

Combined PNF and myofascial release techniques impair acute strength performance: A randomized controlled cross-sectional study

Pedro Augusto Q. Inacio¹, Yuri dos S. Rodrigues¹, Marcelo M. Sales², Sérgio Machado^{3,4}, Irsané Oliveira-Silva¹, Fernanda P. da S. Rocha¹, Adriano C. Silva^{1,5}, Anne Caroline Rodrigues⁵, Davi das A. Caixeta⁵, Silvio R. Barsanulfo Junior¹, Weder A. Silva¹, Thiago Albernaz¹, Izabela L. Monturil¹, Rodrigo Alvaro B. Lopes-Martins¹, Patricia S. L. L. Martins¹, Alberto S. Sá Filho⁵

¹Postgraduate Program at the Evangelical University of Goiás (UniEVANGÉLICA), Anápolis, Goiás (GO), Brazil

²Postgraduate Program in Environment and Society at the State University of Goiás (UEG), South-west Campus, Quirinópolis (GO), Brazil

³Laboratory of Panic & Respiration, Institute of Psychiatry; Federal University of Rio de Janeiro – (IPUB/UFRJ), Rio de Janeiro (RJ), Brazil

⁴Centre of Physical Activity Neuroscience, Neurodiversity Institute, Queimados (RJ), Brazil

⁵Department of Physical Education at the Evangelical University of Goiás (UniEVANGÉLICA), Anápolis, Goiás (GO), Brazil

Abstract:

Background: Numerous strategies can be implemented as preconditioning preparation to increase strength production, including PNF and MFR strategies, however there are still contradictions in the literature regarding competing effects between preconditioning actions and strength performance, which it becomes plausible to look for the impact is effect on strength resistance performance. **Objective:** of the study was to evaluate the acute effects of series of PNF, myofascial release (MFR), or the sum of the methods, on the development of resistance strength in subsequent series of deadlifts. **Methods:** Eight adults of both sexes (25.4 ± 4.1 years) participated in the study, attending the gym on 7 visits. The first visit consisted of a sample characterization. On the second and third visits, participants performed the maximum repetition Deadlift procedure, from the fourth to seventh visits, they were randomly divided into: a) CTL; b) PNF; c) MFR; d) PNF + MFR. All sessions followed three sets of the Deadlift exercise with 80% RM. **Results:** The repeated measures ANOVA showed significant differences between the control condition (no intervention) and the PNF intervention ($p = 0.034$) and MFR + PNF ($p = 0.047$). However, the Control vs. MFR there were no significant differences ($p = 0.07$), as well as PNF vs. MFR ($p = 0.585$), and PNF vs. PNF+MFR ($p = 0.382$). **Conclusion:** Strength performance was influenced by the PNF method, or associated with MFR, both reducing total work.

Keywords: Stretching; myofascial release; repetition maximum.

Corresponding author:

Alberto Souza Sá Filho

E-mail:

doutor.alberto@outlook.com

Received: 16 Feb, 2024.

Accepted: 19 Apr, 2024.

Published: 29 Apr, 2024.

Copyright © 2023. This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License which permits unrestricted non-commercial use, distribution, and reproduction in any medium provided article is properly cited.



BACKGROUND

Numerous strategies can be implemented as pre-conditioning preparation to enhance strength production⁽¹⁻³⁾. Fitness-focused professionals recurrently prescribe stretching exercises before conditioning activity, alone or in conjunction with other methods. We know that the prescription of stretching is primarily aimed at improving flexibility^(4,5). And such an outcome is required for multiple sports. However, the choice of this method as a pre-conditioning activity, for example, before resistance training, can be questioned due to its potentially harmful mechanism associated with force production (change in the length-tension curve)⁽⁶⁾.

Thus, the literature objects to the concomitant use of two physical qualities, the production of strength and flexibility, in the same session, claiming that there is competition between the mechanisms of these two physical capabilities and the reduction of the capacity to produce tension⁽⁷⁾. The magnitude of the harmful effect on strength can vary or even be non-existent depending on the technique, intensity, and volume used. As a rule, it was established that separate sessions be considered for both strategies when planning the general prescription^(4,8,9).

In this sense, the myofascial release technique (MFR) has been proposed as an alternative to stretching work as a pre-conditioning mechanism or at the same time^(10, 11) (static stretching + MFR). It is suggested that the pressure exerted on the muscles during rigid foam rolling reduces excessive muscle tension, influencing passive components (tendons and fascia), remobilizing the fascia to a gel-like state⁽¹²⁾. As a result, the range of motion (ROM) can be sharply increased without competing with strength performance⁽¹³⁻¹⁵⁾. For example, Godwin et al.⁽¹⁶⁾ observed significant improvements in ankle ROM without functional implications on explosive performance from the combined strategy of MFR and dynamic warm-up. In this case, the experimental condition did not induce changes in any vertical jump performance index ($p > 0.05$), with significant maintenance of performance. However, pre-warming alone can significantly improve strength performance and ROM⁽¹⁷⁾.

