MLS - SPORT RESEARCH

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How to cite this article:

Secades Rodríguez, M., Torre Saro, B., Velarde-Sotres, Á. & Mecías-Calvo, M. (2021). Comparison of Foam Roller types evaluating their acute effect on the rectus femoris muscle using tensiomyography. *MLS Sport Research, 1*(1), 7-18.

COMPARISON OF FOAM ROLLER TYPES ASSESSING THEIR ACUTE EFFECT ON THE RECTUS FEMORIS MUSCLE USING TENSIOMYOGRAPHY

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Abstract. The use of the Foam Roller (FR) is a relatively new myofascial release technique that is experiencing a considerable increase in the sport and health environment. The aim of this study was to compare the various types of FR by assessing their acute effect on the rectus femoris (RF) muscle using Tensiomyography (TMG), taking into account the variables Maximum Deformation (Dm) and Contraction Time (Tc). Ten participants from the Faculty of Physical Activity and Sport Sciences (CAFYD) carried out the study with one type of FR each session, spread over three days. Each subject performed 3 sets of 90 seconds with 30 seconds rest, on the dominant leg only. The TMG measurements were two, before and after the use of the RF. When analyzing the effects produced by all the FR on the total number of participants, no significant differences were found in any of the variables. Although we noticed that, when separating the sample by level of sporting activity, the FR Hard (FRD) and FR Relieve (FRR) caused a significant decrease in Tc, causing activation in the Untrained Subjects (SNE). On the contrary, in the Trained Subjects (TS), the effect of FRD produced an increase in Tc, causing a relaxation of RF. The variations become noticeable depending on the sport practice and probably on the muscle tone. Therefore, the user's physical shape and experience with the Foam Roller must be taken into account, as this will directly influence the effect of its use.

Keywords: Foam roller, tensiomyography, rectus femoris, contraction time, maximum deformation.

COMPARACIÓN DE LOS TIPOS DE FOAM ROLLER EVALUANDO SU EFECTO AGUDO EN EL MÚSCULO RECTO FEMORAL MEDIANTE TENSIOMIOGRAFÍA

Resumen. La utilización del rodillo de espuma o Foam Roller (FR) es una técnica de liberación miofascial relativamente nueva que está experimentando un aumento considerable en el entorno del deporte y de la salud. El objetivo de este estudio fue comparar los diversos tipos de FR evaluando su efecto agudo en el músculo Recto Femoral (RF) mediante Tensiomiografía (TMG), teniendo en cuenta las variables Deformación máxima (Dm) y Tiempo de Contracción (Tc). Diez participantes de Ciencias de la Actividad Física y el Deporte (CAFYD) realizaron el estudio con un tipo de FR cada sesión, repartidos en tres jornadas. Cada sujeto llevó a cabo 3 series de 90 segundos con 30 segundos de descanso, sólo en la pierna dominante. Las mediciones en TMG fueron dos, antes y después del uso del FR. Al analizar los efectos producidos por todos los FR en el total de los participantes no se encontraron diferencias significativas en ninguna de las variables. Aunque hemos advertido que, al separar la muestra por nivel de actividad deportiva, el FR Duro (FRD) y el FR Relieve (FRR) causaron una disminución significativa del Tc, provocando una activación en los Sujetos No Entrenados (SNE). Por el contrario, en los Sujetos Entrenados (SE), el efecto del FRD produjo un aumento del Tc, ocasionando una relajación del RF. Las variaciones se vuelven notables dependiendo de la práctica deportiva y probablemente del tono muscular. Por ello, hay que tener muy en cuenta la forma física del usuario y su experiencia con el Foam Roller, ya que esto va a influir directamente en el efecto que le producirá su uso.

Palabras clave: Foam roller, tensiomiografía, recto femoral, tiempo de contracción, deformación máxima.

