Physiological effects of gastrocnemius muscle exercise on cardiopulmonary fitness in students

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Abstract. Physical fitness supports health and productivity among students, who are often prone to reduced physical activity. Strengthening the gastrocnemius muscle may enhance lower limb performance and cardiorespiratory fitness. This quasi-experimental study used a pretest–posttest design without a control group involving 60 purposively selected students of Universitas 'Aisyiyah Yogyakarta. The intervention consisted of gastrocnemius muscle exercises performed over four weeks. Physical fitness was measured using the Harvard Step Test, and data were analyzed using the Wilcoxon Signed-Rank test. There was a significant improvement in fitness scores after the intervention ($p = 0.000$), with the mean increasing from 23.39 to 51.45, indicating better cardiorespiratory endurance and lower limb efficiency. Discussion: Regular gastrocnemius exercise improves physiological performance through musculoskeletal and cardiovascular adaptations. Conclusion: Gastrocnemius muscle training is an effective and practical method to enhance student physical fitness. Research Contribution: This study provides evidence for the role of targeted muscle exercise in improving physiological and cardiorespiratory function among young adults.

1 Introduction

Physical fitness is a person's ability to perform physical activities without experiencing excessive fatigue, while still having enough energy to carry out other activities. According to the World Health Organization (WHO), physical activity is defined as any body movement produced by skeletal muscles that requires energy expenditure. This activity includes various forms, from structured exercise to daily activities such as walking or climbing stairs, all of which cumulatively contribute to the improvement of physical capacity and overall body

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health [1]. According to the Ministry of Youth and Sports of the Republic of Indonesia (Kemenpora RI), physical fitness plays a crucial role in supporting productivity, body endurance, and mental health. Regular physical activity has been proven to improve physical fitness and reduce the risk of various degenerative diseases [2].

As a productive age group, students are very vulnerable to experiencing a decline in physical fitness due to a sedentary lifestyle, academic pressures, and lack of physical activity. According to a report from Kemenpora RI 2023, only 5.04% of Indonesian youth aged 16–30 years have good or higher physical fitness, while 83.55% fall into the poor and very poor categories. This decline worsened during the online learning period, where students' physical activity significantly decreased, which also affected their physical fitness levels [1]. This situation raises serious concerns, as low physical fitness can negatively impact academic performance, heart health, and quality of life for students [3].

Structured physical exercises focused on strengthening the leg muscles, such as the gastrocnemius, have proven effective in improving physical fitness. The gastrocnemius muscle is an essential part of the calf muscles and plays a role in body stability and the efficiency of movement, especially in activities such as walking, jumping, and climbing stairs. Exercises targeting this muscle, such as lunges or squats, have been shown to enhance leg muscle strength and endurance [4]. Kim, J., Lee, & Park (2021) in their research state that gastrocnemius strengthening exercises can improve cardiorespiratory capacity and accelerate heart rate recovery after physical activity [5]. This is supported by findings from Kassiano et al. (2023), who showed that exercises that stretch the muscle to its maximum length lead to greater gastrocnemius muscle hypertrophy, thereby improving muscle efficiency and overall physical fitness [4].

An important method for assessing physical fitness is the Harvard Step Test. This method measures the heart and lung's ability to respond to physical activity by monitoring heart rate post-activity. The Harvard Step Test is considered a practical and reliable tool for evaluating cardiovascular fitness [6]. Furthermore, the Harvard Step Test provides an overview of a person’s aerobic endurance based on how quickly their heart rate returns to normal after moderate to intense physical activity. This test is efficient because it is easy to apply across various population groups, including students. According to Bianco et al. (2025), the Harvard Step Test has been shown to accurately assess physical working capacity, especially in evaluating the body’s ability to recover after physical activity, making it highly relevant for assessing overall physical fitness [7].

