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Acute effect of functional exercise through the use of battle rope on the skeletal muscles of tennis court student-athletes

Mahmuddin^{abde*}, Asep Prima^{abcd}, David Siahaan^{acd},
& Rafika Ardilla^{bcd}

Universitas Negeri Medan, Indonesia

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ABSTRACT

Background Problems: There has not been much research on how exercise strategies affect muscle soreness and activation patterns. **Research Objectives:** This study examines the acute effects of rope-based functional training on muscle group pain response in student athletes at the Faculty of Sport Science, Universitas Negeri Medan tennis court. **Methods:** An experimental method and a pre-post-test time series design were used for analysis. Seven samples were selected using purposive sampling. All participants engaged in a warm-up, a central phase of rope training with a maximum of three sets per exercise, ten hand swing repetitions, a one-minute break between sets, and a cooling phase. Three 100-mm VAS and painometer data collection sessions were conducted. At a 0.05 significance level, the research data was examined using one-way ANOVA for normal data and Friedman for aberrant data. Both studies used SPSS 16.0. **Findings and Results:** The trial demonstrated that rope training induces soreness in all working muscles. However, no muscle group exhibited discomfort above 50 mm. **Conclusion:** In order to optimally activate muscles, determine exercise doses and blood lactate levels in relation to muscle discomfort, it is necessary to understand how battle rope training reduces muscular soreness and improves muscle activation in student-athletes on the tennis court. This understanding can inform the development of personalised training programmes and injury prevention techniques.

Keywords: Resistance training; functional training; battle rope exercise; tennis court; muscle soreness



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Corresponding Author: Mahmuddin, ¹Department of Sports Coaching Education, Faculty of Sports Science, Universitas Negeri Medan, Medan, Indonesia
Email: mahmuddin@unimed.ac.id

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Authors' Contribution: a – Study Design; b – Data Collection; c – Statistical Analysis; d – Manuscript Preparation; e – Funds Collection

INTRODUCTION

The human body has about 40 percent skeletal muscle from the total body weight of each individual, and these muscles contribute significantly to various body functions (Frontera & Ochala, 2015). Size reduction can occur in muscles, either type II or type I fibres, due to decreased training frequency, restriction or removal of load, and passive rest (Vikne et al., 2020). The long-term impact of these three variables results in instability or even loss of function in various parts of the muscle. The tendency of muscle fibre type in men and women is different; men tend to be fast-twitch muscle fibre type (type II), while women tend to be slow-twitch muscle fibre type (type I), but muscle adaptation after being given resistance training intervention has no difference

(Landen et al., 2023). Meanwhile, fibre types in tennis players get a 2:3 ratio between fibre types I and II (Sung et al., 2020). However, this still needs to be debated because it cannot be concluded thoroughly or specifically which muscles are fibre types I and II, and in addition, dominant muscles have the advantage of muscle fibre percentage distribution over non-dominant muscles (Mavidis et al., 2007; Sanchis-Moysi et al., 2010). Muscle fibre type transitions are possible with either slow- or fast-twitch fibres, depending on the characteristics of the exercise and sport (Plotkin et al., 2021).

Currently, there are limited studies that specifically examine the acute effects of functional exercise using battle ropes on the skeletal muscles of tennis court student-athletes (Fernandez-Fernandez et al., 2014; Murphy et al., 2014; Xiao et al., 2023). However, there are several studies that have explored the effects of battle rope training on skeletal muscles in various populations (Calatayud et al., 2015; Chen et al., 2018; Chen et al., 2020). Two studies conducted by Chen et al. (2020) and Calatayud et al. (2015) investigated the acute effects of battle rope exercise on muscle activation and fatigue in trained individuals. They found that battle rope exercises elicited high levels of muscle activation in various muscle groups, including the upper body, core, and lower body. These findings suggest that battle rope exercises might have a beneficial impact on the skeletal muscles of tennis court student-athletes by targeting multiple muscle groups and promoting muscle activation and fatigue resistance.

