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OPTIMIZING WARM-UP STRATEGIES: COMBINING MYOFASCIAL RELEASE AND DYNAMIC STRETCHING IN COLLEGE SOCCER

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Abstract

Optimizing pre-exercise routines is critical for enhancing athletic performance in higher education sports programs. This study investigated the acute effects of three different warm-up protocols self-myofascial release via foam rolling (SMR), dynamic stretching (DS), and a combined SMR+DS protocol on functional performance parameters in university soccer players. Using a randomized crossover experimental design, 60 male sports science students from Universitas Negeri Makassar underwent three testing sessions separated by a 48-hour washout period from February to April. Performance metrics evaluated included flexibility (sit-and-reach), explosive power (vertical jump), speed (20-meter sprint), and agility (Illinois agility test). Repeated measures ANOVA revealed that the combined SMR+DS protocol yielded the highest significant improvements in agility ($p < 0.05$) and speed ($p < 0.05$) compared to standalone interventions. While SMR significantly enhanced flexibility without compromising vertical jump height, the integration of DS following myofascial release provided a synergetic potentiation effect on neuromuscular performance. These findings demonstrate that a sequential combination of SMR and dynamic stretching optimizes acute functional performance. Consequently, coaches and educators should integrate combined warm-up strategies into higher education soccer curricula to maximize explosive power and mechanical efficiency during high-intensity intermittent activities.

Keywords: Agility; Dynamic stretching, Foam rolling, Soccer, Warm-up

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INTRODUCTION

Modern soccer is characterized by high-intensity intermittent activities that require players to repeatedly execute explosive movements such as sprinting, jumping, changing direction, and tackling under the influence of match-induced fatigue. To maintain this demanding physical workload and minimize the risk of musculoskeletal injuries, optimizing pre-exercise routines remains a primary focal point in sports science research (Ningrum et al., 2025; Zainuddin et al., 2024). For decades, traditional preparation models relied heavily on static stretching; however, the scientific consensus has progressively shifted toward dynamic routines due to evidence of acute performance decrements associated with prolonged static muscle lengthening (Molinaro et al., 2026a; Tarigan & Lardika, 2024; Wiguna, 2023). Within the context of higher education sports curricula, where student-athletes balance rigorous academic demands with high-performance training, establishing time-efficient, evidence-based warm-up protocols is essential for fostering mechanical efficiency and enhancing athletic potential.

State-of-the-art literature in athletic preparation has highlighted the evolution of alternative modalities, particularly self-myofascial release (SMR) via foam rolling, which is increasingly being paired with active movement patterns (Intantri et al., 2025; Mitsalina et al., 2025; Syurrahmi et al., 2025). Dynamic stretching (DS) has been widely demonstrated as an effective method for triggering post-activation potentiation (PAP), raising core body temperature, and accelerating neuromuscular transmission velocity (Hamzah et al., 2025; Karabağ et al., 2026). Concurrently, SMR has emerged as a prominent structural intervention targeting fascial restrictions and localized trigger points (Pradita, 2022; Savitri et al., 2020; Zulhasniati, 2024). Empirical investigations indicate that the mechanical pressure applied via foam rolling modifies the thixotropic properties of the extracellular matrix, effectively transitioning the fascia from a dense gel-like state to a more pliable sol state. This physiological transformation improves local blood circulation and increases joint range of motion without inducing the neural depression or force deficits typically observed following static stretching interventions.

Despite a growing body of research validating the individual applications of these modalities, a significant gap persists in current sports science literature regarding the optimal sequencing and synergistic efficacy of combined protocols. Most contemporary studies examining foam rolling utilize relatively small, homogenous sample sizes ($n < 20$) or focus primarily on elite professional athletes, resulting in a scarcity of large-scale empirical data. Furthermore, comparative trials analyzing the acute chronological sequencing of SMR combined with structured dynamic patterns remain inconclusive, particularly when mapped across multidimensional performance metrics such as explosive power, linear speed, and multi-directional agility within a single controlled cohort. This lack of clear programming prescription leaves university-level coaches and sports educators reliant on empirical trial-and-error methods rather than standardized, data-driven frameworks.

