









Research Article

Online ISSN (3219-2789)

Game-Based versus Circuit Training: Impacts on Aerobic Capacity (VO₂max) and Cardiovascular Health Outcomes

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Received: 1 February 2026; Revised: 1 April 2026; Accepted: 8 April 2026

Abstract

Background: Several training models to increase VO₂max capacity have been discussed in previous studies. However, there is a scarcity of research on student engagement to improve outcomes. **Objectives:** To assess the extent to which training and circuit training methods improve students' VO₂max capacity. **Methods:** This study involved 34 students in a comparison/control group and used a two-group pretest-post-test design in a quasi-experimental study. The control group received circuit training, while the experimental group received the play training method. The process was three stages: pretest, therapy, and post-test. Initial data were collected for the pretest, and then there was a 16-session treatment phase, followed by a post-test phase. A multistage fitness test (bleep test) generated VO₂max capacity data. **Results:** The average pre-test score was 36.0±5.2, the average post-test score was 40.3±4.3, and the percentage increase was 11.9% in the Enough category. The experimental group had a significant impact on increasing VO₂max capacity ($p < 0.05$). The control group also significantly increased VO₂max capacity ($p < 0.05$). With an average pre-test score of 35.9±5.3 and an average post-test score of 40.8±5.2 and a percentage increase of 13.6% in the "enough" category. Therefore, the circuit training method provides a greater increase in VO₂max capacity. **Conclusions:** The play-training method and the circuit-training method have been proven to have a positive effect on increasing VO₂max capacity. This research is important for instructors, coaches, and PJOK teachers to be able to apply this training method in increasing VO₂max capacity.

Keywords: Circuit preparing strategy; Play preparing strategy; Students; VO₂max.

التدريب القائم على الألعاب مقابل التدريب الدائري: تأثيرات على القدرة الهوائية (VO₂max) ونتائج صحة القلب والأوعية الدموية

الخلاصة

الخلفية: تم مناقشة عدة نماذج تدريبية لزيادة سعة VO₂max في دراسات سابقة. ومع ذلك، هناك ندرة في الأبحاث حول تفاعل الطلاب لتحسين النتائج. **الأهداف:** تقييم مدى تحسين طرق التدريب وتدريب الدوائر لقدرة الطلاب على VO₂max. **الطرائق:** شملت هذه الدراسة 34 طالباً في مجموعة مقارنة/ضابطة، واستخدمت تصميم ما قبل الاختبار وبعد الاختبار مكون من مجموعتين في دراسة شبه تجريبية. تلقت مجموعة الضابطة تدريباً على الدائرة، بينما تلقت المجموعة التجريبية طريقة تدريب اللعب. كانت العملية تتكون من ثلاث مراحل: الاختبار التمهيدي، والعلاج، وبعد الاختبار. تم جمع البيانات الأولية للاختبار التمهيدي، ثم كانت هناك مرحلة علاج من 16 جلسة، تلتها مرحلة ما بعد الاختبار. اختبر اللياقة متعدد المراحل (اختبار سفارة) يولد بيانات سعة VO₂max. **النتائج:** كان متوسط الدرجة قبل الاختبار 36.0±5.2، ومتوسط الدرجة بعد الاختبار 40.3±4.3، وزيادة النسبة 11.9% في فئة "كاف". كان للمجموعة التجريبية تأثير كبير في زيادة سعة VO₂max ($p < 0.05$). كما زادت مجموعة الضابطة بشكل كبير من سعة VO₂max ($p < 0.05$). بمتوسط درجة قبل الاختبار 35.9±5.3 ومتوسط درجة ما بعد الاختبار 40.8±5.2 وزيادة بنسبة 13.6% في فئة "الكافية". لذلك، توفر طريقة تدريب الدوائر زيادة أكبر في سعة VO₂max. **الاستنتاجات:** لقد ثبت أن طريقة تدريب اللعب وطريقة التدريب على الدائرة لهما تأثير إيجابي في زيادة سعة VO₂max. هذا البحث مهم للمدربين والمدرسين ومعلمي PJOK ليتمكنوا من تطبيق هذه الطريقة التدريبية في زيادة سعة VO₂max.

