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Leg Muscle Endurance and Middle-Distance Running Performance Among High School Athletic Extracurricular Students

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ABSTRACT

Physical education at the senior high school level aims to develop physical fitness components, including muscular endurance, which underpins sport-specific skills like middle-distance running. This study examined the relationship between leg muscle endurance and three-kilometer running performance among male senior high school students in an athletics extracurricular program. Utilizing a quantitative correlational design, 30 male students (aged 15–18) were selected via total sampling. Leg muscle endurance was evaluated using the wall-sit test, while middle-distance running performance was assessed via a three-kilometer run test. Data were analyzed using descriptive statistics, the Shapiro–Wilk normality test, and the Pearson product-moment correlation. Descriptive results indicated adequate categories for both leg muscle endurance (M = 6.19, SD = 2.92) and running performance (M = 14.00, SD = 1.72), with normal data distribution ($p > 0.05$). Correlation analysis revealed a strong, statistically significant negative relationship between leg muscle endurance and running time ($r = -0.693$, $p = 0.000$). This negative coefficient indicates that greater leg muscle endurance is robustly associated with shorter running times (superior performance). These findings demonstrate that localized muscular endurance is a critical determinant of adolescent middle-distance running proficiency. Consequently, physical education curricula and extracurricular training should deliberately incorporate targeted muscular-endurance programs rather than relying exclusively on cardiovascular conditioning.

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1. INTRODUCTION

Physical education is an integral part of the school curriculum and serves as one of the principal means through which adolescents develop motor competence, physical fitness, and lifelong habits of healthy activity (Aksir et al., 2024; Ramires et al., 2023). In the Indonesian senior high school context, physical education and extracurricular sport programs are expected not only to teach sport-specific techniques but also to cultivate the underlying fitness components—strength, speed, flexibility, coordination, and endurance—that allow students to perform and learn movement skills effectively (Auliya et al., 2023; Shabrina et al., 2025). Among these components, muscular endurance is frequently emphasized because it sustains repeated muscle contractions during prolonged activity and is closely linked to students' capacity to participate fully in athletics-based learning (Alhumary et al., 2025).

Running is one of the most accessible and widely taught activities in school physical education, and it forms the foundation of the athletics curriculum. Within athletics, middle-distance running, such as the three-kilometre run, is a popular activity because it requires a combination of aerobic endurance and lower-body muscular endurance to maintain an optimal pace throughout the course (Hao, 2026; Laksana et al., 2021). Several studies in endurance sport have shown that improvements in physiological capacities, including maximal oxygen uptake and muscular endurance, are associated with better running performance over both middle and long distances (Denadai & Greco, 2022; Prieto-González & Sedlacek, 2022). For school-age students, the development of these capacities through structured physical education and extracurricular training is particularly important, as adolescence is a sensitive period for building the physical foundations of later sporting and health behavior (Canli et al., 2024).

Middle-distance running, generally covering distances from 800 to 3000 metres, differs technically from sprinting (Born et al., 2024). In middle-distance events the foot typically contacts the track with the heel first, followed by a push-off through the toes, and a standing start is used (Canata et al., 2022). Because the activity is sustained over several minutes and relies predominantly on the aerobic energy system, the ability of the leg muscles to contract repeatedly without rapid fatigue strongly influences how well a student can maintain rhythm and speed. Consequently, lower-body muscular endurance is widely regarded as a key performance component in athletics teaching and coaching (Song et al., 2024).

The leg muscles support both internal and external loads during everyday and athletic movements such as walking, running, and jumping, and they provide the primary propulsion for the body during activity (Pandy et al., 2021; Usherwood, 2024). Weak leg muscle strength increases the risk of injury and limits movement performance, because the legs are one of the body's main supports (Girdwood et al., 2024). Leg muscle endurance refers to the ability of the upper and lower leg muscles to contract repeatedly over a relatively long period (Zuo et al., 2022). This ability helps to delay fatigue, allowing students to sustain movement quality, maintain motor performance, and reduce the likelihood of injury during prolonged running (Apriyano et al., 2025).