To resolve these empirical ambiguities, this study introduces a large-scale, randomized crossover design to explicitly evaluate the acute neuromuscular outcomes of standalone versus integrated warm-up strategies. The structural novelty of this research lies in its evaluation of a large, academically active cohort ($n = 60$) within the context of Indonesian higher education, precisely isolating the functional consequences of sequencing mechanical myofascial modulation prior to dynamic neuromuscular activation. By assessing flexibility, vertical jump height, linear speed, and agility within a rigorous crossover framework, this study establishes a definitive hierarchy of warm-up efficacy. Consequently, the primary objective of this investigation is to determine and compare the acute effects of standalone self-myofascial release, standalone dynamic stretching, and a sequential combination protocol (SMR+DS) on a comprehensive set of functional performance parameters among sports science students at Universitas Negeri Makassar.

Based on the theoretical review and empirical framework, the study proposes the following hypotheses:

1. Hypothesis 1 (H1): The sequential combined SMR+DS protocol yields significantly greater improvements in multi-directional agility metrics (Illinois agility) and linear speed (20-meter sprint) compared to both the standalone SMR and standalone DS protocols.
2. Hypothesis 2 (H2): The standalone SMR protocol provides a significant increase in flexibility parameters (sit-and-reach) compared to the standalone DS protocol, without inducing depressive effects or acute decrements in lower-limb explosive power capacity (vertical jump).

METHODS

Study Design

This study utilized a randomized crossover experimental design to evaluate and compare the acute effects of three types of warm-up protocols on functional performance parameters. To avoid selection bias and ensure internal validity, the randomization process was conducted using computer-generated random numbers managed by an independent research assistant who was not involved in the direct testing process.

The participant sequence allocation process was strictly organized into three distinct intervention sequences based on a randomized block permutation. Given that this study examined three intervention protocols the standalone Dynamic Stretching protocol (A), the standalone Self-Myofascial Release protocol (B), and the Sequential Combined protocol (C) participants were equally allocated into one of the following three sequential orders: Sequence 1 (A-B-C), Sequence 2 (B-C-A), or Sequence 3 (C-A-B). Under this scheme, 20 participants were assigned to Sequence 1, 20 participants to Sequence 2, and the remaining 20 participants to Sequence 3.

The implementation of this sequence scheme served as a systematic, advanced counterbalancing technique (Williamson's Latin Square Design). This step was required to control for and eliminate order effects as well as residual fatigue from participation in prior testing sessions. In accordance with valid crossover principles, each intervention session was separated by a strictly controlled 48-hour washout period, a duration physiologically proven sufficient to restore participants' muscular homeostasis. The entire series of experimental tests was conducted at the sports facilities of the Faculty of Sports Science and Health, Universitas Negeri Makassar (FIKK UNM), under standardized environmental conditions.

To eliminate residual fatigue and learning effects, each intervention session was separated by a strictly controlled 48-hour washout period. The entire series of experimental tests was conducted at the sports facilities of the Faculty of Sports Science and Health, Universitas Negeri Makassar (FIKK UNM), under standardized environmental conditions.

Participants

The sample size for this study involved 60 active male students enrolled in the Faculty of Sports Science and Health, Universitas Negeri Makassar. The sample size was calculated *a priori* using a statistical power analysis. Parameter calculations were based on a Repeated Measures ANOVA (within-factors) design for three intervention conditions. The effect size was set at a medium-to-large category, f = 0.25 adopted from estimates in similar experimental literature regarding the acute impact of myofascial release and dynamic routines on athletic performance (Ferreira et al., 2022; Karabağ et al., 2026).

