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The Impact of Interval Training and Leg Muscle on The Endurance Capacity of Football Players

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ABSTRACT

This study aimed to assess the impact of lengthy and rigorous interval training methods on aerobic and anaerobic endurance by analyzing leg muscle endurance capabilities. The study employed a quasi-experimental design using a pretest-posttest methodology without a control group, involving 24 athletes under the age of 14, divided into 4 groups. The evaluation instruments utilized were the Balke test for aerobic endurance and the Running-Based Anaerobic Test (RAST) for anaerobic endurance. The studies conducted were the t-test and the ANOVA test. The study's findings revealed that T-test analysis showed a substantial effect on both aerobic and anaerobic endurance, with significance values of p=0.000 for extended training and p=0.000 for intensive interval training. The ANOVA test revealed no significant differences among the training methods, leg muscle endurance levels, or their interaction, as all significance values surpassed 0.005 (p>0.005). Both extensive and demanding interval training enhance anaerobic and aerobic endurance, with no significant distinction between the two approaches. Moreover, variations in leg muscle capacity influence both aerobic and anaerobic endurance; yet, there is no notable difference or interaction between the interval training method and the degree of leg muscular endurance.

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INTRODUCTION

The execution of various football activities necessitates intricate physiology that strains both anaerobic and aerobic energy systems (Dolci et al., 2018). Moreover, explosive movements, including acceleration, deceleration, abrupt directional changes, and jumping, frequently occur at important junctures of the match, for example, instances giving scoring possibilities (Faude et al., 2015). Moreover, leg muscles serve as the primary drivers in football activities, playing a crucial part in sustaining performance during the match. These attributes will facilitate performance and guarantee an adequate level of physical fitness during the contest (Fereday et al., 2020). The physical component underpins other crucial factors and serves as the foundation for cultivating technical, tactical, and strategic skills in football (Thompsett et al., 2016). Consequently, the enhancement of physical ability is a crucial phase that must be meticulously structured through a training methodology aligned with the requirements of game performance.

Physical activity is fundamentally classified into two categories: aerobic exercise, which involves oxygen intake, and anaerobic exercise, characterized by rapid and explosive movements (Radtke et al., 2017). Investigate effective training methodologies to enhance both aerobic and anaerobic endurance, including interval training as a key approach. Interval training is a widely utilized technique among athletes to enhance specific physiological and fitness parameters (Arslan et al., 2020; Franchini et al., 2018; Milanović et al., 2015). During this interval training, an individual or athlete engages in high-intensity physical activity for a specified duration, repeatedly, with each repetition followed by a corresponding recovery period (rest) (García-Hermoso et al., 2016). Interval training is categorized into two primary methodologies: extensive intervals and intensive intervals. Extensive interval training often involves prolonged work durations and moderate intensity. The extensive interval approach is distinguished by moderate load intensity (60 to 80%), a significant load due to the number of repeats, and partial or complete recovery. Increased load volume and repetitions, namely higher 20 or under 30 repetitions per set, with insufficient rest intervals of 45 to 90 seconds between sets (Astuti et al., 2020). According to Alkayis (2019), the intensive interval technique is defined as a load intensity of 80 to 90% of maximal capacity, a moderate load volume of 6 to 10 repetitions each series, and an interval/rest time of 90-180 seconds per series. Both training modalities are purported to enhance the aerobic and anaerobic capacities of athletes, contingent upon the dosage and method of execution (Elamaran, 2015; Karthikeyan, 2024).

While interval training is proven to enhance both aerobic and anaerobic capacity, the efficacy of physiological adaptation is inextricably linked to the athlete's muscle endurance status. Enhancing muscle endurance can be accomplished through frequent and consistent training, including cardiovascular, strength, and speed training (Fanani et al., 2025). Numerous prior studies have investigated the impact of interval training on enhancing both aerobic and anaerobic endurance. Nonetheless, the majority have not incorporated the influence of leg muscle endurance as a critical factor in training adaptation (Feito et al., 2018; Gillen & Gibala, 2015; Haugen et al., 2019). The endurance of leg muscles to maintain repetitive contractions over an extended duration can influence the efficacy of the training regimen and the transference of training outcomes to competitive performance(Rum Bismar et al., 2025).

