Journal of Bodywork & Movement Therapies 27 (2021) 233–238

Contents lists available at ScienceDirect

Journal of Bodywork & Movement Therapies

journal homepage: www.elsevier.com/jbmt

Acute effect of different duration times of application of myofascial release on quadriceps femoris strength: A randomized clinical trial

Tamires Cristina Campos de Almeida [a], Vanessa Paes [a, b], Maurício Soares [a, b], Guilherme de Freitas Fonseca [d], Maicom Lima [a, b], Júlio Guilherme Silva [c, *]

[a] Post-Graduate Program in Rehabilitation Sciences, Augusto Motta University (UNISUAM), Rio de Janeiro, Brazil
[b] Almirante Adalberto Nunes Physical Education Center (CEFAN), Navy of Brazil, Brazil
[c] Federal University of Rio de Janeiro - Medical School - Physiotherapy Department, Rio de Janeiro, Brazil
[d] Post-Graduate Program in Exercise Science and Sports University of Rio de Janeiro State (UERJ), Rio de Janeiro, Brazil

A R T I C L E I N F O

Article history:
Received 2 July 2020
Received in revised form
30 January 2021
Accepted 28 February 2021

Keywords:
Fascia
Isokinetic dynamometer
Musculoskeletal manipulations
Myofascial release

A B S T R A C T

Objectives: To evaluate the effect of Miofascial Release (MFR) on knee extensors strength, at different duration times of application.
Method: 51 healthy individuals were randomly assigned to one of three groups (3min, 5min or placebo) in this randomized clinical trial. The knee extensors strength was assessed in two conditions: pre and post-intervention, using an isokinetic dynamometer, at speeds of 60° and 120°/s. MFR was applied on the anterior surface of the thigh for 3min or 5 min, according to the experimental groups. The placebo group underwent through the application of a non-therapeutic gel, associated with 3min of a light touch on the skin. Peak torque, total work and mean power were the isokinetic variables analyzed through a multivariate analysis of variance (MANOVA) with $p \leq 0.05$.
Results: Our findings suggest a main effect and interaction between moments (pre and post-intervention) and speeds (60° and 120°/s) for total work and mean power ($p < 0.01$). Likewise, main effect and interaction of speed were observed for peak torque ($p < 0.01$). There were no significant differences for the other analyzed variables.
Conclusion: No significant main effect of MFR were detected in any of the proposed application time on peak torque, total work and mean power, in the knee extensors, compared to the placebo group.

1. Introduction

The myofascial system is characterized as a complex network integrated by muscle and fascia (MacDonald et al., 2016). The fascial tissue is a viscoelastic connective tissue that surrounds the human skeleton, arranged in a three-dimensional network which surrounds, protects, and maintains the connections between muscular, skeletal, and visceral components of the body (Adstrum et al., 2016; Findley, 2009; Tozzi et al., 2011; Kwong and Findley, 2014) providing a unique environment for the distribution of the mechanical loads to which the body systems are submitted (Findley, 2009; Kumka and Bonar, 2012). Recently, Schroeder (Schroeder and Best, 2015) and Krause et al. (2016) described the connective tissue of sustentation around the muscular fiber and the muscular fascia as an essential contributor in the transmission of force and neuromotor control of the corporal segments. The force produced by muscles is responsible for the torque production in the joints, which contributes to the development of human body movements, aiding in joint and postural stability.

Myofascial release (MFR) is a manual therapy technique that makes use of low load and long duration mechanical forces to manipulate the myofascial complex (Ajimsha et al., 2015; McKenney et al., 2013). MFR has been widely employed to treat myofascial restrictions and to improve sports performance. The main objectives of MFR are: restoration of tissue length and elasticity, a decrease of pain, improvement of function and reduction of fibrous adhesions occurring between the layers of fascia (Ajimsha et al., 2015; Behara and Jacobson, 2017). These fibrous adhesions may occur from injuries, fatigue and muscular imbalances, in

