔ EG: SV↑	Exergames can improve college students' subjective vitality, making them feel more energetic and happiness

Table 2 (continued)

Authors (Year)	Study purpose	Population characteristics			AVGs & Gameplay	Frequency & duration	Comparison	Measurement	Main Index & outcomes	Key findings
		N	Sex	Age						
Douris, P. C et al (2012) [34] USA	To compare the physiological and psychological responses of college students playing Nintendo Wii F with moderate-intensity brisk walking on a treadmill	21	Mixed F = 12 M = 9	18–25	Nintendo Wii Fit Free Run Gameplay: Run in a virtual environment and record exercise intensity using the Wii Remote or Balance Board	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 happiness, psychological distress, 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	HRmax↑, RPP↑, RPE↑, positive happiness↓, Psychological distress↓ Feelings of fatigue↑	When sedentary college students played Wii Fit, their positive happiness 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) [110] 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 Gameplay: Follow the virtual coach's prompts to perform physical activities and complete exercise goals	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 (2022) [180] Taiwan, China	To assess the effects of playing RFA on college students' 1600-m running times, heart performance indices, and psychological factors	80	Mixed F = 34 M = 46	20–36	Nintendo Ring Fit Adventure Gameplay: Defeat the monsters through Ring-Con with deep squats, running and jumping	Freq: 3 times/week Time: 30 min Length: 4 weeks	EG: Ring Fit Adventure (in adventure mode) CG: maintained their regular habits (no intervention)	Baseline and Week 4: 1. CPSQI to measure sleep quality 2.BSRS-5 to measure mood disorders 3. CFI to measure cardiac status during exercise 4. Zephyr BioPatch to measure physiological parameters	EG: Sleep quality ↔, mood disorders↑, 1600-m run time↓, CFI peak acceleration ↔	RFA maintains the health and fitness of college students and provides a reliable tool for those who don't have time to exercise
Yu, J et al (2023) [181] 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 Gameplay: Virtual trainer guides fitness, sets exercise goals and checks calorie consumption	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

Table 2 (continued)

Authors (Year)	Study purpose	Population characteristics			AVGs & Gameplay	Frequency & duration	Comparison	Measurement	Main Index & outcomes	Key findings
		N	Sex	Age						
Russell, W. D et al. (2013) [135] 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 Gameplay: Use the Wii Remote as a boxing glove, swing your arm to simulate boxing moves and defeat your enemies	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. inexperienced + paired mode	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 (2020) [132] Switzerland	To assess the impact of AVG (Greedy Rabbit) on situational interest and physical activity of college students	60	Mixed F = 29 M = 31	18–25	Greedy Rabbit (design-based bike AVG) Gameplay: Player controls the movement of the character (rabbit) by riding with the aim of collecting food and avoiding obstacles	Freq: 2times/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) using a calibrated metabolic cart and heart rate detector	EG: SI (instant enjoyment, attention demand and total interest) ↑, %HRmax↑, %VO2 max↑	Playing design-based cycling AVGs is a good tool to enhance situational interest (instant enjoyment and attention demand) and physical activity among college students
Huang, H et al (2017) [59, 60] 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 Gameplay: Virtual coaches guide players to fitness	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, happiness, and perceived stress using adapted scales	happiness↑, vigour↑, perceived stress↔	AVG improves mood states (including increased vitality and happiness and reduced perceived stress) in college students and does not change by gender, occupation, or time spent exercising
Yunus, F. W et al (2020) [169] 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 Sports1 + Sport2 Gameplay: Recognise player movements with Kinect. Play virtual football, boxing, athletics, and other sports	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

Table 2 (continued)

Authors (Year)	Study purpose	Population characteristics			AVGs & Gameplay	Frequency & duration	Comparison	Measurement	Main Index & outcomes	Key findings
		N	Sex	Age						
Nguyen, H et al (2018) [111] Taiwan, China	SCT was used to assess the effects of AVG on college students' happiness 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 Gameplay: Virtual coaches guide players to fitness	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 (2012) [117] USA	To access how SDT-enabled AVG affects young people's need satisfaction and gaming experience	160	Mixed F = 49 M = 111	Mean 21	Olympus (Third-person adventure game with SDT functionality) Gameplay: Control your whole body to exercise and complete tasks in the virtual world	Freq: 1 time Time: 15 min	EG1: autonomy on + competence on EG2: autonomy on + competence off EG3: autonomy off + competence on CG: autonomy off + competence off	Before and after the game: Use the modified questionnaire to measure all four groups, including Game enjoyment, effort for gameplay, motivation for future play, self-efficacy for exercise, game recommendation	EG1: Game enjoyment↑ Effort for gameplay↑ Motivation for future play↑ self-efficacy for exercise↑ game recommendation↑	AVG with SDT function support can bring greater fun, motivation, and participation to college students
Rhodes, R. E et al (2009) [126] 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 Gameplay: Ride through the bike and complete gaming tasks such as racing in different virtual games	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 (2023) [62] 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) Gameplay: Virtual dancing games and various virtual mini games that control whole body movements	Freq: 3 times/week Time: 50 min Length: 6 weeks	EG: Xbox One Kinect(Just Dance 2015、Shape Up、Kinect Sports、Zumba Fitness World 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 7. BPNES measures psychological need support 8. PESS measurement self-determination support	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

Table 2 (continued)