Battle rope training is one type of exercise that can be used to activate muscle contractions in the arms and torso through both unilateral waves and bilateral waves (Calatayud et al., 2015; Salzgeber et al., 2019). In addition to making the muscles active, this exercise also has a directly proportional impact on increasing overall body muscle strength for the Double Arm Slams and Double Arm Waves exercises, but for several other types of exercises, it only has an impact on certain muscle parts (Salzgeber et al., 2019). Additionally, functional training through the use of ropes also has acute effects on the metabolic system and is known to be more effective in improving heart-lung endurance than traditional resistance training (Ratamess et al., 2015).

While the potential advantages of battle rope training have been explored in various athletic contexts, its specific impact on the skeletal muscles of tennis court student-athletes remains largely uncharted territory (Fernandez-Fernandez et al., 2014; Reid & Duffield, 2014). Understanding the acute effects of this functional exercise modality on the muscular system could provide valuable insights into optimising training protocols, enhancing performance, and mitigating injury risks for these athletes (Tibana & Sousa, 2018). Investigating the acute effects on muscle activation patterns, fatigue response, and potential adaptations could guide the development of tailored training programmes for tennis court student-athletes (Fernandez-Fernandez et al., 2014). Furthermore, examining the impact of battle rope training on specific muscle groups crucial for tennis, such as the rotator cuff, shoulder, and core musculature, could contribute to injury prevention strategies (Kovacs, 2007; Pas et al., 2018).

Due to the wide variety of exercises that can be performed through the use of ropes, a few exercises will be selected based on the effectiveness of the form of exercise that has been researched and the similarity of the muscles that are contracted (Sarojini & Kavithashri, 2022), between the movements in battle rope training and hitting techniques in tennis courts (Calatayud et al., 2015; Salzgeber et al., 2019). The types of exercises selected include double arm slams, double arm waves, double alternating waves, double outside circles, double inside circles, and single arm waves. After these exercises have been demonstrated by tennis court student athletes, this study will look at the acute impact of functional training through the use of ropes on pain response in almost all parts of the muscle.

METHOD

Type of Research

This study was designed to assess the physical response to exercise through an experimental approach and a pre-post-test time-series design.

Participants

Seven field tennis students were selected based on the requirements that had been met, including (1) active students, (2) technical test results in the maximum category B, (3) participation in the training programme, and (4) participation in the muscle pain test.

Research Procedures

The training protocol is divided into three stages, namely the opening stage through praying activities, explanation of movement implementation, & dynamic stretching; the second stage through Double Arm Slams, Double Arm Waves, Double Alternating Waves, Double Outside Circles, Double Inside Circles, and Single Arm Waves exercises for three sets with repetitions of ten hand swings (up-down and full circular swings) and the duration of rest per set for one minute; finally, the third stage through static stretching activities and praying.

Table 1. Battle Rope Exercise Flow

Name of Exercise	Sets	Exercise Duration per Set (sec.)	Interval Rest Duration per Set (sec.)
1. Double Arm Slams	3	20	40
2. Double Arm Waves	3	20	40
3. Double Alternating Waves	3	20	40
4. Double Outside Circles	3	20	40
5. Double Inside Circles	3	20	40
6. Single Arm Waves - Right Hand	3	20	40
7. Single Arm Waves - Left Hand	3	20	40

Instrument

The data collection procedure was carried out three times and was divided into three value categories, namely the reference, pre-test, and post-test value categories. The reference value category was studied before dynamic stretching, after dynamic stretching, and after treatment without pause. Muscle pain data was obtained through the 100-mm visual analogue scale (VAS) method with a description of 0 without pain indication and 100 indicating severe pain (Mattacola et al., 1997). The VAS scale is used through the utilisation of the Painometer application (de la Vega et al., 2014).

Data Analysis

The research data were analysed through the within-subjects design one-way ANOVA test for normally distributed data, while non-normally distributed data was analysed through the Friedman test. Statistical significance was set at $p > 0.05$, and all data were analysed through SPSS version 16.0.