* Corresponding author. Tel.: + 55 21 3938 2226. Federal University of Rio de Janeiro - medical school - physiotherapy department Prédio do Hospital Universitário Clementino Fraga Filho - 8° Andar - Rua Prof. Rodolpho Paulo Rocco, s/n - Cidade Universitária CEP: 21910, Rio de Janeiro, Brazil.
E-mail address: jgsilva@hucff.ufrj.br (J.G. Silva).

https://doi.org/10.1016/j.jbmt.2021.02.026
1360-8592/

addition to recurrent microtrauma and inflammations (Behara and Jacobson, 2017). MacDonald et al. (2013) analyzed the knee extensor force responses to self-myofascial release (SMR), a therapeutic technique whose objectives are similar to MFR, using a foam roller, on healthy men. Regardless of the increased range of motion (ROM), no difference in muscle strength was detected after the second application.

During the last decade, one of the most popular techniques for SMR was the foam rolling, especially as a pre-training intervention (Behara and Jacobson, 2017). The SMR relation to muscle force has been prior discussed (Healey et al., 2014; MacDonald et al., 2013; Su et al., 2017). In despite of reports from Macdonald et al. (MacDonald et al., 2013), Healey et al. (Healey et al., 2014) and Su et al. (2017) concerning to SMR, there is no body of knowledge with regard to the effects of MFR on muscle strength. Furthermore, the literature is unclear about the required application time for MFR. Hence, the aim of this study was to evaluate the acute effect of MFR on quadriceps femoris strength, at different duration times of application, in healthy men. We hypothesized that MFR would elicit changes in quadriceps femoris strength and present interaction and main effect between peak torque, total work and power.

2. Method

This study was approved by Augusto Motta University Ethics and Research Committee (CEP/UNISUAM), under the register n° CAAE 63905416.0.0000.5235, and registered in the Brazilian Clinical Trials Registry (REBEC number: RBR-8q58cj).

The eligible participants read and signed a written informed consent to participate in this study. They were informed of all risks and benefits associated with this study, as well as all the procedures that would be performed. The study was conducted in a randomized, blinded manner concerning the therapist and evaluator.

The described methods were maintained throughout the entire research. There was no distinction or change during the procedures.

2.1. Participants

51 healthy men participated in the study. G Power 3.1 (Düsseldolf – Germany) software was used to calculate the sample size. The calculation was made with an α error of 0,05 and a test power of 80%, considering three groups (placebo, 3-min and 5-min), two moments (pre- and post-intervention) with an effect size (estimated improvement) of 45% after the MFR. Thus, a sample of 51 subjects, divided into three groups, was necessary. Participants should be aged between 18 and 35 years old and physically active, verified by the international physical activity questionnaire (IPAQ), to be eligible for this study. Subjects would be excluded in case of lower limbs post-operative history in the last 12 months, unconsolidated fractures in the lower limbs, respiratory or cardiovascular diseases considered to be risky or limiting factor for the strength test, lower limb and/or lower back pain during the tests, had performed physical activities, with emphasis on lower limbs, in the last 48 h preceding the tests and difficulty performing the requested procedures (Su et al., 2017). In this study, the sample were divided into 3 groups: 3 min ($n = 17$), 5 min ($n = 17$) and placebo ($n = 17$).

2.2. Procedures

The study was conducted in a randomized, blinded manner with regard to the therapist and evaluator. The therapist and the evaluator received one-year training (Myers's method for MFR and measurement instrumentation, respectively) before the beginning of the present research. Initially, all participants underwent through a strength evaluation in the dominant limb (pre-intervention) and randomly assigned to one of the three groups (3 min, 5 min or placebo). The randomization was carried out by a draw, performed by a third person, using numbered opaque envelopes and kept in an enclosed place. The evaluator had no contact with the envelopes, and the therapist only had them at the moment of the MFR application.