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Article citation: Resmana R, Saputra M, Febrian M, Speriadi S, Arnando M, Effendi R. Game-Based versus Circuit Training: Impacts on Aerobic Capacity (VO₂max) and Cardiovascular Health Outcomes. *Al-Rafidain J Med Sci.* 2026;10(2):79-84. doi: <https://doi.org/10.54133/ajms.v10i2.2819>

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INTRODUCTION

To balance other activities and ensure that kids are physically fit, physical activity is crucial [1]. For junior high school students, physical fitness is crucial [2], as students who are physically fit will be able to perform their learning and playing activities effectively without experiencing severe fatigue [3], and their bodies will feel rejuvenated when they stop and rest [4]. Conversely, a lack of physical fitness will make it difficult to perform everyday tasks [5], as physical conditions will not be able to meet all the

demands of these tasks, leading to increased fatigue and decreased overall performance in both academic and recreational activities. The greatest amount of oxygen that may be absorbed during vigorous exercise before fatigue sets in is known as VO₂max [7]. The greatest measure of aerobic endurance is thought to be the maximum oxygen volume since VO₂max can restrict a person's cardiovascular capability [8,9]. The benefit of VO₂max is the maximum level of oxygen that the body can use during exercise [10]. VO₂max is a combination of the heart's ability to pump oxygen-rich blood and the

efficiency of the muscles in drawing in and using oxygen [11]. Oxygen is inhaled from the atmosphere into the body's cells by the heart-lung system. During exercise, this system functions to support aerobic metabolism [12]. VO₂ max is crucial for junior high school students [12], because pupils with high VO₂max levels can do their learning and play tasks effectively and without feeling overly exhausted [9]. To achieve optimal physical fitness and VO₂max, a person needs to do physical exercise that involves all components of physical fitness with the correct exercise method [13]. One easy and time-efficient physical training method is the circuit training method and play-based training. The Play Practice Method is a process of delivering teaching material or practice in the form of games without ignoring the core material [15]. This play practice method essentially creates a play practice program in the game by implementing play modifications [16]. Meanwhile, circuit training is a training system that can simultaneously improve the overall fitness of the body [17], namely the elements of power, endurance, strength, agility, speed, and other physical components [18]. Circuit training is one way that can simultaneously improve the overall fitness level of our body, which includes basic biomotor components [19]. The method of implementing playing and circuit training can enhance students' motivation to complete movement tasks while also addressing challenges related to inadequate facilities and infrastructure through sports modifications in the form of small games that target all components of physical fitness. As a result, the researcher is motivated to carry out this study to examine the extent to which the playing training technique and the circuit training method affect the VO₂max of MTsN 1 Solok Selatan pupils. To increase students' VO₂max capacity, this finding is crucial for educators, coaches, practitioners, PJOK teachers, athletes, and students.

METHODS

Study design

This quasi-experiment, which used a two-group pre-test-post-test design with a T-test and a control group for comparison, involved only the experimental group receiving the treatment [20]. Two groups were randomly selected for this study, and the experimental group received play training. In contrast, circuit training techniques were applied to the control group. "Random" in the context of this study refers to the process of selecting a sample (random sampling) from the available population, not to the random assignment of subjects to groups (random assignment). Participants were matched based on their initial VO₂max values.

Study participants

By employing the proportionate random sampling technique, thirty-four students took part in the study.

Through a written agreement, these pupils, who attend MTsN 1 Solok Selatan, have acknowledged that they can follow the study's guidelines and that they are willing to participate.

Research procedure

The procedures in this study can be seen and explained in Figure 1.

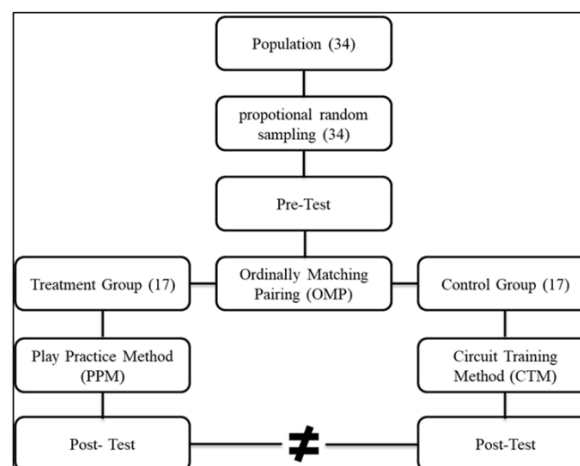


Figure 1: Study design. Population: Research population; Proportional Random: Sampling Techniques; Pre-test: Initial test; OMP: Group division technique; PPM: Playing practice method; CTM: Circuit training method; Post-test: Final test; ≠: Difference in post-test mean of treatment and control groups.