These results are confirmed by the brilliant meta-analysis produced by Cheatham et al.⁽¹⁸⁾, where self-rolling on foam, as a pre-conditioning action, did not harm strength. It is worth highlighting that the authors suggest, as by Mohr, Long, and Goad⁽¹¹⁾, that outcomes on ROM may have marked responses when combined with static stretching, justified by the combination of mechanisms: a) increase in intramuscular temperature resulting in the friction of the foam roller; b) viscoelastic changes and c) changes in intrafusal length. Despite this understanding, we do not know whether this outcome would be replicated with other stretching techniques, such as the Proprioceptive Neuromuscular Facilitation (PNF) technique, or whether it would affect strength.

Given the harmful effects already conceived between the application of the PNF method and force (positive control)^(19,20), we do not know whether the combination of both strategies (PNF and MFR) would additionally affect force production or in some way, would stabilize the proposed adverse effects. Considering the contradictions in the literature, it is plausible to search for the impact of PNF and MFR strategies on strength endurance performance, establishing this as our primary objective (H1). Furthermore, the combination of stretching techniques (PNF) with MFR has not yet been adequately explored regarding strength performance and subsequent strength series (H2). We hypothesize that auto MFR will not affect strength endurance performance (H1), but combined with PNF will cause losses (H2).

METHODS

Experimental Approach

The present study was developed following the assumptions described in the STROBE-statement guideline for randomized and controlled cross-sectional study designs. A total of seven visits were carried out, and there was a public call to a high-end

gym located in the capital of the Brazilian Center-West during the final period of 2021. This study was approved by the research ethics committee of Universidade Paulista nº. 3,735,204 (CAAE: 25231419.3.0000.5512) and conducted in accordance with Resolution 466/2012 of the National Health Council. All participants obtained the necessary information about the study and resolved their doubts. The present study was carried out during the second year of the COVID-19 pandemic, therefore, participation in this study was linked to social rules of distancing and use of adequate masks and hygiene standards. Only the leading evaluator maintained direct contact with the participants, taking due care with the exposure. It is worth noting that the COVID-19 pandemic was an impediment to recruiting participants and, therefore, reaching the expected sample number. Those who accepted and were selected were presented with an understanding of the risks inherent to the exercise, signing the free and informed consent form (TCLE).

Participants

For this study, eight university students of both sexes, male and female (25.4 ± 4.1 years) participated. As an inclusion criterion, all participants should be recreationally trained for multiple physical skills, in addition to having a strength and body weight ratio greater than $1.0^{(21)}$, regular strength training time greater than one year, in addition to being at low risk according to stratification criteria proposed by ACSM⁽²²⁾. As exclusion criteria, participants were removed from the study if they used substances that altered the cardiovascular system or substances that promoted improved strength, any type of ergogenic substance considered as doping by WADA⁽²³⁾, in addition to previous recurrent injuries. Everyone had the procedures agreed in advance, and their doubts were resolved, having signed the TCLE.

To calculate the sample number, a repeated measures ANOVA with interaction between the four groups and two moments was considered. This established an α of 5% and an effect size of $f=0.45$ without correction for sphericity, providing a statistical power of 83% (G*Power, Version 3.1.9.4).

Study Design

The 8 participants responded to an ICF and came to the gym for a total of 7 visits. An interval of 48-72 hours was adopted for each visit, avoiding any compromise related to delayed pain and fatigue in the applied protocols. The first visit consisted of a characterization of the sample based on anthropometric procedures and familiarization with the deadlift movement procedure. On the second and third visits, participants performed the maximum repetition Deadlift procedure, establishing the reliability of the measurement. From the fourth to seventh visits, participants were randomly distributed between 3 experimental interventions and 1 control (CTL): a) CTL session; b) PNF; c) MFR; d) PNF+MFR. All experimental sessions followed three sets of Deadlift exercises with 80% of the maximum load, with a three-minute break between sets. At all visits participants were encouraged to perform to the best of their ability. All procedures were carried out at the same time of day, and at a controlled temperature between 21 and 23°. Throughout the intervention, participants were asked to momentarily give up their activities related to resistance training, and maintain their eating routine patterns.

