Effects of outdoor physical training on VO_2 max, endurance, and power in male Sports Science students

Efectos del entrenamiento físico al aire libre sobre el VO_2 max, la resistencia y la potencia en estudiantes masculinos de Ciencias del Deporte

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Abstract

Background: Physical fitness is a key component of overall health, particularly for students in physical education programs. Outdoor-based physical training has been explored to enhance specific fitness components, including VO2 max, muscle endurance, and leg explosive power. However, evidence of its effectiveness still needs to be improved, particularly in areas such as leg power.
Purpose**:** This study aimed to evaluate the effects of an 8-week outdoor-based physical training program on VO2 max, arm muscle endurance, abdominal endurance, and leg muscle power in first-year male students.
Materials and Methods**:** A pre-experimental, one-group pretest-posttest design was employed. Thirty-three first-year students from the Physical Education, Health, and Recreation program at Bung Hatta University were selected using purposive sampling. Physical fitness was assessed before and after the intervention. The following tests were used: VO2 max via the bleep test, arm endurance with the 1-minute push-up test, abdominal endurance with the 1-minute sit-up test, and leg power with the standing broad jump test. Data were analyzed using paired t-tests with Microsoft Excel and SPSS version 25.
Results: Significant improvements were observed in VO2 max (t = -9.077, p < 0.001), arm endurance (t = -8.433, p < .001), and abdominal endurance (t = -6.571, p < 0.001). However, no significant change was found in leg muscle power (t = 0.924, p = 0.362).
Conclusion: Outdoor-based physical training effectively improves VO2 max and muscle resistance. This does not account for faster or stronger leg explosive power, which may better be obtained from using a longer duration or greater intensity. They differentiate the program from conventional indoor training methods as the facility is adaptive and engages in outdoor settings. Furthermore, changes to the existing training program are recommended to improve physical fitness.

Keywords

Leg explosive power, muscle endurance, outdoor physical training, physical fitness, university students, VO2 max

Resumen

Antecedentes: La aptitud física es un componente clave de la salud en general, particularmente para los estudiantes de programas de educación física. El entrenamiento físico al aire libre ha sido explorado como un medio para mejorar componentes específicos de la aptitud física, como el VO2max, la resistencia muscular y la potencia explosiva de las piernas. Sin embargo, la evidencia sobre su efectividad sigue siendo limitada, especialmente en áreas como la potencia de las piernas.
Objetivo: Este estudio tuvo como objetivo evaluar los efectos de un programa de entrenamiento físico al aire libre de 8 semanas sobre el VO2max, la resistencia muscular de los brazos, la resistencia abdominal y la potencia muscular de las piernas en estudiantes de primer año.
Materiales y métodos: Se empleó un diseño preexperimental de grupo único con medidas pre y post intervención. Treinta y tres estudiantes de primer año del programa de Educación Física, Salud y Recreación de la Universidad Bung Hatta fueron seleccionados mediante un muestreo intencional. La aptitud física se evaluó antes y después de la intervención mediante las siguientes pruebas: VO2max mediante la prueba de bleep, resistencia de los brazos con la prueba de flexiones de 1 minuto, resistencia abdominal con la prueba de abdominales de 1 minuto y potencia de piernas con la prueba de salto largo en el lugar. Los datos fueron analizados mediante pruebas t de muestras relacionadas, utilizando Microsoft Excel y SPSS versión 25.
Resultados: Se observaron mejoras significativas en el VO2max (t = -9.077, p < .001), la resistencia de los brazos (t = -8.433, p < 0.001) y la resistencia abdominal (t = -6.571, p < .001). Sin embargo, no se encontró un cambio significativo en la potencia muscular de las piernas (t = 0.924, p = 0.362). Conclusión: El entrenamiento físico al aire libre mejora eficazmente el VO2max y la resistencia muscular. Sin embargo, puede requerir una duración más larga o una mayor intensidad para mejorar la potencia explosiva de las piernas. Se recomienda realizar ajustes adicionales al programa de entrenamiento para optimizar las mejoras en la aptitud física en general.

Palabras clave

Potencia explosiva de las piernas, resistencia muscular, entrenamiento físico al aire libre, condición física, estudiantes universitarios, VO2 máx.