Although the importance of muscular endurance for running is well established in elite and adult populations, comparatively little attention has been paid to school-age students participating in physical education and extracurricular athletics. Much of the existing evidence is drawn from competitive athletes or adult recreational runners, whose training history and physical maturity differ considerably from those of secondary school students (Mijalković et al., 2024; Peterson et al., 2022; Tingelstad et

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al., 2023). Understanding how leg muscle endurance relates to middle-distance running performance in a high school population is therefore valuable for physical education teachers and extracurricular coaches who design conditioning activities for adolescents. If a clear relationship exists, it will justify the deliberate inclusion of muscular-endurance development in the physical education curriculum rather than a singular emphasis on cardiovascular conditioning or running technique.

To address this background, the present study aimed to examine the relationship between leg muscle endurance and three-kilometer running performance among male senior high school students enrolled in an athletics extracurricular program. It was hypothesized that leg muscle endurance would be significantly related to three-kilometer running performance, such that students with greater leg muscle endurance would record faster running times. The findings are expected to inform physical education pedagogy by clarifying the role of lower-body muscular endurance in adolescent running performance and by guiding the design of conditioning activities within school athletics programs.

2. METHOD

This study used a quantitative approach with a correlational research design. The design was selected to determine the relationship between leg muscle endurance and three-kilometre running performance among senior high school students in an athletics extracurricular program, without any treatment or manipulation of the variables under study. Leg muscle endurance was treated as the independent variable (X), and three-kilometre running performance was treated as the dependent variable (Y), after which the contribution of variable X to variable Y was examined.

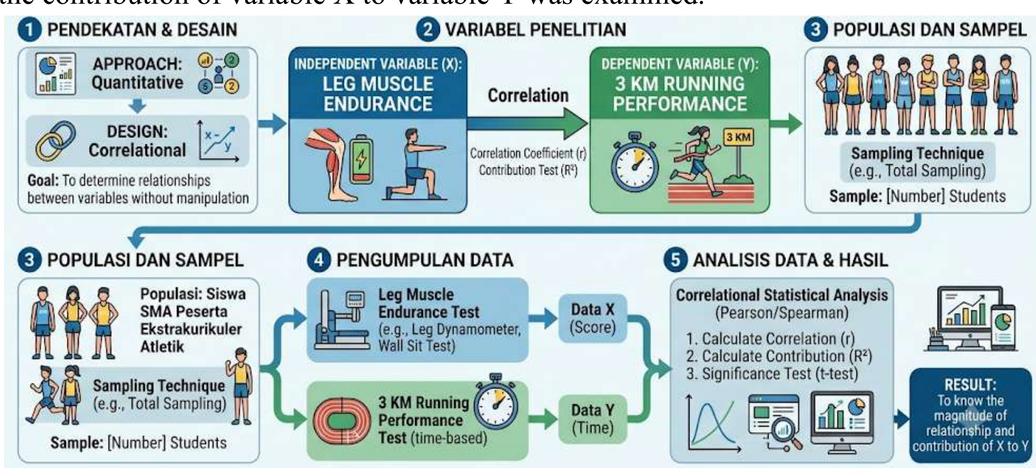

Figure 1. Quantitative Approach with a Correlational Research Design

Data collection was conducted on the school athletics field used by the students' extracurricular program during the regular training period from January to February 2026. All tests were administered in the same field under comparable weather conditions and at the same time of day to minimise environmental variation. The participants were male senior high school students who were active members of the athletics extracurricular program. A total of 30 students took part in the data collection. The sample was drawn from the population using a total sampling technique, in which all members of the population were included as participants. Total sampling was appropriate given the relatively small and clearly defined population of the extracurricular program.

The inclusion criteria were as follows: (1) an active member of the school athletics extracurricular program; (2) aged 15–18 years; (3) male; (4) free of leg injury or illness that could interfere with running; and (5) willing to undergo all tests, comprising the muscular-endurance test and the three-kilometre run. Students who did not meet these criteria or who were unable to complete both tests were not included in the analysis.