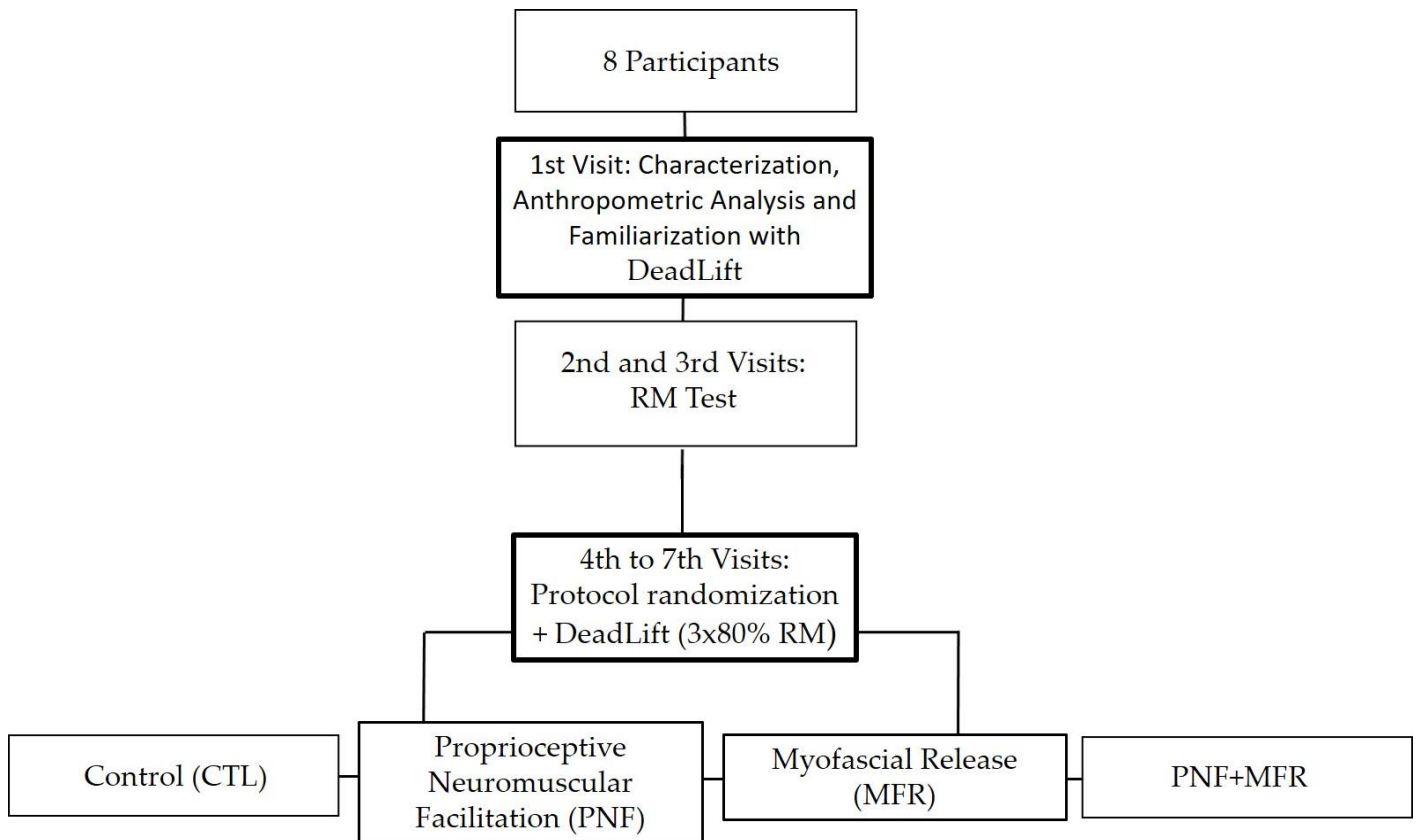


Figure 1: Study design and randomization of protocols

Procedures

Anthropometric Procedures

The anthropometric assessment consisted of the participants' weight, obtained using an electronic scale, and height measured using a standard wall-mounted stadiometer. In addition, skinfold measurements were taken, with assessment of body fat percentage using the seven skinfold protocol (subscapular, triceps, pectoral, mid-axillary, suprailiac, abdominal and thigh)⁽²⁴⁾.

Intervention protocol

Proprioceptive neuromuscular facilitation protocol

In the PNF protocol to stretch the hamstrings, the participant was positioned in the supine position and had their left thigh stabilized by the evaluator. The evaluator passively flexed the participant's right hip with the knee extended to the position in which the participant reported discomfort in the hamstrings, and supported the individual's right lower limb on his left shoulder. At the evaluator's signal, the volunteer was asked to exert force to extend the hip for 10 seconds, against resistance. At the end of 10 seconds, the volunteer then had their hips passively flexed for 30 seconds, which was repeated for three sets with a 60-second interval between sets. The maneuver took a total time of 40 seconds and was repeated on both limbs alternately. Figure 1 demonstrates the PNF exercise procedures in the initial and final position.

