

Original Article

Investigation of the acute effect of myofascial release techniques and dynamic stretch on vertical jump performance in recreationally active individuals

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Abstract

This study aimed to investigate and compare the acute effect of instrument-assisted soft tissue mobilization, foam roller, and dynamic stretch interventions on vertical jump performance in recreationally active individuals. The study included 42 individuals between 18 and 35 years of age. All participants were randomized into groups of 14, and they warmed up by 5-min jogging. Instrument-assisted soft tissue mobilization was applied with Graston Technique®, and foam roller was applied with a Trigger Point Deep Tissue foam roller. On both legs, the hamstring, and gastrocnemius muscles, and plantar fascia were treated with instruments in the Graston Technique® group and with myofascial release using the participant's own body weight in the foam roller group for a total of 16 min. The dynamic stretch protocol consisted of 10 dynamic exercises with 10 min of medium and high intensity exercising. Vertical jump performance was evaluated before and immediately after the application using the "Optojump Next" system with the "Counter movement Jump without Arm Swing" test. IBM SPSS (version 22) was used for statistical analysis. The $p < 0.05$ value was considered statistically significant. The mean age of the participants was 23.0 ± 1.6 , 22.7 ± 3.8 , and 21.5 ± 1.6 years in the Graston Technique®, foam roller, and dynamic stretch groups, respectively. There was a statistically significant difference in the pre- and post-jump performance values of all 3 groups ($p = 0.000$). In the evaluation between the groups, there was no statistically significant difference in the jump performance of Graston Technique® and dynamic stretch ($p = 0.840$), dynamic stretch and foam roller ($p = 0.778$), and Graston Technique® and foam roller ($p = 0.436$) groups. There was a statistically significant increase in the jump performance of all 3 groups, with the biggest change being in the Graston Technique® group. Considering the inter-group comparisons, no statistically significant change was observed between the groups.

Keywords: instrument assisted soft tissue mobilization, graston technique®, foam roller, sport performance, warm up

Introduction

Fascia is a 3-dimensional connective tissue network, which is continuous throughout the body. It surrounds and encloses muscles, organs, and skeletal structures in our bodies (Shah & Bhalara, 2012). The myofascial system consists of a complex muscle network and the fascia associated with these muscles. The myofascial system is involved in the transmission of muscle strength, fibroblastic activity, and the reduction of regional friction through the sliding of fascial layers over one another during movement (MacDonald, Baker, & Cheatham, 2016). Furthermore, our fascia is the richest sensory organ because it contains several various receptors, such as Golgi tendon organs, Krause's terminations, Pacini and Ruffini corpuscles. These receptors report all deformations in the fascia, including pressure, vibration, and shear forces to the brain, and the nervous system may alter muscle tone in response to incoming signals (Myers, 2009).

To reduce muscle spasms, neuromuscular changes, and pain in the event of injury, some limitations occur in the fascia. In the event of restriction, the fascia may adhere to muscles and other body structures and produce fibrous adhesions. In addition, disability, poor posture, or incomplete range of motion (ROM) cause limitations in this system (MacDonald, Baker, & Cheatham, 2016; Sullivan, Silvey, Button, & Behm, 2013; Behara & Jacobson, 2017). Restrictions are thought to result in injuries, muscle imbalance, excessive use and/or inflammation, problems with muscle length and coordination, and decreased muscle power production, which may result in decreased performance in sports (Behara & Jacobson, 2017; Giovanelli et al., 2018).

To prevent these restrictions from impairing performance, a warm-up period is required before competitions or training. In particular, warm-up exercises performed before activities requiring high power output are believed to be essential in determining performance, preventing injury, and reducing muscle pain after exercise (Cilli, Gelen, Yildiz, Saglam, & Camur, 2014; Kyranoudis et al., 2019).

