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Post-Exercise Stretching for Reducing Muscle Pain in Badminton Players: A Parallel Randomized Controlled Trial

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Abstract

Introduction: Muscle pain is a frequent post-exercise complaint resulting from excessive or unaccustomed muscle contractions. Although post-exercise stretching is recommended as a non-pharmacological method to improve flexibility and reduce muscle pain, many university athletes still neglect this practice. This study aimed to evaluate the effectiveness of post-exercise stretching in reducing muscle pain among badminton players.

Methods: A parallel randomized controlled trial was conducted involving 32 active medical students from Universitas Swadaya Gunung Jati (UGJ) who were members of the university badminton club. Participants were randomly assigned in a 1:1 ratio to either a control group (no stretching) or an intervention group performing a supervised 10-minute dynamic stretching protocol after training. Muscle pain was measured using the Numeric Pain Scale (NPS; 0–10) at baseline and three post-test time points within 24 hours. Data were analyzed using the Wilcoxon signed-rank test and Mann–Whitney U test.

Results: All participants completed the study. The intervention group showed a significant reduction in pain scores from 3.3 ± 2.8 to 2.0 ± 1.7 ($p = 0.003$), while the control group experienced an increase from 3.1 ± 2.0 to 5.7 ± 2.2 ($p = 0.001$). Post-test comparison showed lower pain levels in the stretching group than in the control group (median 1.5 vs 5.0; $p = 0.001$), with a large effect size ($r = 0.74$).

Conclusion: Post-exercise stretching effectively reduces muscle pain and helps prevent symptom progression in young badminton players. Implementing structured stretching after training is recommended to enhance recovery.

Keywords
Muscle Stretching Exercises; Muscle Pain; Badminton; Pain Measurement.

Introduction

Regular physical activity and sports participation have become an integral part of a healthy lifestyle in modern society.[1] However, the increased intensity and frequency of training are not always accompanied by appropriate recovery strategies such as post-exercise stretching. This imbalance can contribute to muscle pain, particularly in the form of delayed onset muscle soreness (DOMS), which typically appears 12–24 hours after exercise and may persist for up to 72 hours.[2] DOMS is characterized by muscle pain, stiffness, and reduced function, and can be considered a mild manifestation of musculoskeletal disorders (MSDs) arising from excessive muscle use without adequate recovery.[3]

Myalgia is a common complaint in the general population and is often described as "achy" or "sore" muscles.[4] Muscle pain is not a disease entity but a symptom that may be caused by inappropriate posture or movement patterns during exercise, muscle injury, infection, or adverse drug effects.[4,5] Musculoskeletal complaints are typically episodic, with pain that may subside or disappear but can reappear under similar loading conditions.[5] Stretching is a physical activity aimed at increasing muscle flexibility and joint mobility, reducing muscle tightness and pain, and improving muscle function.[6]

Globally, an estimated 1.71 billion people live with musculoskeletal conditions, with Southeast Asia contributing approximately 369 million cases.[7] In Indonesia, the prevalence of musculoskeletal disorders is reported to be around 7.3%,[8] with higher rates in certain provinces, such as West Java (approximately 8.86%). In Cirebon City, the prevalence of musculoskeletal disorders is about 4.96%, and local health data report 22,648 cases of myalgia.[9,10] Despite this high burden, the practice of post-exercise stretching remains uncommon among active university students in the Faculty of Medicine at Universitas Swadaya Gunung Jati (UGJ), including those involved in competitive sports such as badminton.

Previous studies have demonstrated the beneficial effects of stretching in reducing musculoskeletal complaints. For example, Purwantini et al. reported that stretching exercises effectively reduced musculoskeletal disorder (MSD)–related pain among workers.[11] Similar findings were observed by Andari et al. in office workers with low back pain and by Amalia et al. in nurses with low back pain, where structured stretching programs significantly reduced pain intensity.[12,13] However, most of these studies were conducted in occupational settings rather than in student or athlete populations, and few specifically examined the effects of post-exercise stretching in badminton players.