A preliminary study conducted on 10 students from Universitas ‘Aisyiyah Yogyakarta showed that all respondents had Harvard Step Test scores in the 'very poor' category. This result indicates the need for physical fitness improvement through targeted interventions. Therefore, this study was conducted to examine the effect of gastrocnemius muscle training on the physical fitness of students at Universitas ‘Aisyiyah Yogyakarta. This study was chosen because of the low physical activity levels among students, which lead to a decline in physical fitness, as well as the lack of simple, targeted interventions that can be routinely applied to improve overall fitness. It is hoped that the results of this study can contribute to the development of strategies to improve physical fitness in higher education environments.

2 Methods

This study uses a quantitative approach with a pre-experimental one-group pretest-posttest design. This design allows researchers to measure changes in the dependent variable, namely physical fitness, before and after the treatment, which in this case is the gastrocnemius muscle training. The study was conducted at Universitas 'Aisyiyah Yogyakarta over five months, from February to June 2025.

The population in this study consisted of all active students at Universitas 'Aisyiyah Yogyakarta. The sample was selected using purposive sampling, with inclusion criteria being students aged 18–23 years, willing to participate in the exercise intervention during the study period, and without a history of injury or musculoskeletal disorders that would limit physical activity. A total of 60 respondents who met the criteria and were willing to complete the entire activity were included.

The independent variable in this study is the gastrocnemius muscle training, while the dependent variable is physical fitness. The intervention consisted of physical exercises focusing on the gastrocnemius muscle strengthening through lunges. This exercise was performed in two sets of eight repetitions per set, three times a week for four consecutive weeks. All exercises were conducted in groups with researcher supervision to ensure correct movement techniques and prevent injury.

The instrument used to measure physical fitness was the Harvard Step Test, which evaluates the cardiovascular system's recovery capacity after physical activity. In the implementation, respondents were asked to step up and down a bench 40 cm high (for women) or 50 cm (for men) for five minutes at a constant pace. Afterward, their pulse rate was measured at three time intervals (1–1.5 minutes, 2–2.5 minutes, and 3–3.5 minutes), which was then used to calculate the Physical Efficiency Index (PEI). The PEI value was classified into five categories: very good (≥96), good (83–95), average (68–82), poor (54–67), and very poor (<54).

Data from the pretest and posttest were analyzed using the Wilcoxon Signed-Rank Test because the data did not follow a normal distribution according to the Shapiro-Wilk test. The Wilcoxon test was chosen to determine whether there were significant differences in physical fitness before and after the gastrocnemius muscle training, with a significance level set at 5% ($\alpha = 0.05$).

3 Results and discussion

3.1 Result

From the research results, the characteristics of the respondents were obtained based on gender, age, and pulse as following table:

Table 1. Characteristics of the respondents

No.	Demographic Data	n	%
1.	Gender		
	Female	52	86.7

	Male	8	13.3
	Total	60	100
2.	Age		
	18 years	32	53.3
	19 years	28	46.7
	Total	60	100
3.	Heart rate		
	Low	6	10.0
	Normal	45	75.0
	High	9	15.0
	Total	60	100

Based on the data from Table 1, characteristics of the respondents, it is known that out of a total of 60 students participating in the study, the majority are female, with 52 individuals (86.7%), while males comprise 8 individuals (13.3%). This indicates the dominance of female respondents in this study.

Table 2. Results of the Harvard Step Test assessment before the gastrocnemius muscle training.

Gender	Very poor	%
Male	8	100
Female	52	100
Total	60	100

Based on the results of physical fitness measurements using the Harvard Step Test before the intervention of gastrocnemius muscle training, all respondents (100%) fell into the "very poor" category. This applied to both male respondents (8 respondents) and female respondents (52 respondents), all of whom demonstrated a very low level of physical fitness.

Table 3. The results of the Harvard Step Test assessment after performing gastrocnemius muscle training.

Gender	Kategori						Total
	Very poor	%	Poor	%	Fair	%	
Male	1	13	6	75	1	13	8
Female	2	4	50	96	0	0	52
Total	3	5	56	93	1	2	60

Based on the results from table 3, after the intervention consisting of gastrocnemius muscle training for four weeks, there were significant changes in the physical fitness levels of the respondents measured using the Harvard Step Test. Most of the respondents experienced an improvement in fitness category from previously “very poor” to “poor” and “fair”.