Authors (Year)	Study purpose	Population characteristics			AVGs & Gameplay	Frequency & duration	Comparison	Measurement	Main Index & outcomes	Key findings
		N	Sex	Age						
Russell, W. D & Newton, M (2008) [136] 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 Gameplay: Interactive video game bicycle (cycling) smuggling in the virtual world	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) [65] USA	To evaluate the feasibility of using Wii Fit for weight loss among undergraduate students	5	F = 5	> 18	Nintendo Wii Fit Gameplay: Use the Wii Balance Board for yoga, aerobics, balance training, and more	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 BREQ-2 to measure 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 scale [140], *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 [101], *HR* Heart rate, *RFA* Ring Fit Adventure, *CPSQI* Chinese Version of the Pittsburgh Sleep Quality Index [160], *BSRS-5* Five-item Brief Symptom Rating Scale (M.-B. [83]), *CFI* Cardiac force index, *SF-36* The short-form 36-item version scale [171], *POMS* The Profile of Mood States [33]; SI, situational interest; PANAS, Positive and Negative Affect Schedule [72]; RER, respiratory exchange ratio; PA, positive affect; NA, negative affect; DASS-21, Depression, Anxiety, and Stress Scale-21 [113]; FOQS, Functional Outcome Sleep Questionnaire [173]; SCT, Social Cognitive Theory; MC-SDS, Marlowe-Crowne Social Desirability Scale [22]; TAG, The Attentional Grid [50]; PES, Perceived Exertion Scale [13]; EX-GAME, exergame; TRAD, traditional group aerobic training; SCQ-2, Sport Commitment Questionnaire 2 [146]; BPNES, Basic Psychological Needs in Exercise Scale [166]; BREQ-2, The Behavioural Regulation in Exercise Questionnaire 2 scale [96]; PESS, Perceived Environmental Supportiveness Scale for Exercise Settings [97]; PAL, physical activity level

studies that reported gender ($n=15$), there were a total of 718 males and 757 females. One study included only males [126], and one study included only females [65]. (3) Age: All studies reported age. Because the subjects were college students, the age of the four studies was set at greater than 18 years [58, 62, 65, 109]. The maximum age of subjects included in the studies was 40 [111]. (4) BMI: Six of the included studies reported BMI, and the subjects were overweight (BMI > 25) or obese (BMI > 30) [34, 65, 109, 118, 135, 137]. (5) Educational level: Nine studies reported the educational level of the participants. Seven of these studies had undergraduate participants [62, 65, 109, 117, 118, 132, 169] and two studies included both undergraduate and graduate students [111, 181].

Intervention characteristics

The intervention characteristics of the included studies are shown in Table 2, focusing on the following aspects: (1) Type of intervention: All the included studies used AVGs as the main intervention modality. A total of 15 studies were using AVGs alone as the intervention modality. Two studies required the use of AVGs in combination with other devices, namely an iPad-equipped exercise bike and a game bike [126, 132]. (2) Types of AVGs: Microsoft's Xbox was used in the largest number of studies, with a total of seven studies [58–60, 62, 110, 111, 169, 181]. The second-largest number of studies used Nintendo's Wii, with a total of five studies using "Wii sports," "Free Run," "Ring fit adventure," "punch-out," and "Wii fit" [34, 65, 109, 135, 180]. Two studies used a third-person role-playing game based on self-determination theory [117, 118]. Two studies used Sony's PlayStation [126, 135]. One study used "Greedy Rabbit" combined with a training bike [132]. (3) Duration of each session: Two studies did not specify the duration of each intervention [118, 132]. The duration of each AVG intervention in the remaining studies ranged from 15 to 50 min [62, 111]. Most of the studies (12/17) used AVGs for 30 min at a time. (4) Frequency of intervention: two studies conducted only one intervention [117, 135]. The rest of the studies ranged in the frequency of AVG usage from once a week to four times a week [3–60, 65, 111]. The intervention frequency chosen for most studies (8/17) was three times a week. (5) Duration of the intervention: The shortest duration of the intervention in the included studies was nine days, and the longest was 12 weeks [34, 65]. Only one study did not specify the duration of the intervention [135]. (6) Gameplay: Most studies used "Your Shape Fitness Evolved", with a total of five [58–60, 110, 111, 181]. The gameplay of this game is to follow the virtual coach to complete various training tasks after Kinect recognizes the player's movements. There are three studies combining AVG with interactive bicycles [126, 132, 135]. The gameplay of this type of game is to ride a bicycle and pass levels in the game to get rewards. There are also three role-playing adventure games [117, 118, 180]. This type of game requires players to play virtual characters and complete tasks or defeat monsters in the virtual world through full-body movements (running, jumping, climbing, etc.). In the remaining six studies, the gameplay of AVG is mainly to simulate real-life sports competitions such as boxing, golf, and tennis through somatosensory devices [34, 62, 65, 109, 135, 169]. This type of game increases players' physical activity by adding competitive elements.

Outcome and measures

Mental health is a broad and multidimensional concept; different organisations and institutions have varied definitions. According to WHO, mental health is a state of mental happiness that not only involves the absence of mental disorders but enables individuals to cope with life's stresses and live well [177]. Understanding the meaning of mental health reveals that it includes not only the absence of psychopathology but also aspects such as eliminating negative emotions, positive emotional experiences, adapting to stress, healthy relationships, and good social functioning [73, 74]. This systematic review focuses on three aspects of mental health. In terms of emotions and moods. Four studies assessed happiness, three of which used adapted scales to measure happiness [3–60, 111], and one study assessed happiness using the Subjective Exercise Experience Scale (SEES), which is commonly used to evaluate psychological responses after exercise [34]. Three studies assessed psychological distress. Two of the studies assessed overall psychological distress in college students using the Subjective Exercise Experience Scale (SEES) and the Five-item Brief Symptom Rating Scale (BSRS-5) [34, 180]. Another study used the Depression, Anxiety, and Stress Scale-21 (DASS-21) to evaluate the depression, anxiety, and stress aspects of psychological distress [169]. The scale consists of three subscales assessing depression, anxiety, and stress, with higher total scores on the scale indicating higher levels of psychological distress. Two studies used the Profile of Mood States (POMS) and the Positive Affect and Negative Affect Schedule (PANAS) to assess changes in college students' moods after using AVGs [135, 135]. The POMS measures six mood states, while the PANAS directly assesses positive and negative moods through 20 questions.