Pre-test, therapy, and post-test are the three phases of the methodologies used in this study. Before the athletes are given the playing training program "experiment" and the circuit training program "control", a pre-test is conducted to collect preliminary data. After the 16-session treatment phase, participants enter the post-test phase where they receive interventions tailored for this study, and the final round of data collection takes place. The intervention protocol in this study consisted of two training approaches: game-based training and circuit training, designed with the principle of training load equivalency to maintain internal validity. Game-based training was implemented in the form of modified games, such as small-sided games (3 vs. 3 or 4 vs. 4), reaction games, and sport-specific task-based competitive activities. Each session lasted approximately 60 min and included a warm-up (10 min), core training (40 min), and cool-down (10 min). In the core phase, participants performed 4–6 sets of games, each lasting 4–5 min and with a work-to-rest ratio of 1:1. Training intensity was controlled by manipulating the field size, number of players, and game rules, with a target heart rate zone of 70–85% of HR_{max} and a Rating of Perceived Exertion (RPE) value ranging from 13 to 16. Meanwhile, circuit training was implemented through 6–8 exercise stations that included various components of physical conditioning, such as squat jumps, push-ups, planks, lunges, shuttle runs, and core exercises. Each station was done for 30 to 45 seconds, with a 15 to 30 second break between stations. The whole circuit was done 3

to 4 times, with a work-to-rest ratio of about 2:1. The training intensity in this group was also controlled to stay within the 70–85% HR_{max} (maximum heart rate) zone, with an RPE (Rating of Perceived Exertion) of 13–16, which is equivalent to the game-based training group. To ensure equivalence of the intervention, both groups underwent the same training frequency, namely three times per week for approximately 60 min per session throughout the intervention period (6–8 weeks). The total training volume was adjusted based on active work time to avoid significant differences in training loads between groups. Furthermore, training intensity was monitored objectively using a heart rate monitor and subjectively using the Borg scale (6–20). Intensity data was recorded at each training session to ensure

Table 1: Male VO₂max norms

Age	Less than once	Not enough	Enough	Good	Very good	Superior
13-19	< 35.0	35.0 – 38.3	38.4 – 45.1	45.2 – 50.9	51.0 – 55.9	> 55.9
20-29	< 33.0	33.0 – 36.4	36.5 – 42.4	42.5 – 46.4	46.5 – 52.4	> 52.4
30-39	< 31.5	31.5 – 35.4	35.5 – 40.9	41.0 – 44.9	45.0 – 49.4	> 49.4
40-49	< 30.2	30.2 – 33.5	33.6 – 38.9	39.0 – 43.7	43.8 – 48.0	> 48.0
50-59	< 26.1	26.1 – 30.9	31.0 – 35.7	35.8 – 40.9	41.0 – 45.3	> 45.3
60+	< 20.5	20.5 – 26.0	26.1 – 32.2	32.3 – 36.4	36.5 – 44.2	> 44.2

Note: units in ml/kg/min.

To maintain measurement consistency, all pre- and post-intervention tests were administered by the same examiner following standardized procedures. Testing was conducted at relatively the same time of day (in the morning) and under controlled environmental conditions, including a uniform temperature and location, to minimize the influence of external factors on participant performance. Before the test, all participants participated in a familiarization session to understand the procedure and rhythm of the bleep test, thus reducing potential bias due to learning effects. VO₂max values in this study were not measured directly using respiratory gas analysis but were estimated based on the level and number of shuttles achieved during the bleep test. Estimated VO₂max was calculated using a prediction equation developed by Ramsbottom *et al.*, which has been widely used in sports fitness research.

Ethical considerations

All participants provided written informed consent prior to participation, and the research was conducted in accordance with the principles of the Declaration of Helsinki.

Statistical analysis

Each variable in this study was described using descriptive statistics, and Levene's test was used to examine homogeneity for the normalcy test, which was analyzed using the Shapiro-Wilk test. The researcher's hypothesis is then tested using the paired sample test. The paired samples test, which is based on the difference between the average before and after treatment, is one method for evaluating the effectiveness of a treatment [21]. The statistical software IBM SPSS version 24 was used to examine all of the study's data.

consistency and compliance with established targets. With this structured and standardized protocol, the study is expected to have a high level of reproducibility and allow for replication in similar research contexts.

Instrument

A multistage fitness test (bleep test) is the research tool used to determine students' VO₂max. By monitoring the maximum oxygen uptake, this test aims to determine the degree of efficiency of heart and lung function. Test takers' VO₂max quantity is determined by the level and return (shuttle) they can achieve using the norms in Table 1.

RESULTS

The average VO₂max values for the treatment group using the play training technique were 36.0 ± 5.2 on the pre-test and 40.3 ± 4.3 on the post-test, according to this study. Circuit training results for the control group were 35.9 ± 5.3 for the pre-test and 40.8 ± 5.2 for the post-test. This indicates that the group receiving therapy from both the play training approach and the circuit training method has significantly increased (Table 2).