Introduction

Physical fitness plays a vital role in everyday life, encompassing four key components: endurance, strength, speed, and flexibility (Gäbler et al., 2018; Tomkinson et al., 2018). Over the past decade, numerous studies have highlighted the importance of maintaining physical fitness, not only for overall health but also for mental well-being and quality of life (Angulo et al., 2020; Haverkamp et al., 2021; Herbert et al., 2020; Mahindru et al., 2023; Raghuveer et al., 2020; Yuksel et al., 2020). Maintaining physical fitness is essential across all age groups, offering diverse benefits supporting physical and mental health. In younger populations, it promotes athletic performance and general vitality, yet it is a key way of utilizing muscle to reduce age-related challenges in older people. For instance, in older adults, regular physical activity helps counteract muscle mass decline, reduces the risk of falls, and supports the ability to perform daily activities, which are critical for maintaining independence and quality of life (Chaabene et al., 2021; Esmail et al., 2020; Fiorilli et al., 2022; Islas-Cruz, 2021; Langhammer et al., 2018; Nikitas et al., 2022). Thus, promoting physical fitness across the lifespan is key to improving movement efficiency, reducing disability, and enhancing overall well-being.

Engaging in regular physical activity reduces mortality risk by up to 13%, enhances movement efficiency, and decreases disability, as demonstrated in prior studies (Becheva et al., 2023; Campos et al., 2019; Janssen & Leblanc, 2010; Malm et al., 2019; Posadzki et al., 2020; Sun et al., 2013; Suud et al., 2022). Despite these well-documented benefits, the physical fitness level of Indonesian adolescents remains concerning. According to the Indonesian Ministry of Youth and Sports (2021), only 0.14% of students in Indonesia achieve an excellent level of physical fitness, with just 2.1% classified as very active (En.antaranews.com, 2021). This indicates that more than half of Indonesian adolescents have poor physical fitness. This issue exists among first-year Physical Education, Health, and Recreation (PJKR) program students. Previous data suggest new students have relatively low physical fitness, especially in aerobic endurance, strength, speed, and lower body explosive power. Given that the PJKR program demands significant physical activity, a high level of physical fitness is essential for students to perform optimally in both academic and practical courses.

Participation in exercise is hindered by factors such as limited facilities, busy schedules, and low self-confidence (Ilham et al., 2024; Piggott et al., 2023; Salim, 2022). Outdoor programs can increase motivation and address these barriers effectively. Additionally, boredom from indoor exercise, resistance to exercising at home, work-related constraints, and health issues further discourage physical activity (Ahn et al., 2021; Hawley-Hague et al., 2022; Yoshida et al., 2021). Participation motivated by health advice or to achieve physical and mental health benefits may be another case (Borges-Machado et al., 2023). However, when motivation is insufficient, barriers to exercise become dominant, preventing individuals from being active. Understanding this complex interplay between barriers and motivation is critical for developing effective strategies to promote physical activity (Scalco et al., 2021). Research indicates that “green exercise”, or physical activity performed outdoors, enhances motivation and promotes better health outcomes. Moreover, outdoor exercise is often associated with higher intensity and greater effectiveness (Miller et al., 2020). Physical training programs, such as HIIT, continuous running, circuit training, and cross-country running, have been shown to enhance physical fitness significantly (Rifki et al., 2023; Wen et al., 2019; García-Pinillos et al., 2017; Giannaki et al., 2016; Suud et al., 2022; Wu et al., 2017). HIIT is highly effective in improving VO2 max (Wen et al., 2019). Despite extensive research on these methods, their implementation in outdoor environments remains insufficiently explored (Gray et al., 2015; Marcos-Pardo et al., 2024; Noseworthy et al., 2023; Pasanen et al., 2018; Pasek et al., 2020). Outdoor exercise, however, provides unique advantages, including enhanced mental health, reduced stress, and improved learning outcomes (Eigenschenk et al., 2019; Faude et al., 2015; Thompson Coon et al., 2011). Additionally, time spent in natural environments is associated with lower stress levels and better physical health (Kondo et al., 2018).