By setting the Type I error rate (α) at 0.05, the number of treatments at 3 sessions, and the correlation among repeated measures at 0.50, the analysis indicated that a minimum sample size of 42 participants was required to achieve a statistical power (1 - β) of 0.95. The rationale for setting the sample size at 60 participants in this study was to anticipate a potential attrition rate (or drop-out risk) of up to 30% during the testing transition period from February to April. Furthermore, increasing the quota to 60 participants was intentionally done so that the sequence allocation within the counterbalancing scheme (Latin Square Design) could be perfectly and evenly distributed into the three sequential groups (n = 20 participants per sequence).

The final sample selection was performed using a purposive sampling technique with strict inclusion criteria, including: (a) actively participating in the university soccer training program at least 3 times a week for the past 6 months; (b) being between 19–22 years of age; (c) having a Body Mass Index (BMI) within the normal category (18.5–24.9 kg/m^2); dan and (d) being willing to comply with all testing instructions and signing an informed consent form. Meanwhile, the exclusion criteria applied were: (a) having a history of lower-extremity musculoskeletal injury within the past 3 months; (b) consuming ergogenic supplements or pharmacological substances that affect the central nervous system during the study period; and (c) failing to attend any of the three scheduled intervention sessions. The comprehensive anthropometric characteristics of all 60 participants were recorded in detail before the intervention phase commenced to ensure the homogeneity of the baseline data.

Data Collection and Instrumentation

To ensure methodological transparency and future research replication, all instruments used in this experiment underwent rigorous standardization testing. For the measurement of flexibility using the Standard Sit-and-Reach Test and the measurement of lower-limb explosive power using the Vertical Jump Test, the instruments demonstrated highly superior reliability. The exact reliability value via the Intraclass Correlation Coefficient (ICC) for the vertical jump instrument was 0.91 (95% CI: [0.88, 0.94]), while the sit-and-reach instrument recorded an ICC value of 0.92 (95% CI: [0.89, 0.95]). These coefficient achievements were significantly above the minimum safe threshold for instrument reliability required in sports performance research (>0.75).

In addition to instrument reliability, the specifications of the tools used in the intervention and data collection were explicitly detailed. The self-myofascial release (SMR) protocol was performed using an industry-standard Trigger Point Foam Roller (Grid 13") to ensure consistent material density and uniform mechanical pressure across all samples. Meanwhile, to minimize manual parallax errors and guarantee time-recording accuracy to one-hundredth of a second for the 20-meter sprint test and the Illinois Agility Test, this study utilized a premium wireless timing gate system, namely the Microgate Witty (Italy), precisely positioned at the participants' waist height on each track boundary line.

Functional data collection was performed using a structured chronological approach to measure four primary components of motor performance: flexibility, explosive muscle power, linear speed, and multi-directional agility:

1. Flexibility: Measured using the Standard Sit-and-Reach Test with a functional calibration box that features a 0.1 cm precision scale. Participants performed a gradual hip joint reach without jerking movements. The furthest value from two trials was recorded as the final data point.
2. Explosive Power: Evaluated using the Vertical Jump Test. Participants stood next to a digital measuring board and performed a maximal vertical jump applying the countermovement jump (CMJ) technique without excessive arm swinging. The difference between the standing reach height and the peak point of the jump was calculated in centimeters (cm).
3. Linear Speed: Tested via a short-distance dash (20-Meter Sprint Test). Travel time was measured using electronic timing gates positioned at waist height at the start and finish lines to minimize manual parallax errors.
4. Multi-directional Agility: Assessed using the Illinois Agility Test (IAT). A 10 x 5-meter track was precisely set up using standard marker cones. Participants initiated the test from a prone position and then ran as fast as possible following the designated winding route. Completion time was automatically recorded via the timing gates.

Experimental Procedures and Data Analysis

This experimental series was executed consistently over a timeframe spanning from February to April. During the first week prior to the intervention (familiarization phase), all participants gathered to undergo baseline anthropometric measurements. Additionally, participants were provided with simulations of correct foam rolling techniques and the agility test route to minimize visual adaptation bias.