Badminton is a high-intensity racket sport that involves rapid changes in direction, jumping, lunging, and repetitive overhead movements, all of which impose substantial mechanical loads on the musculoskeletal system and increase the risk of DOMS and overuse complaints.[14] The novelty of the present study lies in its focus on evaluating the effectiveness of a structured post-exercise dynamic stretching protocol in reducing muscle pain among university badminton players using a randomized controlled design. This is particularly relevant in the Indonesian context, where data on recovery strategies in student athletes remain limited.

Given the high prevalence of musculoskeletal complaints and the frequent neglect of post-exercise stretching among active university badminton players, there is a clear need to evaluate its effectiveness scientifically in this population. Therefore, this study was conducted to provide evidence that can inform preventive strategies and recovery protocols in sports medicine and physiotherapy.

This study aimed to evaluate the effectiveness of post-exercise stretching in reducing muscle pain among badminton players who are medical students at UGJ by comparing changes in muscle pain scores between an intervention group receiving post-exercise stretching and a control group without stretching. The study hypothesized that post-exercise stretching would significantly reduce muscle pain intensity in badminton players compared with no stretching intervention.

Methods

This study was designed as a parallel randomized controlled trial with a 1:1 allocation ratio between the intervention and control groups. The study protocol did not undergo any changes after the trial commenced. The trial was conducted at GOR KORPRI, Cirebon, Indonesia, which is the regular training venue for the badminton student activity unit (Kelompok Kegiatan Mahasiswa/KKM Badminton) of the Faculty of Medicine, Universitas Swadaya Gunung Jati (UGJ). All data collection took place between April and May 2025. Participants were recruited from active medical students who were members of KKM Badminton FK UGJ. Recruitment was carried out on 17 April 2025. All participants were followed for 24 hours after the intervention, with standardized post-test measurements during this period.

Participants included active medical students from the Faculty of Medicine at UGJ who were registered members of the KKM Badminton group, aged approximately 15–27 years, in good general health, able to participate in regular badminton training, and willing to provide informed consent. Exclusion criteria encompassed any current musculoskeletal injury or ongoing treatment for musculoskeletal conditions, any known acute or chronic medical conditions that could affect exercise tolerance or pain perception, and the current use of analgesics, muscle relaxants, vitamins, or special diets that might influence recovery or pain perception. Drop-out criteria included withdrawal of consent during the study, failure to attend scheduled training and measurement sessions within the data collection period, or incomplete participation in the post-exercise stretching protocol for those in the intervention group.

A total sampling approach was used, whereby all eligible members of KKM Badminton FK UGJ (n = 32) were invited and enrolled in the study. Therefore, no a priori sample size calculation based on power and effect size was performed. All 32 participants were randomized and included in the final analysis. The random allocation sequence was generated using a computer-based random number generator. Simple randomization without stratification or blocking was applied. Participants were randomly assigned in a 1:1 ratio to either the intervention group (post-exercise stretching) or the control group (no stretching).

Allocation concealment was implemented using sequentially numbered, opaque, sealed envelopes. The randomization sequence was prepared by researcher A, participant recruitment was conducted by researcher B, and group assignment was administered by researcher C, who opened the envelopes only after participants had been enrolled. This procedure was used to minimize selection bias. Due to the nature of the intervention, neither participants nor outcome assessors were blinded to group allocation. No attempt was made to simulate similar interventions in the control group, as the comparison of interest was stretching versus no stretching.

The independent variable was a supervised post-exercise dynamic stretching protocol administered to the intervention group immediately after each training session. The protocol consisted of nine dynamic stretching exercises targeting major muscle groups used in badminton (e.g., neck flexors, neck rotators, shoulder girdle, trunk, hip flexors and extensors, hamstrings, quadriceps, and calf muscles). Each exercise was performed for approximately 40 seconds, resulting in a total intervention duration of around 10 minutes per session. The stretching program was standardized and guided by a physiotherapist to ensure correct technique and to minimize the risk of over-stretching or injury. The control group did not receive any structured post-exercise stretching and was instructed to continue their usual post-training activities, which did not include a standardized stretching protocol.

The primary outcome was muscle pain intensity, measured using the Numeric Pain Scale (NPS), a unidimensional scale ranging from 0 to 10, where 0 indicates no pain and 10 indicates the worst imaginable pain. The NPS was chosen because it is simple, sensitive to individual variations in acute pain, and does not require complex visuomotor coordination, making it suitable for repeated assessments in a sports setting.