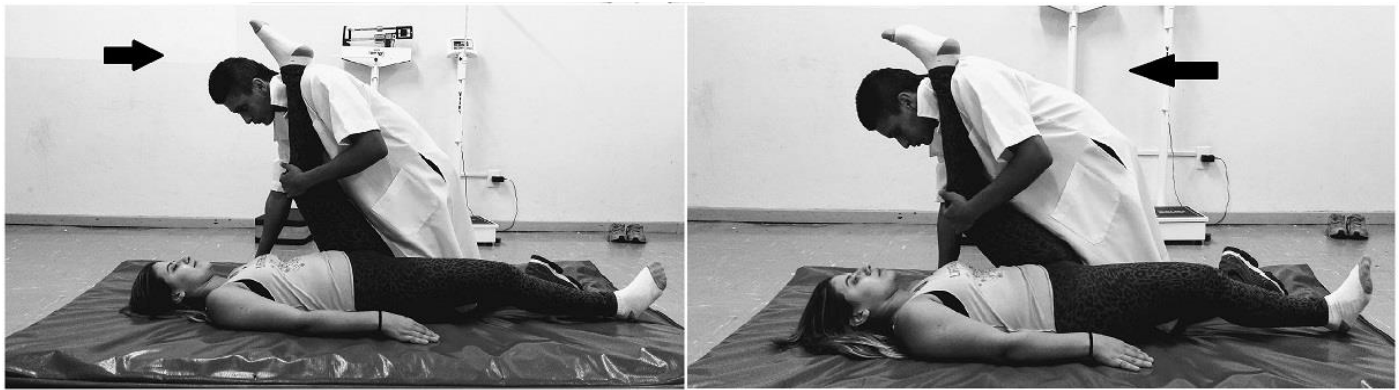


Figure 1. PNF - stretching and contraction against resistance / passive stretching

Myofascial Release Procedure

In the myofascial self-release protocol, participants were instructed by the evaluator to sit on the floor positioning a high-density foam roller with dimensions of thirty centimeters in length and fifteen centimeters in diameter in a cylindrical shape, with a weight of 250 g and composed of expanded polypropylene (Foam Rolling®), below the hamstring muscles. With the hands and one of the feet supported on the floor (in a three-way position with the anterior surface of the trunk facing upwards), the volunteer applied pressure in a uniform and bidirectional manner using the individual's total body weight on the limb, performing the movement. Intervention⁽²⁵⁾, moving in the longitudinal direction of the foam roller (same direction as the direction of the fibers) along the entire length of the hamstring muscles.

The protocol consisted of 3 series of 30 seconds (bidirectional). Then, after the 30 seconds of movement requirement, the subject was asked to position the roller over possible painful points located in the muscles for another 10 seconds (without displacement), totaling 40 seconds of action in each series. Finally, there was a 60-second break between sets. Figure 2 shows the positions held during the MFR.



Figure 2. Self myofascial release – Foam Rolling – hamstring. 30 seconds of rolling throughout the hamstring muscles and a final 10 seconds under the point of greatest sensitivity on the thigh

Combined PNF and MFR Procedure

The same muscular reference points were used, as well as procedures used and standardized in both PNF and MFR strategies. The procedure was initiated by the MFR strategy, later migrating to the PNF strategy. A total of 3 series of movements were performed with a total intervention time added between the two strategies, that is, 80 seconds of work, in addition to an interval of 60 seconds between series.

1 Maximal Repetition Protocol

The maximum load determination protocol was previously carried out to determine the 80% work load in the deadlift exercise. The protocol was divided into the following steps: 1) joint mobility under the joint involved; 2) specific warm-up with weights (simulation of the movement to be performed); 3) execution of the movement with 50% of the load estimated by the participant (approx. 6 to 8 repetitions – 3 min recovery interval); 4) execution of the movement with 75% of the estimated load (approx. 3 to 5 repetitions – 3 min recovery interval); 5) first attempt at performing a maximum repetition. In case of development of more than one repetition, a new attempt was designated after an interval of 5 min. Total of maximum 3 attempts were provided.

Exercise Protocol

The exercise protocol consisted of performing the deadlift movement after the randomized experimental intervention conditions. Performing three sets with a three-minute recovery break between sets. The overload stipulated for performing the task was 80% of the load defined in the one-repetition maximum test. The movement began with the bar on the ground, and with the weight plates positioned on the bar. The subjects lifted the load to the waist line, maintaining adequate spinal curvature during as many repetitions as possible. During the entire movement, participants were instructed to maintain the same positioning of arms and legs; the use of equipment and accessories that could improve performance, such as belts and straps, was not permitted. The maximum number of repetitions was recorded and entered for final analysis of the results. The total work carried out was used for comparative analysis. The deadlift movement is shown in Figure 3 below.

