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Comparative effects of exergame intervention on cardiorespiratory function in obese and normal-weight adults

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ABSTRACT

Background: Obesity is a major risk factor for cardiovascular disease and metabolic disorders. Exergaming offers an accessible, interactive alternative to promote physical activity. This study aimed to assess the changes in the 6-minute walk test (6MWT), heart rate recovery (HRR), and maximal oxygen uptake (VO2max) in adults with obesity and normal weight after a six-week exergame intervention.

Methods: A quasi-experimental pre-post study involved 29 adults (15 obese, 14 normal BMI) who participated in exergame sessions three times of 40 minutes weekly for six weeks. Inclusion criteria included adults aged 18–45 years with a BMI of 18.5–24.9 kg/m^2 (normal) or ≥25 kg/m^2 (obese), normal or corrected vision, and willingness to complete the intervention. Exclusion criteria included individuals with cardiovascular, neurological, or uncontrolled medical conditions, recent surgery or hospitalization, pregnancy, participation in other exercise programs within the previous four weeks, cognitive or sensory impairments, withdrawal from the study, repeated absences, or adverse events such as cybersickness. Outcomes included 6MWT distance, HRR, and VO2max. The paired *T*-test or Wilcoxon test was used for within-group comparisons, and the independent *T*-test or Mann-Whitney test for between-group analysis.

Results: Significant within-group improvements were observed after the intervention. The 6MWT distance increased by 26.21 m, from 364.48 ± 46.92 m to 390.69 ± 43.17 m ($p < 0.001$). HRR improved by 11.14 bpm, from 24.41 ± 8.35 bpm to 35.55 ± 8.92 bpm ($p = 0.003$). VO2max increased by 0.79 mL/kg/min, from 14.91 ± 1.85 to 15.70 ± 1.84 mL/kg/min ($p < 0.001$). However, between-group differences were not statistically significant for 6MWT ($p = 0.397$), peak heart rate ($p = 0.739$), HRR ($p = 0.220$), and VO2max ($p = 0.397$), indicating similar improvements in both groups.

Conclusion: Six weeks of exergaming significantly improved functional capacity and cardiorespiratory fitness comparably in both obese and normal-weight adults, suggesting it was an inclusive and practical option for community-based physical activity programs.

Keywords: Adult, cardiorespiratory fitness, exergame, functional capacity, heart rate recovery, obesity.

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INTRODUCTION

Obesity, defined by the World Health Organization (WHO) as abnormal or excessive fat accumulation that poses a health risk, has reached pandemic proportions.[1] In 2016, over 1 billion people worldwide were obese, including 650 million adults, 340 million adolescents, and 39 million children, with projections estimating an additional 167 million cases by 2025. In Indonesia, the prevalence of obesity increased from 10.5% in 2007 to 21.8% in 2018. Obesity is a major risk factor for non-communicable diseases (NCDs) such as type 2 diabetes, cardiovascular diseases, cancer, and metabolic syndrome, and is linked to increased mortality from these conditions.[2]

Beyond its metabolic impact, obesity can impair physical function, particularly cardiorespiratory capacity. While some studies report normal cardiopulmonary responses in individuals with obesity, others show reduced aerobic capacity due to excess adiposity, which compromises pulmonary and cardiovascular function.[3,4] Lifestyle modifications involving diet and physical activity remain the cornerstone of obesity management, with exercise interventions being critical for improving cardiometabolic health. The American College of Sports Medicine (ACSM) recommends both aerobic and anaerobic exercise to counter obesity, often quantified using metabolic equivalents (METs).[5]

In recent years, exergaming—combining exercise with interactive video games—has emerged as an innovative approach to increasing physical activity. When integrated with immersive virtual reality (IVR) technology, exergames create interactive 3D environments that encourage real-time physical engagement. Such interventions can elicit significant physiological responses while reducing perceived exertion, making them appealing for populations with obesity.[6] Previous studies have shown that exergaming can enhance energy expenditure, functional capacity, and adherence compared to traditional exercise modalities, including in clinical populations such as patients with heart failure.[6,7,8]

Obese individuals typically present with reduced aerobic capacity, impaired gait mechanics, and increased joint loading, which can limit their tolerance for conventional weight-bearing aerobic exercise. Virtual reality (VR)-based exergaming provides a low-impact and engaging alternative that can be adapted to individual fitness levels while minimizing biomechanical strain. Its immersive and interactive features may enhance intrinsic motivation and exercise adherence by integrating gamified objectives, real-time feedback, and distraction from perceived exertion. However, most existing research on exergaming has centered on children and adolescents, with limited evidence in adults—particularly regarding comparisons between obese and normal-weight populations.[9] To date, no study has directly examined differences in cardiorespiratory responses between these two groups during VR-based exergaming interventions.