For descriptive analysis, muscle pain intensity measured using the Numeric Pain Scale (NPS) was categorized into three levels: 0–3 indicating mild pain, 4–6 indicating moderate pain, and 7–10 indicating severe pain. Pain intensity was assessed at one pre-test and three post-test time points. The pre-test measurement was conducted once, directly before the intervention as the baseline value. Post-test 1 was conducted immediately after the training session (and the stretching protocol for participants in the intervention group), post-test 2 was carried out more than 12 hours after the intervention, and post-test 3 was conducted more than 24 hours after the intervention. These sequential measurements allowed for the evaluation of immediate and short-term changes in muscle pain following exercise and stretching.

Measurements were conducted over three consecutive weekly training sessions, and the same time points were repeated in each session. For the main analysis, pre-test and the last post-test values (within 24 hours) were used to reflect the overall effect of the intervention on DOMS-related pain. No secondary outcomes were assessed.

The study protocol was reviewed and approved by the Health Research Ethics Committee of the Faculty of Medicine, Universitas Swadaya Gunung Jati, Cirebon, Indonesia (Ethical Clearance No. 49/EC/FKUGJ/III/2025). All participants were informed about the study procedures, potential risks, and benefits, and provided written informed consent prior to participation.

Data analysis was performed in two stages. First, univariate analysis was used to describe participant characteristics and the distribution of pain categories through frequencies and percentages. Second, inferential statistics were employed to evaluate the study hypotheses. Prior to hypothesis testing, assumption checks were carried out by assessing the normality of pain scores using the Shapiro–Wilk test and examining homogeneity of variance between groups using Levene's test. The results indicated that the data were homogeneous but not normally distributed, necessitating the use of non-parametric statistical methods.

Accordingly, within-group comparisons of pre-test and post-test pain scores were analyzed using the Wilcoxon signed-rank test, while between-group comparisons were conducted using the Mann–Whitney U test. A significance level of $p < 0.05$ was applied for the primary analysis, and effect sizes (r) were calculated from Mann–Whitney U Z-values to determine the magnitude of the intervention effect. No interim, subgroup, or adjusted analyses were performed. All randomized participants (n = 32) were included in the analysis according to their assigned groups, with no missing data.

Results

A total of 32 active medical students who were members of KKM Badminton FK UGJ met the eligibility criteria and consented to participate. All 32 participants were randomized in a 1:1 ratio into the intervention group (post-exercise stretching; n = 16) and the control group (no stretching; n = 16).

No participants were excluded after randomization, no drop-outs occurred during follow-up, and no missing data were recorded. Thus, all participants were included in the final analysis in their originally assigned groups.

Recruitment was conducted on 17 April 2025, and the follow-up period for each participant was 24 hours after the training and intervention session. No long-term follow-up was performed. A CONSORT-style participant flow can be summarized as follows (Figure 1):

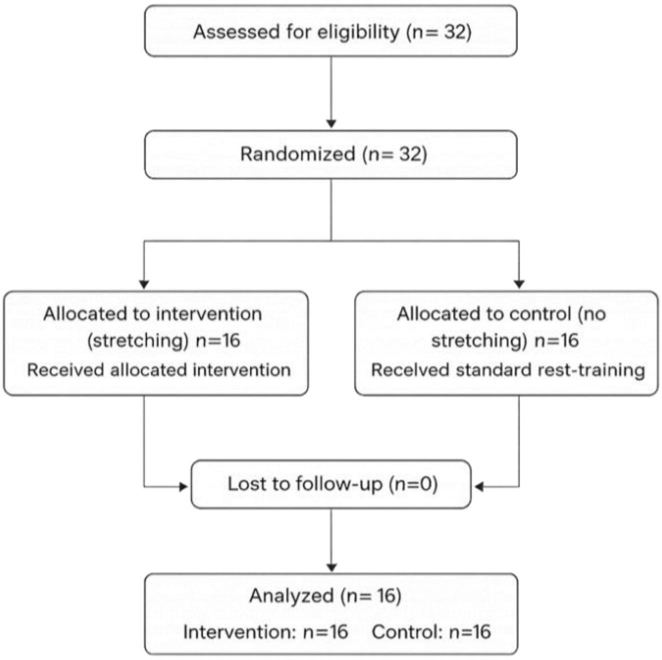

Figure 1. Participant Flow Chart

Baseline characteristics of the participants are presented in Table 1. The majority of participants were adolescents or young adults aged 15–20 years (75%), with the remaining 25% aged 21–27 years. Males comprised 56.3% of the sample, and females 43.8%. All participants were active badminton players, had no reported injuries or relevant medical conditions, and were not accustomed to performing structured post-exercise stretching.