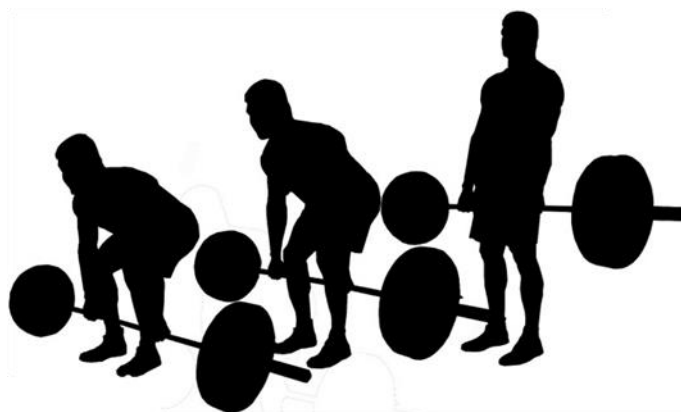


Figure 3. Phases of the deadlift movement

Randomization Procedure

Simple randomization was applied. For the randomization process, one of the evaluators organized four numbers on paper, referring to the four experimental sessions. All numbers were placed inside an opaque bag. A third evaluator, not a direct participant in data collection, was instructed to sequentially remove the numbers, assigning the experimental sessions in which each participant would be conditioned. This evaluator maintained a blind sequence for the main evaluators. The third evaluator allocated the sequence in an electronic spreadsheet, informing the type of intervention to be carried out only on the day of the evaluation.

Statistical analysis

A descriptive analysis of the data will be previously carried out, and presented as mean \pm standard deviation. After testing the assumptions of normality and heteroscedasticity, a repeated measures ANOVA was used to compare the dependent variables of range of motion (expressed in degrees and centimeters) and number of repetitions. The intra-class correlation coefficient determined the degree of reliability of the measurements. The magnitude of the differences (effect size - TE) were determined and qualified according to Cohen's "d" index. All analyzes will be carried out using the SPSS 20.0 for Windows® software (Chicago, USA) with a statistical significance of $p = 0.05$.

RESULTS

The sample characterization data were expressed as mean and standard deviation, and are presented in Table 1.

Table 1. Sample characterization

	Age (years)	Mass (kg)	Height (m)	BMI	Lean Mass (kg)	Fat (%)
Average	25,4	70,0	1,7	23,8	34,0	10,2
SD	4,1	6,6	0,1	1,9	3,6	3,4

Note: BMI = body mass index; sd = standart deviation.

The reliability of the maximum repetition measurement was previously established, showing a significant relationship between the deadlift maximum repetition sessions ($p < 0.001$) and is presented in Table 2. The intraclass correlation coefficient showed a high relationship between sessions. The average overload values used in the experimental interventions are presented in the same table

Table 2. Average maximum repetitions

	Session 1 (kg)	Session 2 (kg)	80% MR (kg)
Average	127,5	131,9	105,5
SD	29,6	29,6	23,7
ICC		0,99	

Note: MR = maximal resitance; ICC = Intraclass Correlation Coefficient.

The normality of the data was presented, however, there was no sphericity, therefore, the Greenhouse-Geisser adjustment was applied for data analysis ($p = 0.095$). Table 3 presents the data individually by intervention performed and the number of repetitions for each series performed.

Table 3. Individual analysis by series.

	Series 1	Series 2	Series 3
Control	10,0 \pm 3,2	9,6 \pm 1,8	9,1 \pm 1,8
PNF	8,5 \pm 3,2	9,0 \pm 2,5	8,6 \pm 1,8
MFR	9,9 \pm 1,9	9,3 \pm 1,8	7,9 \pm 2,4
PNF + MFR	10,0 \pm 2,9	7,6 \pm 1,4	7,1 \pm 1,5

Caption: PNF = proprioceptive neuromuscular facilitation; MFR = myofascial release.

For the final analysis of the effects of the experimental interventions, the sum of repetitions in the three series performed was used, with the total work being determined as a reference. The repeated measures ANOVA showed significant differences between the control condition (no intervention) and the PNF intervention ($p = 0.034$) and MFR+PNF ($p = 0.047$). However, the Control vs. MFR there were no significant differences ($p = 0.07$), as well as PNF vs. MFR ($p = 0.585$), and PNF vs. PNF+MFR ($p = 0.382$). The data is presented in Figure 4 and Table 4.

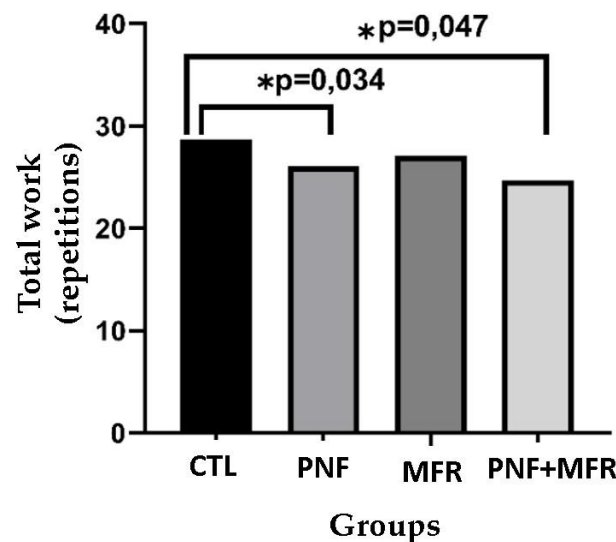


Figure 4. Number of total repetitions performed per group

Note: CTL= control group; PNF= proprioceptive neuromuscular facilitation; MFR= Myofascial release. * significant differences in relation to CTL. $p < 0.05$.