Regarding psychological constructs, the outcome indicators mainly include attitude, satisfaction, motivation, and enjoyment. Two studies respectively assessed attitudes using adapted scales and 7-point semantic differential scales based on the theory of planned behaviour

[110, 126]. Three studies assessed satisfaction. Two of these studies used adapted scales [117, 118] and the other study used the Basic Psychological Needs in Exercise Scale (BPNES) [62]. This scale was designed based on SDT and assesses how individuals' basic psychological needs are satisfied during exercise. Four studies assessed motivation. For intrinsic and total motivation, two studies measured it using the Behavioural Regulation in Exercise Questionnaire-2 (BREQ-2), which is designed based on SDT theory to assess different types of motivation [62, 65]. Two studies used an adapted scale to assess future game motivation [117, 118]. Four studies assessed enjoyment using different scales. These were the Physical Activity Enjoyment Scale (PACES), the French 19-item Situational Interest Scale (SIS), the Sport Commitment Questionnaire 2 (SCQ-2) and the adapted scales [62, 117, 118, 132]. The remaining two studies assessed subjective vitality via the Subjective Vitality Scale (SVS) [109] and mental health in quality of life via the 36-Item Short Form Survey (SF-36) [181]. Two studies measured sleep quality. One used the Chinese Version of the Pittsburgh Sleep Quality Index (CPSQI). This scale assesses an individual's sleep quality [180]. Another study used the Functional Outcome Sleep Questionnaire (FOSQ) to assess the impact of sleep problems on daily functioning. Higher scores on this scale indicate higher sleep problems [169].

Effect of AVGs on emotion and mood

Four studies addressed happiness but did not have the same results. Three of the studies using the Xbox 360 game "Your Shape Fitness Evolved" indicated that AVGs positively affected college students' happiness, especially for those interested in exercise and weight management [58–60, 111]. Conversely, a study comparing AVGs to brisk walking on a treadmill found a significant post-exercise decrease in positive happiness after self-selected intensity use of Wii Fit "Free Run" by college students [34]. Three studies on psychological distress and mood disorders did not provide consistent results. One study found that college students' levels of psychological distress decreased after using Wii Fit "Free Run" (self-selected intensity). The decrease was comparable to the reduction observed after brisk walking on a treadmill [34]. A study using the Xbox 360 Kinect as a training programme showed that compared to the control group, the AVG group had significantly improved depression, anxiety and stress [169]. Only one study found that college students' stress and anxiety increased after a 4-week AVG (Ring Fit Adventure) training programme, leading to an increase in mood disorders. However, it did not reach the level of mild mood disorders [180]. The effects of AVG on short-term psychological responses were evaluated in two studies. The results showed that AVG had a positive effect on mood in the short term, but the effect of this positive effect was limited. An intervention using the Wii Punch-out boxing game showed that, while there were positive mood improvements in the game-experienced group immediately after the intervention, this improvement was not sustained after 15 min. Additionally, Wii Punch-out did not result in significant mood improvements across different experience levels (experienced vs. inexperienced) and social conditions (single vs. paired) [135]. Another study measured college students ten minutes after playing Smuggler's Run for PS. The results showed similar mood benefits and higher positive emotions when using AVGs and traditional training (cycling) compared to sitting and playing the game. However, the AVGs group did not demonstrate more excellent mood benefits than the conventional training group [135].

Effect of AVGs on psychological construct

Two studies assessed the effects of AVG on attitudes. One study found that 12 weeks of AVG training improved college students' attitudes and intentions toward other forms of exercise. Playing AVG increased such attitudes and intentions for college students who exercised regularly but not for college students with no fitness habits [110]. Another study found that college students playing AVG on a Gamebike significantly increased their affective attitudes and adherence (attendance) compared to traditional cycling. AVG was more conducive to college students' adherence to exercise [126]. Three studies explored psychological need satisfaction, and two used action-adventure AVGs developed based on SDT. They found that AVGs with functions addressing autonomy and competence needs increased both autonomy and competence needs satisfaction among college students [117]. A study utilizing AVGs with all SDT features showed improvement not only in autonomy and competence need satisfaction but also in relevance need satisfaction, compared to both a negative game group (sitting and playing games) and a control group. This led to an overall psychological need satisfaction [118]. Hwang discusses the effects of AVGs compared to traditional aerobic training and finds that AVGs increase autonomy need satisfaction in the short term (1 – 3 days post-exercise) and the long term (after six weeks) [62]. Four studies focused on the effects of AVG on different aspects of motivation, and all found that AVG was beneficial in improving exercise motivation. Two studies illustrated the positive effects of AVGs on exercise motivation. One of the studies found that playing AVGs significantly increased college students' intrinsic motivation both in the short and long term compared to traditional aerobic training [62]. Another study indicated that a single group of female college