After the first evaluation (pre-intervention), all subjects were invited to return to the laboratory for a second evaluation (post-intervention), with a 48 h interval between the two visits to avoid a possible cumulative effect of strength test, which could compromise the study results. The strength test was performed using the Biodex System 4 Pro isokinetic dynamometer (Biodex Medical System, Shirley, New York, USA). The participant, suitably dressed, was positioned in a seated position. The trunk, pelvis and thigh were stabilized by belts attached to the apparatus to avoid any contribution from the upper limbs or other part of the body (DVIR, 2002). Once seated (Fig. 1A and B), the participant received information about the procedures that would be performed. The dynamometer was displaced along the horizontal plane, being positioned on the external face of the dominant lower limb. The height of the seat was adjusted towards the dynamometer, or in the opposite direction, for fine adjustment. The rotational axis of the device remained aligned with the rotational axis of the knee joint, at the height of the femoral epicondyle. The leverage of the equipment was positioned parallel to the dominant lower limb, with the support cushion attached two fingers above the lateral malleolus (Buyukvural Sen et al., 2015). The muscular performance was assessed in the dominant limb, with angular velocity of 60°/s and 120°/s in concentric/concentric mode.

Prior to the test, the participants underwent a familiarization with the procedures, performed on the isokinetic dynamometer, composed by a two-repetitions set of knee extension/flexion, with the dominant limb, at angular velocities of 60°/s 120°/s.

The weighting of the dominant limb, relaxed at 30°, was performed to correct the gravity action in the flexion movement (this correction factor is performed by the isokinetic dynamometer itself). All participants were equally encouraged, both verbally and visually, to perform as much force as possible. All tests were applied by the same evaluator.

The peak torque, expressed in Newton per meter (Nm), the total work, defined as the area under the time curve, expressed in joule (J), and the mean power, defined as the total work divided by time and expressed in watt (W), were obtained at the end of all the evaluations performed in the dynamometer (Lund et al., 2005; Su et al., 2017).

All participants completed the entire procedure, with no loos of data to be reported.

2.3. Protocol

MFR were applied by only one experienced physical therapist, who was trained to provide both MFR and placebo. In order to minimize the risk of contact between the participants, their visits were scheduled for different moments. The interventions were applied with no cost for the participants.

MFR was applied on the anterior surface of the thigh (unilaterally - dominant limb only), while the participant remained seated on the isokinetic dynamometer. MFR could be applied for 3min or 5 min, according to the randomization. The MFR technique consisted of slow and sustained pressure maneuvers, performed with longitudinal movements of deep sliding (Fig. 2).

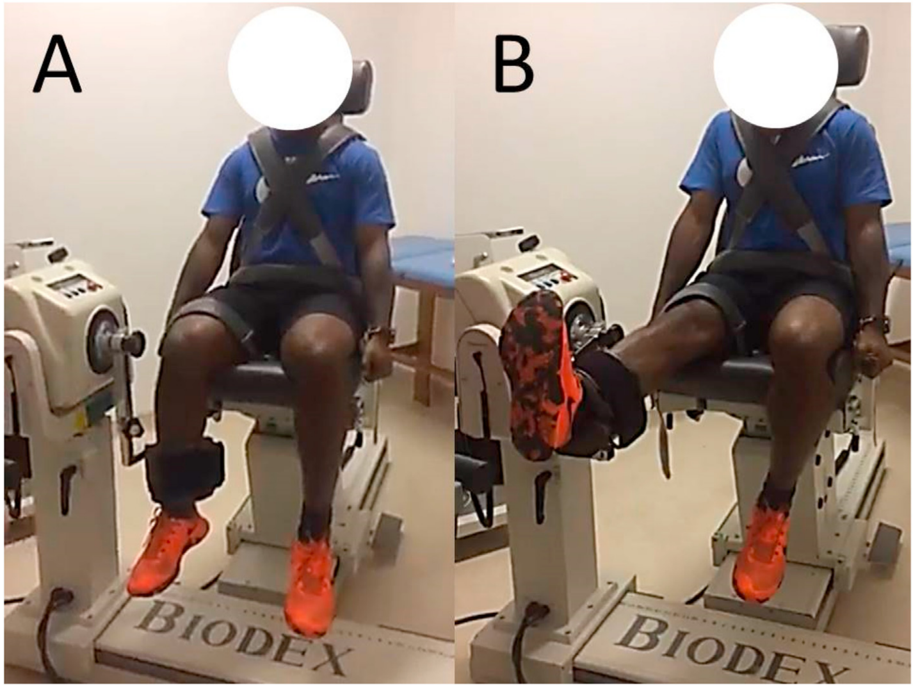

Fig. 1. Participant position in the isokinetic dynamometer. A: Initial position; B: Maximal knee extension.