Jumping force is one of the most important features, and it considerably affects performance in sports that require jumping (Çimenli, Koç, Çimenli, & Kaçoğlu, 2016). Jump performance ability is governed by an individual's ability to utilize the elastic and neural benefits of the stretch shortening cycle (Fischetti, Cataldi, & Greco, 2019). It is essential for the muscle to produce sufficient strength so that it could bounce to a sufficient height (Cieślicka et al., 2019). In recent years, increasing jumping performance has become the focus of interest. Dynamic stretch (DS), foam roller (FR), and instrument-assisted soft tissue mobilization (IASTM) are recommended for improving jumping performance.

DS includes controlled movements in the active ROM of a joint. This type of exercise is actually the basis of sports movements used in training or competition. For example, moving drills include calisthenics movements (e.g., lunge, anterior and lateral runs) and reversing movements to different sides (Chatzopoulos, Galazoulas, Patikas, & Kotzamanidis, 2014). Moderate-to-high intensity voluntary contractions activate nerve muscle functions to increase power production and performance (Cilli, Gelen, Yildiz, Saglam, & Camur, 2014). Therefore, DS can be used as part of the warm-up phase to increase vertical jump performance (VJP) (Perrier, Pavol, & Hoffman, 2011).

Myofascial release techniques include various methods used to separate soft tissue from tight fascia and to release adhesion in the layers of deep fascia. This can be achieved by stretching the muscular elastic components of the fascia along the cross bridges and changing the viscosity of the fascia's ground substance. There are various myofascial release techniques that the clinician applies to the patient (e.g., GT®) or that the patient can self-administer, i.e., perform a self-myofascial release, such as FR (Shah & Bhalara, 2012).

FR is one of the most popular self-myofascial release methods. FR is a dense foam cylinder that the person rolls before using the body weight to warm up and increase their ROM. There are different types that vary in size, shape and density (Kalichman & Ben David, 2017). It is assumed that during rolling, direct and sweep pressure is applied to the soft tissue, causing facial mobilization and increased ROM. At the same time, the frictional force is generated during the rolling motion, which causes an increase in the fascia temperature and a decrease in the viscosity of the extracellular matrix. This change causes the fragmentation of facial adhesions between different layers of the fascia and restores soft tissue extensibility (Myers, 2009; Sullivan, Silvey, Button, & Behm, 2013). In addition, this approach aims to improve mobility and ROM, relax scar tissue and adhesions, reduce muscle tone and relieve overactive muscles, and improve movement quality (Kalichman & Ben David, 2017).

The IASTM technique is frequently used by sports medicine professionals to treat myofascial limitations (MacDonald, Baker, & Cheatham, 2016). There are many brands of instruments. One of these instruments, which is widely described in the literature, is Graston Technique® (GT®). Specifically, the instruments create a local inflammation response with micro trauma in the damaged areas, increase scar tissue destruction, loosen adhesion, increase collagen synthesis, and stimulate connective tissue remodeling (Baker, Nasypany, Seegmiller, & Baker, 2013). In addition, these instruments stimulate the nerves in the muscles, increase muscle strength, performance, and endurance, and affect muscle strength through the activation of the nervous system (MacDonald, Baker, & Cheatham, 2016; Markovic, 2015; Laudner, Compton, McLoda, & Walters, 2014; Schaefer & Sandrey, 2012).

There are studies in the literature that compare GT® with FR and DS with FR; however, the results of these studies are contradictory. To our knowledge, there are no studies comparing these 3 techniques with one another. Therefore, the aim of this study is to investigate the effect of DS, FR, and GT® interventions on VJP and to compare them.

Materials and methods

Participants

A total of 42 students (21 females, 21 males) who were recreationally active met the inclusion criteria. "Recreationally active" was defined as doing physical activity, including running a minimum of 3 times a week for at least 30 min (Baggaley, Noehren, Clasey, Shapiro, & Pohl, 2015). The participants were randomized into 3 groups with 14 participants per group. The participants who were between 18 and 35 years of age, were recreationally active, had no pain complaints, and volunteered to participate in the study were included in this study. Exclusion criteria were a body mass index of 30 kg/m² or higher; history of lower extremity surgery; injury of joint, meniscus, or ligament; chronic knee instability; cardiac, musculoskeletal, vestibular, and neurological problems; long-term use of corticosteroids; pregnancy. Before the study, all participants were informed about the intervention and its potential complications, and all of them read and signed the informed consent form. Interventions and evaluations were performed at the Bahçeşehir University Faculty of Health Sciences Physiotherapy and Rehabilitation Laboratory. This study was approved by the decision of the İstanbul Medipol University Non-Interventional Clinical Research Ethics Committee dated 19/07/2019 and numbered 10840098-604.01.01-E.33228.