students experienced a significant increase in total and intrinsic motivation after playing Wii Fit [65]. Two other studies reached similar conclusions, showing that college students had higher future gaming motivation after using an AVG designed based on SDT [117, 118]. Four studies evaluated the effect of AVG on enjoyment. Most studies (three out of four) supported that AVG can bring more enjoyment to college students and make them happier. Two of the studies used open-world adventure games designed based on SDT and found that games with SDT features can bring more enjoyment to college students [117, 118]. An AVG called Greedy Rabbit, developed by Vescape (Vescape GmbH, Berlin, Germany) and used in conjunction with an exercise bike, increased immediate enjoyment and attentional demands, thereby enhancing situational interest among college students [132]. Only one study, after comparing six weeks of AVG training (games for the Xbox One Kinect) with coach-directed traditional exercise, found that college students get more enjoyment participating in traditional exercise [62]. The remaining two studies evaluated the effects of AVG by assessing subjective vigour and quality of life. College students trained with 10 weeks of Wii Sports significantly improved their subjective vigour, resulting in better mental performance [109]. Using Your Shape: Fitness Evolved for 12 weeks can improve the mental health component of the quality of life of college students, especially those trying to control their weight [181]. Given the myriad of mental health issues resulting from overweight and obesity among college students, particular attention was given to the BMI of the included to observe the impact of AVGs on the mental health of obese college students. In six of the studies, participants were overweight and obese. Five studies found that AVGs increased psychological satisfaction, subjective vigour, positive mood, and motivation to exercise while reducing psychological distress among college students [34, 65, 109, 118, 135]. However, one study found no benefit of Wii Punch-out for acute mood states [135].

Effect of AVGs on sleep quality

Two studies focused on AVG's effects on college students' sleep quality but yielded different findings. One study used the Ring Fit Adventure to train college students thrice a week (30 min each time) for four weeks. Sleep quality was assessed at the end of the 4-week training period, and the results showed that this AVG did not significantly improve sleep quality in college students compared to a control group [180]. Another study conducted an intervention with college students using 12 games from Xbox Kinect Spots 1 and 2. The duration and frequency of training were also three sessions per week, with each session lasting 30 min, but the training period was 6 weeks. The results showed that AVG could significantly improve the sleep quality of college students [169].

Effect of AVGs on physical activity and health-related factors

Eight studies addressed the impact of AVGs on physical activity and health-related outcomes among college students. One study tested Nintendo's Ring Fit Adventure and found that it significantly reduced college students' time to run 1600 m and improved their physical fitness [180]. Four studies evaluated the intensity of physical activity that could be achieved with AVGs. AVGs based on SDT designs can increase MVPA time for college students [118]. Mean maximum heart rate, heart rate pressure product, and RPE while using Wii Fit "Free Run" were significantly higher than brisk walking on a treadmill, exceeding the threshold for moderate to vigorous physical activity [34]. College students can maintain moderate-intensity physical activity levels and promote weight control during Wii Fit exercises [65]. Vigorous physical activity levels were achieved while playing Greedy Rabbit [132]. The last three studies showed that the benefits of health-related outcomes were not significant, mainly because the AVG selected for these studies did not involve much whole-body movement. Among them, Wii Punch-out provided minimal physiological stimulation for college students, falling short of the target heart rate recommended by the American College of Sports Medicine (ACSM) [135]. Wii Sports also did not positively affect college students' body weight, body mass index (BMI), maximal oxygen uptake, and maximal heart rate [109]. Compared to using the Xbox One Kinect, traditional aerobic training (coach-directed sports) has resulted in more significant energy expenditure [62].

Discussion

Effect of AVGs on emotion and mood

Three studies have found that AVG can improve the happiness of college students, especially those who are passionate about sports and want to control their weight. All three studies used AVG (Your Shape: Fitness Evolved) to conduct a 2-week intervention (once a week for 30 min) with college students. The results of the studies found that a short intervention period (2 weeks) can significantly improve happiness and can also bring relaxation and perceived energy to college students, which can play a role in regulating emotions [3–60, 111]. This AVG needs to be used with Microsoft's Xbox and Kinect. Its main gameplay is based on body-sensing interaction. Players can use the movements captured by Kinect to follow the guidance of virtual coaches in the game to complete various fitness tasks and training [91]. This gaming experience, like that of a personal fitness coach, can

better allow college students to get real-time feedback so that they can immerse themselves in the game, focus more on exercise, and experience flow. The experience of flow is a state of extreme concentration [24]. This state of mind is conducive to promoting PA among college students and making them have a pleasant experience, thus enhancing their sense of happiness [81, 88]. For college students who want to control their weight, the effect of AVG on improving happiness is even better. This result can be explained using social cognitive theory, which posits that behaviour is influenced by the environment [6]. College students, who often care about other's perceptions, may exert more effort while using AVGs, making these games more effective for those predisposed to weight control. Previous studies using Xbox Kinect have also validated these findings, showing favourable results in improving children's vitality and mood [2, 3] and improving mental health and emotional happiness in older adults [186]. The only study that concluded AVGs reduce happiness used Wii Fit "Free Run," a game that uses the Wii Balance Board and remote control to simulate running in real-life scenarios, allowing the player to choose the intensity and speed of the run freely [34]. This study included overweight and obese university students with sedentary habits. The decline in happiness may be due to two reasons. First, the intensity of the 'Free Run' game can be selected independently. College students completed more than moderate-intensity physical activity during training. Excessive exercise intensity may cause physical discomfort and reduce positive psychological states after exercise [36], while moderate exercise can bring more happiness [175]. Second, the psychological state of sedentary people after exercise differs [11], and acute exercise may increase negative stress [39]. When trying to improve college students' happiness through AVG, it seems that AVGs with virtual characters guiding exercise and moderate exercise intensity are a better choice.