Fig. 2. Deep sliding myofascial release technique.

MFR was not applied to participants from the placebo group. For those, only manual contacts with application of a non-therapeutic gel was performed, during 3min, with a light touch on the skin, using the same anatomical points (anterior surface of the thigh) as the intervention group but without application of force.

2.4. Statistical analysis

Socio-anthropometric data were analyzed by descriptive statistics with determination of central tendency values (mean and median) and dispersion (standard deviation). Subsequently, the Kolmogorov-Smirnov test was performed and the sample distribution was found to be normal. Regarding the variables of interest, an analysis of the interaction and main effect between the factors group (placebo, 3min and 5min), moment (pre and post-intervention) and speed (60° and 120°/s) and the dependent variables (peak torque, total work and mean power), provided by the isokinetic assessment, was performed. For this, a multivariate analysis of variance (MANOVA) was used, with a significance level greater than or equal to 95% ($p \leq 0.05$). The data was analyzed by the IBM SPSS 20.0 version for Windows software.

3. Results

51 healthy men were invited to participate in this study. The total amount of volunteers met the inclusion criteria and completed all phases of the study. There were no exclusions or withdrawals to be reported. The recruitment and data collection were carried out at the Almirante Adalberto Nunes Physical Education Center (CEFAN), located at 10590, Avenida Brasil - Penha, Rio de Janeiro - RJ - Brazil, during the period from April 2017 to October 2017.

The participant's characteristics (age, weight, height, body mass index and level of physical activity) are presented in Table 1.

The mean values and their respective standard deviations (SD) of the dependent variables (peak torque, mean power and total work) of the dominant limb, during the knee extension movement at angular speeds of 60°/s and 120°/s, in the placebo, 3 min and 5 min groups are presented in Table 2.

Regarding the dependent variables of interest (peak torque, total work and mean power), a MANOVA was performed and our results pointed out a main effect and interaction between the moments for total work and mean power. As for the speed factor, there was interaction and main effect for the dependent total work, mean power and peak torque. In the other analyzed variables, no significant differences were found. The results mentioned above are shown in Table 3.

4. Discussion

The purpose of this study was to evaluate the effect of MFR on knee extensors strength, at different duration times of application. The results indicate interactions and main effect between angular speeds (60° and 120°/s) and between moments (pre and post intervention), for the dependent variables, peak torque, total work,

Table 1
Participant characteristics and between-groups differences (ANOVA).

	Placebo (n = 17)	3 Minutes (n = 17)	5 Minutes (n = 17)	*p* value
Age (years)	26.88 ± 5.79	24.28 ± 4.46	25.94 ± 6.57	0,391
Weight (kg)	80.16 ± 14.79	79.67 ± 23.16	80.06 ± 8.58	0,996
Height (cm)	179 ± 0.07	177 ± 0.08	176 ± 0.05	0,617
BMI (Kg/m^2)	25.04 ± 3.79	24.99 ± 4.97	25.74 ± 2.70	0,826
IPAQ (Activity Level)	High (65%) Moderate (30%) Low (5%)	High (78%) Moderate (22%)	High (76%) Moderate (12%) Low (12%)	

BMI: Body Mass Index; IPAQ: International Physical Activity Questionnaire.

Table 2
Mean values and standard deviations of the variables analyzed by the isokinetic dynamometer.