The purpose of this study is to look at the impact of intensive and extensive interval training on the anaerobic and aerobic endurance of football players, with relation to the review variable of leg muscle endurance. The study's findings are expected to assist in the creation of more personalized and effective training programs tailored to the athletes' physical circumstances.

METHODS

This study employs a quantitative descriptive technique utilizing a quasi-experimental research design with two independent variables with one variable with a moderating structure. This study used a pretest-posttest design with two groups. The study sample comprised 24 male individuals from the Sleman Timur Football Academy, all under 14 years of age and having engaged in regular training for one year. The employed sample method is purposive sampling. The categorization of this group is predicated on individuals chosen from the muscle endurance ability assessment, the outcomes of which are subsequently organized from the highest leg muscle endurance scores to those with the lowest, with an upper limit of 27% denoting a high value and a lower limit of 27% indicating a low value (Ketut Wartika et al., 2015). The sample size consists of 12 athletes in the leg muscle endurance ability group and 12 individuals in the leg muscle endurance ability group. The subsequent phase will involve the separation or division utilizing match subject ordinal pairing (MSOP) following the 1 2 2 1 pattern, designed to guarantee equitable treatment among groups. Consequently, the treatment group will be categorized into four high and low groups, with one group comprising six athletes who will undergo extensive interval training and intensive intervals. Exemplar MSOP Pretest group: extensive interval high and low leg muscle endurance, as well as intense interval high and low muscle endurance.

Table 1.
Experimental Group

Independent Variable Interval Training (A)	Variable moderate (B) Leg Muscle Endurance	
	High (B_1)	Low (B2)
Extensive Interval (A_1)	(A_1B_1)	(A_1B_2)
Intensive Interval (A_2)	(A_2B_1)	(A_2B_2)

(A1B1): High leg muscle endurance group engaging in extensive interval training
(A1B2): High leg muscle endurance group engaging in intensive interval training
(A2B1): Low leg muscle endurance group engaging in extensive interval training
(A2B2): Low leg muscle endurance group engaging in intensive interval training

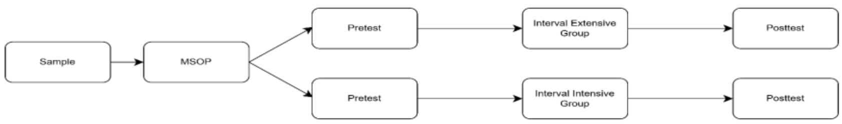

Figure 1.
Pretest and Posttest Group Design

This study took place over six weeks, with three sessions per week. The training occurred over three sessions. During the initial session, namely the opening, athletes will receive an overview of the training program and engage in a warm-up utilising dynamic stretching (Behm et al., 2023; Seçer & Özer Kaya, 2022). The second session is core training, where the extended interval training group maintains an intensity of 60% to 80% HR, executing 9-12 repetitions over distances of 100-400 meters, with rest intervals ranging from 1:0.5 to 1:1. The intensive interval training group engages in activities at an intensity of 80-90% HR, performing 12-15 repetitions over distances of 100-400 meters, with rest intervals ranging from 1:0.5 to 1:5. Before the implementation of the comprehensive interval training programs, a pretest will be conducted to assess the initial aerobic and anaerobic endurance capacities of the athletes. Data acquisition. The Balke test assesses aerobic endurance capacity. The Balke test results will be transformed into VO2max using the formula {(X meters: 15) – 133} x 0.172 + 33.3 (Romero-Gallardo et al., 2022). The anaerobic endurance capacity assessed using running-based anaerobic sprint tests yields results represented as a fatigue index (Shiu et al., 2024). Data analysis employing the paired t-test to compare the outcomes of the pretest and posttest following a comprehensive interval training intervention. An ANOVA test was conducted to analyse how prolonged versus intensive interval training affects anaerobic and aerobic endurance differently. The difference in the influence of muscle endurance on the capacities of aerobic and anaerobic endurance. The correlation between leg muscle endurance and interval training for both aerobic and anaerobic endurance capacities.

