Impact of Immersive Virtual Reality Exercise on Physiological and Psychological Outcomes in College Students: A Comparison with Traditional Cardiorespiratory Exercise

Original Research

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Abstract

Introduction: Research suggests virtual reality (VR) exercise could be useful in promoting physical activity, particularly among college students who often engage with video games. The aim of this study was to compare physiological and psychological effects of immersive VR exercise to traditional cardiorespiratory exercise.

Methods: Twenty-four participants completed two separate 20-minute exercise sessions (immersive VR exercise and cardio equipment of choice) in a randomized and counter-balanced order. Average and maximum heart rate, perceived exertion, and psychological outcomes of enjoyment, intrinsic motivation, and mood were assessed.

Results: There was no significant difference in heart rate parameters or perceived exertion indicating similar exercise intensity between both sessions. However, the VR session resulted in significantly greater enjoyment ($p<.001$), improved mood (tension $p=.011$, depression $p=.026$, vigor $p<.001$, happiness $p=.003$), higher interest/enjoyment and perceived competence ($p<.001$ and $p=.018$, respectively), and less effort ($p=.022$) compared to traditional exercise.

Conclusions: VR exercise is a highly motivating and enjoyable alternative to traditional exercise and could be a valuable tool for improving physical activity and mental well-being in college-aged individuals. Future research should investigate different VR exercise modalities and long-term effects to optimize VR's potential in sustaining physical activity.

Key Words: physical activity, mood, motivation.

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Introduction

The World Health Organization recommends at least 150 minutes of moderate-intensity aerobic activity, or equivalent high-intensity activity, per week[1]. However, only 24.2% of U.S. adults aged 18 and older meet the guidelines[2]. College students are at an increased risk for physical inactivity as this population often faces lifestyle decisions autonomously for the first time[3]. According to the 2024 ACHA-National College Health Assessment III, only 42.7% of college students meet the recommended physical activity guidelines[4]. To improve physical activity levels among college students, more engaging and enjoyable activity formats are essential. According to the Pew Research Center, 60% of U.S. college-aged adults aged (18 to 29 years) engage in video games regularly, which suggests a unique opportunity to leverage gaming technology to promote physical activity[5]. Immersive virtual reality (VR) exercise in particular shows promise as a tool to encourage physical activity. While prior research on VR has primarily focused on cognitive and psychological well-being[6,7] or clinical rehabilitation[8], recent studies have begun exploring its potential for

enhancing physical activity. Initial findings indicate that VR exercise can improve both physiological and psychological outcomes related to physical activity[9-11]. However, many studies have limitations, and further research is needed to fully understand VR's potential in promoting physical activity.

According to the self-determination theory, three core psychological needs - autonomy, competence, and relatedness are essential for fostering intrinsic motivation[12]. When these needs are met, individuals are more likely to engage in and enjoy physical activity[13,14]. Recent studies suggest that VR exercise may help fulfill these needs by offering an immersive, engaging experience that increases enjoyment, reduces perceived exertion, and enhances motivation[15]. To date, research on VR exercise has focused on comparing a VR exercise format to its traditional non-VR equivalent, such as cycling, boxing, or high-intensity interval training[16-18]. Research suggests that self-directed exercise, where an individual can select their preferred exercise modality and intensity, can improve exercise adherence by fostering a sense of control and enhancing enjoyment[12]. Therefore, the aim of this study was to expand upon existing research by investigating the effects of a VR exercise session compared to a traditional exercise session with cardio equipment selected by the individual. Specifically, this study aimed to assess the physiological and psychological differences between the two approaches, with the intention of identifying effective strategies for promoting physical activity among college students.

It was hypothesized that compared with traditional cardiorespiratory exercise, VR exercise would elicit similar average and maximum heart rate, lower rating of perceived exertion (RPE), improved mood, and higher levels of enjoyment and intrinsic motivation. Cardiorespiratory exercise was the primary focus of this research due to its critical role in overall health, reducing risk of chronic diseases such as cardiovascular disease, diabetes, and hypertension[19]. The goal of the study is to provide valuable insights that can inform the development of more effective physical activity promotion strategies for college students, addressing the low levels of physical activity observed in this population.