Table 4. Harvard Step Test Results

Variabel	Mean	SD	Min	Max	p-value
Pre test Harvard Step Test	23.39	1.218	20	44	0,000
Post test Harvard Step Test	51.45	1.207	40	66	

Table 4. Analysis of statistics using the Wilcoxon Signed-Rank Test was conducted to determine the difference in Harvard Step Test scores before and after gastrocnemius muscle training intervention. The Wilcoxon test showed a statistically significant difference (p = 0.000) between Harvard Step Test scores before and after training. The average score before the intervention was 23.39 and increased to 51.45 after training. These results reinforce the finding that gastrocnemius training directly contributes to improving physical capacity and fitness.

3.2 Discussion

3.2.1 Characteristics of the respondents

In terms of age, the respondents consisted of students aged 18 and 19 years. A total of 32 people (53.3%) were 18 years old, and 28 people (46.7%) were 19 years old. Thus, all respondents fall into the late adolescence or early adulthood age group, which is the ideal age phase for receiving physical interventions as they are physiologically at the peak of physical capability development.

The dominance of females in this study needs to be noted because the response to physical training, including gastrocnemius muscle training, may show differences based on gender. According to Werneck et al. (2021), gender and age factors can influence physical fitness capacity due to physiological, hormonal, and metabolic differences [8].

Dominelli & Molgat-Seon (2022) also highlight that women tend to have different lung capacity and ventilation responses during physical activity compared to men, which also affects cardiorespiratory performance. Nevertheless, the research shows that both male and female respondents responded positively to gastrocnemius muscle training in terms of improving physical fitness [9].

Referring to the heart rate categories prior to intervention, the majority of respondents were in the normal category (70-89 beats/min) with 45 individuals (75%). A total of 9 individuals (15%) had a resting heart rate in the high category (≥90 beats/min), and the remaining 6 individuals (10%) were in the low category (<70 beats/min). This indicates that most students participating in the study had relatively stable cardiac physiological conditions.

However, the presence of a small group with a high pulse before intervention needs to be a concern as this may indicate poor heart efficiency or low cardiorespiratory fitness levels [10]. In the study by Kim, J., Lee & Park (2021), individuals with low fitness scores tended to have a higher resting pulse due to the heart working harder to meet the tissue's oxygen demands. Therefore, interventions in the form of gastrocnemius muscle exercises are expected to improve the balance of circulatory function and lower the resting pulse through increased heart efficiency [5].

3.2.2 The results of the Harvard Step Test assessment before and after

The findings in Table 2 indicate that the majority of students from Universitas 'Aisyiyah Yogyakarta who participated as respondents do not have an adequate level of physical fitness.

This condition may be caused by a lack of regular physical activity, particularly aerobic exercises that involve the lower limb muscles, such as the gastrocnemius muscle [11]. This situation aligns with the survey results from Kemenpora RI (2023), which state that more than 80% of Indonesian adolescents have a physical fitness level classified as inadequate or very inadequate [12].Therefore, these initial results provide a strong basis for implementing interventions in the form of gastrocnemius exercises as an effort to improve physical fitness through physiological mechanisms such as increased blood pumping efficiency, improved peripheral circulation, and enhanced endurance of the lower limb muscles.

As seen in Table 3, out of a total of 60 respondents, 56 individuals (93%) fell into the "poor" category, 3 individuals (5%) remained in the "very poor" category, and 1 individual (2%) reached the "satisfactory" category. In the male group, 6 out of 8 respondents (75%) were in the "poor" category, 1 respondent (13%) remained in the "very poor" category, and 1 respondent (13%) was in the "satisfactory" category. Meanwhile, in the female group, a large majority of 50 out of 52 respondents (96%) were in the "poor" category, 2 individuals (4%) remained in the "very poor" category, and none reached the "satisfactory" category.