Table 2.
The Eight-Week Training Programs

Training	Sessions	Training Program							
		1-week	2-week	3-week	4-week	5-week	6-week	7-week	8-week
Interval Extensive	Intensity	70	70	75	75	75	75	80	80
	Volume	3	3	3	3	3	3	3	3
	Repetition	30	30	20	25	25	30	20	25
	Distance	300	400	200	300	200	300	100	200
	Rest	1:0,5	1:1	1:0,5	1:1	1:0,5	1:1	1:1	1:1
Interval Intensive	Intensity	80	80	85	85	85	90	90	90
	volume	3	3	3	3	3	3	3	3
	Repitition	6	6	7	8	8	9	10	10
	Distance	300	400	200	300	200	300	100	200
	Rest	1:1	1:1	1:2	1:3	1:3	1:4	1:5	1:5

RESULTS AND DISCUSSION

Result

This section will present the research findings, which encompass the following: (1) descriptive outcomes and (2) preliminary assessments (3) analytical tests employing the t-test and ANOVA.

Result Description

The findings of comprehensive research on interval training, both extensive and rigorous, regarding aerobic and anaerobic endurance in regards to leg muscle endurance in football athletes are outlined as follows:

Aerobic Endurance

The findings of comprehensive interval training studies on aerobic and anaerobic endurance. The findings regarding leg muscle endurance in football athletes are detailed in Table 3. Extensive interval training efficiently enhances both aerobic and anaerobic capacities. This is evident from the usual results before and after the implementation of a training regimen utilizing substantial interval training.

Table 3.
Description of Aerobic Endurance Test Result Data

Treatment	Leg muscle endurance level	Statistics	*Pre-test*	*Post-test*
An extensive interval training method	Height (A1B1)	Mean ± SD	45.31 ± 1.79	48.59 ±1.56
	Low (A1B2)	Mean ± SD	44.09 ± 3.76	47.07 ± 4.62
Intensive interval training method	Height (A2B1)	Mean ± SD	43.90 ± 5.45	46.72 ± 4.36
	Low (A2B2)	Mean ± SD	43.67 ± 4.18	46.43 ± 4.13

After doing extended interval training, both the high and low leg muscle endurance groups showed gains in aerobic endurance ability of 3.28 and 2.97, respectively. This means that the difference is bigger in the high leg muscle endurance group, which has a value of 0.31, than in the low leg muscle endurance group. Both the high and the low leg muscle endurance groups showed gains of 2.82 and 2.76, respectively, under intensive interval training. This shows that the high leg muscle endurance group is 0.06 higher than the low leg muscle endurance group.

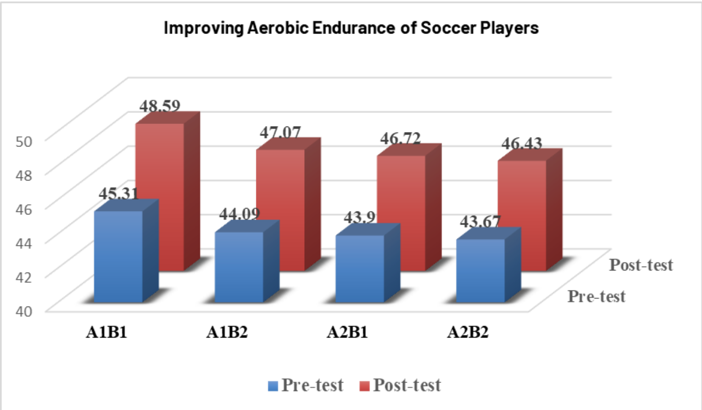

Figure 2.
Histogram of Increase in Aerobic and Anaerobic Endurance of Football Players

Anaerobic Endurance

The descriptive results of the comprehensive and severe interval training groups for anaerobic endurance, namely leg muscle endurance in football participants, are presented in the table. Four Intensive interval training sessions efficiently enhance both aerobic and anaerobic capacities. This is evident from the typical outcomes before and after athletes undergo a training regimen that employs extensive interval training.

Table 4.
Description of Anaerobic Endurance Test Result Data

Treatment	Leg muscle endurance level	Statistics	*Pre-test*	*Post-test*
An extensive interval training method	Height (A1B1)	Mean ± SD	4.85 ± 2.13	3.23 ± 1.56
	Low (A1B2)	Mean ± SD	3.31± 1,24	2.90 ± 1.11
Intensive interval training method	Height (A2B1)	Mean ± SD	3.22 ± 1.17	2.11± 0.52
	Low (A2B2)	Mean ± SD	3.33 ± 1.72	2.22 ± 1.64

The enhancement in anaerobic endurance capacity resulting from comprehensive interval training was observed in both high and low leg muscle endurance groups, with increases of 1.62 and 0.41, respectively. This indicates a more significant disparity of 1.21 for the high leg muscle endurance group in comparison to the low leg muscle endurance group. During severe interval training, both high and low leg muscular endurance groups exhibited an identical gain of 1.12.