Methods

Participants

Twenty-four healthy full-time undergraduate students were recruited from a large, public university in southeastern United States. Inclusion criteria were: (1) enrolled at the University; (2) aged 18 to 22 years; and (3) healthy (i.e., no diseases/conditions preventing physical activity participation). The study was approved by the University Institutional Review Board and all participants gave informed consent prior to participation. To characterize the sample population, participants were asked to self-report age, height, weight, gender identity, and year of enrollment. Participants also reported previous VR playing experience as "never", "rarely", "sometimes", or "often." The Godin-Shephard leisure-time physical activity questionnaire was used to evaluate self-reported leisure-time physical activity. Participants reported the number of days per week they engage in more than 15 minutes of strenuous, moderate, and mild physical activity. Each category is multiplied by a factor (9, 5, and 3, respectively) and summed to determine the weekly leisure time activity score. A health contribution score is calculated by combining strenuous and moderate categories for a value that can be categorized into active (24+ units), moderately active (14-23 units), or insufficiently active (<14 units)[20].

Protocol

Participants completed two separate 20-minute exercise sessions in a randomized and counter-balanced order during a single visit: one consisting of immersive VR exercise and the other using their preferred cardio equipment. Both sessions were conducted in a controlled indoor environment to minimize external variables. The 20-minute duration was selected as a representative of a typical gameplay session, provides sufficient time to confer health benefits, and aligns with previous research[11]. To limit potential carryover effect, as suggested by other exercise studies21, participants had a 10-minute break between sessions to allow for heart rate and blood pressure to return to baseline levels. After each exercise session, participants completed questionnaires assessing enjoyment, mood, and motivation based on the session they had just completed.

For the traditional cardiorespiratory exercise session, participants selected their preferred cardio equipment with options including a treadmill, stationary bike, stairmaster, or elliptical machine, and were instructed to complete the session at a self-directed intensity level. For the VR exercise session, participants used the Meta Quest 3 headset to play the game "Flow" in Supernatural. The game involves functional movements such as squats, lunges, and trunk rotations while participants used handheld controllers to hit virtual targets with virtual baseball bats. The session was set at the beginner, low-intensity level, which is choreographed with flowing, full-body movements at a slower pace. A

1-meter by 1-meter safety boundary was set to provide participants with sufficient space to move freely and safely in the game. Participants who wore prescription glasses were permitted to keep them on.

Heart rate was continuously monitored during each exercise session using a Polar H7 chest strap monitor, which has been validated for heart rate monitoring during exercise activity[22]. Peak and average heart rate were recorded for each session. Perceived exertion was measured using the modified Borg CR10 RPE scale[23], a well-established tool with proven construct validity for assessing exertion in exercise contexts[24]. Following each exercise session, participants were asked to rate their perceived exertion by selecting a number on the scale ranging from 0 ("no effort) to 10 ("maximal effort").

Physical activity enjoyment was assessed with the Physical Activity Enjoyment Scale (PAES), which consists of 16 items rated on a 5-point scale ranging from 1 ("totally disagree") to 5 ("totally agree"). Scores can range from 16 to 80 points, with higher scores indicating greater enjoyment of physical activity. The PAES has demonstrated reliability and validity[25,26]. Intrinsic motivation was assessed with the Intrinsic Motivation Inventory (IMI), a multidimensional self-report tool designed to assess intrinsic motivation and self-regulation dimensions based on the self-determination theory[27]. The IMI assesses motivation by measuring the underlying factors of interest/enjoyment, perceived competence, effort, value/usefulness, pressure and tension, perceived choice, and relatedness, yielding seven scores. Shorter versions have been used to assess specific dimensions or to adapt to a specific activity context. The present study utilized the 18-item version of the IMI which focuses on the following three dimensions: interest/enjoyment, perceived competence, and effort/importance. Participants responded to a list of statements on a 7-point scale ranging from 1 ("not at all true") to 7 ("very true"). Multidimensional scores were determined by calculating the mean scores for each of the subscales and overall intrinsic motivation was determined by summing the subscales[28]. Lastly, mood was assessed using the Brunel Mood Scale (BRUMS), a 24-item questionnaire measuring six mood states: tension, depression, anger, vigor, fatigue, and confusion. Participants rated a list of adjectives on a 5-point Likert scale ranging from 0 ("not at all") to 4 ("extremely"). Examples of tension items include "worried" and "anxious," anger items included "furious" and "bad-tempered," fatigue items included "worn out" and "exhausted," vigor items included "lively" and "energetic," confusion items included "mixed-up" and "uncertain", and depression items included "miserable" and "downhearted"[29].