Accordingly, the present study aimed to evaluate and compare the effects of exergaming on cardiorespiratory function in obese and normal-weight adults. The findings were expected to guide tailored exercise prescriptions and support the incorporation of exergaming into obesity management strategies.

METHODS

A prospective cohort study was conducted to investigate the effect of exergame training using Nintendo Switch Fitness Boxing (Nintendo, Japan) on cardiorespiratory function among adults with normal and obese body mass index (BMI) classifications. The study was carried out in Makassar, Indonesia, over a six-week period from February 2025 to March 2025. Sample size was calculated using the formula for comparing two means with a 95% confidence level and 80% statistical power, assuming a standard deviation of 2.3 and a minimum clinically significant mean difference of 2, based on Negishi et al. (2014).[10] The minimum required sample was 30 participants, consisting of 15 individuals with normal BMI and 15 with obesity.

Inclusion criteria were adults aged 18–45 years, BMI 18.5–24.9 kg/m² (normal) or ≥25 kg/m² (obese), able to see a television screen from two meters with or without corrective lenses, and willing to complete the intervention period. Exclusion criteria were adults with a history of cardiovascular or neurological disorders, uncontrolled hypertension, diabetes mellitus, pregnancy, recent surgery or hospitalization due to stroke or heart disease within the past six months, cognitive impairment, participation in other structured exercise programs within the previous four weeks, peripheral neuropathy, or other uncontrolled medical conditions. Participants were also excluded if they withdrew voluntarily, were absent repeatedly, or experienced adverse events such as cybersickness.

Before the intervention, participants provided written informed consent and completed baseline assessments, including demographic data, vital signs, BMI, Montreal Cognitive Assessment–Indonesian version (MoCA-Ina), 6-minute walking test (6MWT), Borg's rating of perceived exertion (RPE), and exercise readiness and safety screening. The intervention comprised a structured six-week exergame program. Each session consisted of a 2-minute dynamic stretching warm-up, followed by 30 minutes of Nintendo Switch Fitness Boxing performed at progressive intensity, starting at 40–60% heart rate reserve (HRR) with a medium tempo during weeks 1–3 and increasing to over 60% HRR with a fast tempo during weeks 4–6, and ended with 5–10 minutes of static stretching for cool-down.

Heart rate recovery was recorded at the first- and second-minute of post-exercise. Vital signs and RPE were measured before and after each session. Post-intervention assessments repeated all baseline measures.

This study analyzed changes in 6-minute walk test distance (6MWT distance), heart rate recovery (HRR), and maximal oxygen uptake (VO2max). Differences within each group (baseline vs. post-treatment) were analyzed using the Paired T-test or Wilcoxon Signed-Rank Test. Differences in the score changes (Δ values) between the obese and normal-weight groups were compared using the Independent T-test or Mann-Whitney U Test. Statistical significance was set at a *p*-value <0.05.

RESULTS

Table 1 summarizes the demographic and physical characteristics of the respondents. A total of 29 participants (obese = 15, normal = 14) were included in the final analysis, with one dropout due to the respondent being unable to complete the intervention because of severe illness. Most participants in the obese group were male (60.0%), while in the normal group, the majority were female (57.1%). The obese group was dominated by those aged 26–30 years (53.3%), whereas the normal BMI group was mostly in the 31–35 age range (50.0%). Most respondents in both groups had a sedentary lifestyle. There were no statistically significant differences between the obese and normal BMI groups in terms of sex, age distribution, or physical activity level (PAL), with all *p-values* > 0.05.