The study explores innovative training strategies such as Fartlek, plyometrics, and circuit training in natural environments to address the limitations of conventional training methods. These outdoor approaches aim to provide physical and motivational benefits, enhancing engagement and making fitness programs more effective. Recognizing the importance of physical fitness for academic success, particularly in courses with significant theoretical and practical physical demands, this research's aim

is to evaluate the effectiveness of outdoor training in improving students' overall physical fitness.

Materials and Methods

Participants

The study sample comprised 33 male students (n = 33) aged 18 to 21 years, all enrolled in the Physical Education, Health, and Recreation (PJKR) program at Bung Hatta University. These participants were first-year students from the 2023 cohort actively registered in the Physical Conditioning course. Participants were selected through purposive sampling based on specific inclusion criteria: non-athlete status, absence of a history of degenerative diseases or significant sports injuries, and good physical health suitable for the training program. Before the study began, participants were provided detailed information about the objectives, procedures, and potential risks. Each participant gave written informed consent prior to enrollment.

Procedure

The study employed a pre-experimental, one-group pretest-posttest design to assess changes in physical fitness metrics following an eight-week outdoor training regimen. This design is widely used for initial interventions where control groups are impractical (Montgomery, 2013). Baseline fitness levels were measured through pre-intervention tests (pretest) to establish initial values for VO2 max, arm muscle endurance, abdominal muscle endurance, and leg explosive power. The training program was structured over eight weeks, with 16 sessions (two per week), as follows: weeks 1-2: Focused on improving VO2 max with continuous running and fartlek training on an outdoor tennis court; weeks 3-4: Emphasized arm and abdominal muscle endurance through exercises like push-ups, sit-ups, planks, triceps dips, bicycle crunches, and circuit training at the beachside; weeks 5-6: Targeted leg muscle explosive power with plyometric exercises, including squat jumps, box jumps, single-leg hops, and broad jumps conducted at the beachside and on campus; week 7: Involved in a 15 km city run to enhance aerobic endurance, performed in the city centre; week 8: Combined all training forms in integrated sessions conducted at the beachside. Post-intervention tests (post-tests) were administered after the training program was completed to assess changes in the measured fitness components.

Instrument

Validated instruments were employed to assess the fitness metrics reliably:

- VO2 max: Evaluated using the beep test, a widely acknowledged method for measuring aerobic capacity through progressive shuttle running (Léger & Gadoury, 1989).
- Arm muscle endurance: Measured using the push-up test.
- Abdominal muscle endurance: Assessed with the sit-up test.
- Leg explosive power: Evaluated using the standing broad jump test.
- Running speed: Measured via the 60-meter sprint test (Highton et al., 2012; Huerta et al., 2020).

  These methods were chosen for their reliability and frequent use in diverse physical fitness assessments.

Data analysis

Data analysis incorporated both descriptive and inferential statistical methods. Descriptive statistics included calculating mean (M ± SD), minimum and maximum values, and percentages. Pretest-posttest differences were analyzed using paired t-tests, preceded by normality and homogeneity tests, to ensure valid statistical analysis assumptions. All statistical computations were conducted using SPSS version 27.

Results

Table 1 shows the descriptive statistics for the pretest and post-test values of VO2 max, arm muscle endurance, abdominal muscle endurance, and leg muscle explosive power, reporting minimum (Min), maximum (Max), mean (M), and standard deviation (SD) for each variable. For VO2 max, the pretest

mean was 35.17 (SD = 5.23), increasing to 40.12 (SD = 5.54) in the post-test. In the post-test, arm muscle endurance improved from a pretest mean of 31.06 (SD = 11.56) to 44.42 (SD = 12.51). Abdominal muscle endurance also showed gains, with the pretest mean rising from 36.54 (SD = 7.64) to 43.87 (SD = 7.40) in the post-test. Similarly, leg muscle explosive power increased, with the pretest mean of 2.13 (SD = 0.27) improving to 2.93 (SD = 0.26) in the post-test. These results suggest significant improvements across all measured variables following the intervention. Before conducting the paired test, all pretest and post-test data were tested for normality and were found to be normally distributed.