Statistical Analysis

A Wilcoxson signed-rank test was used to compare differences in PAES, IMI, and BRUMS scores between the two exercise sessions. A chi-square test of independence was performed to examine the relationship between the order of treatment (VR exercise first or traditional cardiorespiratory exercise first) and average and maximum heart rate (yes or no that the second session was higher) across the two trials. Descriptive statistics are presented as mean (±SD). Data were analyzed using SPSS (Version 29.0.1.0) with statistical significance set at $p<0.05$.

Results

The leisure-time activity scores for participants ranged from 25 to 101 units with an average of 55.7 (± 20.8). Three participants were categorized as moderately active with the remaining 21 categorized as active. Descriptive statistics for additional demographic variables are presented in Table 1. There was no significant difference between average heart rate (VR exercise: 139.8 ± 21.4, traditional cardiorespiratory exercise: 143.6 ± 22.4, $p = .386$) or maximum heart rate (VR exercise: 173.8 ± 20.3, traditional cardiorespiratory exercise: 165.5 ± 23.9, $p = .241$). Similarly, there was no significant difference in RPE (VR exercise: 5.3 ± 1.8, traditional cardiorespiratory exercise: 5.4 ± 1.6, $p = .682$). A chi-square test of independence was performed to examine the relationship between the order of treatment (VR exercise first or traditional cardiorespiratory exercise first) and heart rate parameters to determine if there was any carryover effect. There was no significant relationship between the order of treatment on average heart rate, X^2 (1, N = 24) = 1.510, $p = .219$, or maximum heart rate, X^2 (1, N = 24) = .734, $p = .392$.

Physical activity enjoyment was assessed with the PAES questionnaire. A Wilcoxon signed-rank test revealed a significant difference in enjoyment between VR exercise (71.0 ± 6.1) and traditional cardiorespiratory exercise (57.5 ± 12.1), z = -3.940, $p<.001$, with a large effect size (r = -0.8) indicating participants reported significantly greater enjoyment of VR exercise compared to traditional cardiorespiratory exercise. Intrinsic motivation was assessed with the IMI questionnaire. A Wilcoxon signed-rank test revealed a significant difference between treatments with VR exercise demonstrating greater interest/enjoyment and perceived competence ($p<.001$ and $p = .018$, respectively) and less effort than traditional cardiorespiratory exercise ($p = .022$) (Table 2).

Table 1. Descriptive statistics of demographic variables.

Variable	N (%)
Class Standing	
Freshman	6 (25%)
Sophomore	3 (12.5%)
Junior	4 (16.7%)
Senior	11 (45.8%)
Enrollment Status	
Full time	24 (100%)
¾ time	0 (0%)
½ time or less	0 (0%)
Gender Identity	
Male	14 (58.3%)
Female	10 (41.7%)
Non-binary/other	0 (0%)
Previous Use of VR technology	
Never	17 (70.8%)
Rarely	5 (20.8%)
Sometimes	2 (8.4%)
Often	0 (0%)

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Table 2. Intrinsic motivation inventory.

	VR exercise	Traditional cardiorespiratory exercise	*p* value
Overall IMI Results	5.3 ± 0.8	5.1 ± 1.2	<.001*
IMI Subscales			
Interest/enjoyment	5.1 ± 1.3	4.8 ± 2.0	<.001*
Perceived competence	5.5 ± 0.7	5.0 ± 1.0	.018*
Effort	5.3 ± 1.0	5.7 ± 1.1	.022*

Data are Means ± SD; * p <0.05

To assess mood, participants completed the BRUMS questionnaire. A Wilcoxon signed-rank test revealed a significant difference between VR exercise and traditional cardiorespiratory exercise. VR exercise resulted in lower levels of tension (z=-2.555, p = .011, r = -0.52) and depression (z = -2.232, p =. 026, r = -0.455), as well as higher levels of vigor (z = -3.535, p<.001, r = -0.72) and happiness (z = -2.996, p = .003, r = -0.72). No significant differences were found for the other mood measures. Table 3 displays the results for all subscales.

Table 3. Brunel mood scale.