Introduction

FR is one of the latest trends in the world of fitness and sports training, used both in warm-up and cool-down to improve flexibility, post-workout recovery and sports performance. It is a kind of roller that acts on the fasciae that surround the muscles by releasing the tensions that exist in these, allowing the tissue to be more flexible and soft (Schleip and Müller, 2013). The technique of use consists of rolling the FR over the muscle to be worked, from the proximal part to the distal part of the muscle or vice versa (Paolini, 2009). The application times of the myofascial release technique range from a series of 5 seconds on one muscle to 40 minutes on different muscle areas (Ferreira, 2016). There are different types depending on their stiffness, hardness, contact surface, or vibration. We can find scientific studies showing that the stiffness of the FR influences the pressure on the muscle (Martínez-Cabrera and Núñez-Sánchez, 2016). A multilevel rigid FR achieves greater pressure with a smaller contact area on the muscle while with a bio-foam FR the pressure exerted on the muscle is less and the contact area greater (Curran, Fiore and Crisco, 2008). The study by Cheatham, Stull, and Kolber (2017) provided the information that the use of vibratory FR can increase pain tolerance more than a non-vibratory one. The specific benefits of using FR are far from clear. There is scientific evidence that the use of FR after return to calm improves performance in some tests versus passive stretching (Rey, Padrón-Cabo, Costa, & Barcala-Furelos, 2017), and that, unlike passive stretching, the use of FR improves flexibility without decreasing force production (Halperin, Aboodarda, Button, Andersen, & Behm, 2014). Its use on the triceps surae produces increases in ankle range of motion (ROM) (Škarabot, Beardsley, & Štirn, 2015; Halperin et al., 2014). With respect to strength and activation, no significant changes were found after performing a protocol, of 2 sets of 1 minute with FR, in either the hamstrings or the quadriceps (MacDonald, Penney, Mullaley, Cuconato, Drake, Behm, & Button 2013; MacDonald, Button, Drinkwater, & Behm, 2014). More compelling were the results of Miller and Rockey (2006) making it clear from their analysis that FR did not increase hamstring flexibility. In recent years, its influence on flexibility, strength, recovery, activation or pain is being studied.

New technologies are making it possible not only to directly check the condition of our athletes, but also to evaluate the effects of a program, an exercise, a training program, or a piece of equipment through their assessments or measurements. Neuromuscular function has been the subject of study in recent years. As we see in Martínez and Nuñez (2016), various techniques have been used to know the adaptations generated, such as: magnetic resonance imaging, ultrasound, electrostimulation, TMG, or a combination of them. TMG is a relatively new technique used to know the morphological and anatomical characteristics of the muscle, muscle tone (stiffness), balance between muscle structures, and also for the analysis of the mechanical characteristics and contractile capacity of the muscle (Rodríguez-Matoso, Rodríguez-Ruiz, Quiroga, Sarmiento, De Saa, and García-Manso, 2010). This device was developed in the early 1990s at the faculty of electrical engineering at the University of Ljubljana (Slovenia) by Professor Valencic (Rodriguez-Matoso et al., 2010). In recent years it has been used to assess different types of muscles in different sports modalities (García-García, Hernández Mendo, Serrano Gómez, and Morales-Sánchez, 2013), as well as parameters collected in different control tests (Gil, Loturco, Tricoli, Ugrinowitsch, Kobal, Cal Abad, and Roschel, 2015). According to Rodríguez-Matoso et al. (2010), the TMG is shown to be a non-invasive, reliable, and easily reproducible method of muscle tone assessment that requires no effort on the part of the subject to whom it is applied, evaluating the superficial muscles through the measurement of the Deformation or Maximum Radial Displacement of the muscle belly, Contraction Time, Reaction Time (Td), Time that maintains the contraction (Ts), and Relaxation Time (Tr). Despite being a reliable and valid tool, its use as an evaluation tool in scientific studies is minimal due to its high cost.

As can be seen, there is great controversy in the results of research on the benefit of using FR, although after reviewing abundant literature on the subject, it could be said that the benefits outweigh the detriments and many professionals suggest its use. Rey et al. (2017) advise that soccer coaches and physical trainers working with high-level players use a structured recovery session lasting 15-20 minutes based on FR exercises to improve recovery between training loads. Ferreira (2016) also recommends the use of FR as part of the warm-up and cool-down.