Two instruments were used in this study. Leg muscle endurance was measured using the *wall-sit test*, in which the participant maintained a seated position against a wall with the thighs parallel to the ground and the knees at approximately a ninety-degree angle for as long as possible; the holding time, recorded in minutes, represented the level of leg muscle endurance. Middle-distance running performance was measured using a *three-kilometre run test*, in which the time taken to complete the distance was recorded in minutes. For the wall-sit test, a longer holding time indicates better leg muscle endurance, whereas for the three-kilometre run a shorter time indicates better running performance.

Before testing, the purpose and procedures were explained to the participants, and a standardised warm-up was conducted. Direct observation and documentation were used to record performance, and the test administrators ensured that each participant performed the tests according to the standardised protocol. The wall-sit test was administered first, followed by an adequate recovery period before the three-kilometre run test, so that residual fatigue would not confound the running performance.

Data were analysed using quantitative descriptive analysis to summarise the participants' performance, the Shapiro–Wilk test to assess the normality of the data, and the Pearson product-moment correlation to examine the relationship between the two variables. The strength of the correlation was interpreted using standard correlation-coefficient criteria. All analyses were conducted with the assistance of SPSS software, with statistical significance set at $p < 0.05$. The normality test indicated that the data for both variables were normally distributed, satisfying the assumptions required for parametric correlation analysis. The data were therefore considered reliable and suitable as a basis for drawing the study's conclusions.

3. RESULTS AND DISCUSSION

Results

Descriptive Results

Data collection was executed through rigorous, field-based physiological protocols, wherein localized leg muscle endurance was quantified via the isometric wall-sit test, and aerobic-anaerobic capacity was operationalized through a standardized three-kilometer running time-trial. To establish a baseline profile of the high school student-athletes participating in the extracurricular athletics program, a comprehensive descriptive statistical analysis was performed. As detailed in Table 1, the participants exhibited an average wall-sit isometric endurance time of 6.19 minutes (SD = 2.92), with individual performances spanning a wide range from a minimum of 1.11 minutes to a maximum of 11.29 minutes.

Concurrently, the descriptive metrics for the three-kilometer running performance yielded a mean completion time of 14.00 minutes (SD = 1.72), with observed values distributed between a peak performance of 10.48 minutes and a lower bound of 17.01 minutes. Evaluated against normative adolescent fitness baselines, the collective cohort's localized muscular endurance and cardiorespiratory endurance fell predominantly within the "adequate" classification. However, the substantial standard deviations and extensive data ranges underscore a high degree of inter-individual variability in physiological conditioning within this specific athletic group, emphasizing the heterogeneous nature of physical adaptation among adolescent trainees.

Table 1. Descriptive analysis of leg muscle endurance and three-kilometre running performance

Variable	N	Min	Max	Mean	Std. Deviation
Wall-sit test (min)	30	1.11	11.29	6.19	2.92
3-km run (min)	30	10.48	17.01	14.00	1.72

Normality Test Results

To evaluate the distribution characteristics of the dataset and ensure compliance with the mathematical assumptions underlying parametric statistical inference, a formal normality assessment was conducted. The Shapiro–Wilk test was specifically selected for this purpose due to its superior statistical power and sensitivity in detecting deviations from normality within moderate sample sizes (N = 30). As delineated in Table 2, the empirical distribution for both physiological metrics demonstrated a high level of conformity to Gaussian assumptions. The isometric wall-sit test yielded a significance value of $p = 0.078$, while the three-kilometer running time trial generated a significance value of $p = 0.482$.

Because both calculated p-values comfortably exceeded the conventional alpha threshold of 0.05 (alpha = 0.05), the null hypothesis of non-normal distribution was confidently rejected. Consequently, it was empirically established that the raw data for both localized muscular endurance and cardiorespiratory performance did not deviate significantly from a normal distribution curve. Meeting these rigorous criteria satisfied the classical assumptions of homoscedasticity and linearity, thereby providing a robust statistical justification to proceed with parametric evaluation—specifically the Pearson product-moment correlation analysis—to examine the underlying relationship between the variables.