Fewer studies are exploring the effects of AVG on psychological distress and mood disorders in college students, with only three studies. A 6-week intervention using 12 games (e.g., bowling, boxing, track and field, and darts) on the Xbox 360 Kinect. The results of the study show that Kinect Sports games are effective in reducing depression, anxiety and stress in college students, thereby improving overall psychological distress [169]. The primary game mode of this AVG is to allow players to participate in multiple sports in a virtual game scenario by simulating real-life sports competitions [56]. College students may be unable to participate in many sports (e.g., golf, baseball) due to the limitations of sports fields and facilities at different schools. However, college students can participate in these sports through AVG and play cooperatively with their classmates. Participation in sports, especially team sports, can improve neurotransmitter balance and alleviate adverse emotions such as depression and stress [68]. Previous studies, such as the Kinect Sports training for older adults, the Zumba Fitness intervention for young women, and the Wii Fit Plus intervention for people with type 2 diabetes, have confirmed that AVG is effective in reducing depression, anxiety, and stress while improving physical health [71, 127, 164]. The other two studies both used AVGs from Nintendo but with different results. One study found that college students using a Wii Fit experienced reductions in psychological distress similar to those walking briskly on a treadmill [34]. Wii Fit Free Run provides a multi-sensory sight and sound experience, where college students can see virtual scenes and characters in motion, accompanied by encouraging sound effects. These additional sensory stimuli help to divert attention, reduce anxiety, and negative emotions, and make it easier to enter a relaxed state. Another study using Nintendo's 2019 Ring Fit Adventure (RFA) found that after a 4-week intervention (30 min three times a week), both groups experienced increased mood disorders. The RFA includes an adventure mode (fitness moves to defeat monsters and break through levels), a mini-game mode and a training combo mode [145]. The richness of the game seems like it should be more conducive to improving mood, but an increase in mood disorders was observed. This may be due to the timing of the pre-test and post-test,the pre-test was conducted before the Chinese New Year, when students generally had higher moods due to festive activities, while the post-test was after the New Year and before the midterm exams when academic stress was higher [180]. It is worth noting that for future interventions on psychological distress, not only the choice of AVG is essential, but also the time point of measurement. Based on current research and understanding of AVGs, previous studies have shown that third and fourth-grade primary school students experience a reduction in negative mood effects after participating in a 30-min AVG session [82]. Additionally, sedentary patients with SLE have been shown to have reduced fatigue and lower anxiety levels after using Wii Fit [182]. Thus, we can still see a range of features that AVGs possess, making them potentially beneficial tools for mental health.

Two studies explored the effects on mood using Nintendo's Wii and Sony's PlayStation (PS). College students with gaming experience had improved mood measured at 5 min after using the Wii Punch-out compared to inexperienced college students, but this improvement disappeared at 15 min [135]. The likely reason for this is that Wii Punch-out is an AVG that requires only an upper body movement and a punching motion to play, thus

providing a lower intensity of physical activity and less physiological stimulation. The low physiological stimulus did not have a corresponding emotional benefit. In a study using PS, college students reported higher positive emotions after ten minutes of AVG training, similar to those in the traditional training group [135]. The benefits of AVG on short- and long-term mood are well-documented. For example, in a virtual environment, adults riding static bicycles at moderate intensity (60–70% of maximum heart rate) can enhance emotional benefits [122]. Recent systematic reviews have expressed a similar view that AVG increases emotional experience by performing physical activity, which facilitates an increase in positive emotions. AVG can be used as a leisure activity to promote health and emotional regulation [98]. Recent surveys have found that even non-active play can have the benefit of reducing psychological distress and increasing life satisfaction [35]. However, the active nature and physical activity elements of AVG may allow players to become more deeply engaged in the game and have more significant advantages in improving mental health. Overall, AVGs are a potential tool for improving the mood and emotions of college students. AVG training for at least 30 min once a week and choosing AVGs with in-game guidance cuts that provide moderate-intensity physical activity seem more beneficial for improving college students' moods.

Effect of AVGs on psychological construct

Unlike traditional physical activities and training methods, the content and gameplay of AVGs can have a decisive effect on the intervention effect on different aspects of psychological structure. For attitudes, using Your Shape: Fitness Evolved to intervene with college students for 12 weeks (30 min three times a week) found that AVGs are a double-edged sword. AVGs enhance their attitudes and intentions towards other types of exercise for college students who exercise regularly, while for college students who do not exercise regularly, the effect is the opposite [110]. People who do not have exercise habits usually have less positive emotional responses to exercise than those who exercise regularly [125]. College students who exercise regularly may be able to feel the fun of AVG based on their existing exercise experience, thus maintaining a high willingness to participate in sports. This is consistent with the view that players with frequent AVG gaming experience have a higher degree of engagement with the game [14]. The unique value of this virtual coaching approach to AVG is that it provides a more relaxed way for students who do not exercise regularly to get started. Using AVG as a supplement or transitional tool for traditional sports can gradually increase students' interest and willingness to participate in other forms of exercise by first cultivating their positive attitude towards AVG. Compared to traditional sports (cycling), inactive male university students who participated in 6 weeks of AVG (Gamebike) training (30 min three times a week) had better emotional attitudes and compliance [126]. The gameplay of riding in a virtual world through the Gamebike provides a more novel way of exercising for university students. This is like the findings of another study on adults using the Gamebike, which found that the Gamebike can provide more energy expenditure and fun than traditional power bikes and can be an alternative to conventional bicycles [106]. The advantages of the AVG in enhancing exercise attitudes, affective attitudes, and adherence, especially its effectiveness in maintaining exercise participation and improving attendance, provide college students with a fun and sustainable way to exercise.