Some studies comparing normal FR with vibratory appear, but there is no reference to a comparison of the different effects produced by different types of stiffness, relief or vibration by means of TMG. Therefore, the study aims to demonstrate that the effects produced by the use of FR will be different depending on the type of material, stiffness, or vibration. Another hypothesis is that the impact caused will be different depending on the level of sport activity, therefore we will divide the sample into Untrained Subjects (UTS) and Trained Subjects (TS). The aim of this study is to compare the different types of FR by evaluating their acute effect on FR muscle by means of TMG (Dm and Tc) in the total sample of CAFYD students. Another of the objectives is to check if there are differences in the results when dividing the sample by whether or not regular and federated sports practice is carried out.

Method

Participants

A total of 10 CAFYD subjects (age 23.30 ± 2.5 years, height 175.10 ± 6.10 cm, weight 70.90 ± 6.33 kg) from the Universidad Europea del Atlántico (Santander) participated in the study. Before carrying out the study and after an explanation of the study, all subjects signed a consent document in which they authorized the use of the data obtained for the study. In addition, they completed a questionnaire on personal data, previous injuries, physical activity habits, and sports practice. To meet the inclusion criteria, the participants had to perform moderate physical activity at least 3 days a week during the last year, according to the ACSM classification (3-6 METs). They had to be in optimal health and not have suffered any lower limb injury for at least 3 months prior to the study. When analyzing the results, the sample was also divided into two groups, the UTS, who only performed moderate physical activity, and the TS, who had a regular and federated sports practice. The experimental protocol was approved by the Ethics Committee of the Universidad Europea del Atlántico.

Study design

The various acute effects produced by the use of the different types of FR on the responses of the rectus femoris muscle were evaluated by means of TMG (Tc and Dm). The evaluation was performed in 3 study days, organized in three weeks. On each day, the protocol was performed with one type of FR. Each subject was measured twice through TMG in the rectus femoris of the dominant leg. The first measurement was taken at baseline, followed by the FR protocol and then the second measurement was taken.

Procedures

TMG uses a pressure sensor (GK 40, Panoptik d.o.o., Ljubljana, Slovenia) placed perpendicularly on the belly of the selected muscle with a pressure of approximately 1.5 x 10-2 N/mm2 over an area of 113 m2 (Rodríguez-Matoso et al., 2010). The sensor is placed individually according to the anatomical characteristics of each subject. To provoke the contraction, a bipolar electric current is applied through two electrodes located at the proximal and distal ends of the muscle, avoiding that its placement affects the tendons of insertion of these muscle structures. The thickest part of the muscle belly was determined visually and by palpation in a voluntary concentric contraction and following the anatomical indications of Delagi, Perotto, Lazzeti and Morrison (1975). The electrodes should be separated between 2 and 5 centimeters (cm) with respect to the point of measurement; once placed, the area on which to place the sensor should be marked with a dermatological pencil. The duration of the electrical stimulus should be standardized at 1 millisecond (ms). A TMG-S2 electro-stimulator (EMF-FURLAN & Co. d.o.o., Ljubljana, Slovenia) was used. The position of the tested subject must be comfortable to ensure that the musculature to be tested is relaxed, so the subject should be placed on a stretcher, placing a triangular foam wedge under the leg to achieve the articular angles between segments.

Protocol

The mechanical properties of the rectus femoris muscle in the dominant leg were measured by means of TMG in each subject. Then, they performed a performance protocol with the FR, in the dominant leg, 3 series of 90 seconds resting 30 seconds between series. A digital metronome at 20 beats per minute (BPM) was used to maintain a constant speed during the FR work. And to conclude, the second measurement was performed again with TMG on the rectus femoris on the dominant leg. Before carrying out the FR work, the subjects were explained how to use the FR, loading the body weight on the dominant leg and rolling the FR with the impulse of the arms from the proximal portion of the muscle to the distal portion and vice versa, repeating this movement at a constant speed.