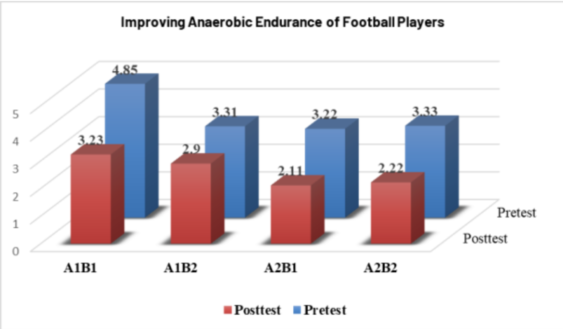

Figure 2.
Histogram of Increase in Aerobic and Anaerobic Endurance of Football Players

Following an explanation of the descriptive results concerning the impact of prolonged and intensive interval training on aerobic and anaerobic endurance, contingent upon the level of leg muscle endurance, the subsequent stage is to perform a statistical analysis. The analysis phase commences with a precondition assessment, namely a normality and homogeneity test, to verify that the data satisfies the fundamental assumptions of parametric analysis. A paired t-test was performed to assess the difference between pretest and posttest values in each treatment group(Kusuma et al., 2023). The two-way ANOVA test was employed to examine the main effects of the independent variables (exercise style and leg muscle endurance criteria) and their interaction on both endurance of aerobic and anaerobic (Sari et al., 2023).

Normality Test

The normality test is a precondition designed to ascertain whether the data for all variables follows a normal distribution. This study used the Kolmogorov-Smirnov analytic technique for the normality test, with calculations facilitated by SPSS 25 software. Data is deemed normally distributed if the significance value surpasses 0.005. The results of the normality test are presented in Table 5 as follows:

Table 5.
Summary of Data Normality Test Results

Group	Variable							
	Aerobic Endurance				Anaerobic Endurance			
	A1B1	A1B2	A2B1	A2B2	A1B1	A1B2	A2B1	A2B2
Pretest	0.219	0.119	0.865	0.671	0.655	0.111	0.900	0.338
Posttest	0.129	0.063	0.161	0.108	0.806	0.094	0.458	0.186

According to Table 5, the test of normality findings indicates that all study variables exhibit a significance value over 0.05, so establishing that all variables are normally distributed, allowing for the continuation of the data precondition test with the homogeneity assessment.

Homogeneity Test

The homogeneity test is a prerequisite in data analysis that aims to test whether the variables of two or more distributions are the same. The homogeneity test in this study was carried out with the help of *software SPSS* 25. The results of the homogeneity test can be seen in Table 6 as follows:

Table 6.

Summary Results of Data Homogeneity Test

Variables	*Sig.*	Information
Aerobic endurance	0.350	Homogen
Anaerobic endurance	0.194	Homogen

The homogeneity test is a fundamental requirement in data analysis that seeks to determine whether the variables of two or more distributions are identical. The homogeneity test in this study was conducted using the SPSS version 25 program. The outcomes of the results of the homogeneity test are displayed in Table 6 as follows:

T-test

Extensive Interval

The hypothesis is tested using the paired sample T-test that "extensive interval training significantly affects aerobic and anaerobic endurance," based on pretest and posttest findings. If the analysis findings indicate a considerable difference, it signifies an effect of aerobic and anaerobic endurance. The analysis in this study indicates that a significant value below $p.0.000 < 0.05$ is observed. The outcomes of the data analysis are presented in Table 7 below:

Table 7.