This category change indicates that gastrocnemius muscle training interventions have a positive impact on the improvement of physical fitness in students, particularly in enhancing cardiovascular system function and muscle endurance. This exercise works by strengthening the lower leg muscles, especially the gastrocnemius muscle, which plays a crucial role in functional activities such as walking, climbing stairs, and maintaining balance, thereby improving blood circulation and enhancing the body's recovery capacity after physical activity [13].

A study by Bianco et al., (2025) also shows that the Harvard Step Test scores have a strong correlation with aerobic capacity that can be improved through regular physical exercise, including lower limb exercises such as jump rope or lunges [6]. Another study by Abdurrochim, (2020) indicates that consistent lunging exercise can enhance lower limb muscle strength and positively affect the body's functional capacity [14]. Similarly, Chatterjee et al., (2020) state that lower limb muscle training contributes significantly to the overall physical fitness improvement of students [15]. Furthermore, Kassiano et al. (2023) emphasizes that the Harvard Step Test is an effective tool for detecting changes in physical fitness levels, as it can reflect improvements in heart and lung work capacity after physical exercise intervention [4].

The improvement in physical fitness is also reinforced by the physiological adaptations of the gastrocnemius muscle, which plays a role in movements such as squatting, bearing body weight, and stabilising the knee joint. Research by Kassiano et al. (2023) asserts that consistent training of the gastrocnemius muscle results in muscle hypertrophy and increased muscle metabolism, which also contributes to the efficiency of oxygen consumption during physical activity. This adaptation directly impacts the increase in physical fitness scores among students [4].

The results in Table 4 are consistent with the study by Chatterjee et al. (2020), which states that lower limb muscle training significantly improves physical fitness performance [15]. Another study by Kim et al. (2021) also supports that lunges and squats can significantly strengthen the leg muscles of students [5]. Therefore, it can be concluded that gastrocnemius muscle training not only increases local muscle strength but also has a positive impact on

overall cardiovascular fitness. Additional support also comes from Kudo et al. (2020) research, which proves that lunge exercises can improve leg muscle strength as well as movement efficiency in sports activities [2].

Langland et al. (2021) highlights that physical activities such as running can increase the tension in the gastrocnemius-soleus muscles as a form of neuromuscular adaptation [12]. This trained muscle tension enhances the efficiency of contractions and the elasticity of the lower leg muscles, which impacts the body's ability to perform aerobic activities. This is directly related to improved performance in the Harvard Step Test, where the gastrocnemius muscle plays a key role in stability and the repetition of the up-and-down steps. Additionally, Bianco et al. (2025) demonstrate that structured physical activity can improve pulse rate and breathing frequency, important indicators of physical fitness. Thus, training the gastrocnemius muscle not only affects local strength but also the efficiency of the cardiorespiratory system [6].

Overall, the significant improvement in the Harvard Step Test scores indicates that the gastrocnemius exercise intervention has great potential as a simple yet effective method for enhancing physical fitness, especially among students who tend to be less physically active.

4 Conclusion

This study shows that gastrocnemius muscle training has a significant effect on improving physical fitness among students of 'Aisyiyah University Yogyakarta. Before the intervention, the average score of the Harvard Step Test was 23.39, with all respondents (100%) falling into the 'very low' category. After undergoing a gastrocnemius muscle training programme for four weeks, the average score increased to 51.45, with the majority of respondents (93%) moving to the 'low' category and a small portion (2%) achieving the 'sufficient' category. The Wilcoxon test results showed a p-value of 0.000, indicating a statistically significant difference between physical fitness scores before and after the intervention ($p < 0.05$).

Referring to this, gastrocnemius muscle training has been proven effective in improving the physical fitness of students measured using the Harvard Step Test. This exercise can serve as a simple, cost-effective, and practical intervention to improve the physical condition of students.

Based on these results, it is recommended that students perform gastrocnemius muscle exercises regularly as part of their daily physical activity. Higher education institutions are expected to support the implementation of such physical exercise programmes in order to enhance the overall quality of life and physical fitness of students. Future research is encouraged to explore variations in duration, intensity, and different training methods, as well as to involve a wider sample to make the results more comprehensive and applicable in general.