Three types of FR were used for this protocol; a "Blackroll Standard" FR of medium hardness, 15 cm in diameter, and 30 cm long. For the second measurement, a "Domyos" soft hardness FR with a diameter of 12.5 cm and a length of 38 cm was used. For the last measurement, a "Blackroll Booster" vibrating core was used at 56 Hz of intensity inserted in the "Blackroll Standard" used in the first measurement, configuring the vibrating FR (FRV).

Statistical Analysis

The data were analyzed using SPSS 22.0 software (IBM Corp). Descriptive statistics were determined for all variables and the normality of the variables was tested using the Kolmogorov-Smirnov test (2005). A paired samples t-test was performed to determine whether there were statistically significant differences between the variables of each intervention. The effect size (ES) was calculated by Cohen's d using means and standard deviations. The results were analyzed according to Rhea's (2004) table (<0.25 insignificant, 0.25-0.50 small, 0.50-1 moderate, >1 large).

Results

Table 1 shows the results obtained in the normality tests, all the variables complied with it according to the Kolmogorov-Smirnov values (>0.05).

Table 1
Normality Test

Type	*Variable*	*Take*	*N*	*Media*	*SD*	*Z*	*Sig.*
HFR	**Tc**	**Pre**		29.48	3.97	0.48	0.974
		Post		28.96	4.82	0.56	0.912
	Dm	**Pre**		7.52	2.15	0.41	0.996
		Post		7.34	2.16	0.70	0.704
FRR	**Tc**	**Pre**		32.09	4.63	0.47	0.982
		Post		31.43	6.49	0.54	0.930
	Dm	**Pre**		6.70	2.51	0.50	0.965
		Post		6.40	1.48	0.92	0.362
FRV	**Tc**	**Pre**		30.50	3.85	0.43	0.992
		Post		29.38	3.39	0.31	1000
	Dm	**Pre**		7.59	1.78	0.62	0.841
		Post		7.44	2.18	0.89	0.413

Note: HFR= Hard Foam Roller; FRR= Foam Roller Relief; FRV= Foam Roller Vibratory; Tc= Time of Contraction; Dm= Maximum Deformation; N= Number of participants; SD= Standard Deviation; Z= Kolmogorov-Smirnov Z statistic; Sig.= Significance Normality Test

Table 2 shows the p-values obtained by means of the t-test Related Samples. There are no significant differences in any of the variables.

Table 2
Test Related Samples

Type	*Variable*	*Media*	*p*
HFR	**Tc**	0.52±4.09	0.696
	Dm	0.17±1.18	0.657
FRR	**Tc**	0.65±3.96	0.615
	Dm	0.29±1.38	0.522
FRV	**Tc**	1.12±3.06	0.279
	Dm	0.15±1.52	0.769

Note: HFR= Foam Roller Hard; FRR= Foam Roller Relief; FRV= Foam Roller Vibratory; Tc= Time of Contraction; Dm= Maximum Deformation; p= significance of related samples.

Table 3 shows the effect size, where most of the results are inconsequential, except for the FRV, which has a small effect on Tc.

Table 3
Effect size

Type	*Variable*	*ES*	*Result*
HFR	**Tc**	0.12	Intranscendent
	Dm	0.08	Intranscendent
FRR	**Tc**	0.11	Intranscendent
	Dm	0.15	Intranscendent
FRV	**Tc**	0.31	Small
	Dm	0.08	Intranscendent

Note: HFR= Foam Roller Hard; FRR= Foam Roller Relief; FRV= Foam Roller Vibratory; Tc= Time of Contraction; Dm= Maximum Deformation; ES= Effect Size; Res. =Results

Figure 1 shows the averages of the results obtained in the different FRs by means of TMG. The pre and post evaluation of Tc and Dm are compared. It can be seen that there are no major differences, and the results in the two variables remain identical or decrease minimally.