RESULTS AND DISCUSSION

In detail, Figure 1 obtained a comparison between pain test results where the highest data distribution is in the thigh muscle pain test with a value range of 13 to 17, while the lowest data distribution is in the calf muscle pain test with a value range of 6 to 11. The uniqueness of this diagram is shown by the position of the median line (whole line) not in the centre of the box plot, and the whiskers lines of both the upper and lower groups for almost all test items do not have the same length and do not even have lines, so the kurtosis curve is not

symmetrical or skewed, and this can be interpreted as indicating that the data distribution is not normal. For test items that do not have a lower group (lower whiskers line), it means that the data is gathered in the middle group (box plot). In addition, there are some test items that have mean (dashed line) and median (solid line) values that are almost and even the same, such as in the forearm, shoulder, and calf muscles, while the other three test items have mean values that are higher than the median value or vice versa. In addition, the upper arm and shoulder muscle pain tests have almost extreme data (outliers), and the curves of these data tend to be skewed to the right (positive skewness), while the thigh muscles tend to be skewed towards the left (negative skewness).

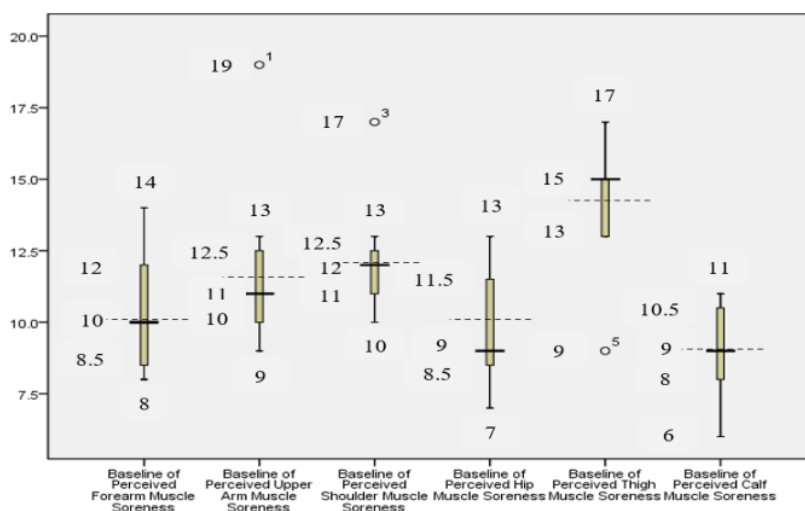


Figure 1. Diagram of Baseline Values of Muscle Pain Scale

Furthermore, the interpretation of the Boxplot diagram displayed in Figure 2 in detail obtained the distribution of data in the form of a difference of one point sequentially in the calf, pelvis, forearm, and thigh muscle pain tests, with the lowest value range (whiskers and box plot) being 8 to 11, while the other test results obtained values of 13 to 14. Then, the highest value data distribution on the whiskers and box plot lines has a value range of 15 to 17 for upper arm, shoulder, and pelvis and calf muscle pain (the same value). Other results were obtained with a value range of 19 to 20 for the forearm and thigh muscles. It can be concluded from the data distribution of each muscle pain test that both the lowest and highest values are in the range of values that are not far apart. Meanwhile, the distribution of data in the middle group (box plot) looks more varied. Of all the test items, only the upper arm muscle pain test does not have whiskers lines, which means that the data is gathered in one group.

The diagram of the pre-test data (Test 1) presents a symmetrical shape of the kurtosis curve because the median line is in the centre of the box and the size of the whiskers lines is almost the same between the upper and lower groups in the calf muscle pain test, so it can be concluded that the distribution of data is normal. The data distribution for other test results obtained a skewed curve because the position of the median line and/or whiskers line is not equal. Another fact is that almost all test items that obtained mean and median values were almost and even overlapping each other, except for, yes, upper arm muscle pain. Additional info: the upper arm muscle pain test has outlier data with negative skewness and extreme data with positive skewness, and the outlier value of the shoulder muscle is positive skewness.