On testing days, all sessions commenced at a uniform time in the morning (07:00–09:30 WITA) to minimize circadian rhythm fluctuations. Each participant performed a low-intensity, 5-minute jog as a standard general warm-up before entering one of the following specific intervention protocols:

1. DS Protocol: Involved 8 active dynamic stretching movements targeting lower-limb muscle groups (quadriceps, hamstrings, gastrocnemius, adductors, and gluteals), executed rhythmically in 2 sets of 10 repetitions per movement.
2. SMR Protocol: Utilized a high-density foam roller. Participants applied their own body weight pressure to the same lower-limb muscle groups at a constant frequency (1 roll per 2 seconds) for 60 seconds per muscle group.
3. SMR+DS Protocol: Participants executed the entire sequence of the SMR procedure first, followed by a 1-minute passive rest phase, and then immediately proceeded to the full sequence of DS movements.

Immediately after completing the warm-up protocol (with a transition interval of exactly 2 minutes), participants underwent functional performance testing sequentially, starting with the Sit-and-Reach, followed by the Vertical Jump, the 20-Meter Sprint, and concluding with the Illinois Agility Test.

All numerical data obtained were analyzed using SPSS statistical software version 26.0. Data normality testing was conducted via the Shapiro-Wilk test. Because the data proved to be normally distributed, comparative analysis of significance between protocols was evaluated using a Repeated Measures ANOVA, followed by a Bonferroni post-hoc test to identify the location of specific differences among the three intervention conditions. The statistical significance level was set at a threshold value of $p < 0.05$.

RESULT AND DISCUSSION

Result

Baseline Characteristics of Participants

A total of 60 male students from the Faculty of Sports Science and Health, Universitas Negeri Makassar (FIKK UNM) completed the entire series of the randomized crossover trial with no missing data (zero attrition). Anthropometric and baseline physical characteristic measurements were taken during the familiarization phase to ensure sample homogeneity. The descriptive analysis results indicated that all participants fell within normal and homogeneous ranges for age, weight, height, and

Body Mass Index (BMI), as summarized in Table 1.

Table 1. Anthropometric and Baseline Physical Characteristics of Participants (N = 60)

Physical Parameter	Mean ± Standard Deviation (SD)	Range (Minimum – Maximum)
Age (Years)	20.4 ± 1.1	19.0 – 22.0
Body Weight (kg)	64.8 ± 5.2	55.5 – 74.5
Height (cm)	171.2 ± 4.6	162.5 – 180.0
Body Mass Index (kg/m2)	22.1 ± 1.4	19.3 – 24.6

Functional Performance Baseline (Pre-Test) Data

Before participants underwent the three experimental warm-up protocols (standalone SMR, standalone DS, and combined SMR+DS), all participants (N = 60) attended a baseline (pre-test) testing session after performing a standard general warm-up consisting of a low-intensity, 5-minute jog. This measurement was conducted to verify that the initial capabilities of the entire sample were equivalent before specific interventions were administered. The average baseline (pre-test) values of the four evaluated functional metrics are summarized in Table 2.

Table 2. Baseline (Pre-Test) Values of Participants' Functional Performance (N = 60)

Functional Performance Parameter	Mean ± Standard Deviation (SD)	Range (Minimum – Maximum)
Flexibility (Sit-and-Reach)	33.4 ± 2.9 cm	28.5 – 39.2 cm
Explosive Muscle Power (Vertical Jump)	52.1 ± 4.4 cm	44.0 – 60.5 cm
Linear Speed (20-Meter Sprint)	3.29 ± 0.17 Second	2.98 – 3.62 Second
Multi-directional Agility (Illinois Agility)	16.32 ± 0.71 Second	14.95 – 17.80 Second

Acute Impact on Flexibility and Explosive Muscle Power

Testing the acute effects of the three different warm-up protocols revealed varying changes in flexibility parameters (sit-and-reach test) and lower-limb explosive muscle power (vertical jump test). Statistical analysis using a Repeated Measures ANOVA demonstrated a significant influence of the warm-up protocol type on participants' flexibility levels ($F = 24.15$, $p < 0.001$).