Speed: 60°/s	Placebo (n = 17)		3 min (n = 17)		5 min (n = 17)	
	Pre	Post	Pre	Post	Pre	Post
Peak Torque (Nm)	242.51 ±52.07	248.57 ±54.44	224.48 ± 51.12	241.32 ± 45.09	248.63 ±44.88	258.85 ±43.51
Total Work (J)	1151.32 ±302.42	1164.61 ±313.97	1031.48 ± 97.37	1164.04 ± 296.63	1170.85 ±198.84	1265.50 ±248.40
Mean Power (W)	156.00 ±37.55	164.48 ±35.75	139.58 ± 32.55	161.99 ± 30.83	163.18 ±36.55	174.95 ±32.66
Speed: 120°/s	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
Peak Torque (Nm)	200.68 ±47.98	210.35 ±46.46	193.68 ±38.47	201.59 ±39.39	205.85 ±33.31	213.93 ±36.26
Total Work (J)	1022.84 ±303.86	1058.42 ±278.52	956.66 ±217.51	1038.98 ±237.58	984.32 ±264.22	1058.89 ±255.52
Mean Power (W)	233.17 ±60.43	247.98 ±60.88	222.42 ±52.83	238.49 ±45.95	239.60 ±62.53	261.96 ±52.34

Table 3
Multivariate analysis of variance (MANOVA).

Peak Torque	F	Sig.
Group	0.070	0.932
Moment	2.591	0.109
Speed	41.939	**<0.01**
Total Work		
Group	0.038	0.963
Moment	3.870	**0.05**
Speed	13.732	**<0.01**
Mean Power		
Group	0.087	0.917
Moment	6.405	**0.012**
Speed	161.374	**<0.01**

and mean power. However, no difference was found between the experimental (3 min and 5 min) and placebo groups. Therefore, it was not possible to evidence the effect of MFR on knee extensors strength at different duration times of application.

In this study, three parameters were chosen for analysis: peak torque, total work and mean power. Previously, some studies (Davies and Heiderscheit, 1997; Impellizzeri et al., 2008; Saenz et al., 2010) using similar experimental designs, analyzed the muscular function and attested good inter-test reproducibility of the mentioned parameters. Our results are in agreement with the studies described above, once the application of the method was relatively easy to perform and presented low variation in the standard error of the measurement.

The main findings, regarding the dependent variables are as follows: I: For peak torque, higher performance were seen at the lowest angular speed (60°/s) in both, experimental and placebo groups, which can be explained by the fact that the lower the speed tested, the longer the contraction time required to overcome the resistance imposed by the isokinetic dynamometer, consequently, the greater the amount of muscle fibers recruited, producing more force (Ferreira et al., 2010). The greatest results for peak torque were seen for the group that underwent through longer intervention (5 min), nevertheless, the results did not show statistical differences ($p > 0.05$). II: Concerning total work, we noticed similar behavior to torque peak in all the analyzed groups, in which higher performance were found at lower speed. The total work represents the torque generated during the whole range of motion, being inversely proportional to the angular speed (Dias et al., 2001; Petersen and Holmich, 2005; Portes et al., 2007). III: In contrast to the other analyzed dependent variables, mean power presented better performance at the highest angular speed (120°/s), in all groups. Our findings are in agreement with the results found by (Zabka et al., 2011), in which power was reduced at lower angular speed (60°/s).

In a study using foam roller as an instrument for SMR, Healey et al. (2014) did not find effects of SMR on athletes vertical jump performance. Their results are consonant to the ones found by MacDonald (MacDonald et al., 2013) that did not show significant interaction between SMR and force. The present study observed significant improvement for moments (pre and post-intervention), mainly in relation to total work. Notwithstanding, concurring to previous studies using foam roller, it was not possible to evidence the effect of MFR on muscle strength when comparing intervention groups to placebo. The interaction and main effect between the pre and post-intervention differences may happen due to familiarization with the isokinetic dynamometer. Although all participants, mandatorily, did two repetitions for familiarization at each speed, the second visit had an inevitable learning factor (Healey et al., 2014; MacDonald et al., 2013).