Table 2: VO₂max findings for every group (n= 17 in both groups)

Group	Data	Range	mean±SD
PPM (Experiment)	Pre-Test	27.2-45.5	36.0±5.2
	Post-Test	32.9-49.6	40.3±4.3
CTM (Control)	Pre-Test	24.4-44.9	35.9±5.3
	Post-Test	31.0-39.0	40.8±5.2

Note: VO₂max is the dependent variable, and its units are "ml/kg/min."

Furthermore, Table 3, Figure 2, and Figure 3 showed that the data from the experimental and control groups are homogeneous ($p>0.05$) and pass the normality and homogeneity tests.

Table 3: Test Conditions for analysis of normality and homogeneity

Group	Normality test (Shapiro-Wilk)	Homogeneity test (Levene's)		
	<i>p</i> -value	df 1	df 2	<i>p</i> -value
PPM Pre-test (Experiment)	0.821			
Post-test PPM (Experiment)	0.851	3	38	0.792
CTM Pre-Test (Control)	0.953			
Post-test CTM (Control)	0.451			

Note: The data is homogeneous and regularly distributed ($p>0.05$).

Following fulfillment of the analytic conditions, the results of the paired samples test (t-test) are shown in Table 4. The results indicate a substantial improvement in VO₂max following treatment with the

playing training technique and the circuit training method ($p<0.05$).

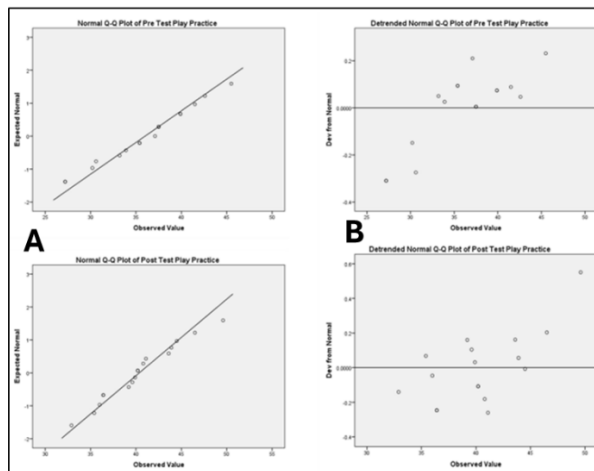


Figure 2: PPM group (Experiment). A) Graph of normality plots; B) Non-normality plot graph.

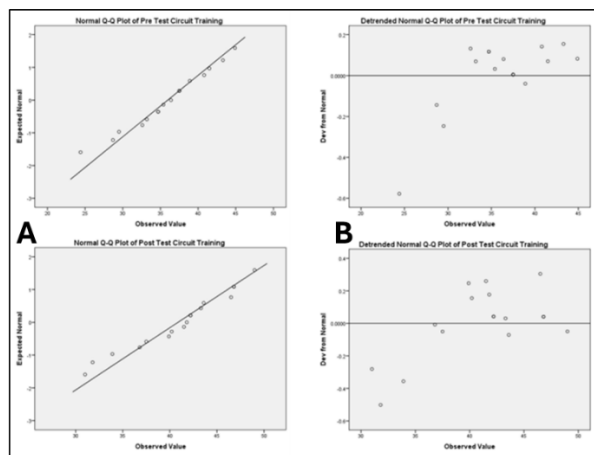


Figure 3: CTM group (control). A) Graph of normality plots; B) Non-normality plot graph.

In Figure 4, according to the VO₂max difference test between the experimental and control groups, the group that received play training and circuit training was able to significantly raise their VO₂max ($p<0.05$). To compare the pre-test and post-test results for each group, the paired t-test is used to derive the p -value.

Table 4: Paired samples t-test results

Group	Data	mean±SD	p -value
PPM (Experiment)	Pre-test vs. Post-test	-4.35±2.53	<0.0001
CTM (Control)	Pre-test vs. Post-test	-4.90±2.23	<0.0001

Note: The dependent variable is VO₂max.

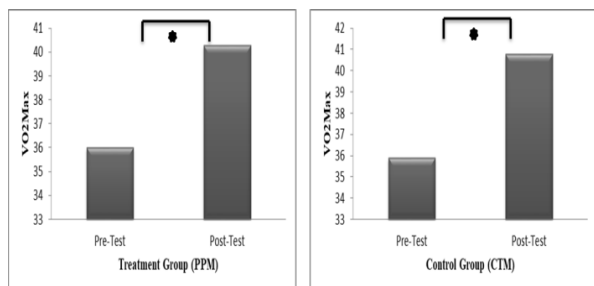


Figure 4: The differences in VO₂ max pre- and post-test both groups. The data is displayed with the mean and standard error; * $p<0.05$.