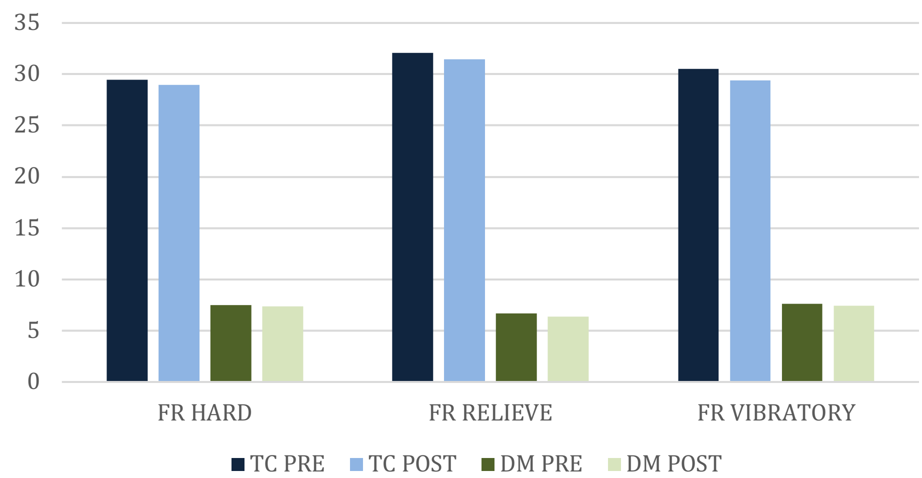


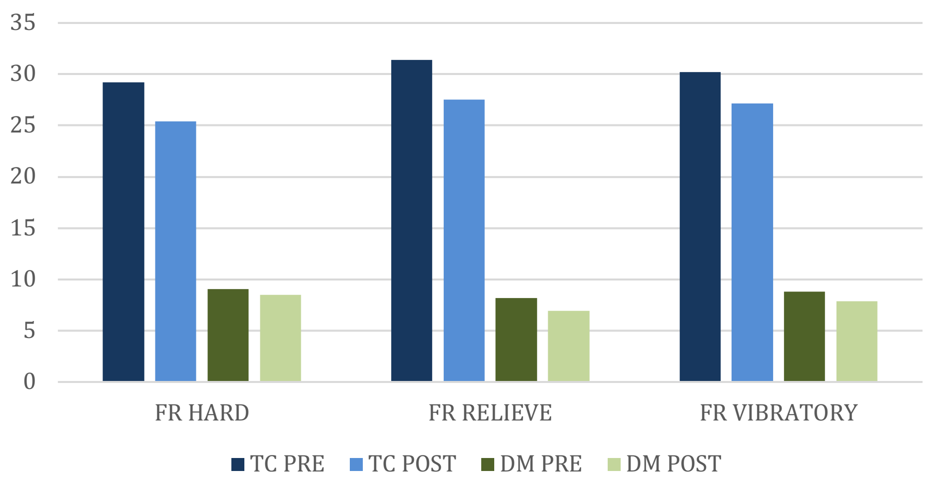
Figure 1. Pre and post results for FR (Tc and Dm)

Once the convenient statistics for the complete sample have been evaluated, the effects produced by the FRs will be presented below, dividing the sample according to the performance of Physical Activity. Table 4 presents the products of the same statistics performed above, but only for the Untrained Subjects (UTS). In the p-values for Related Samples, significant results were obtained for the Tc of the HFR and FRR. The effect size also reveals that HFR and FRR are likely to have larger effects on Tc. Figure 2 graphically compares the means of the pre and post data collection results for the 3 types of FR in the UTS.