In addition, Su et al. (2017) compared the effect of different warm-up strategies – foam rolling, static stretching, and dynamic stretching – on muscle strength and flexibility. Peak torque measurements, during knee extension and flexion, were carried out at 60°/s using an isokinetic dynamometer. Knee extension peak torque was significantly improved after foam rolling, which also induced greater improvements in flexibility. Recently, Lee et al. (2018), with similar assessment methods, found that vibration rolling (VR) and nonvibration rolling (NVR) promoted significant improvements in knee extension peak torque. No significant effect was found for static stretching. It is worth to mention that, in contrast to our study, Su et al. (2017) and Lee et al. (2018) did not test a control group or placebo intervention.

Summarizing the available data, a recent meta-analysis (Wiewelhove et al., 2019) reported that the use of foam rolling as a pre-test intervention is able to promote small improvements in sprint performance and flexibility. On the other hand, no effect was detected on jump and strength performance. With regard to the effect of several massage techniques as strategies for athletes to enhance strength and functional performance, a systematic review (Mine K Fau - Lei et al., 2018) concluded that its use should be reconsidered, once there is no evidence to support this practice. Besides that, from nine studies selected to this systematic review, six had low quality, two were of moderate-quality and only one was high-quality. These findings evidence a lack of knowledge surrounding this topic. Another gap in the literature refers to the effects of MFR, applied by a therapist, on muscle strength. Most of the studies investigate the SMR and the use of apparatus, such as foam roller or vibration rolling, while MFR remains poorly studied.

With respect to the duration times of MFR application, it is important to emphasize that the duration times used in the study methods were 3 and 5 min, as previously described by Ercole et al. (2010) who evaluated the required duration time to modify the fascial tissue and suggested that this time may differ according to the characteristics of subjects. The mean time obtained in the cited study was 3.24 min in patients with acute or chronic low back pain. Some studies (Kuruma et al., 2013; Rodriguez-Huguet et al., 2020; Stanek et al., 2018; Tozzi et al., 2011) used MFR to evaluate different outcomes, such as variation in pain perception and range of motion, and found significant results. However, the application of the technique was performed for longer times. To date, this is the first study to evaluate the effect of MFR on knee extensors strength. Therefore, there is no standard protocol to be followed for such analysis.

Our findings suggest that MFR, applied for 3 and 5 min, is not able to elicit changes in knee extensors strength. Considering the escalating popularity of MFR, especially as a pre-training intervention with the aim of improving performance, caution is need before adopting this technique. The MFR on muscle strength, especially when applied by a therapist, is still poorly investigated and further researches are required to better elucidate this topic.

4.1. Limitations

In this experimental study, some limitations that justify the discussion: the first one refers to the shortage of previous studies in the literature to compare to our results, even with the availability of several studies regarding the applicability of MRF on muscle performance. Another aspect is that the lack of statistical significance may be due to a treatment effect which is lower than expected. Although the participants were instructed not to perform physical activities, with emphasis in the lower limbs, during the 48 h preceding the tests, the only available method to control this variable was asking the volunteers, before the tests, if they fulfilled the previous recommendations. Another bias was the impossibility to quantify the amount of pressure applied during the 3min, 5min and placebo interventions even considering it was done by a trained therapist.

5. Conclusion

The MFR had no acute effect on knee extensors peak torque, total work and mean power, at any of the proposed duration times of application. Further researches are required on this topic, focusing on longitudinal designs, to elucidate the mechanisms of MFR involved in kinetic parameters. It is suggested that future studies apply longer duration time of MFR in healthy individuals. Beside of that, to replicate our protocol in individuals with reported myofascial restrictions, to enable new comparisons and inferences. Especially, towards the analysis of MFR as a pre-training resource in muscle strength exercise.

This research did not receive financial support

The Augusto Motta University Center Ethics and Research Committee (CEP/UNISUAM) approved all the procedures performed in this study (register n° CAAE 63905416.0.0000.5235). The authors declare no conflict of interest.

Clinical relevance

- MFR has been widely used to treat myofascial restrictions and as a pre-training strategy to improve performance.
- In practical terms, this study indicates that MFR is not an effective pre-exercise tool to improve knee strength in healthy individuals.