Table 1. Baseline Characteristics of Participants (n = 32)

Characteristic	Category	n	%
Age (years)	15–20	24	75.0
	21–27	8	25.0
Sex	Male	18	56.3
	Female	14	43.8

At baseline, there was no significant difference in pre-test NPS scores between the control and intervention groups (p = 0.923), indicating comparable initial levels of muscle pain (Table 7). Table 2 summarizes the distribution of muscle pain categories prior to the intervention. In both groups, most participants reported mild pain.

Table 2. Distribution of Muscle Pain Before Stretching (Pre-test)

Group	Pain category	n	%
Control	Mild (0–3)	12	75.0
	Moderate (4–6)	3	18.8
	Severe (7–10)	1	6.3
	Total	16	100.0
Intervention	Mild (0–3)	13	81.3
	Moderate (4–6)	1	6.3
	Severe (7–10)	2	12.5
	Total	16	100.0

These findings indicate that mild muscle pain was the most prevalent category in both groups at baseline. Table 3 presents the distribution of pain categories after the intervention. In the control group, the majority of participants experienced a shift toward higher pain categories, whereas in the intervention group there was a trend toward lower pain severity.

Table 3. Distribution of Muscle Pain After Stretching (Post-test)

Group	Pain category	n	%
Control	Mild (0–3)	2	12.5
	Moderate (4–6)	9	56.3
	Severe (7–10)	5	31.3
	Total	16	100.0
Intervention	Mild (0–3)	14	87.5
	Moderate (4–6)	1	6.3
	Severe (7–10)	1	6.3
	Total	16	100.0

These results demonstrate that, after the intervention period, muscle pain in the control group tended to increase to moderate and severe levels, whereas in the stretching group it remained predominantly mild. The Wilcoxon signed-rank test showed a significant change in pain scores within both groups, but in opposite directions.

Table 4. Wilcoxon Test Results in the Control Group (n = 16)

Variable	Median (min–max)	p-value
Pre-test pain	2.50 (1–8)	0.001
Post-test pain	5.00 (2–10)	

In the control group, pain intensity increased significantly from pre-test to post-test (Z = –3.546, p = 0.001), with a median difference of +2.50 points and mean values rising from 3.1 ± 2.0 to 5.7 ± 2.2.

Table 5. Wilcoxon Test Results in the Intervention Group (n = 16)

Variable	Median (min–max)	p-value
Pain before stretching	2.00 (0–10)	0.003
Pain after stretching	1.50 (0–7)	

In the intervention group, pain intensity decreased significantly from pre-test to post-test (Z = –3.019, p = 0.003), with a median difference of –0.50 points and mean values decreasing from 3.3 ± 2.8 to 2.0 ± 1.7.
These findings indicate that, without stretching, muscle pain increased significantly after exercise, whereas post-exercise stretching led to a significant reduction in pain. Table 6 shows the results of the Mann–Whitney U test for post-test pain scores between the two groups.

Table 6. Post-test Pain Comparison Between Control and Intervention Groups (Mann–Whitney U Test)

Group	Median (min–max)	p-value
Stretching	1.50 (0–7)	0.001
No stretching	5.00 (2–10)	

The post-test comparison showed a statistically significant difference between the control and intervention groups (Z = –4.157, p = 0.001). The median difference between groups was 3.5 points (95% CI 2.1–4.8). The calculated effect size (r = 0.74) indicated a large effect of the stretching intervention in reducing muscle pain compared with no intervention.