As presented in Table 3, the standalone SMR protocol produced a statistically significant increase in flexibility compared to the standalone DS protocol ($p < 0.05$). The highest flexibility value was achieved following the implementation of the Combined SMR+DS Protocol (38.4 ± 3.2 cm), which was noticeably superior to the other standalone intervention conditions ($p < 0.01$).

Conversely, for the lower-limb explosive power parameter (vertical jump), no statistically significant performance decrements were detected across the three intervention protocols ($F = 1.08$, $p = 0.345$). The mean vertical jump height after the standalone SMR protocol was 52.3 ± 4.5cm, after the standalone DS protocol was 53.1 ± 4.8, and after the SMR+DS protocol was 53.4 ± 4.6cm. The SMR protocol did not induce a decrease or impairment in muscle explosive power output when compared to either the standalone dynamic stretching or the combined protocols.

Acute Impact on Linear Speed and Multi-directional Agility

The functional performance test results for sprint metrics (20-meter sprint test) and agility (Illinois agility test) revealed statistically significant performance differences among the three treatments. For the short-distance linear speed parameter, there was a significant effect of the warm-up protocol on sprint travel time ($F = 12.64$, $p < 0.001$). The Combined SMR+DS Protocol recorded the fastest travel time (3.12 ± 0.14Second), followed by the standalone DS protocol (3.18 ± 0.15Second), while the standalone SMR protocol logged the slowest travel time (3.26 ± 0.16Second). Post-hoc testing confirmed that sprint performance in the SMR+DS protocol was significantly faster than in the standalone SMR protocol ($p < 0.01$, 95% CI [0.08, 0.20]).

For the multi-directional agility parameter, the Repeated Measures ANOVA detected a highly significant variance difference among the three warm-up conditions ($F = 35.82$, $p < 0.001$). Participants who completed the Combined SMR+DS Protocol demonstrated optimal agility performance, with the shortest Illinois agility test completion time (15.24 ± 0.58Second). This time record was significantly faster than achievements in the standalone DS protocol (15.62 ± 0.62Second, $p < 0.05$) and the standalone SMR protocol (16.15 ± 0.68Second, $p < 0.01$). A comprehensive summary of these inferential statistical metrics for functional performance is presented in Table 3.

Table 3. Comparison of Functional Performance Metrics Based on Warm-Up Protocols (N = 60)

Performance Parameter	**Standalone SMR Protocol**	**Standalone DS Protocol**	**Combined SMR+DS Protocol**	**p-value (ANOVA)**
Flexibility (cm)	36.2 ± 2.8	34.1 ± 3.1†	38.4 ± 3.2*‡	< 0.001
Vertical Jump (cm)	52.3 ± 4.5	53.1 ± 4.8	53.4 ± 4.6	0.345
20-M Sprint (Second)	3.26 ± 0.16	3.18 ± 0.15	3.12 ± 0.14*	< 0.001
Illinois Agility (Second)	16.15 ± 0.68	15.62 ± 0.62†	15.24 ± 0.58*‡	< 0.001

Desc:

1. *: Denotes a statistically significant difference ($p < 0.05$) compared to the Standalone SMR Protocol.
2. †: Denotes a statistically significant difference ($p < 0.05$) compared to the Standalone SMR Protocol..
3. ‡: Denotes a statistically significant difference ($p < 0.05$) between the Standalone DS Protocol and the Combined SMR+DS Protocol. *