Table 1. Descriptive Statistics of Pretest and Post-test Values for VO2max, Arm Muscle Endurance, Abdominal Muscle Endurance, and Leg Muscle Explosive Power: Increases and Decreases

Variable	N	Phase of testing	Min	Max	M ± SD
VO2max	33	Pretest	26.8	46.8	35.17±5.23
	33	Posttest	28.3	51.4	40.12±5.54
Arm Muscle Endurance	33	Pretest	9	61	31.06±11.56
	33	Posttest	26	90	44.42±12,51
Abdominal Muscle Endurance	33	Pretest	20	53	36.54±7.64
	33	Post-test	28	58	43.87±7.40
Power leg	33	Pretest	1.08	1.8	2.13±0.27
	33	Posttest	3.03	2.65	2.93±0.26

Table 2. Kolmogorov-Smirnov test for normality

	Item Test		Kolmogorov-Smirnov		
		Statistic	df	Sig.	Interpretation
Pretest	VO2 Max	0.098	33	0.200	Normal
	Push Up	0.095	33	0.200	Normal
	Sit Up	0.104	33	0.200	Normal
	Standing Broad Jump	0.157	33	0.038	Normal
Post-test	VO2 Max	0.160	33	0.031	Normal
	Push Up	0.123	33	0.200	Normal
	Sit Up	0.129	33	0.177	Normal
	Standing Broad Jump	0.141	33	0.093	Normal

A paired sample t-test was conducted to assess the significance of the changes between pretest and post-test values for the measured variables. The results of this analysis are presented in Table 2.

Table 3. Paired Sample t-Test Results for Physical Fitness Variables

Phase and Test	Mean	Std. Deviation	Std. Error Mean	t	Sig. (2-tailed)	Cohen's d
Pretest VO2Max Post-test VO2max	-5.10	3.22	0.56	-9.07	<.001	-1.58
Pretest Arm Muscle Endurance Post-test Arm Muscle Endurance	-13.36	9.10	1.58	-8.43	<.001	-1.47
Pretest Abdominal Muscle Endurance - Post-test Abdominal Muscle Endurance	-7.33	6.41	1.11	-6.57	<.001	-1.14
Pretest Leg Muscle Power Post-test Leg Muscle Power	0.04	0.25	0.04	0.92	0.362	0.16

Table 2 presents the paired t-test results comparing pretest and post-test outcomes for VO2 max, arm muscle endurance, abdominal muscle endurance, and leg muscle explosive power. A significant improvement in VO2 max was observed, with a mean difference of -5.10 ($t = -9.07$, $p < .001$), indicating a substantial increase in aerobic capacity following the intervention. The effect size, as measured by Cohen's d, is -1.58, which indicates a significant effect. This suggests that the training had a substantial impact on improving aerobic fitness. Arm muscle endurance also significantly improved, with a mean difference of −13.36 ($t = −8.43$, $p < .001$). The effect of this variable is significant (Cohen's d = -1.47). Therefore, this shows how useful the training program is in improving muscular endurance. Abdominal muscle endurance also showed significant enhancement, with a mean difference of -7.33 ($t = -6.57$, $p < .001$). Cohen's d value of -1.14 suggests a medium to significant effect, reinforcing the positive impact of the intervention on core strength. However, no significant difference was observed in leg muscle explosive power, as the mean difference was 0.04 ($t = 0.92$, $p = 0.362$). This outcome aligns with findings from short-duration interventions, indicating that plyometric exercises may require higher intensity or frequency for measurable improvements. (Suud et al., 2022) . With a Cohen's d of 0.16, which indicates a small effect, this component did not improve significantly following the training program. The analysis

indicates that the training program improved aerobic capacity and muscular endurance while leg muscle explosive power remained unchanged.

Discussion

The results of the paired sample t-test analysis in this study demonstrate a significant increase in VO2max among students following participation in the outdoor-based training program, with a t-value of -9.07 and a significance level (Sig. 2-tailed) of 0.001 ($p < 0.05$). The training program incorporated various methods, including Fartlek training, continuous running, cross-country running, and interval training conducted outdoors.