Table 4
Test results in untrained subjects

Type	***Variable***	***Take***	***N***	***Media***	***SD***	***p***	***TE***	***Res.***
HFR	**Tc**	Pre	5	29.24	4.52	0.047	1.05	Grande
		Post	5	25.41	2.49			
	Dm	Pre	5	9.05	1.79	0.380	0.27	Small
		Post	5	8.50	2.32			
FRR	**Tc**	Pre	5	31.41	2.68	0.023	1.10	Grande
		Post	5	27.55	4.16			
	Dm	Pre	5	8.21	2.75	0.050	0.52	Moderate
		Post	5	6.96	2.00			
FRV	**Tc**	Pre	5	30.20	4.62	0.086	0.8	Moderate
		Post	5	27.16	2.68			
	Dm	Pre	5	8.80	1.60	0.280	0.41	Small
		Post	5	7.87	2.79			

Note: HFR= Foam Roller Hard; FRR= Foam Roller Relief; FRV= Foam Roller Vibratory; Tc= Shrinkage Time; Dm= Maximum Deformation; N= Number of participants; SD= Standard Deviation; p=significance of related samples; TE= Effect Size; Res. =Results



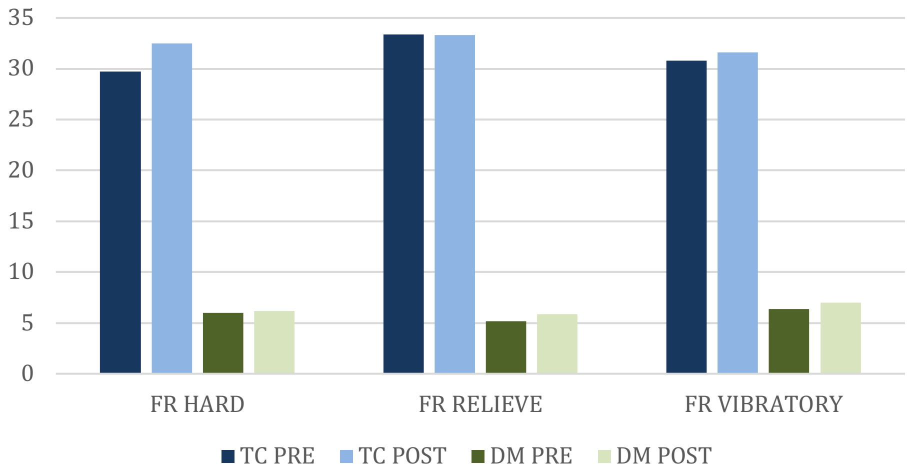
Pre and post results for FR (Tc and Dm) in untrained subjects.

Table 5 reveals the statistics of the Trained Subjects (TS). The p-values for Related Samples indicate the significance on Tc of the HFR. The effect size also reveals that HFR is likely to have greater effects on Tc. Figure 3 presents graphically the means of the results for the TSs.

Table 5
Test results in trained subjects

Type	*Variable*	*Take*	*N*	*Media*	*SD*	*p*	*ES*	*Res.*
FRD	**Tc**	Pre	5	29.72	3.85	0.004	-0.72	Moderate
		Post	5	32.50	3.83			
	Dm	Pre	5	5.98	1.15	0.695	-0.17	Intranscendent
		Post	5	6.19	1.31			
FRR	**Tc**	Pre	5	33.36	6.43	0.973	0.01	Intranscendent
		Post	5	33.32	7.72			
	Dm	Pre	5	5.18	0.95	0.189	-0.92	Moderate
		Post	5	5.85	0.40			
FRV	**Tc**	Pre	5	30.80	3.45	0.345	-0.27	Small
		Post	5	31.61	2.53			
	Dm	Pre	5	6.37	0.92	0.198	-0.5	Moderate
		Post	5	7.01	1.55			

Note: HFR= Foam Roller Hard; FRR= Foam Roller Relief; FRV= Foam Roller Vibratory; Tc= Time of Contraction; Dm= Maximum Deformation; N= Number of participants; SD= Standard Deviation; p=significance of related samples; ES= Effect Size; Res. =Results



Pre and post results for FR (Tc and Dm) in trained subjects.

Discussion and conclusions

The main objective of this study is to compare the acute effects of HFR, FRR and FRV on Tc and Dm of the rectus femoris muscle, measured by TMG. Despite the fact that the 3 types of FR produce changes in the two variables, no significant differences were observed for the total sample, thus refuting our first hypothesis. Regarding the Effect Size, based on Rhea's (2004) table, it was observed that the FRV causes small changes in Tc.