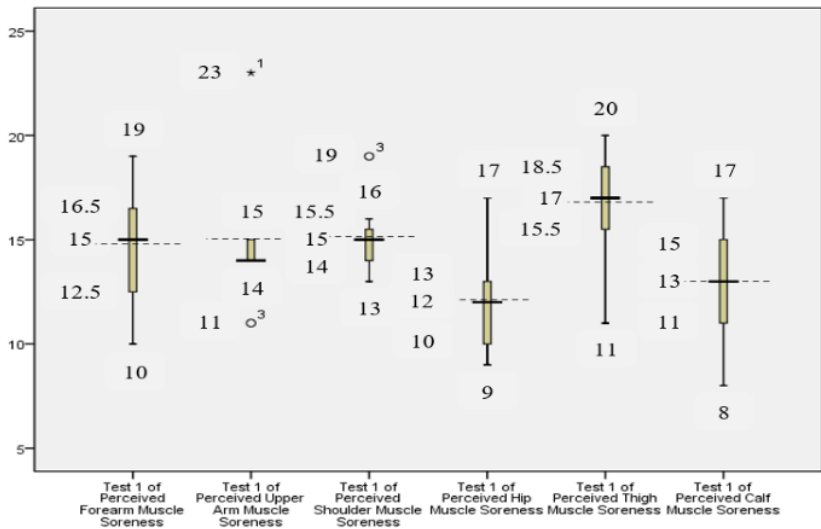


Figure 2. Diagram of Pre-Test Values of Muscle Pain Scale

The last figure is the post-treatment muscle pain test (Test 2) and shows a normal distribution of data only in the shoulder muscle pain test, so that through this data, a symmetrical curve will be formed. Then, the difference in values between the lowest and highest values (outside the extreme values) obtained the lowest data in the calf muscle pain test and the highest in the forearm muscle pain test. There are no outlier values in each test item, but there are extreme values only in the upper arm pain test. Almost all test items obtained mean and median values that were almost the same because the two lines were close together and even overlapped, except for the upper arm pain test, which was far apart. Comparison of the size of the whiskers lines in various tests obtained almost the same length difference in the lower and upper groups. However, the forearm muscle pain test obtained contrasting line lengths, which means that there is a considerable range of values between the upper and middle groups.

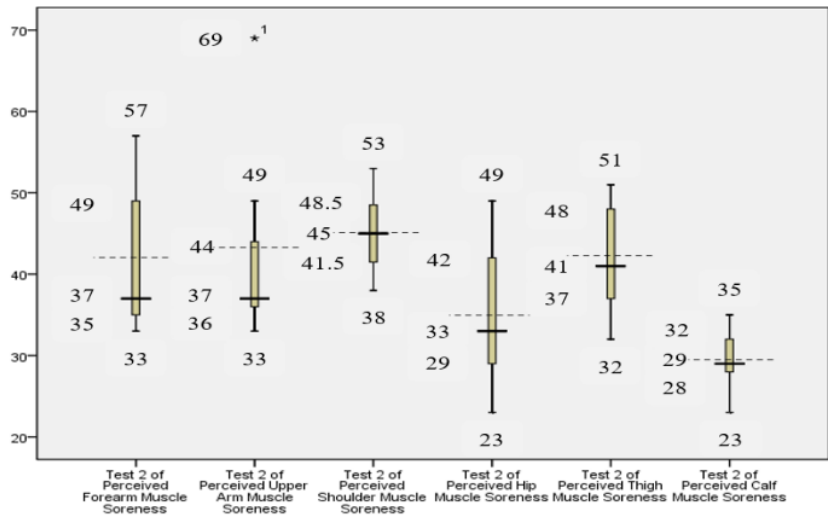


Figure 3. Diagram of Post Test Values of Muscle Pain Scale

From a sample of 17 tennis court student athletes, the data from all muscle pain test items were normally distributed, where the significance value (sig.) was greater than the probability value (p-value) of 0.05. However, the upper arm muscle pain item was not obtained from normally distributed data because the sig. values at the pre-test and post-test were 0.015 and 0.012, respectively, and the value was smaller than the p-value. Therefore, all test items will proceed to the hypothesis testing stage through the within-subjects design one-way ANOVA test, except for the upper arm muscle pain test tested through the Friedman test.