CRediT authorship contribution statement

Tamires Cristina Campos de Almeida: Conceptualization, Project administration, Supervision, Visualization, Writing – review & editing, Writing – original draft, Data curation, Validation, Methodology, Formal analysis, Investigation, Resources. **Vanessa Paes:** Data curation. **Maurício Soares:** Data curation. **Guilherme de Freitas Fonseca:** Writing – review & editing. **Maicom Lima:** Data curation. **Júlio Guilherme Silva:** Conceptualization, Project administration, Supervision, Visualization, Writing – review & editing, Writing – original draft, Validation, Methodology, Formal analysis, Investigation, Resources.

Declaration of competing interest

The authors declare no conflicts of interest. This research did not receive any type of funding.

References

Adstrum, S., Hedley, G., Schleip, R., Stecco, C., Yucesoy, C., 2016. Defining the fascial system. J. Bodyw. Mov. Ther. 21.
Ajimsha, M.S., Al-Mudahka, N.R., Al-Madzhar, J.A., 2015. Effectiveness of myofascial release: systematic review of randomized controlled trials. J. Bodyw. Mov. Ther. 19, 102–112.
Behara, B., Jacobson, B.H., 2017. Acute effects of deep tissue foam rolling and dynamic stretching on muscular strength, power, and flexibility in division I linemen. J. Strength Condit Res. 31, 888–892.
Buyukvural Sen, S., Ozbudak Demir, S., Ekiz, T., Ozgirgin, N., 2015. Effects of the bilateral isokinetic strengthening training on functional parameters, gait, and the quality of life in patients with stroke. Int. J. Clin. Exp. Med. 8, 16871–16879.
Davies GJ, Heiderscheit BC 1997 Reliability of the Lido Linea closed kinetic chain isokinetic dynamometer. J. Orthop. Sports Phys. Ther. 25, 133-136.
Dias EP, Marchiori E, Coutinho JÃºnior AnC, Domingues RmCr, Domingues RCr 2001 Avaliação por ressonânncia magnética das injúrias musculares traumáticas. Radiol. Bras. 34, 327-331.
DVIR, z, 2002. Isocinética: avaliações musculares, interpretações e aplicações