Table 4. Total work performed (repetitions)

	Total work (repetitions)			
	CTL	PNF	MFR	PNF+MFR
Average	28,7	26,1*	27,1	24,7*
SD	7,3	6,2	5,2	4,0
Cohen <i>d</i>		0,18	0,06	0,37

Note: PNF = proprioceptive neuromuscular facilitation; MFR = myofascial release; * significant differences in relation to CTL (control). The effect size was determined between the control intervention and the other sessions; CTL vs. PNF ($d = 0.18$); CTL vs. MFR ($d = 0.06$); CTL vs. PNF+MFR ($d = 0.37$).

DISCUSSION

The objective of the present study was to determine the acute effects of the PNF/MFR stretching series as a preconditioning strategy, or the sum of the methods, on strength endurance performance in the deadlift exercise. The study's main findings showed that the PNF and MFR+PNF groups had their total work negatively affected, implying a reduction in strength performance, therefore accepting our primary hypothesis (H1). On the other hand, there was no substantial change in the MFR protocol. Despite this, the clinical significance of the individual intervention was classified as minor, Sullivan and Feinn⁽²⁶⁾, MFR ($d = 0.06$), and PNF ($d = 0.18$), which could be questioned regarding its real relevance in terms of recreational performance.

In this sense, our results align with Barroso et al.⁽²⁷⁾, who demonstrated a significant reduction in strength when PNF stretching was previously developed. Fowles et al.⁽²⁸⁾ explain that the decrease in strength obtained after stretching may be related to the length-tension change of the muscle, plastic deformation of the connective tissue, and changes in viscoelastic properties⁽²⁹⁾. The literature shows us that when it comes to stretching, we must consider the volume-intensity binomial before tasks related to strength development. Avila et al.⁽³⁰⁾, for example, analyzed the mechanical and neural responses of the gastrocnemius and soleus after 1 hour of passive stretching and observed a reduction in maximum voluntary contraction. This reduction is probably justified by the time of exposure to the stretching protocol. Therefore, our results suggest that PNF protocols and preconditioning are not the best strategies for visualizing performance in subsequent tasks when they require strength valences.

The MFR strategy has been included in the pre and post-physical conditioning phases, with different objectives⁽³¹⁾. In the pre-physical conditioning phase, it is proposed that the release promotes the reduction of acute joint restrictions or limitations. In the post-conditioning phase, it is expected to promote relaxation and reduce muscle pain⁽³²⁾. In our study, as we hypothesized, the effects of applying MFR did not negatively affect force production ($p = 0.07$). This result is in line with the positioning of Healey et al.⁽³³⁾, where MFR did not negatively affect isometric strength performance, nor in vertical jump and agility tests when compared to the group that performed activation exercises in body plank in positions of lateral decubitus, prone position and elevated lower limbs (exercises related to the control condition). Furthermore, self-reported post-exercise fatigue (Likert-type scale, 0-10) and perceived exertion in the MFR group were significantly lower than for individuals who performed only the plank exercise ($p \leq 0.05$). Su al.⁽³⁴⁾ also did not demonstrate any losses in muscle strength after using the MFR strategy on the foam roller, corroborating our findings.

Therefore, the scope of this article did not address issues related to fatigue (biochemical indices and specific scales). However, we initially hypothesized (H2) that whether fatigue can be affected to mitigate its effects through MFR strategies, performance could be improved by increasing the total volume of repetitions performed⁽³³⁾. The total volume performed is known to be influenced by hypertrophy and strength outcomes⁽³⁵⁾. Therefore, we created the rationale that MFR could positively change this outcome. However, this rationale has been refuted.

Finally, in our study, the MFR, when associated with the PNF method, showed a more significant decrease in strength performance in successive deadlift series ($p = 0.047$) compared to the control. Our rationale for this increase and reduction is the binomial volume of pre-conditioning activities and the total execution time. The PNF+MLR group performed a more time-consuming task (80 seconds); as already stated in the literature, the total execution time overstretching seems to be the determining factor for a possible reduction in resistance strength performance or no⁽³⁶⁾, where stretches of less than or equal to 60 seconds promote trivial deleterious effects on strength and power⁽³⁷⁾, this explains the findings in the present paper, our approach of offering a longer time on the combined group.

Based on our findings and the present body of literature, we recommend that when engaging in preconditioning tasks, be it stretching and its variations or MFR, activities that do not exceed a time greater than 60 seconds can be employed when the final work is the performance of resistance force.