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References

[1] Y. Mogi, "Muscle architecture of the medial gastrocnemius during growth," *J. Physiol. Anthropol.*, vol. 4, pp. 1–5, 2024, doi: 10.1186/s40101-024-00381-4.

[2] S. Kudo, T. Sato, and T. Miyashita, "Effect of plyometric training on the fascicle length of the gastrocnemius medialis muscle," pp. 277–280, 2020.

[3] P. Gentil, D. Souza, M. Santana, and R. R. Alves, "Multi- and Single-Joint Resistance Exercises Promote Similar Plantar Flexor Activation in Resistance Trained Men".

[4] W. Kassiano *et al.*, "Greater Gastrocnemius Muscle Hypertrophy after Partial Range of Motion Training Performed at Long Muscle Lengths.," *J. Strength Cond. Res.*, vol. 37(9), pp. 1746–1753, 2023.

[5] S. Kim, J., Lee and H. Park, "Effect of gastrocnemius muscle strengthening on cardiorespiratory endurance in college students.," *J. Phys. Act. Heal.*, vol. 18(3), pp. 241–247, 2021.

[6] M. Bianco *et al.*, "Differences in Arrhythmia Detection Between Harvard Step Test and Maximal Exercise Testing in a Paediatric Sports Population," pp. 1–12, 2025.

[7] A. A. Vasquez, B. José, A. Trejos, M. Daniel, and R. Valverde, "Gastrocnemius muscle oxygenation asymmetry as a predictor of exercise intensity in professional soccer players : a cross - sectional study," *Sport Sci. Health*, no. 0123456789, 2025, doi: 10.1007/s11332-025-01479-7.

[8] A. O. Werneck, D. R. Silva, and A. Oliveira, "Gender differences in physical fitness: A cross-sectional analysis.," *J. Exerc. Sci. Fit.*, vol. 19(1), pp. 45–51, 2021.

[9] P. B. Dominelli and Y. Molgat-Seon, "Sex, gender and the pulmonary physiology of exercise.," *Eur. Respir. Rev.*, vol. 31(163), 2022.

[10] K. U. Akkaya and H. E. Akkaya, "Statik Germe Süresinin Gastroknemius Kas Vaskülarizasyonu Üzerine Akut Etkilerinin Superb Mikrovasküler Görüntüleme Yöntemi ile İncelenmesi An Examination of the Acute Effects of Static Stretching Duration on Gastrocnemius Muscle Blood Flow by Superb Microvascular Imaging Method," vol. 56, no. August, pp. 94–98, 2023, doi: 10.20492/aeahtd.1249355.

[11] I. Panidi *et al.*, "A Cross-Sectional Study of Gastrocnemius Medialis Muscle Fascicle Length and Anatomical Cross-Sectional Area in 8- to 18-Year-Old Female Volleyball Athletes," pp. 1–11, 2024.

[12] J. T. Langland, N. Sathnur, Q. Wang, and A. P. J. Olson, "Do assessments of cardiorespiratory and muscular fitness influence subsequent reported physical activity ? A randomized controlled trial," pp. 1–8, 2021.

[13] K. Appelqvist-schmidlechner, J. P. Vaara, T. Vasankari, A. Häkkinen, and M. Mäntysaari, "Muscular and cardiorespiratory fitness are associated with health-related quality of life among young adult men," pp. 1–8, 2020.

[13]"9.+Angria+Pradita_Effectiveness+of+Core+StabilitAngria+PraditaAngria+Praditay+Exercise+in+Physiotherapy+Approach+to+Improve+Cardiorespiratory+Fitness+in+College+Students.pdf."

[15] P. Chatterjee, S. Sarkar, and S. Sen, "Pengaruh latihan otot tungkai bawah terhadap kebugaran jasmani mahasiswa.," *J. Ilmu Keolahragaan Indones.*, vol. 12(1), pp. 35–42., 2020.