Tabel 2 shows that after six weeks of exergaming intervention, both obese and normal-weight adults experienced statistically significant improvements in 6-minute walk distance, heart rate recovery, and VO2max (*p*-values= 0.003~0.000). These results indicate that exergaming was effective in enhancing cardiorespiratory fitness and physical performance across different nutritional status groups.

Table 3 shows that after six weeks of exergaming intervention, both obese and normal-weight adults showed improvements in all cardiorespiratory parameters measured (6MWT distance, peak heart rate, HRR, and VO2max). However, none of these improvements were statistically significant when compared between the two groups (*p*-values= 0.064~0.739)). These results indicate that while the intervention tended to improve fitness markers, it did so similarly across both groups without a significant difference.

DISCUSSION

This study showed no significant differences between the obese and normal BMI groups regarding sex distribution, age categories, and PAL. The similarity in baseline characteristics between groups is important, as it reduces the likelihood that differences in post-intervention outcomes were influenced by demographic or lifestyle factors rather than the intervention itself. The predominance of sedentary individuals in both groups suggests that improvements in physical performance following exergaming may be more pronounced due to the participants' initially low activity levels, which can increase responsiveness to exercise-based interventions. Furthermore, while sex and age distributions differed slightly, these variations were not statistically significant and are unlikely to have biased the results, particularly given that cardiorespiratory adaptations to moderate-intensity exercise have been observed across both sexes and various adult age ranges.

This study demonstrated that a six-week exergame intervention significantly improved physical performance in both obese and normal-weight adults, as evidenced by increased 6MWT distances. This study demonstrated that a six-week exergame intervention significantly improved physical performance in both obese and normal-weight adults, as evidenced by increased 6MWT distances.

Table 1. Respondent characteristics stratified by weight status

Characteristic	Obese (n=15)	Normal (n=14)	*P*-value
Sex			
Male	9 (60.0%)	6 (42.9%)	0.356
Female	6 (40.0%)	8 (57.1%)	
Age, years			
21–25	4 (26.7%)	4 (28.6%)	0.077
26–30	8 (53.3%)	2 (14.3%)	
31–35	3 (20.0%)	7 (50.0%)	
36–40	0 (0.0%)	1 (7.1%)	
Physical activity level			
Sedentary	14 (93.3%)	9 (64.3%)	0.141
Active	1 (6.7%)	5 (35.7%)	

n, frequency

Table 2. Pre- and post-intervention changes in cardiopulmonary fitness and functional capacity following six weeks of exergaming

Group	Variable	Pre-Intervention Mean ± SD	Post-Intervention Mean ± SD	*P*-value
Obese	6MWT	354.0 ± 43.6	382.7 ± 40.8	0.000[b]
Normal	6MWT	375.7 ± 32.0	399.3 ± 36.7	0.002[b]
Obese	HRR	21.1 ± 6.6	32.5 ± 11.2	0.001[a]
Normal	HRR	27.9 ± 12.0	38.8 ± 12.4	0.003[a]
Obese	VO2max	14.6 ± 1.31	15.5 ± 1.2	0.000[b]
Normal	VO2max	15.3 ± 1.0	16.0 ± 1.1	0.002[b]

6MWT, 6-minute walk test; HRR, heart rate recovery; SD, standard deviation, VO2max, maximal oxygen consumption.
[a]Paired T-test, [b]Wilcoxon signed rank test.

Table 3. Differences in cardiopulmonary fitness and functional capacity after six weeks of exergame intervention between obese and normal-weight adults

Variable	Intervention	Group	Mean	SD	Median	Min	Max	*P*-value
6MWT (meters)	Pretest	Obese	354.0	43.6	380	280	400	0.346[b]
		Normal	370.7	36.5	380	300	410	
	Posttest	Obese	382.7	40.8	400	320	430	0.397[b]
		Normal	395.3	38.5	410	300	430	
Peak heart rate, bpm	Exercise-1	Obese	155.1	11.3	150	141	175	0.064[a]
		Normal	147.2	8.4	146	135	166	
	Exercise-18	Obese	147.5	10.9	146	130	166	0.739[a]
		Normal	148.6	10.0	150	126	164	
HRR, bpm	Exercise-1	Obese	21.1	6.6	21	12	34	0.104[a]
		Normal	27.9	11.6	26	13	57	
	Exercise-18	Obese	32.5	11.2	31	19	57	0.220[a]
		Normal	37.9	12.5	37	21	59	
VO2max, ml/kg/min	Pretest	Obese	14.6	1.3	15.4	12.4	16.0	0.346[b]
		Normal	15.1	1.1	15.4	13.0	16.3	
	Posttest	Obese	15.5	1.2	15.6	13.6	16.9	0.397[b]
		Normal	15.8	1.2	16.3	13.0	16.9	