LIMITATION

The main limitation of our study could be related to the sample size, implying a type II error. However, the “statistical power” does not seem to have been affected since it was possible to detect significant differences between the strength series. Another limitation that can be raised about combined protocols is the increased exposure time, therefore differing in total work between the other protocols. However, this decision regarding the combination of strategies and, thus, time increases external validity since, in large training centers, pre-physical conditioning routines are carried out in a combinatorial manner (MFR + stretching + dynamic stretching + mobility). We encourage future research to be carried out with a combination of more procedures to reflect day-to-day procedures (greater external validity).

CONCLUSION

We concluded that strength endurance performance was significantly influenced by the PNF protocol alone or associated with MFR, although the latter alone did not reverberate in strength endurance performance. MFR strategies can be inserted as pre-conditioning attributes in the face of resistance training without decreasing exercise performance.

Author Contributions: A.S.S.F., S.R.B., M.M.S. and S.M. contributed equally in all phases of the project; P.A.Q.I., R.A.B.L-M., P.S.L.L.M. and I.O.S. participated in the construction of the final document and revision; F.P.S.R., A.C.S., A.C.R., D.A.C., W.A.S., T.A., and I.L.M. acted in the process of data collection and summarization; Y.S.R., S.M., P.A.Q.I., and A.S.S.F. participated in multiple revisions, the drafting of the final document and the submission process.

Financial Support: There was no external funding.

Conflict of Interest: We declare no conflicts of interest.

REFERENCES

1. Suchomel TJ, Nimphius S, Stone MH. The Importance of Muscular Strength in Athletic Performance. *Sports Med.* 2016;46(10):1419-49.
2. Boulosa D, Del Rosso S, Behm DG, Foster C. Post-activation potentiation (PAP) in endurance sports: A review. *Eur J Sport Sci.* 2018;18(5):595-610.
3. Paulo AC, Ugrinowitsch C, Leite GdS, Arsa G, Marchetti PH, Tricoli V. Efeito agudo dos exercícios de flexibilidade no desempenho de força máxima e resistência de força de membros inferiores e superiores. *Motriz: Revista De Educação Física.* 2012;18(2):345-55.
4. McHugh MP, Cosgrave CH. To stretch or not to stretch: the role of stretching in injury prevention and performance. *Scand J Med Sci Sports.* 2010;20(2):169-81.
5. Small K, Mc Naughton L, Matthews M. A systematic review into the efficacy of static stretching as part of a warm-

- up for the prevention of exercise-related injury. *Res Sports Med.* 2008;16(3):213-31.
6. Page P. Current concepts in muscle stretching for exercise and rehabilitation. *Int J Sports Phys Ther.* 2012;7(1):109-19.
 7. Afonso J, Ramirez-Campillo R, Moscaio J, Rocha T, Zacca R, Martins A, et al. Strength Training versus Stretching for Improving Range of Motion: A Systematic Review and Meta-Analysis. *Healthcare (Basel).* 2021;9(4).
 8. Opplert J, Babault N. Acute Effects of Dynamic Stretching on Muscle Flexibility and Performance: An Analysis of the Current Literature. *Sports Med.* 2018;48(2):299-325.
 9. Simic L, Sarabon N, Markovic G. Does pre-exercise static stretching inhibit maximal muscular performance? A meta-analytical review. *Scand J Med Sci Sports.* 2013;23(2):131-48.
 10. Skarabot J, Beardsley C, Stirn I. Comparing the effects of self-myofascial release with static stretching on ankle range-of-motion in adolescent athletes. *Int J Sports Phys Ther.* 2015;10(2):203-12.
 11. Mohr AR, Long BC, Goad CL. Effect of foam rolling and static stretching on passive hip-flexion range of motion. *J Sport Rehabil.* 2014;23(4):296-9.
 12. Okamoto T, Masuhara M, Ikuta K. Acute effects of self-myofascial release using a foam roller on arterial function. *J Strength Cond Res.* 2014;28(1):69-73.
 13. MacDonald GZ, Penney MD, Mullaley ME, Cuconato AL, Drake CD, Behm DG, et al. An acute bout of self-myofascial release increases range of motion without a subsequent decrease in muscle activation or force. *J Strength Cond Res.* 2013;27(3):812-21.
 14. Wiewelhove T, Doweling A, Schneider C, Hottenrott L, Meyer T, Kellmann M, et al. A Meta-Analysis of the Effects of Foam Rolling on Performance and Recovery. *Front Physiol.* 2019;10:376.
 15. Konrad A, Nakamura M, Behm DG. The Effects of Foam Rolling Training on Performance Parameters: A Systematic Review and Meta-Analysis including Controlled and Randomized Controlled Trials. *Int J Environ Res Public Health.* 2022;19(18).
 16. Godwin M, Stanhope E, Bateman J, Mills H. An Acute Bout of Self-Myofascial Release Does Not Affect Drop Jump Performance despite an Increase in Ankle Range of Motion. *Sports (Basel).* 2020;8(3).
 17. Fradkin AJ, Zazryn TR, Smoliga JM. Effects of warming-up on physical performance: a systematic review with meta-analysis. *J Strength Cond Res.* 2010;24(1):140-8.
 18. Cheatham SW, Kolber MJ, Cain M, Lee M. The Effects of Self-Myofascial Release Using a Foam Roll or Roller Massager on Joint Range of Motion, Muscle Recovery, and Performance: A Systematic Review. *Int J Sports Phys Ther.* 2015;10(6):827-38.
 19. Hindle KB, Whitcomb TJ, Briggs WO, Hong J. Proprioceptive Neuromuscular Facilitation (PNF): Its Mechanisms and Effects on Range of Motion and Muscular Function. *J Hum Kinet.* 2012;31:105-13.
 20. Marek SM, Cramer JT, Fincher AL, Massey LL, Dangelmaier SM, Purkayastha S, et al. Acute Effects of Static and Proprioceptive Neuromuscular Facilitation Stretching on Muscle Strength and Power Output. *J Athl Train.* 2005;40(2):94-103.
 21. Santos Junior ERT, de Salles BF, Dias I, Ribeiro AS, Simão R, Willardson JM. Classification and Determination Model of Resistance Training Status. 2021;43(5):77-86.
 22. Wilkins LW. *ACSM's Health-related Physical Fitness Assessment.* 5 ed 2017.
 23. *The World Anti-Doping Code International Standard Prohibited List,* (2018).
 24. Jackson AS, Pollock ML. Generalized equations for predicting body density of men. *Br J Nutr.* 1978;40(3):497-504.
 25. Couture G, Karlik D, Glass SC, Hatzel BM. The Effect of Foam Rolling Duration on Hamstring Range of Motion. *Open Orthop J.* 2015;9:450-5.
 26. Sullivan GM, Feinn R. Using Effect Size-or Why the P Value Is Not Enough. *J Grad Med Educ.* 2012;4(3):279-82.
 27. Barroso R, Tricoli V, Santos Gil SD, Ugrinowitsch C, Roschel H. Maximal strength, number of repetitions, and