Study Design

A randomized clinical trial using a pre-test/post-test design was applied. All participants completed baseline tests after which they were randomly assigned to 3 intervention groups. Each participant filled out a form evaluating the demographic characteristics and physical activity levels. Baseline testing included the

countermovement jump (CMJ) without armswing test. Subsequently, the intervention groups were instructed about DS, FR, and GT®. DS exercises and FR application were shown in a video. In addition, a physiotherapist accompanied the participants during the application. Immediately after the intervention, the CMJ without armswing test was conducted again. Figure 1 summarizes the study flow.

Randomization

The participants were randomly assigned to 1 of 3 parallel groups to receive either DS, or FR, or GT® (ratio: 1:1:1). To allocate the participants, “Research Randomizer”, which is an online randomization web service (<https://www.randomizer.org/>), was used. Simple randomization procedures (computerized random numbers) were used, and sequentially numbered index cards with the random assignment were prepared by an investigator with no clinical involvement in the study. The index cards were folded and placed in sealed, opaque envelopes. Then, the blind investigator opened each envelope and allocated the participants to the DS, FR, or GT® groups according to the selected index card. A total of 3 physiotherapists participated in this study. The GT® intervention was performed by a GT®-certified physiotherapist; DS and FR interventions were performed by another physiotherapist. The assessment and data collection were conducted by another physiotherapist. The interventionist was aware of the allocated arm; the outcome assessor was blinded to the allocation procedure.

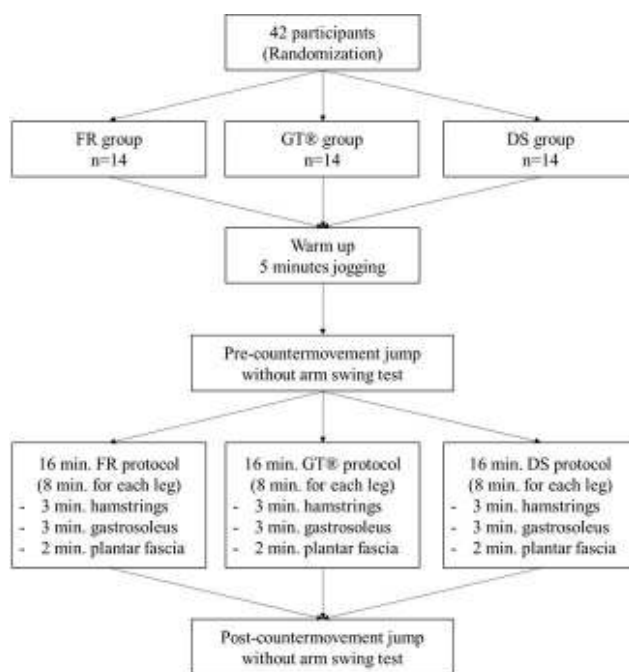


Fig.1. Flow chart of the study

Warm-up protocol

The participant was asked to do jogging at light tempo for 5 min at the speed he/she felt comfortable with. The time was tracked with a stopwatch. Participants who completed the warm-up phase were included in the first jump evaluation.