6MWT, 6-minute walk test; bpm, beat per minute; HRR, heart rate recovery; max, maximum; min, minimum; ml/kg/min, milliliter per kilogram per minute; SD, standard deviation; VO2max, maximal oxygen consumption.
[a]Paired T-test, [b]Wilcoxon signed rank test.

On average, 6MWT distance increased by 28.7 meters in the obese group (from 354.0 ± 43.6 m to 382.7 ± 40.8 m) and 23.6 meters in the normal-weight group (from 375.7 ± 32.0 m to 399.3 ± 36.7 m). These changes exceed the lower range of clinically meaningful improvements reported in prior literature (14–30 m) for functional capacity, suggesting that the gains observed here are not only statistically but also practically significant. The findings collectively emphasize the potential of exergames as effective tools for improving submaximal aerobic capacity and cardiovascular endurance.

The results align with prior research that exergame-based aerobic exercise improved 6MWT performance in older adults. Similarly, another study emphasized the role of physical training in enhancing 6MWT outcomes and overall symptoms in obese individuals with comorbidities.[11] In this study, although obese participants had lower baseline 6MWT distances than their normal-weight counterparts, both groups exhibited statistically significant improvements post-intervention, indicating comparable physiological adaptations to the exergame program.

Previous studies support these outcomes across diverse populations. For instance, exergaming VR training improved the motor competence and balance among college women and increased the lower limb strength and balance in older adults.[12,13] Furthermore, previous studies highlighted the broader psychosocial benefits of home-based exergaming, such as enhanced self-efficacy and quality of life.[14,15]

Interestingly, while a meta-analysis study reported non-significant effects on 6MWT improvements, clinically meaningful changes were still observed, underscoring the potential functional benefits of exergames.[16] Additionally, the exergaming VR could be the alternative or complement to traditional endurance training.[17] Overall, the findings indicate that exergames are both engaging and effective in enhancing cardiorespiratory fitness across different nutritional status groups, supporting their broader implementation in health promotion and rehabilitation settings.

This study revealed that a six-week exergame intervention significantly improved HRR in both obese and normal-weight adults, indicating enhanced cardiorespiratory fitness. It might have improved autonomic cardiovascular function, particularly increased parasympathetic reactivation, which is associated with reduced cardiovascular risk and mortality. These findings support earlier studies that emphasized the role of physical activity in improving HRR regardless of body composition.[8,18] Although obesity is generally associated with slower HRR due to autonomic imbalance, this study showed comparable HRR improvements in both groups, aligning with previous study results.[13,19]

The lack of significant change in peak HR implied that the exergame protocol, though effective for recovery, might require a longer duration or higher intensity to impact peak exertion parameters. These results demonstrated that exergame-based training coould effectively improve autonomic cardiovascular responses in adults across weight categories. As a non-invasive, enjoyable, and accessible intervention, exergames showed strong potential as an intervention to support heart function and reduce cardiovascular risk in diverse adult populations.