Another objective was to check whether there were variations in the results when the sample was divided according to whether or not sport was practiced. We have noticed that when separating the sample into UTS and TS, statistically significant differences are obtained in both Tc and Dm. On performing the statistical analyses and comparing the baseline means of both variables between trained and untrained individuals, we found several changes with respect to the total sample. In the UTS, with higher Dm and lower muscle tone, the effect of HFR and FRR produced an activation of the Rectus Femoris. In addition, Tc and Dm values decreased to a greater or lesser extent with the three FRs, activating the muscle and increasing its stiffness. In the TS, with a lower Dm and greater muscle tone, the effect of the HFR produced a relaxation of the Rectus Femoris and the Tc and Dm variables increased in most cases with the three FR, relaxing the muscle and decreasing its stiffness. The variations in the impact produced depending on the group accept our other hypothesis.

Although there is little scientific evidence on the comparison of the types of FR by means of TMG, we can find some studies that compare them by studying the physiological adaptations they provoke. Cabrera (2009) evaluates by means of TMG the acute effects on the mechanical properties of the rectus femoris muscle in Chinese soccer players, after a protocol of 4 series of 15" in the dominant leg, no significant differences were obtained in the Dm and Tc of the rectus femoris. The Dm was maintained in the dominant leg while, in the non-dominant leg, on which no FR protocol was performed, the Dm is higher. It concludes that short duration protocols with FR can be a good strategy to activate the muscles before exercise.

In a study conducted by Cheatham, Stull, and Kolber (2017) comparing FR with vibration and without vibration on ROM in knee flexion, similar results have been obtained between both types of FR, increasing in both cases the acute effect on ROM in knee flexion. In another comparison of FR with vibration and without vibration on ankle dorsiflexion carried out by Sierra (2017) no significant differences have been found between the different groups, although the Effect Size shows that the combination of FR with vibration is the best procedure to increase dorsiflexion during warm-up.

Curran, Fiore, and Crisco (2008) compare a bio-foam FR with a rigid multilevel FR, finding that the multilevel FR exerts more pressure on the soft tissue. Showing that the design of the FR affects the contact area, being significantly lower in the multilevel FR.

For this study, a protocol of 3 series of 90" was carried out, resting 30" between series and at a speed of 30 beats per minute. According to Ferreira and Martin (2016) these values would be within the recommendations for the use of FR as a means of relaxation, since they establish a set duration of 45" to 90", a pace of 2"-3" and 30" rest between sets. They also make recommendations for the use of FR as a means of preparation, 30"-60" per set, pace 1"-2" and 30" rest between sets. This contrasts with the results obtained in our study, since for untrained subjects the relaxation protocol causes activation.

Our findings suggest that there are differences in the effect produced by the Foam Roller depending on its surface, stiffness, or vibration. The variations become noticeable depending on the sports practice and probably on the muscle tone. Therefore, the user's physical shape and experience with the Foam Roller should be taken into account, as this will directly influence the effect produced by its use.

These results should be evaluated in future studies with a larger, homogeneous, and sport-specific sample. The assessment could be carried out on more muscles and thus also compare the effect produced by the different FR according to the type of superficial musculature. Other important factors to be determined would be the guidelines of the protocols appropriate to the objective, duration, speed, and pressure.

Several limitations should be considered in this research. The sample size varied due to the difficulty of evaluating the subjects after 48 hours of non-exercise, having problems with some participant's shots and therefore not validating their results. The used FRR was of soft compound and the FRV was tested at a frequency of 56 Hz; other FRRs with other compound and other FRVs at other frequencies could have different results. The FR protocol used throughout the study is recommended for recovery, other protocols changing the time and number of sets may get other results. The test examiner was not blinded to the results of the study.

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Date of receipt: 03/30/2021
Revision date: 04/21/2021
Date of acceptance: 05/08/2021