Discussion

Physiological and Neuromuscular Mechanisms

The primary findings of this study confirm that the sequential combination protocol of self-myofascial release and dynamic stretching (SMR+DS) provides the most significant optimization of functional performance in students from the Faculty of Sports Science and Health, Universitas Negeri Makassar. Physiologically, the effectiveness of SMR using a foam roller lies in its capacity to modify the mechanical properties of fascial tissue via the thixotropy phenomenon (Intantri et al., 2025; Zulhasniati, 2024). Although this study did not directly measure neuromuscular activity through electromyography (EMG), the significant increase in functional flexibility following the standalone SMR protocol is strongly suspected to be related to neurophysiological responses to mechanical pressure. Based on previous literature, manual stimulation of fascial connective tissue is estimated to capable of stimulating slow mechanoreceptors (Ruffini endings) and fast mechanoreceptors (Pacinian corpuscles). This theoretical modulation contributes to a reduction in the motor neuron excitability threshold, which in turn triggers myofascial tissue relaxation without compromising the contractile capacity of the lower-limb muscles. This process directly lowers local arterial stiffness and enhances muscle-tendon compliance, explaining why the standalone SMR and SMR+DS protocols yielded the highest flexibility metrics on the sit-and-reach test without inducing acute strength deficits.

The absence of performance depression in lower-limb explosive power parameters (vertical jump) post-SMR stands as a critical finding in this study. Unlike traditional static stretching which frequently triggers a reduction in muscle spindle sensitivity and reduces actin-myosin cross-bridge capacity mechanical pressure from foam rolling increases joint range of motion purely through modification of central nervous system pain tolerance and fascial elasticity, without negatively altering the muscle length-tension relationship. The acute potentiation effect observed in speed and agility parameters following the dynamic stretching (DS) intervention can be explained through the theoretical lens of Post-Activation Potentiation (PAP). Because this study did not evaluate intracellular physiological markers or motor unit activity mechanistically, the explanation regarding this functional performance enhancement is based on established sports literature foundations. Repetitive dynamic contractions theoretically induce phosphorylation of the myocyte regulatory light chains, which positions the myosin heads closer to the actin filaments and indirectly optimizes cross-bridge sensitivity to calcium (Ca^{2+}). This biomechanical pathway is likely what underlies the increased mechanical efficiency during the execution of explosive movement patterns.

Critical Comparison with Related Literature

When confronted with the global research landscape captured within the citation records, these large-scale findings (N = 60) in FIKK UNM students reinforce and extend the conceptual boundaries developed by prior investigators. The superiority of a structured combined protocol in mitigating acute fatigue and optimizing neuromuscular readiness aligns with the comparative analyses of (Fajar et al., 2026; Karabağ et al., 2026), who found that foam roller interventions integrated into dynamic warm-up routines effectively accelerate performance recovery and reduce pain perception in university soccer players. Furthermore, findings regarding the vital role of dynamic stretching as a primary modality for muscle temperature conditioning are supported by the comprehensive review of (Hamzah et al., 2025), which positions a dynamic warm-up as the most superior evidence-based strategy in sports physiotherapy to stimulate mechanical efficiency prior to high-intensity intermittent activities.

Nonetheless, the complexity of neuromuscular responses to the use of self-myofascial release instruments demands a critical evaluation of methodological variability. These findings align with the umbrella review by (Ferreira et al., 2022; Suryadi, 2024), which states that while SMR is proven consistent in increasing Range of Motion (ROM) and accelerating post-exercise recovery, its direct impact on short-term functional performance output depends heavily on dosage parameters, including duration, tool material density, and the level of pressure applied. The consistency of positive results in this study also corroborates the experimental study of (Savitri et al., 2020) regarding the effectiveness of foam rolling in modulating flexibility without sacrificing muscle strength (as seen in our stable vertical jump data). The potentiation phenomenon produced by the SMR-followed-by-DS sequence proves that fascial restrictions released firsthand via SMR will ease the target muscle in executing dynamic movement patterns more efficiently, creating an accumulative effect beneficial to the linear speed and agility of student soccer athletes (Alamsyah et al., 2022; Fitrian, 2025; Fuadi et al., 2023).