Evaluation of Jumping Performance

The Optojump system (Microgate, Bolzano, Italy), which consists of 2 parallel bars (receiver and transmitter units) with photoelectric cells positioned at ground level, allows direct surface interaction for the athlete because it can be placed on all surfaces except for sand (Glatthorn et al., 2011). The Optojump system is a dual beam optical device that measures contact and light times during a series of bounces (or a single bounce). Flight time (T air) was used to calculate the height of the body’s center of gravity from the ground (Sattler, Sekulic, Hadzic, Uljevic, & Dervisevic, 2012). The Optojump system showed excellent reliability and reproducibility for jumping tests (high intraclass correlation coefficient mean: 0.998) (Glatthorn et al., 2011). Moreover, it showed excellent reliability in 4 different vertical jump types (squat jump, CMJ, block jump, and attack jump) (Sattler, Sekulic, Hadzic, Uljevic, & Dervisevic, 2012).

CMJ without armswing test

This test is an eccentric center jump with hands held on the waist; it evaluates lower limb strength enhanced by the stretching–shortening cycle. Players squat and jump using explosive force. Thus, they minimize the amortization phase, which is a transition phase between eccentric and concentric contractions. The CMJ without arm swing test measures lower limb strength, which is essential for other jump variations (e.g., Sargent or one-step jump), by eliminating the upper body contribution. The ability to achieve a high vertical jump with

minimal upper body contribution is important for players who need to rise off the ground with minimal contribution of arm swing (Wen, Dalbo, Burgos, Pyne, & Scanlan, 2018).

In the initial position during the test, the participants stood in the middle of the Optojump device with their feet open about a hip width (Figure 2a). With hands on hips, the participants were asked to squat until their thighs were parallel to the floor and then to immediately jump up (Figure 2b). The participants had to keep their hands on their hips and their legs in extension, and they kept this position during the jump and even when they landed (Figure 2c). The flexion of hips and knees before landing increases flight time and reduces the accuracy and reliability of the results. During testing, the participants were wearing sneakers (Needham, Morse, & Degens, 2009). The CMJ without arm swing test was repeated 3 times, and the best value was evaluated (Cilli, Gelen, Yildiz, Saglam, & Camur, 2014).

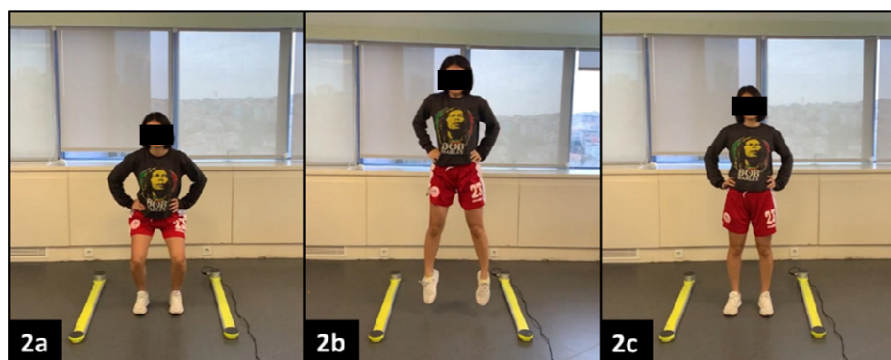


Fig.2. The CMJ without arm swing test with Optojump

DS Intervention

The DS protocol was prepared with reference to Faigenbaum et al. (Faigenbaum, Bellucci, Bernieri, Bakker, & Hoorens, 2005). The protocol consisted of 10 dynamic exercises of 10 min of medium and high intensity. Each DS exercise was performed at a distance of 13 m. The participants were given a 10-second rest period before each exercise. The participants were given verbal feedback about their posture during the exercises and the video records of exercises were shown to the participants. The exercises for DS are shown in Table 1.

Table 1. Dynamic stretch protocol

Movement	Definition of Movement
High knee walk	While walking, lift knee towards chest, raise body on toes, and swing alternating arms
Straight-leg march	While walking with both arms extended in front of body, lift one extended leg towards hands then return to starting position before repeating with other leg
Hand walk	With hands and feet on the ground and limbs extended, walk feet towards hands while keeping legs extended then walk hands forward while keeping limbs extended
Lunge walks	Lunge forward with alternating legs while keeping torso vertical
Backward lunge	Move backwards by reaching each leg as far back as possible
High-knee skip	While skipping, emphasize height, high knee lift, and arm action
Lateral shuffle	Move laterally quickly without crossing feet
Back pedal	While keeping feet under hips, take small steps to rapidly move backwards
Heel-ups	Rapidly kick heels towards buttocks while moving forward
High-knee run	Emphasize knee lift and arm swing while quickly moving forward