Table 7. Pre-test Pain Comparison Between Control and Intervention Groups (Mann–Whitney U Test)

Group	Median (min–max)	p-value
Control	2.50 (1–8)	0.923
Intervention	2.00 (0–10)	

There was no significant difference in pre-test pain scores between the two groups (Z = –0.097, p = 0.923), confirming that both groups had comparable baseline levels of muscle pain. This strengthens the inference that post-intervention differences were attributable to the stretching intervention rather than pre-existing differences in pain. No adverse events, injuries, or unwanted effects related to the stretching protocol or training sessions were reported during the study. Thus, the intervention appeared safe for adolescent and young adult badminton players under physiotherapist supervision.

Discussion

This parallel randomized controlled trial demonstrated that post-exercise stretching significantly reduced muscle pain among adolescent and young adult badminton players, whereas the absence of stretching was associated with a significant increase in pain intensity. Participants in the control group experienced a shift toward moderate and severe pain categories after training, while those in the stretching group predominantly remained in the mild pain category. The large effect size (r = 0.74) underscores the clinical relevance of the observed differences.

These findings support the study hypothesis that post-exercise stretching is more effective than no stretching in attenuating exercise-induced muscle pain in badminton players. They also align with previous studies reporting beneficial effects of stretching in reducing musculoskeletal complaints among workers and other physically active populations.[10-13] Although the participant characteristics and occupational or sporting demands differ across those studies, the underlying mechanism targeted stretching to alleviate muscle tension and discomfort appears to yield consistent positive outcomes.

From a physiological perspective, post-exercise stretching can help restore muscle length after repeated contractions, reduce muscle stiffness, and facilitate the clearance of metabolic by-products such as lactate, which contribute to DOMS.[15,16] Stretching is also thought to enhance local blood flow and oxygen delivery to working muscles, thereby promoting recovery and reducing microtrauma-related pain.[15]

Mechanically, stretching activates the Golgi tendon organs (GTOs), which function as tension sensors in the musculotendinous junction. When tension reaches a certain threshold during stretching, GTO activation can trigger reflex muscle relaxation, preventing excessive contraction and contributing to an analgesic effect.[16] In addition, stretching may stimulate the release of endorphins, endogenous opioids that modulate pain perception and mood, further contributing to subjective pain relief.[16]

Guidelines from organizations such as the American College of Sports Medicine (ACSM) recommend stretching as a component of post-exercise recovery to improve flexibility, reduce muscle stiffness, and facilitate the restoration of musculoskeletal function after strenuous activity. The present trial provides empirical support for these recommendations in the specific context of badminton training among university students.

The results of this trial are consistent with previous research showing that stretching can reduce musculoskeletal complaints and pain intensity in various populations. Purwantini et al. reported that stretching exercises were effective in reducing MSD-related discomfort in workers.[10] Andari et al. and Amalia et al. found that stretching interventions significantly reduced low back pain among office workers and nurses, respectively.[12,13] Although these studies were conducted in occupational settings rather than in athletes, their findings collectively support the role of stretching as a non-pharmacological strategy for managing musculoskeletal pain.

However, the literature on stretching and DOMS is not entirely uniform. Some systematic reviews and meta-analyses have reported that the effect of stretching on DOMS may be small or not clinically meaningful in certain contexts, depending on the timing, duration, intensity, and type of stretching applied.[16,17] These discrepancies highlight that the efficacy of stretching may be context-specific and influenced by individual characteristics, exercise modality, and adherence to protocol.[18]

In the present study, a structured dynamic stretching protocol of 10 minutes duration applied immediately after badminton training may have contributed to the clearer and more substantial reduction in pain compared with studies that used different protocols. The high effect size suggests that, at least in this population and setting, the chosen stretching regimen was effective in modulating post-exercise muscle pain.

Several factors can influence pain perception and response to exercise, including age, sex, training status, and baseline fitness.[19] In this study, most participants were male and aged 15–20 years, representing adolescent to young adult recreational athletes. Some evidence suggests that women may have lower pain thresholds than men, and individuals with higher fitness levels may recover more rapidly from exercise-induced muscle damage.[16,20] These variables were not analyzed separately in this trial due to the relatively small sample size and the primary focus on the main intervention effect.