Table 2. Shapiro–Wilk normality test

Variable	Statistic	df	Sig.	Description
Wall-sit test	0.938	30	0.078	Normal
Three-kilometre run	0.968	30	0.482	Normal

Pearson Product-Moment Correlation

To examine the physiological association between localized muscular capacity and aerobic-anaerobic efficiency, a Pearson product-moment correlation analysis was performed. As detailed in the inferential metrics presented in Table 3, the statistical analysis yielded a significance value of $p = 0.000$. Because this probability falls substantially below the conventional alpha threshold of 0.05 ($p < 0.05$), the null hypothesis was rejected, demonstrating a highly significant statistical relationship between the student-athletes' leg muscle endurance and their three-kilometer running proficiency. The calculated correlation coefficient reached $r = -0.693$, which, according to established psychometric and physiological interpretation criteria, denotes a robust and strong correlation between the two variables.

Biophysically, the negative direction of this correlation coefficient ($r = -0.693$) represents a critically important inverse relationship within the context of athletic performance. Given that superior isometric endurance is operationalized by longer maintenance times in the wall-sit test, whereas enhanced running efficiency is characterized by a minimized time-trial duration, this negative value explicitly indicates that greater localized leg muscle endurance is fundamentally associated with faster three-kilometer running times. This finding provides clear empirical evidence that localized skeletal muscle endurance in the lower extremities serves as a pivotal performance determinant that directly influences the velocity and metabolic sustainability required during adolescent middle-distance running execution.

Table 3. Pearson product-moment correlation between leg muscle endurance and three-kilometre running performance

Variables	Correlation (r)	Sig.	Description
Leg muscle endurance × 3-km run	−0.693	0.000	Significant

Synthesizing the empirical findings, the descriptive and inferential metrics conclusively demonstrate that both localized leg muscle endurance and three-kilometer running proficiency among the adolescent student-athletes fall within an acceptable physiological threshold, characterized as generally adequate. The preliminary data screening via normality testing confirmed that the raw scores for both fitness components adhered strictly to a Gaussian distribution, thereby validating the structural integrity of the dataset for parametric modeling. This statistical homogeneity underscores that the sample exhibits a well-distributed range of athletic capabilities, providing a reliable baseline for interpreting the physiological interactions between localized muscular capacity and systemic cardiorespiratory endurance in a high school sports context.

Crucially, the integration of these outcomes reveals a strong, statistically significant inverse relationship between isometric lower-limb endurance and middle-distance running time-trial performance. This robust association empirically underscores that localized muscular endurance is not merely an isolated physical attribute, but a vital physiological determinant that directly influences running efficiency and velocity maintenance. Ultimately, these synchronized results indicate that superior mechanical sustainability in the lower-extremity musculature serves as a critical foundation for optimizing aerobic-anaerobic pathways, thereby dictating the overall technical proficiency and time-trial success of adolescent runners.

Discussion

Leg Muscle Endurance of the Students

The leg muscle endurance test showed that most senior high school students were in the adequate category, indicating that most participants possessed sufficient lower-body muscular endurance to support middle-distance running, although some students still displayed lower levels of endurance. This variation is to be expected in a school population, where students differ in physical maturity, training experience, and habitual activity. Muscular endurance plays a crucial role in middle-distance running: students with good leg muscle endurance tend to withstand fatigue better during prolonged running, and a sound level of conditioning can also improve muscle coordination and stability while running. Conversely, students with lower muscular endurance tend to fatigue more quickly (Kusmita et al., 2022; Pavlović et al., 2024). From a pedagogical perspective, the presence of students with low endurance highlights the value of including progressive conditioning activities within physical education and extracurricular athletics so that all students can build the physical foundation needed to participate effectively (Nguyen, 2025).