Research has proven that outdoor training programs effectively develop VO 2 max, with the same results as HIIT or indoor circuit training (Wen et al., 2019; García-Pinillos et al., 2017). Outdoor activities matching or exceeding what is conventionally done indoors tap into the stress-relieving aspects and provide opportunities to spend time in natural environments. Indoor HIIT necessitates specific equipment and controlled environment, but outdoor training also draws on nature to achieve similar results; in addition, nature brings its own psychological bonus (Pasanen et al., 2018). Although no significant gains in leg explosive power were noted in some cases, these findings align with studies suggesting that plyometric-focused training may require higher intensity or frequency to produce measurable results (Rifki et al., 2023). The VO2 max among adolescents was also significantly improved by outdoor interval training programs (Ramadhan et al., 2022; Soylu et al., 2021; Zouhal, 2024). Also, continuous running at moderate intensity and Fartlek training, characterized by alternating fast and slow running intervals, have been linked to enhanced VO2 max, endurance, and cardiovascular fitness (Nadimikeri & Joshi, 2022; Yunus et al., 2019). As a continuous training modality, cross-country running has also proven effective in improving VO2 max (Grzebisz et al., 2019). HIIT and Fartlek training have been particularly effective, significantly boosting VO2 max and improving aerobic capacity, making them valuable approaches for cardiovascular fitness development (Festiawan et al., 2020). The findings show that other training methods utilizing diverse outdoor setting may offer potential for enhancing both VO2 max and cardiovascular fitness.

In addition to improvements in VO2 max, this study noted significant increases in arm and abdominal muscle endurance, with t-values of -8.43 and -6.57, respectively, and a significance level of 0.001 ($p < 0.05$). These results are consistent with previous studies indicating that exercises such as push-ups, sit-ups, planks, triceps dips, bicycle crunches, and circuit training significantly improve arm and abdominal muscle endurance (Amiruddin et al., 2023; Ariani, 2021; Christoph et al., 2020; Kumar & Zemková, 2022; Posnakidis et al., 2022). Incorporating these exercises into outdoor training programs will be especially effective in achieving the best results. However, such intervention did not facilitate significant augmentation in this parameter, that is, an improvement of leg muscle explosive power, although the intervention was genetically designed to augment this parameter. The statistical analysis yielded a t-value of 0.92 and a p-value of 0.362. A p-value more significant than the commonly accepted significance level (e.g., 0.05) suggests that the observed changes are not significant enough to demonstrate a meaningful effect of the intervention on leg muscle explosive power. This might be the result of the way the programming of the eight-week intervention was constructed, with plyometric exercises being focused and condensed in a small time window (Weeks 5—6), resulting in less effectiveness. Plyometric training should be distributed more evenly throughout the intervention, or its volume and intensity should be increased in future studies to achieve more significant improvement.

Conclusions

The findings of this study highlight the effectiveness of the outdoor physical training program in improving specific components of physical fitness among first-year students enrolled in the Physical Education, Health, and Recreation program. From structured outdoor activity, VO2 max, arm muscle endurance, and abdominal muscle endurance all improved significantly, with outdoor activity beneficial to aerobic capacity and muscular strength. These results reflect previous findings concerning the beneficial effect of outdoor training environments on physical and psychological health. Despite these

successes, the program yielded insignificant leg muscle explosive power improvements. This may indicate that the particular design of the plyometric exercises included in the program needs to be adjusted in some way to improve outcomes in this area or that there is simply a need to increase the intensity or duration of plyometric exercise incorporated in the program. Previous studies have similarly indicated that plyometric training often requires higher intensity or frequency to elicit meaningful changes in explosive power.

The results are highly suggestive of the possibility that outdoor-based training programs, as a cost-effective and engaging means of training, maybe a valid and attractive alternative to classic indoor methods. By addressing common barriers such as motivation and facility limitations, these programs leverage the psychological benefits of natural environments to enhance training outcomes. However, future iterations should incorporate more targeted and intensive exercises to optimize improvements across all fitness components. This study offers valuable insights into designing and implementing outdoor fitness programs, particularly for university students in physically demanding academic settings. Further research is recommended to refine these programs and expand their applicability to broader populations. Additionally, this approach could be a practical model for resource-limited educational institutions or public health initiatives, promoting wellness and physical fitness through cost-efficient strategies.

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