Table 1. Results of Normality Test through Saphiro-Wilk Test

Muscle Pain Test	Degree of Freedom	Baseline Values		Pre-Test Values		Post Test Values	
		Statistic	Sig.	Statistic	Sig.	Statistic	Sig.
Forearm muscle pain	7	0.909	0.389	0.963	0.842	0.847	0.116
Upper arm muscle pain		0.822	0.067	0.757	0.015	0.747	0.012
Shoulder muscle pain		0.830	0.081	0.869	0.182	0.907	0.373
Hip muscle pain		0.886	0.253	0.913	0.414	0.909	0.389
Thigh muscle pain		0.888	0.263	0.939	0.631	0.920	0.468
Calf muscle pain		0.927	0.529	0.916	0.440	0.951	0.742

The results of the hypothesis test obtained in the Greenhouse-Geisser section show that the sig. value ranging from forearm muscle pain to calf muscle pain is smaller than the p-value of 0.05. This can be interpreted as indicating that there is a difference in the average value in each category, both reference, pre-test, and post-test. In other words, functional training using ropes significantly reduces the level of muscle pain in the forearms, shoulders, pelvis, thighs, and calves of tennis court student athletes at the Faculty of Sport Science, Universitas Negeri Medan. Then, the results of the upper arm muscle pain test through the Friedman test obtained a sig. asymptotic value smaller than the sig. alpha level of 0.05, so there is a real difference in average values, and it can be concluded that this exercise has a significant impact on the level of upper arm muscle pain.

Table 2. Hypothesis Test and Mean Value Comparison

Muscle Pain Test	One-Way Anova Test Within-Subjects Design			Mean Value Comparison		
	Degree of Freedom	F	Sig.	Baseline	Pre-Test	Post Test
Forearm muscle pain	1.037	63.576	0.001	10.429	14.571	42.143
Shoulder muscle pain	1.087	185.642	0.001	12.286	15.143	45.143
Hip muscle pain	1.035	60.390	0.001	9.857	12.000	35.286
Thigh muscle pain	1.034	120.024	0.001	13.857	16.571	42.000
Calf muscle pain	1.285	115.892	0.001	9.000	12.857	29.571

Muscle Pain Test	Friedman Test		Mean Value Comparison			
	Degree of Freedom	Chi-Square	Asymptotic Sig.	Baseline	Pre-Test	Post Test
Upper arm muscle pain	2	14.000	0.001	12.000	15.143	42.174

The research findings in the document offer valuable insights into the impact of utilising ropes for functional training on muscle discomfort among tennis court student athletes at the Faculty of Sport Science at Universitas Negeri Medan. The study examined muscle pain levels in various body areas such as forearms, upper arms, shoulders, hips, thighs, and calves at different stages: baseline, pre-test, and post-test. The results revealed a substantial difference in average muscle pain levels across all tested areas, indicating that functional rope training significantly reduced muscle discomfort. These results align with previous studies showing the effectiveness of functional training in alleviating muscle pain and enhancing overall physical performance (Chen et al., 2018; Chen et al., 2020; Xiao et al., 2021).

Further data interpretation on the comparison of mean values between reference, pre-test, and post-test values obtained a significant increase in muscle pain from the pre-test value to the post-test value (Chen et al., 2020), and in addition to the effects of pain, damage is also experienced by working muscles, especially in

high-intensity endurance activities (Khajehlandi & Janbozorgi, 2018). Meanwhile, the low difference between the reference value and the pre-test is perceived as an acute effect of the muscle after dynamic stretching (Opplert & Babault, 2018). However, overall, the data on the increase in muscle soreness level after being given the training treatment was not at more than 50 mm, so the Faculty of Sport Science Universitas Negeri Medan tennis student athletes did not really feel the effects of intense pain after being given the selected rope training movements with predetermined sets, repetitions, and treatment-rest intervals. Thus, there is a need to regulate the training load through the number of sets, reps, and duration between treatment and rest given so that this will be in line with the increase in muscle pain, and the pain stimulus makes the muscles adapt to the next increase in training load (Tufano et al., 2017). Additionally, the weight of the rope can be an alternative in analysing the acute effects of training and improving the physiological capabilities of athletes (Bornath & Kenno, 2022).