Three studies demonstrated that AVGs could satisfy psychological needs, thereby improving the psychological structure of college students. The games used in these studies were designed based on SDT. SDT aims to explain the theory of human intrinsic motivation and the driving forces behind individual behaviour [135]. In SDT, intrinsic motivation is considered the highest form of motivation because it is closely related to an individual's personality and values, not just the pursuit of extrinsic rewards or avoidance of punishments [29]. SDT suggests that basic psychological needs (i.e., the need for competence, autonomy, and relatedness) must be met to live a healthy life [138, 139]. Autonomy is the extent to which individuals feel and control their behaviour, competence is the need to produce the outcomes, and relatedness focuses on the need to connect with others and social support [141]. The first study evaluated measures of two core elements of SDT (autonomy and competence) using internally tested AVGs called Olympus. Through a 15-min game, it was found that the group with autonomy support and competence support had higher levels of psychological need satisfaction and positive effects on outcomes related to motivation and game participation [117]. Another study built on this by adding relevant support to AVGs. The game incorporated voice and dialogue for relevance support, allowed players to customise their characters for autonomy support, and dynamically adjusted game difficulty for competence support. This satisfied the three essential core factors of SDT. College students with SDT features enabled were found to have higher psychological need satisfaction and greater MVPA and game-related engagement [118]. AVGs selected for prior research are typically produced earlier. They may not consider long-term playfulness, leading to reduced playtime and burnout later in the intervention [93], which can affect the effectiveness of AVGs. Meeting the

psychological needs of college students through theory-supported AVGs can stimulate their intrinsic motivation and enhance their play experience, promoting greater engagement in play. The importance of theoretical guidance in interventions cannot be overstated [15]. Therefore, theoretically guided AVGs in interventions for college students' mental health is recommended. A comparison of the psychological effects of traditional aerobic training and AVGs revealed that AVGs produced higher levels of autonomy satisfaction and intrinsic motivation in the short and long term. The level of enjoyment was similar to that of traditional aerobic training [62]. Previous studies have also verified that autonomy satisfaction, intrinsic motivation, and enjoyment are positively correlated (Teixeira et al., 2012), indicating they can be pleasurable. Other studies have confirmed that AVGs can lead to higher satisfaction, positive expectations, and enjoyable characteristics [2, 3, 69].

Four studies, although evaluating different motivational types, affirmed the potential value of AVG in promoting motivation. It seems that the improvement of exercise motivation in college students is not limited by the type of AVG. College students can increase their intrinsic motivation by playing a series of games (e.g., Just Dance, Zumba Fitness) with the Xbox One Kinect for 6 weeks (50 min three times a week) [62]. After 12 weeks of training (three times a week for 30 min) with the Wii Fit series of games, overweight and obese female college students increased their intrinsic and total exercise motivation [65]. Intrinsic motivation is often associated with happiness and enjoyment [27, 28], and increased motivation not only suggests that college students enjoy the sport while using AVGs and tend to sustain participation for more extended periods. This intrinsic enjoyment promotes positive emotional experiences and enhances self-efficacy. The other two studies both used adventure games based on SDT design, so they paid particular attention to the benefits of the games themselves [117, 118]. When the game features fulfilled the three essential elements of SDT, namely autonomy, competence, and relevance, college students showed higher attendance rates, suggesting that they were more willing to engage in AVGs and play for longer periods. Simultaneously, the increase in game enjoyment, ratings, and motivation to play in the future suggests that college students greatly enjoy gaming. Increased game participation indicates better adherence and physical activity, contributing to improved mental health [141]. The motivation is improved because of the game characteristics of AVG. AVG provides college students with more opportunities to exercise and lowers the threshold for exercise. Compared to traditional sports, AVG allows students to exercise in a comfortable indoor environment, reducing the psychological resistance of students not used to exercising and gradually cultivating their interest and motivation in sports. Increased motivation will enhance students' persistence in exercising, which will, in turn, positively impact their mental health [87]. AVG can increase self-efficacy [76, 154]. When players complete a series of game tasks in the virtual world (such as breaking through levels and getting high scores), they will constantly experience their progress in the sport. This sense of progress will enhance their self-confidence and self-efficacy and make them more confident to continue participating [147]. Previous studies have also demonstrated the effectiveness of AVG in improving the exercise motivation of children and adolescents [95].

Although AVGs can potentially improve enjoyment in college students, there is still a need to focus on selecting and using AVGs. Three studies have found that AVGs can lead to more enjoyment after the intervention. Two studies used third-person role-playing games with SDT features. It was found that regardless of the length of the intervention cycle (15 min to 4 weeks), AVGs can improve college students' enjoyment and increase their sense of pleasure [117, 118]. AVG, designed based on SDT theory, allows players to personalise their game characters (choose gender, appearance, skin colour, etc. autonomously), satisfying the need for autonomy. The dynamic game difficulty adjustment mechanism satisfies the need for competence. Supportive dialogue and game voiceovers in the game create a social environment, satisfying the need for relatedness. Compared to an AVG without these features, when an AVG can meet these three basic psychological needs, college students will feel more enjoyable and even increase the likelihood of recommending the game. This is in line with the SDT's view that the satisfaction of basic psychological needs is conducive to psychological health [27]. After completing a 2-week, twice-weekly training programme based on the fitness bike designed AVG (Greedy Rabbit), college students' physical activity, momentary enjoyment, and attentional needs improved [132]. The gameplay of this AVG features players controlling a rabbit through cycling to navigate a maze, collecting flowers while avoiding a hedgehog chasing after them, and finally obtaining a reward (carrot). College students interact with the environment by controlling the movement of the rabbit. This immersive experience allows players to fully absorb the game, enhancing immediate enjoyment [103]. Only one study found that AVG training lasting six weeks (50 min three times a week) was less effective than a coach-led exercise group in improving enjoyment among university students [62]. The difference in the choice and use of AVG compared to traditional exercise training groups may be the reason for this result. In this study,