Conversely, some literature exhibits outcome variability indicating population sensitivity limitations.. (Molinaro et al., 2026b) reported slightly different performance responses in child soccer athletes (10–11 years old) when responding to variations of dynamic warm-ups and foam rolling, inducing the hypothesis that the level of central nervous system maturity and mature fascial architecture in sports university students (aged 19–22 years) in our study provides a far more stable and massive potentiation (PAP) adaptation space. The importance of standardizing and supervising structured warm-up protocols in physical education higher curricula also reflects the methodological principles of physical conditioning put forward by fitness experts in Indonesia (Wiguna, 2025; Zaimsyah et al., 2025). The use of electronic timing gates in our research at FIKK UNM ensured the validity of sprint and agility metric data, while simultaneously eliminating manual measurement bias that is frequently criticized in several similar studies at the regional level (Setiawan et al., 2025; Wiguna, 2025).

Global Scientific Contribution and Curriculum Relevance

Globally, this manuscript provides a robust theoretical contribution to the strength and conditioning literature by presenting large-scale empirical evidence (N = 60) based on a crossover design, confirming that the chronological sequence of a warm-up dictates the quality of physical performance output. This study scientifically proves that coaches and sports practitioners should not treat SMR and DS as two interchangeable modalities, but rather as a complementary, single sequential series.

In academic and practical domains, the results of this study carry high relevance for direct integration into soccer learning curricula, coaching methodologies, and athlete performance development programs within Teacher Training Institutions (LPTK), particularly at Universitas Negeri Makassar. By implementing the Combined SMR+DS Protocol in a standardized manner before training or matches, educators and coaches can ensure students attain optimal neuromuscular readiness, enhance the biomechanical efficiency of kicking, sprinting, and directional changes, while minimizing the risk of non-contact injuries resulting from muscle stiffness and fascial restriction.

This study possesses methodological limitations, as the evaluation of the acute intervention impact focused solely on macro functional performance outcomes. This study did not utilize Electromyography (EMG) to track neuromuscular activity, nor did it test biochemical physiological markers in a laboratory setting. Therefore, the explanations regarding the role of fascial mechanoreceptors (Ruffini/Pacinian) and intracellular phenomena at the myosin and calcium (Ca^{2+}) levels within this manuscript are theoretical interpretations based on supporting literature rather than direct measurements. Future research is advised to integrate electrophysiological analysis and biochemical markers to empirically validate these internal mechanisms.

CONCLUSION

This large-scale randomized crossover study provides empirical proof that a sequential warm-up strategy combining self-myofascial release using a foam roller prior to active dynamic exercise (SMR+DS Protocol) is the most effective method for optimizing acute functional performance in university soccer students. Standalone SMR interventions proved reliable in engineering flexibility levels without inducing neuromuscular depressive effects on lower-limb explosive muscle power (vertical jump). However, integrating dynamic stretching immediately following the fascial restriction release phase generated a far more massive post-activation potentiation effect, thereby significantly accelerating short-track sprint times and maximizing the mechanical efficiency of multi-directional agility in athletes under controlled conditions.

Nonetheless, the successful application of this protocol still leaves limitations concerning absolute control over off-campus activities, individual body weight pressure variability during foam rolling, and the retention duration of acute effects throughout a full match, which remain untracked. Theoretically and practically, these findings bear significant implications for physical conditioning curricula and management within LPTK environments, specifically Universitas Negeri Makassar, serving as an applicable, evidence-based guide to reform traditional warm-up procedures to achieve motor readiness while mitigating non-contact injury risks. For future research development, it is recommended to employ advanced kinematics technology such as three-dimensional (3D) motion analysis, wireless electromyography (EMG) recording, internal biochemical marker tracking, and

Spopulation diversification across genders and age groups to expand external validity and the global generalizability of these findings.

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