FR Intervention

FR was applied to the hamstring (Figure 3a), gastrosoleus (Figure 3b), and plantar fascia (Figure 3c) for 3 min on a single leg. The TriggerPoint Grid X FR and Nano Foot X Roller were used in the application. The treatment lasted 8 min on one leg and was applied equally to both legs for a total of 16 min. Before the application, the participants were informed about how to perform the applications with verbal and visual warnings. During the application, the participants were kept posted about the time with a stopwatch. The participant himself regulated the pressure applied to the FR; however, the participant was instructed to apply to FR as much body weight as possible (Pearcey et al., 2015). The frequency of application was approximately 0.5 Hz (i.e., each rolling cycle lasted for approximately 2 s) (Aboodarda et al., 2018).

GT® Intervention

The technique was applied by a GT® certified therapist with 12 years of experience in orthopedic rehabilitation and multiple types of soft tissue treatments. The hamstring (Figure 3d) and gastrosoleus (Figure 3e) muscles and the plantar fascia (Figure 3f) were scanned with GT® instruments and treated. The instruments used differed according to the application protocol, and regions were determined with reference to the GT® manual

(Carey-Loghmani, Schrader, & Hammer, 2014). The treatment lasted 8 min for each leg and was equally applied to both legs by the same person for a total of 16 min. The GT® application protocol is summarized in Table 2, and the application photographs are shown in Figure 3.



Fig.3. Foam roller exercises and Graston Technique® application

Table 2. Graston technique® application protocol

Region	Instrument	Technique	Period
Hamstrings	GT 1, GT 4	Sweep, Fanning	1 min
Distal hamstrings	GT 2	Frame	1 min
Local lesions	GT 3	Strum	1 min
Calf	GT 5	Sweep	1 min
Local lesions	GT 2	Strum	1 min
Achilles tendon	GT 2	Frame	1 min
Plantar fascia	GT 2	Sweep	1 min
Between metatarsal bones	GT 6	Swivel-Frame	1 min

Statistical Analysis

Statistical analyses were performed using the SPSS software version 22.0 (SPSS Inc., IL, Chicago, IL, USA). The mean, standard deviation, median, minimum, maximum value frequency, and percentage were used for descriptive statistics. The distribution of variables was checked with the Kolmogorov–Simonov test. The paired sample t-test was used for intra-group comparison. The one-way ANOVA test was used for comparison between groups.

Results

The groups were homogenous in terms of gender, age, weight, height, body mass index, and initial maximum jump height, and these characteristics are shown in Table 3.

Intra-group comparison

There was a significant increase in the maximum jump height of all intervention groups (Table 4). While the mean change between pre-treatment and post-treatment values was the highest in the GT® group (5.28 cm), the change was 4.71 and 3.64 in the DS and FR groups, respectively.

Table 3. Demographic characteristics of groups

	DYNAMIC STRETCH (n = 14)	FOAM ROLLER (n = 14)	GRASTON TECHNIQUE (n = 14)	p
	Mean±SD	Mean±SD	Mean±SD	
Age (year)	21.5 ± 1.6	22.7 ± 3.8	23.0 ± 1.6	0.260 ⁰
Gender	Female (n, %)	7	7	1.000 ^{x²}
	Male (n, %)	7	7	
Height (cm)	175.6 ± 8.2	171.7 ± 10.1	170.7 ± 10.7	0.770 ⁰
Weight (kg)	68.2 ± 11.7	65.3 ± 13.0	65.2 ± 12.7	0.390 ⁰
BMI (kg/cm²)	21.9 ± 2.7	22.0 ± 2.7	22.2 ± 2.3	0.950 ⁰
Max. Jump Height	19.85 ± 7.17	17.14 ± 7.40	21.29 ± 7.40	0.270 ⁰