Therefore, the findings are most directly generalizable to adolescent and young adult recreational badminton players with similar training backgrounds. Caution is needed when extrapolating the results to elite or professional athletes, older adults, individuals with chronic musculoskeletal conditions, or participants in sports with different loading patterns.

The findings of this study have several practical implications for sports medicine, physiotherapy, and coaching. First, post-exercise stretching should be integrated as a routine component of training and recovery programs for badminton players, as it can help reduce muscle pain and may lower the risk of overuse injuries. Second, stretching represents an accessible, low-cost, and non-pharmacological strategy for managing exercise-induced muscle pain, which may reduce reliance on analgesic medications. Third, adherence to structured stretching routines is often low among university students and recreational athletes due to time constraints or lack of awareness; therefore, physiotherapists and coaches can use these findings to reinforce the importance of consistent post-exercise stretching to support optimal recovery.

Despite its strengths, this study has several limitations that warrant consideration. Age and sex were not stratified during randomization, and their potential moderating effects on pain response were not examined. Genetic and individual factors that may influence pain perception and recovery such as sleep quality, nutrition, or lifestyle were not assessed. The training load outside supervised sessions was not monitored, which may have introduced variability in DOMS. The use of a subjective outcome measure (the Numeric Pain Scale) without objective physiological markers, such as inflammatory biomarkers or muscle stiffness assessments, also limits the depth of interpretation. In addition, the relatively small sample size of 32 participants reduces statistical power and precludes subgroup analyses. The short, 24-hour follow-up period limits conclusions about longer-term recovery effects. Finally, the study population consisted exclusively of active badminton players who were medical students at a single institution, which restricts the generalisability of the findings to other populations, sports, and competitive levels.

Future studies should consider larger and more diverse samples, include objective outcome measures (e.g., range of motion, muscle stiffness, biomarkers of muscle damage), and explore different stretching modalities (static, dynamic, proprioceptive neuromuscular facilitation) and durations. Stratified analyses based on age, sex, and fitness level, as well as comparisons across different sports, would further clarify for whom and under what conditions post-exercise stretching is most effective.

Conclusion

Based on the statistical analyses and interpretation of findings, this parallel randomized controlled trial concludes that post-exercise stretching is effective in reducing muscle pain among adolescent and young adult badminton players at the Faculty of Medicine, Universitas Swadaya Gunung Jati (UGJ). The intervention group, which performed a 10-minute dynamic stretching protocol after training, exhibited predominantly mild pain levels, whereas the control group without stretching showed a shift toward moderate and severe pain.

These results strengthen the evidence that post-exercise stretching is an important non-pharmacological strategy to prevent and alleviate muscle pain in high-intensity sports such as badminton. Accordingly, structured post-exercise stretching is recommended as a routine component of training and recovery protocols for both athletes and physically active university students.

Author Contribution

All authors contributed substantially to the conception and design of the study, data collection, data analysis, and interpretation of results. Nirmala Putri Nendasari led the study design and supervised the overall research process. Taufan Herwindo Dewangga conducted data collection and intervention supervision. Muhammad Duddy Satrianugraha Wahidin performed the statistical analysis and prepared the first draft of the manuscript. All authors critically reviewed, revised, and approved the final version of the manuscript and agreed to be accountable for all aspects of the work.

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Nirmala Putri Nendasari: Conceptualization, Methodology, Supervision, Validation, Writing original draft, Writing review and editing.
Taufan Herwindo Dewangga: Methodology, Data curation, Investigation, Writing review and editing.
Muhammad Duddy Satrianugraha Wahidin: Formal analysis, Validation, Writing original draft, Writing review and editing.
All authors have read and approved the final version of the manuscript and agreed to be accountable for all aspects of the work.

Conflict of Interest Statement

The authors declare that there are no conflicts of interest—financial, personal, or professional—related to the publication of this manuscript.

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Ethics Statement

This study was conducted in accordance with the ethical standards set forth in the Declaration of Helsinki. Ethical approval was granted by the Health Research Ethics Committee of the Faculty of Medicine, Universitas Swadaya Gunung Jati (UGJ), Cirebon, Indonesia (Ethical Clearance No. 49/EC/FKUGJ/III/2025). Written informed consent was obtained from all participants prior to their involvement in the study.

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