The pain caused in the muscles is a stimulus from rope resistance training (Ratamess et al., 2015), and the effect is metabolic stress that triggers mitochondrial adaptation to produce energy (Fontaine & Schmidt, 2015; Groennebaek & Vissing, 2017). Adaptations to the mitochondria allow the body to be able to deal with the load, so it has a relationship to increase its ability in muscle tissue (Ibraheem et al., 2019; Panchabhai & Kulkarni, 2019). Then, it also has abundant chronic effects on various physical dimensions, especially upper body performance (Chen et al., 2018).

The importance of these findings lies in their potential to inform training practices for tennis players and other athletes. Muscle pain can be a significant barrier to optimal performance and can increase the risk of injury (Delos et al., 2013; Teixeira et al., 2016; Wiewelhove et al., 2015). By demonstrating the effectiveness of functional training using ropes in reducing muscle pain, this study provides a potential strategy for athletes and coaches to incorporate into their training regimens. Moreover, the results suggest that this type of training may have broad applicability across multiple muscle groups, making it a versatile tool for addressing muscle pain in various parts of the body. The implications of these findings extend beyond tennis, as functional training using ropes could potentially benefit athletes in other sports that involve similar muscle groups and movement patterns (Chen et al., 2018; Xiao et al., 2021). Furthermore, the study's methodology, which involved comparing muscle pain levels at different stages of training, could serve as a model for future research investigating the effects of various training interventions on muscle pain and other performance-related outcomes.

The study has several limitations that may impact the interpretation and generalizability of the results. Firstly, the sample size of seven tennis court student-athletes is relatively small, which could limit the statistical power and external validity of the findings (Faber & Fonseca, 2014). A larger sample size would provide more robust and representative results. Secondly, the study lacks a control group, making it difficult to attribute the observed changes in muscle pain solely to the battle rope training intervention (Hariton & Locascio, 2018). The inclusion of a control group would help to account for potential confounding factors and strengthen the internal validity of the study. Additionally, the study relies on subjective measures of muscle pain using the visual analogue scale (VAS), which may be influenced by individual perceptions and biases (Hawker et al., 2011). Incorporating objective measures, such as electromyography or muscle biopsy, could provide more accurate and reliable data on muscle activation and adaptation (Jain & Garg, 2021; Schoenfeld, 2012). Furthermore, longitudinal studies with follow-up assessments would provide valuable insights into the chronic effects of this training modality on skeletal muscles and athletic performance (Legerlotz et al., 2016).

CONCLUSION

In the present invention, it can be concluded that rope training elicits a pain response in actively contracting muscles. Overall, pain was felt in the muscles of the upper body due to muscle engagement during the movements. In addition, the same thing was also felt in the muscles of the lower body, but only in the thighs. This was due to isometric contraction during the activity. The other findings suggest that this training modality can be a valuable tool for athletes and coaches to incorporate into their training regimens, as it has the potential to alleviate muscle discomfort and enhance overall physical performance. In particular, this exercise is most often used during the general and specific preparation phases of periodization to develop a foundation of

strength, power, and endurance, which can then translate into sport-specific performance. The study's methodology, which involved comparing muscle pain levels at different stages of training, could serve as a model for future research investigating the effects of various training interventions on muscle pain and other performance-related outcomes. The monitoring of fatigue as a result of exercise is crucial for the determination of the training load. This is achieved through the use of inexpensive equipment, namely the visual analogue scale (VAS) method. Despite the limitations of a small sample size, lack of a control group, and reliance on subjective measures, the results have practical implications for tennis players and athletes in other sports involving similar muscle groups and movement patterns. Further research with larger sample sizes, control groups, objective measures, and longitudinal designs would strengthen the understanding of the acute and chronic effects of battle rope training on skeletal muscles and athletic performance.

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CONFLICT OF INTEREST

There are no conflicts of interest for any party in this research or finding.

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