T-test Result of Extensive Interval

Variable	Average	Group	Sig.
Aerobic Endurance	44.96	Pretest	0.000
	48.16	Posttest	
Anaerobic Endurance	4.08	Pretest	0.000
	3.28	Posttest	

*Aerobic endurance uses VO2max, and Anaerobic Endurance uses Fatigue Index

The paired sample t-test results indicate a significance value of 0.000, which is below 0.005, signifying a substantial difference. Thus, the hypothesis stating "extensive interval training significantly affects aerobic and anaerobic endurance capabilities" is accepted. The mean VO2max for aerobic endurance capacity rose from 44.96 in the pretest to 48.16 in the posttest, an increase of 3.20. The mean pretest fatigue index for anaerobic endurance capacity was 4.08, which diminished to 3.28 during the posttest, reflecting a decrease of 0.8.

Intensive Interval

The paired sample T-test is utilized to verify the hypothesis that "intensive interval training significantly influences aerobic and anaerobic endurance," derived from the outcomes of the pretest and posttest. If the analysis results reveal a significant

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difference, it indicates an impact of aerobic and anaerobic endurance. The analysis in this study reveals a significant value below p. 0.000, which is less than 0.05. Table 8 below shows the outcomes of the data:

Table 8.
T-test Result of Extensive Interval

Variable	Average	Group	Sig.
Aerobic Endurance	43.78 46.57	Pretest Posttest	0.000
Anaerobic Endurance	3.28 2.16	Pretest Posttest	0.000

The results of the paired sample t-test indicate a significance value of 0.000, which is below the threshold of 0.005, highlighting a significant difference. As a result, the hypothesis stating that "extensive interval training significantly influences both aerobic and anaerobic endurance capabilities" is accepted. The average VO2max pretest result for aerobic endurance capacity was 43.78, which increased to 46.57 in the posttest, reflecting an enhancement of 2.79. The average pretest fatigue index for anaerobic endurance capacity was 3.28, which decreased to 2.16 following the posttest, a reduction of 1.12.

ANOVA Test

The effects interval training method on aerobic and anaerobic endurance capacity

This study hypothesises that there is a significant difference in the effects of extensive interval training versus intensive interval training on aerobic and anaerobic endurance. The analytical results demonstrate that the data in Table 9 are as follows:

Table 9.
ANOVA Result of the Interval Method

Variable	*Source*	*Degree of Freedom*	*Mean Square*	*F Value*	*Sig.*
Aerobic endurance	Practice	1	9,425	0,630	0,437
Anaerobic Endurance	method	1	4,905	2,962	0,101

Table 9 indicates that the ANOVA test results yield a significant value of 0.437. The p-value of 0.437, exceeding the threshold of 0.05, shows no notable difference in the impact of long interval training versus short interval training on the aerobic endurance of football players.

The effect of leg muscle endurance on aerobic and anaerobic endurance capabilities

The second hypothesis examined in this study posits that "There exists a significant disparity in the impact of football players with high versus low leg muscle endurance on both aerobic and anaerobic endurance." According to the analytical results, the data presented in Table 9 are as follows:

Table 10.
ANOVA Result of Leg Muscle Endurance

Variable	*Source*	*Degree of Freedom*	*Mean Square*	*F Value*	*Sig.*
Aerobic endurance	Leg muscle endurance	1	9,425	0,630	0,437
Anaerobic Endurance		1	4,905	2,962	0,101

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The ANOVA test results presented in Table 10 indicate a value of 0.573, which is deemed significant. The p-value stands at 0.573, exceeding the threshold of 0.05. This indicates that there is minimal variation in the impact of leg muscle endurance on aerobic endurance among football players, regardless of whether they possess high or low endurance levels.

Relations of the interval training method and leg muscle endurance

The third hypothesis examined in this study posits that there is an interaction between extensive interval training and intense interval training, as well as leg muscle endurance (both high and low), on the aerobic and anaerobic endurance of football players. The analytical results indicate that the data presented in Table 10 are as follows:

Table 10.
ANOVA Result: Interaction Between the Effects of Interval Training and Leg Muscle Endurance

Variable	*Source*	*Degree of Freedom*	*Mean Square*	*F Value*	*Sig.*
Aerobic Endurance	Training Method	1	9,425	0,630	0,437
Anaerobic Endurance	*Leg muscle endurance	1	4,905	2,962	0,101

Table 10 shows that the ANOVA test results have a significant value of 0.700. Since the significance is 0.700, which is higher than 0.05, we can say that there is no relationship between leg muscle endurance (high and low) and extended interval training and intensive interval training on the aerobic endurance of football players.