Three-Kilometre Running Performance

The three-kilometre run test indicated that the participants' overall running ability was within the adequate range, with most students completing the distance in a time considered reasonable for their age and training context, though variation among individuals was again evident. Middle-distance running relies predominantly on the aerobic energy system, so the ability of the leg muscles to work continuously for a relatively long period substantially affects overall running performance. For this reason, leg muscle endurance is a crucial component for maintaining rhythm and speed during middle-distance running (Prieto-González & Sedlacek, 2022). In a school setting, this means that performance in distance-running activities is shaped not only by cardiovascular fitness but also by the capacity of the leg muscles to sustain repeated contractions, a capacity that physical education teachers can deliberately develop (Severin et al., 2021).

Relationship Between Leg Muscle Endurance and Running Performance

The correlation analysis revealed a strong, statistically significant relationship between leg muscle endurance and three-kilometre running performance among the students ($r = -0.693$, $p = 0.000$). The negative coefficient indicates that students with greater leg muscle endurance recorded faster running times, because better endurance corresponds to a shorter completion time. These findings suggest that the better a student's leg muscle endurance, the better their ability to sustain running performance over the three-kilometer distance (Polevoy, 2023). Leg muscle endurance is central to running because the leg muscles work continuously to support body weight and propel the body forward; students with good leg muscle endurance are generally able to delay muscular fatigue, allowing them to maintain running rhythm and speed longer than those with lower endurance (Stojanović et al., 2023; Yu et al., 2025).

These results are consistent with the broader literature indicating that lower-body muscular endurance and running-specific strength contribute to endurance-running performance (Prieto-González & Sedlacek, 2022; Yu et al., 2025). The present study extends this evidence to an adolescent, school-based population participating in an extracurricular athletics program, a group that has received comparatively little attention. The finding that the relationship is strong even among non-elite secondary school students reinforces the argument that muscular endurance is a meaningful target for physical education instruction and adolescent athletic development.

Implications for Physical Education

The results carry several practical implications for physical education at the senior high school level. First, they support the integration of structured muscular-endurance training—such as bodyweight exercises, isometric holds, and progressive resistance activities—into physical education lessons and extracurricular athletics, rather than concentrating solely on cardiovascular conditioning or running technique. Second, because students vary in their endurance levels, teachers can use simple field tests such as the wall-sit test to identify students who would benefit from additional conditioning and to monitor progress over time. Third, embedding muscular-endurance development within athletics learning may help students participate more fully, reduce the risk of fatigue-related injury, and build the physical foundations that support continued engagement in physical activity beyond school.

Several limitations should be acknowledged. The study used a relatively small sample of 30 male students from a single school's athletics extracurricular program, which limits the generalisability of the findings to female students, other schools, and the wider student population. The correlational design establishes association but not causation, and other factors that influence running performance—such as aerobic capacity, body composition, motivation, and training history—were not controlled. Future research could employ larger and more diverse samples, include female participants, and use experimental or longitudinal designs to examine whether targeted muscular-endurance training within physical education produces measurable improvements in students' running performance.

4. CONCLUSION

This study found a strong and statistically significant relationship between leg muscle endurance and three-kilometre running performance among male senior high school students in an athletics extracurricular program. Students with better leg muscle endurance tended to maintain running speed and complete the three-kilometre distance in a better time. In general, the participants' leg muscle endurance and running ability were considered adequate, although there was meaningful variation among individuals.

These findings indicate that leg muscle endurance is an important factor influencing middle-distance running performance in adolescents, because the leg muscles support the body and generate continuous propulsion throughout the run.

Accordingly, efforts to improve running performance among senior high school students should not focus only on cardiovascular endurance but should also deliberately develop leg muscle endurance, so that students can sustain running rhythm and speed more effectively. Embedding muscular-endurance development within physical education and extracurricular athletics may therefore enhance both students' performance and their broader physical literacy. Further research with larger and more diverse samples and experimental designs is recommended to confirm these findings and to evaluate the effectiveness of specific conditioning interventions in the school setting.

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