The findings revealed a statistically significant improvement in VO2max across all participants, regardless of their body weight classification. This indicates that exergaming could serve as an effective alternative form of physical activity to improve aerobic capacity. The results were consistent with previous studies that reported significant improvements in VO2max, heart rate, blood pressure, and LDL cholesterol following home-based exergaming VR.[20] Likewise, another study found that exergaming could elicit heart rate and oxygen consumption levels reaching up to 91.5% of peak values, demonstrating the cardiovascular challenge imposed by such digital exercises.[21] In this study, the average VO2max increased from 14.91 to 15.70 mL/kg/min after the intervention, reflecting a positive adaptation of the cardiorespiratory system. The magnitude of improvement was approximately 0.79 mL/kg/min similar in both groups. While these increments were statistically significant, they fall slightly below the commonly cited minimal clinically important difference (MCID) threshold of ~1.0 mL/kg/min for healthy adults. Nevertheless, even sub-MCID improvements in VO2max can be relevant for sedentary populations, especially when combined with gains in functional performance (6MWT) and HRR. These findings suggested that while exergaming enhances aerobic fitness, it might not induce significantly different responses based on body composition within the intervention period. Several factors could explain this lack of intergroup difference. Obese individuals often face unique physiological challenges, including reduced cardiovascular efficiency, higher mechanical loading, insulin resistance, and autonomic dysfunction. These barriers might blunt training responses despite absolute increases in workload. Moreover, the moderate intensity and fixed duration of the intervention might have been insufficient to produce distinguishable outcomes between groups.[22]

Nonetheless, the observed increase in VO2max in both groups was clinically meaningful. For obese individuals, the improvement indicated that despite their lower initial fitness level, physiological adaptations could still occur with consistent and structured interventions. For normal-weight individuals, the results confirmed that exergaming provides adequate cardiovascular stimulus. Given that VO2max is closely linked to reduced risk of non-communicable diseases, the increase observed in both groups suggested a broader public health benefit. Furthermore, existing literature supports the use of various forms of structured exercise—whether aerobic, resistance, or high-intensity interval training—to improve cardiorespiratory fitness in overweight and obese adults.[23,24] Interventions combining aerobic and resistance training, in particular, have been shown to reduce visceral fat, enhance insulin sensitivity, and improve overall physical function, especially in older obese adults.[25]

This study has several limitations that should be considered when interpreting the findings and designing future research. First, the relatively short duration of the intervention (six weeks) might not have been sufficient to reveal more distinct physiological adaptations between obese and normal-weight groups, particularly given the metabolic and mechanical challenges faced by individuals with obesity. Second, VO2max was estimated using a formula derived from the 6-minute walk test rather than measured directly via gas analysis, which could have affected the precision of the cardiorespiratory fitness assessment. Third, the study lacked a pure control group and had a limited sample size, which reduces the strength of causal inferences regarding the specific effects of the exergaming intervention. Lastly, participant characteristics such as baseline physical activity levels, dietary habits, and sleep quality were not strictly controlled, potentially introducing confounding effects on physiological outcomes like heart rate recovery and walking performance.

CONCLUSION

This study confirmed that a six-week exergame intervention significantly improved multiple indicators of cardiorespiratory fitness, including VO2max, 6MWT performance, and HRR, in both obese and normal-weight adults. Both groups showed comparable physiological improvements, suggesting that exergaming is an inclusive and effective form of physical activity regardless of body composition. These findings were clinically meaningful and support the role of exergames as a valuable tool for promoting cardiovascular health, reducing disease risk, and increasing physical activity levels in diverse adult populations. Future studies with longer intervention durations and varied intensity levels are recommended to further explore the long-term benefits and potential dose-response effects of exergaming-based training.

CONFLICT OF INTERESTS

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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ETHICAL CONSIDERATION

Ethical approval for the study was obtained from the Health Research Ethics Committee, Faculty of Medicine, Universitas Hasanuddin, Makassar, Indonesia, with registration number 115/UN-4.6.4.5.31/PP36/2025. Written informed consent was obtained from all participants prior to enrollment, and confidentiality of participant information was maintained throughout the study. The complete study protocol can be made available by the corresponding author upon reasonable request.

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AUTHOR CONTRIBUTIONS

AMKD contributed to the conception, design, clinical studies, data acquisition, data analysis, statistical analysis, and manuscript preparation. HM was responsible for the definition of intellectual content, literature search, and acted as a guarantor of the study. SEA contributed to the definition of intellectual content, literature search, manuscript review, and also served as a guarantor. NS participated in the definition of intellectual content, manuscript review, and guarantor roles. MW contributed to the literature search, manuscript review, and guarantor duties. AAZ was involved in manuscript review and also served as a guarantor. All authors were involved in critical revision of the manuscript and approved the final version.

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