the intervention selected a wide variety of AVGs. Participants were exposed to three games in the first week, and four new games were introduced in the fourth week. Frequent game changes can be disruptive, causing college students to switch to the next game before they have fully mastered a game or experienced the fun in-depth, resulting in an overall poor experience. The control group used the physical education instructor to guide the exercise and teaching strategies based on SDT theory to provide exercise feedback and suggestions. SDT teaching models are an excellent way to improve student performance [174]. In future research, depending on the length of the intervention cycle, providing only one or two AVGs with SDT functions is a better choice to improve enjoyment. At the same time, an intervention programme of at least 2 to 4 weeks (2–3 times per week) is required to obtain stable positive results. In the last two studies, AVGs showed promising results in terms of subjective vitality and quality of life. Ten weeks of exercise with Wii Sports (three times a week for 30 min) and 12 weeks of exercise with Your Shape: Fitness Evolved (three times a week for 30 min) can improve subjective vitality and quality of life in terms of mental health, respectively [109, 181]. A long intervention period (at least ten weeks) seems necessary to improve vitality and quality of life. Given the positive nature of AVG, which allows participants to exercise actively, the benefits of both AVG on physical and mental health are worth affirming [123, 161].

Effect of AVGs on sleep quality

Sleep is an important modifiable factor related to mental illness [64]. There is a close relationship between sleep and mental health, and sleep difficulties may lead to impaired mental health [41]. Sleep problems can also increase feelings of loneliness [57]. Good sleep quality benefits mental health [67]. Therefore, sleep quality somewhat determines mental health [148]. Two studies have addressed the effects of AVGs on sleep quality, but their conclusions are not consistent. The intervention using Ring Fit Adventure found no significant change in sleep quality. This lack of change may be attributed to the holiday interval (Chinese New Year) before and after the measurements and the intense exercise intensity in both Adventure Mode (storyline breakthroughs) and Custom Mode (combinations of various workouts) in RFA, which may excite college students and interfere with their sleep if they work out close to bedtime [180]. Previous meta-analyses have shown that sleep quality is also affected by age, health level, type, and duration of exercise [77, 78]. Therefore, it is essential to carefully consider the duration and intensity of exercise when using RFA as a sleep intervention. In the study using the Xbox 360, an improvement in sleep quality for college students was found after a 6-week intervention (30 min, three times a week). This measurement was taken continuously over the semester, without significant activity before or after the measurement, thus ensuring that the college students' mood and sleep patterns were manageable [169].

Both exercise and rest, such as restorative sleep, are known to bring about many physiological changes that promote happiness and improve physical and mental health [31, 54, 170]. Physical activity is associated with improved sleep quality, sleep latency, and sleep disturbance [162]. AVGs are designed to promote physical activity, which is known to improve sleep. There are currently few studies on the effect of AVGs on sleep quality, but there is general support for the benefits of AVGs on sleep quality. Twelve weeks of AVG (Wii Fit Plus) training provided moderate physical activity, improved sleep disturbance and increased total sleep time in patients with acute lymphoblastic leukaemia [158]. In older adults, 6 weeks of Xbox Kinect gaming (three times per week for 60 min) also improved sleep quality by reducing anxiety [38]. A recent study on sleep quality with RFA intervention showed that middle-aged women with poor sleep quality could reduce their sympathetic nerve activity and significantly improve sleep quality after 12 weeks of RFA training (twice a week for 60 min) (Lin et al., 2024). This result differs from the conclusion in the included study that RFA cannot improve the sleep quality of college students. The reason may be that the participants included in this study had poor sleep quality and were more likely to improve their sleep. Narrative reviews of AVG and sleep quality also found that AVG is beneficial for improving sleep, but moderate-intensity gaming for 30 min daily should be maintained, and blue light exposure should be reduced [130]. In summary, AVG has the potential to improve sleep quality through regular physical activity, which can help enhance mental health and create a beneficial cycle for mental health. However, using AVG to improve sleep quality requires at least a 6-week intervention. The selected AVG should achieve moderate-intensity physical activity, and training time should avoid times of the day that are likely to affect sleep, such as in the evening.

Effect of AVGs on physical activity and health-related factors

The mental health benefits of exercise are self-evident [7]. Physical activity and its levels are also crucial components of mental health promotion that cannot be ignored. Therefore, this systematic review also focused on the effects of AVGs on physical activity as well as health-related factors in the included studies. Five studies indicated positive effects of AVGs on physical activity and health-related physical fitness. Four of them

illustrated the intensity of exercise achievable with the choice of AVGs, and overall, they all resulted in moderate to vigorous physical activity. College students playing Wii Fit were found to achieve moderate-vigorous physical activity, as measured by the RPE each time they played [65]. The Wii Fit "Free Run" also showed greater RPE and average maximal heart rate compared to treadmill exercise, and due to the ability to self-select the intensity, it was possible to surpass moderate physical activity levels [34]. Other RCT studies using the Wii series of games have also demonstrated the ability to achieve moderate to vigorous physical activity and improved health risk indices [12]. Adventure-based AVGs based on SDT design led to higher MVPA levels and illustrated that AVGs can promote more physical activity if they can achieve a basic need [118]. Design-based cycling AVGs like Greedy Rabbit can lead to strenuous intensity physical activity [132], and other studies using Greedy Rabbit with college students have found that it can increase physical activity levels in this demographic [116]. Because it can also increase situational interest, it can be used as a tool to promote exercise adherence in diverse populations. One study illustrated that the use of RFA improved performance in the 1600-m run among college students [180]. The positive effects of AVGs on physical fitness in children and young adults have been validated in previous studies [59, 60, 90], indicating that AVGs can be an effective tool for improving physical fitness.