total volume are differently affected by static-, ballistic-, and proprioceptive neuromuscular facilitation stretching. *J Strength Cond Res.* 2012;26(9):2432-7.

28. Fowles JR, Sale DG, MacDougall JD. Reduced strength after passive stretch of the human plantarflexors. *J Appl Physiol* (1985). 2000;89(3):1179-88.

29. Rubini EC, Costa AL, Gomes PS. The effects of stretching on strength performance. *Sports Med.* 2007;37(3):213-24.

30. Avela J, Finni T, Liikavainio T, Niemela E, Komi PV. Neural and mechanical responses of the triceps surae muscle group after 1 h of repeated fast passive stretches. *J Appl Physiol* (1985). 2004;96(6):2325-32.

31. Oliveira LP, Vieira LHP, Aquino R, Manechini JPV, Santiago PRP, Puggina EF. Acute Effects of Active, Ballistic, Passive, and Proprioceptive Neuromuscular Facilitation Stretching on Sprint and Vertical Jump Performance in Trained Young Soccer Players. *J Strength Cond Res.* 2018;32(8):2199-208.

32. Kerautret Y, Guillot A, Daligault S, Di Rienzo F. Foam Rolling Elicits Neuronal Relaxation Patterns Distinct from Manual Massage: A Randomized Controlled Trial. *Brain Sci.* 2021;11(6).

33. Healey KC, Hatfield DL, Blanpied P, Dorfman LR, Riebe D. The effects of myofascial release with foam rolling on performance. *J Strength Cond Res.* 2014;28(1):61-8.

34. Su H, Chang NJ, Wu WL, Guo LY, Chu IH. Acute Effects of Foam Rolling, Static Stretching, and Dynamic Stretching During Warm-ups on Muscular Flexibility and Strength in Young Adults. *J Sport Rehabil.* 2017;26(6):469-77.

35. Schoenfeld BJ, Contreras B, Krieger J, Grgic J, Delcastillo K, Belliard R, et al. Resistance Training Volume Enhances Muscle Hypertrophy but Not Strength in Trained Men. *Med Sci Sports Exerc.* 2019;51(1):94-103.

36. Reid JC, Greene R, Young JD, Hodgson DD, Blazevich AJ, Behm DG. The effects of different durations of static stretching within a comprehensive warm-up on voluntary and evoked contractile properties. *Eur J Appl Physiol.* 2018;118(7):1427-45.

37. Chaabene H, Behm DG, Negra Y, Granacher U. Acute Effects of Static Stretching on Muscle Strength and Power: An Attempt to Clarify Previous Caveats. *Front Physiol.* 2019;10:1468.