	VR exercise	Traditional cardiorespiratory exercise	*p* value
Anger	0.3 ± 0.6	0.7 ± 1.5	.256
Tension	0.3 ± 0.8	1.0 ± 1.4	.011*
Depression	0.0 ± 0.0	0.8 ± 1.4	.026*
Vigor	12.4 ± 2.8	9.3 ± 3.2	<.001*
Fatigue	3.7 ± 2.9	4.7 ± 3.6	.152
Confusion	0.8 ± 1.3	0.6 ± 1.3	.642
Happy	10.7 ± 3.2	8.7 ± 3.7	.003*
Calmness	8.0 ± 3.5	7.0 ± 3.7	1.76

Data are Means ± SD; * p <0.05

Discussion

Recent research suggests that VR exercise offers a promising solution for promoting physical activity, particularly among college students, who often engage with video games and digital technology[5]. The aim of the present study was to assess differences in physiological and psychological effects of VR exercise compared to traditional cardiorespiratory exercise, providing insights into the potential role of VR exercise in addressing the low physical activity levels observed in college-aged individuals. Overall, the results found VR exercise offers similar physiological benefits and greater psychological benefits compared to traditional cardiorespiratory exercise.

Although the present study did not assess the percentage of maximum heart rate achieved during the session, average and maximum heart rates were comparable between the two exercise sessions. These findings align with previous research where exercise intensity measured by heart rate was found to be comparable between VR and non-VR exercise and the conclusion that VR exercise can be equally effective as traditional cardiorespiratory exercise[17,30,31]. While previous studies found VR exercise to be perceived as less strenuous as measured by RPE[10,11,17], the present study found no significant difference between RPE between the two sessions. This discrepancy may have arisen from participants being able to select their preferred cardio equipment, introducing variability in the results compared to a more standardized approach.

VR exercise has been shown to improve psychological outcomes, including higher enjoyment and self-efficacy[10,11,32] and providing a high-flow experience contributing to enhanced motivation[17]. The present study enhances those findings by noting VR exercise to result in significantly higher levels of enjoyment and motivation compared to traditional cardiorespiratory exercise, which further supports the use of VR as a motivational tool for promoting physical activity, potentially increasing participation and adherence. Higher intrinsic motivation resulting from VR exercise could make it a more effective alternative to traditional cardiorespiratory exercise, helping to overcome barriers to physical activity. Collectively, these findings support VR exercise as an effective, enjoyable, and motivating tool for promoting physical activity[10,16].

VR exercise has been linked to improved psychological benefits, such as increased focus, positive emotions, and energy[16,18]. In the present study, VR exercise resulted in significantly higher levels of happiness and vigor, as well as lower levels of tension and depression. These findings are consistent with previous research[10] and highlight the positive impact of VR exercise on mood. Given that college students commonly report high levels of stress and anxiety[4], these results are particularly relevant, as VR exercise may provide an intervention that promotes mental well-being in additional to the physical, health benefits.

Overall, the present study demonstrates that VR exercise can effectively enhance psychological well-being while providing the same level of physiological benefits as traditional cardiorespiratory exercise. As a result, VR exercise holds potential as a method for increasing physical activity among a college-aged population, potentially fostering long-term exercise adherence. However, there are several limitations to considered. The present study relied on a single VR exercise game, limiting the generalizability of the findings and not fully representing other VR exercise experiences. Additionally, the study was based on a single session, so it is not possible to evaluate the long-term effects of VR exercise. Lastly, due to practical constraints, blinding was not implemented in the study. Future research should consider using a blinded statistician to reduce bias and improve the reliability and validity of findings. Opportunities for future research include comparison of different VR exercise games, assessing additional physiological outcomes (e.g., pulmonary ventilation, oxygen uptake), exploring the long-term effects of VR exercise on behavior change, and investigating the impact of group VR exercise sessions.

Conclusions

The present study provides valuable insights into the physiological and psychological benefits of VR exercise compared to traditional cardiorespiratory exercise. It demonstrates that VR exercise is equally effective as traditional exercise in terms of exercise intensity and perceived exertion, while also promoting greater enjoyment, motivation, and positive psychological outcomes such as improved mood and reduced tension. These findings align with previous research suggesting VR exercise be a highly motivating and enjoyable alternative, potentially increasing long-term physical activity participation and adherence. However, limitations such as the use of a single VR exercise session and the lack of long-term data should be considered. Future research should explore the effects of different VR exercise games, incorporate a broader range of physiological measures, and examine the long-term impact of VR exercise to fully understand its potential for promoting sustained physical activity.

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