Discussion

The data analysis results indicate a substantial impact on both aerobic and anaerobic endurance following lengthy and severe interval training. The extensive interval training group had superior average aerobic endurance results compared to the intensive interval training group. These findings align with the research undertaken by Sulastio (2016), which demonstrated that prolonged interval training is superior to intensive interval training. Moreover, a study conducted by Yamin and Gusril (2020) demonstrates that prolonged interval training surpasses intensive interval training in enhancing aerobic endurance. Football players with well-developed leg muscles outperform those with less muscular legs in both aerobic and anaerobic endurance. Consistent with prior research, players exhibiting high leg muscle endurance demonstrate superior aerobic and anaerobic endurance relative to those with low leg muscle endurance (Adhi & Soenyoto, 2017; Ahsan & Ali, 2021; Mackała et al., 2020; Prakoso & Sugiyanto, 2017). Subsequent analysis utilizing the ANOVA test revealed no effect of the training strategy on leg muscular endurance, nor a significant interaction among the three hypotheses posited by the researcher. This outcome may be attributable to the demographic age of the study population.

Numerous studies have demonstrated variations in endurance capabilities across different age demographics. Research on the U-10 age group indicated an average endurance capacity of 42.70 ml/kg/min (Jukic et al., 2019). A research by Di Giminiani and Visca (2017) involving elite athletes under 15 years, who had been trained for around seven years, revealed an average endurance capacity of 48.04 ml/kg/min for Under 13 years, 49.84 ml/kg/min for 14 years, and 50.74 ml/kg/min for U-15. Moreover, a study on elite junior players from U-17 to U-21 indicates an average endurance capacity of 56.9 ml/kg/min for 17-year-olds, 54.9 ml/kg/min for 19-year-olds, and 55 ml/kg/min for 21-year-olds (Hoppe et al., 2020). The 13-year-old male football players involved in this study were younger than the age cohorts utilized in earlier comparable training research (Alkayis, 2019; Di Giminiani & Visca, 2017; Hoppe et al., 2020; Jukic et al., 2019). Children of this age have a more generalized training response in contrast to adults. Murphy et al. (2015) indicated that children struggle to comprehend the distinction between maximum and submaximal contraction intensity. Children exhibit reduced fatigue levels, making concurrent training less prone to induce overtraining stress. Moreover, several elements influencing endurance capacity include hereditary or genetic characteristics that determine the functionality of the heart, lungs, red blood cells, and haemoglobin (Pandey & Kitzman, 2021; Romain et al., 2019). The research concludes that the maximum aerobic endurance capacity is 93.4% influenced by genetic factors, which can only be modified through exercise (Bıçakçı et al., 2024), indicating that individuals with high endurance will transmit this trait to their offspring. Genetics accounts for around 40% of cardiovascular capacity, which can be modified via consistent exercise (Abassi et al., 2019). Genetic factors influence variations in strength, limb mobility, running velocity, response time, flexibility, and balance among individuals (Akbar et al., 2022; Appel et al., 2021; Polak & Wojtuń-Sikora, 2022). Numerous factors affect aerobic endurance, such as the maximal capacity of the respiratory and circulatory systems, an enlarged heart, and an increased quantity of red blood cells and haemoglobin (Joyner & Dominelli, 2021; Mohamed & Alawna, 2020). Leg muscle endurance is regulated by various factors, including fundamental muscular characteristics such as muscle mass, muscle integrity, and muscle activation. Moreover, there are overarching aspects such as physical activity (resistance training) and sports therapy, endocrine and metabolic influences, nutrition and vitamins, as well as demographic variables. Specific aspects include joint degradation, biomechanical elements, inflammatory indicators, and discomfort (De Zwart et al., 2018).

CONCLUSION

The authors found that both extensive and intensive interval training significantly enhance aerobic and anaerobic endurance, with no notable differences between the two approaches. Moreover, variations in muscle capacity influenced both aerobic and anaerobic endurance; however, no significant difference or interaction was found between interval training methods and levels of muscle endurance capacity. Subsequent research recommendations advocate for the inclusion of older participants and a greater number of professional athletes as subjects in the study. Furthermore, it is feasible to incorporate evaluative criteria beyond leg muscle endurance to enhance the optimization and maximization of both aerobic and anaerobic endurance capacities.

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