Only three studies did not account for the benefits of AVGs on physical activity and health factors. Two of these used Nintendo's game, Wii sports, and were not found to have a significant effect on college students' body composition (weight, BMI) and cardiorespiratory fitness (maximal oxygen uptake and maximal heart rate) [109]. Wagener's study also found that AVGs had less of an effect on the BMI of obese adolescents, possibly because adolescents believe that exercise burns calories and, therefore, they can eat more [168]. The Wii Punch-out had a limited increase in physical activity, as evidenced by the low number of steps measured during gameplay [135]. Using the Xbox One Kinect did not burn as much energy as the Unity group aerobic training, possibly because the group of AVGs was given seven games to switch and choose from at will, and creating characters to add functionality all affected the exercise intensity during the intervention [62]. Future research to improve physical activity and health among college students needs to consider the selection of AVGs with rich and attractive game content and whether the selected AVGs can lead to adequate levels of whole-body and physical activity. At the same time, it is also essential to pay attention to the control of eating behaviour.

Potential for digital addiction in AVGs

Digital addiction is often associated with computer games, mobile games, and other common video games, as these games attract players to repeatedly participate in them with a constant reward mechanism, leading to potential overuse and psychological dependence [4, 49]. AVG and common video games have many differences in terms of addiction and may not cause digital addiction in college students. First, the core purpose of AVG is different from that of ordinary video games. AVG aims to promote physical activity, enhancing college students' health through exercise and physical activity [167]. In contrast, ordinary video games mainly attract players to participate in the game for a long time based on entertainment, achievement and competition [159]. Secondly, unlike traditional games that promote addiction through continuous sedentary gameplay, AVG requires physical activity to play [155]. Game time is naturally limited by physical exertion. Players usually cannot continue playing for a long time because physical fatigue will shorten the game time, thereby reducing the risk of addiction. Finally, the benefits of AVG on physical and mental health have been demonstrated [75]. The development of AVG dependence among university students may be beneficial rather than harmful, as it promotes regular physical activity and contributes to mental health. Although the likelihood of AVG leading to digital addiction among university students is low, further research could be conducted in the future to determine whether there is a risk of excessive AVG dependence in specific groups (e.g., children and people with low motivation to exercise).

Limitations and future research

The included studies provide the most recent evidence of the impact of AVGs on the mental health of college students, but there are still some limitations. Firstly, the choice of keywords and search strategies affect the selection of studies. As the variety of AVGs grow, future studies need to include keywords for new AVGs. Secondly, heterogeneity needs to be accounted for. Regarding sample heterogeneity, differences arise because, although populations are all college students, the age range and entry criteria for college students vary by country and region. Multiple studies included populations with different educational backgrounds (including undergraduate and graduate students), and one study also included faculty members [59, 60]. Differences in qualifications and occupations can also exacerbate these differences, potentially affecting external validity. It is also worth considering whether the prior status of college students will affect the effectiveness of AVG interventions for mental health. With only two studies illustrating that college students are inactive [118, 126], future studies should

further divide the sample to explore differences between subgroups.

In terms of intervention heterogeneity, the study included many types of AVGs, ranging from those published by large manufacturers (e.g., Microsoft, Sony, Nintendo) to those based on theoretical design and cycling design. Although the different types of AVGs have exerted different effects on psychological happiness, further research is needed to classify AVG game modes, styles, themes, and levels of difficulty to explore their effects on college student's mental health fully. Concerning intervention time, five studies explored acute responses to mental health [34, 117, 132, 135, 135]. Future studies should extend the intervention time and include a longer follow-up period to observe the long-term effects of AVGs better. In conclusion, this systematic review focuses on the impact of AVG on college students' mental health. However, the factors that affect college students' mental health are complex, including social culture, lifestyle, etc. Future research can fully consider these factors.

Conclusion

This systematic review provides the available evidence on the different effects of AVGs on the mental health of college students. Due to the characteristics and gameplay of different AVGs, some AVGs did not show sufficient benefits for emotional improvement and sleep quality. This may be because the gameplay of these AVGs is relatively monotonous and does not provide sufficient whole-body exercise. However, most AVGs showed promising effects in reducing psychological distress, improving satisfaction, promoting exercise motivation, increasing enjoyment, and improving attitudes towards other forms of exercise. It is worth mentioning that AVGs with SDT support can fully meet college students' psychological needs (autonomy, competence, and relatedness) and show advantages in-game participation. Most included studies showed that AVGs can achieve moderate to vigorous physical activity, which is the internationally recognised recommended intensity of physical activity. Long-term use of AVGs at this intensity can affect the physical health of college students and have a beneficial effect on mental health. Given the many benefits of AVGs, they have the potential to be an effective tool for future interventions in college student's mental health and an effective supplement to address public health issues. As new AVGs are developed, and the content and gameplay become more diverse, future research should consider using newly released AVGs and further consider the specific situation of college students (sedentary or active) to study the impact of AVGs on mental health.

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Authors' contributions
YZ drafted this systematic review and completed the literature search and collation. The development of literature inclusion and exclusion criteria, methodological assessment, and article screening were done by YZ, WCR, SHA, QL and XZW and subsequently determined in discussion with KGS. YZ analysed and interpreted the data, which was ultimately checked and revised by KGS. All authors approved the final version.

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Declarations

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