clínicas. manole, São Paulo.
Ercole, B., Antonio, S., Julie Ann, D., Stecco, C., 2010. How much time is required to modify a fascial fibrosis? J. Bodyw. Mov. Ther. 14, 318–325.
Ferreira AP, Gomes SrA, Ferreira CES, Arruda Md, França NMd 2010 Avaliação do desempenho isocinético da musculatura extensora e flexora do joelho de atletas de futsal em membro dominante e não dominante. Revista Brasileira de Ciências do Esporte 32, 229-243.
Findley, T., 2009. Fascia research II: second international fascia research congress. Int J Ther Massage Bodywork 2, 4–9.
Healey, K.C., Hatfield, D.L., Blanpied, P., Dorfman, L.R., Riebe, D., 2014. The effects of myofascial release with foam rolling on performance. J. Strength Condit Res. 28, 61–68.
Impellizzeri, F.M., Bizzini, M., Rampinini, E., Cereda, F., Maffiuletti, N.A., 2008. Reliability of isokinetic strength imbalance ratios measured using the Cybex NORM dynamometer. Clin. Physiol. Funct. Imag. 28, 113–119.
Krause, F., Wilke, J., Vogt, L., Banzer, W., 2016. Intermuscular force transmission along myofascial chains: a systematic review. J. Anat. 228, 910–918.
Kumka, M., Bonar, J., 2012. Fascia: a morphological description and classification system based on a literature review. J. Can. Chiropr. Assoc. 56, 179–191.
Kuruma, H., Takei, H., Nitta, O., Furukawa, Y., Shida, N., Kamio, H., Yanagisawa, K., 2013. Effects of myofascial release and stretching technique on range of motion and reaction time. J. Phys. Ther. Sci. 25, 169–171.
Kwong, E.H., Findley, T.W., 2014. Fascia-Current knowledge and future directions in physiatry: narrative review. J. Rehabil. Res. Dev. 51, 875–884.
Lee, C.L., Chu, I.H., Lyu, B.J., Chang, W.D., Chang, N.J., 2018. Comparison of vibration rolling, nonvibration rolling, and static stretching as a warm-up exercise on flexibility, joint proprioception, muscle strength, and balance in young adults. J. Sports Sci 36, 2575–2582.
Lund, H., Sondergaard, K., Zachariassen, T., Christensen, R., Bulow, P., Henriksen, M., Bartels, E.M., Danneskiold-Samsoe, B., Bliddal, H., 2005. Learning effect of isokinetic measurements in healthy subjects, and reliability and comparability of Biodex and Lido dynamometers. Clin. Physiol. Funct. Imag. 25, 75–82.
MacDonald GZ, Penney MD, Mullaley ME, Cuconato AL, Drake CD, Behm DG, Button DC 2013 an acute bout of self-myofascial release increases range of motion without a subsequent decrease in muscle activation or force. J. Strength Condit Res. 27, 812-821.
MacDonald, N., Baker, R., Cheatham, S.W., 2016. The effects of instrument assisted soft tissue mobilization on lower extremity muscle performance: a randomized controlled trial. Int J Sports Phys Ther 11, 1040–1047.
McKenney, K., Elder, A.S., Elder, C., Hutchins, A., 2013. Myofascial release as a treatment for orthopaedic conditions: a systematic review. J. Athl. Train. 48, 522–527.
Mine K Fau - Lei, D., Lei, D., Nakayama, T., 2018. Is pre-performance massage effective to improve maximal muscle strength and functional performance? A systematic review. Int J Sports Phys Ther 13, 789–799.
Petersen, J., Holmich, P., 2005. Evidence based prevention of hamstring injuries in sport. Br. J. Sports Med. 39, 319–323.
Portes, E.M., Portes, L.A., Botelho, V.G., Souza Pinto, S., 2007. Isokinetic torque peak and hamstrings/quadriceps ratios in endurance athletes with anterior cruciate ligament laxity. Clinics 62, 127–132.
Rodriguez-Huguet, M., Rodriguez-Almagro, D., Rodriguez-Huguet, P., Martin-Valero, R., Lomas-Vega, R., 2020. Treatment of Neck Pain with Myofascial Therapies: A Single Blind Randomized Controlled Trial. J Manipulative Physiol Ther. https://doi.org/10.1016/j.jmpt.2019.12.001. . LID - S0161-4754(20)30010-5 [pii] LID -.
Saenz, A., Avellanet, M., Hijos, E., Chaler, J., Garreta, R., Pujol, E., Sandoval, B., Buen, C., Farreny, A., 2010. Knee isokinetic test-retest: a multicentre knee isokinetic test-retest study of a fatigue protocol. Eur. J. Phys. Rehabil. Med. 46, 81–88.
Schroeder AN, Best TM 2015 Is self myofascial release an effective preexercise and recovery strategy? A literature review. Curr. Sports Med. Rep. 14, 200-208.
Stanek, J., Sullivan, T., Davis, S., 2018. Comparison of compressive myofascial release and the graston technique for improving ankle-dorsiflexion range of motion. J. Athl. Train. 53, 160–167.
Su, H., Chang, N.J., Wu, W.L., Guo, L.Y., Chu, I.H., 2017. Acute effects of foam rolling, static stretching, and dynamic stretching during warm-ups on muscular flexibility and strength in young adults. J. Sport Rehabil. 26, 469–477.
Tozzi, P., Bongiorno, D., Vitturini, C., 2011. Fascial release effects on patients with non-specific cervical or lumbar pain. J. Bodyw. Mov. Ther. 15, 405–416.
Wiewelhove, T., Doweling, A., Schneider, C., Hottenrott, L., Meyer, T., Kellmann, M., Pfeiffer, M., Ferrauti, A., 2019. A meta-analysis of the effects of foam rolling on performance and recovery. Front. Physiol.
Zabka, F.F., HGa, Valente, Pacheco, A.M., 2011. AvaliaÃ§Ã£o isocinÃ©tica dos mÃºsculos extensores e flexores de joelho em jogadores de futebol profissional. Rev. Bras. Med. do Esporte 17, 189–192.