DISCUSSION

This result indicates that offering play training and circuit training techniques to raise students' VO₂ max capacity significantly increases the number of pupils. This study obtained the average VO₂ max results for the play training method treatment group, namely 36.0 ± 5.2 (pre-test) and 40.3 ± 4.3 (post-test), a percentage increase of 11.9% with ($p<0.05$). Meanwhile, for the control group, the circuit training method was a 35.9 ± 5.3 (pre-test) and 40.8 ± 5.2 (post-test) percentage increase of 13.6% with ($p<0.05$). These findings are in line with other studies that showed that a carefully planned play training approach can maximize pupils' VO₂max capacity [22,23] and a planned circuit training method can also provide optimal results in increasing the VO₂max capacity of students [24]. The VO₂max capacity of students is one of the determining factors for athletes in achieving success [25]. Similarly, a good VO₂max capacity can help students progress in their learning at school, leading to optimal achievements. In addition, physical fitness is the general condition and ability of a person's body to carry out daily physical activities efficiently and without feeling too exhausted [27]. VO₂max capacity encompasses various aspects, including cardiorespiratory fitness [28]. The application of the play training method to increase VO₂max capacity in students is very appropriate; students do not become bored easily in carrying out the training method [29]. Not only that, but the method of playing to increase VO₂max capacity is an approach that combines game elements into physical activities to improve physical fitness in a fun way [30]. Physical education, fitness programs, and athletic training frequently employ this method due to its ability to enhance motivation, engagement, and sustained participation. The main elements of the play method are healthy competition, activity variation, social involvement, gradual levels of difficulty, and the embedding of fitness goals. Overall, the play method is an effective way to increase VO₂max capacity by emphasizing fun, variety, and social interaction, making physical activity more intriguing and sustainable [31]. Additionally, using the Circuit Training Method during the learning process might help students adhere closely to it [32] because children become more engaged in learning when their hemoglobin levels increase, which aids in supplying oxygen to the brain. The circuit method incorporates three elements simultaneously: intensity, repetition, and duration. The rise in VO₂max has a significant impact on cardiovascular endurance and can strengthen the respiratory muscles, which is beneficial for maintaining heart and lung fitness. When viewed based on VO₂max norms, the increases in both groups still indicate improvements in the cardiorespiratory fitness category, indicating that both training methods are effective in increasing aerobic capacity. It is important to emphasize that VO₂max is an indicator of cardiorespiratory fitness and does not directly reflect other components of a physical condition, such as muscle strength, flexibility, or body composition.

Both groups can explain the increase in VO₂max physiologically through adaptations to their cardiovascular and metabolic systems. In game-based training, intermittent activity at moderate to high intensity promotes repeated increases in heart rate, which contributes to increased cardiac output, stroke volume, and oxygen utilization efficiency at the muscle level through increased capillarization and oxidative enzyme activity. The novelty of this study lies in the direct comparative approach between game-based training and circuit training, with strict control of training volume and intensity, and its application to a specific population. Thus, this study provides an empirical contribution in determining the relative effectiveness of both training methods in increasing VO₂max. Thus, students actively improve their abilities through the physical activities they engage in, aiming to increase their VO₂max capacity, which is the primary target of the training provided. The Play Training Method and Circuit Method approaches are two of the methods applied to develop physical fitness; in other words, both methods used in this study, namely the Play Method and the circuit method can be applied to improve overall physical fitness for students. As much as feasible, this study was carried out to prevent mistakes in the way pupils were treated, ensuring that the training methods were applied consistently and effectively to maximize the benefits for their physical fitness development. Despite these encouraging results, this study still faces challenges.

Conclusions

The play-training method has a significant effect on increasing VO₂max capacity if it is carried out according to the program given. The circuit training method has a significant effect on increasing VO₂max capacity if it is conducted according to the training program given. The circuit training method has a more effective effect than the play training method if it is carried out according to the training program given to students, particularly in improving cardiovascular endurance and overall fitness levels.

ACKNOWLEDGMENTS

The authors thank Universitas Negeri Padang for its institutional support and all participants for their voluntary involvement and commitment during the study.

Conflict of interests

The authors declared no conflict of interest.

Funding source

The authors did not receive any source of funds.

Data sharing statement

Supplementary data can be shared with the corresponding author upon reasonable request.

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