⁰ One-way ANOVA / ^{x²} Chi-square test

Comparisons between groups

There was no difference between the groups ($p = 0.468$) in the comparison of changes in the maximum jump height before and after treatment with the one-way ANOVA test (Table 4). Owing to the homogeneity of different analysis results ($p < 0.05$), the difference between the DS and FR groups in the inter-group comparison with the Tukey test was $p = 0.778$ (Mean±SD: -0.85 ± 1.26), the difference between the DS and GT® groups was $p = 0.840$ (Mean±SD: 0.71 ± 1.26), and the difference between the FR and GT® groups was $p = 0.436$ (Mean±SD: 1.57 ± 1.26). Thus, no group was better compared to other groups regarding an increase in the maximum jump height. The between-group effect sizes were calculated using partial eta squared. An effect size of 0.2 was considered small, 0.5 moderate, and 0.8 large. Considering the obtained averages, the effect size was calculated to be 0.679.

Table 4. Intra- and intergroup comparison of the maximum jump height

	DYNAMIC STRETCH (n = 14)	FOAM ROLLER (n = 14)	GRASTON TECHNIQUE (n = 14)	
<i>Max-Jump Height</i>	Mean±SD	Mean±SD	Mean±SD	p
Pre-treatment	19.85 ± 7.17	17.14 ± 5.69	21.28 ± 7.40	
Post-treatment	24.57 ± 9.31	20.78 ± 5.72	26.57 ± 8.17	
Post/Pre difference	4.71 ± 3.62	3.64 ± 2.70	5.28 ± 4.02	
t	4.86	5.03	4.91	0.468**
Intragroup difference *	0.00*	0.00*	0.00*	

*Paired samples t-test, **One-way ANOVA

Discussion

Although there are studies in the literature that examined changes in jump performance after using DS, FR, and IASTM interventions during the warm-up period (Behara & Jacobson, 2017; Stroiney, Mokris, Hanna, & Ranney, 2020; Peacock, Krein, Silver, Sanders, & Von Carlowitz, 2014), to our knowledge, there are no studies comparing these 3 interventions. Therefore, our study contributes to the existing body of literature. A proper and adequate warm-up phase before physical activity or competition contributes to performance improvement and is very important to prevent disability. Our aim was to evaluate the acute effect of DS, FR, and GT® interventions on jump performance. According to our results, jump performance was increased in all 3 groups. When the interventions were compared, no one group was observed to be superior to others. Regarding the ease of application and no need for equipment, the use of DS during the warm-up phase is considered to be preferable to other interventions.

Dynamic Stretch

Previous studies in this field have shown that moderate-to-high intensity voluntary contractions, such as dynamic warming, increase nerve production and performance by activating nerve muscle functions. Active dynamic warming improves many aspects of athletic performance (e.g., speed, balance, and power energy production) during vertical jump (Chatzopoulos, Galazoulas, Patikas, & Kotzamanidis, 2014; Vetter, 2007; Jagers, Swank, Frost, & Lee, 2008; Ferrara, Forte, Senatore, & D’elia, 2019; Forte, Ferrara, & Altavilla, 2019). This increase can be attributed to post-activation potentiation (PAP) (Cilli, Gelen, Yildiz, Saglam, & Camur, 2014), which is a decrease in the viscous resistance of muscles owing to an increase in the heat (Opplert & Babault, 2018), heart rate, and movement rehearsal, which causes a temporary increase in the muscular contraction ability after previous contraction (Ryan et al., 2014). By progressively increasing the intensity of DS, fast and slow contractions of muscle fibers can be activated to further enhance the PAP mechanism. In addition, it has been suggested that individuals who have the ability to produce higher strength can obtain greater benefit from strengthening after activation (Needham, Morse, & Degens, 2009).

When the studies investigating the effect of DS on jump performance are examined, it is observed that DS increases jump performance in the majority of participants (Perrier, Pavol, & Hoffman, 2011; Needham, Morse, & Degens, 2009; Ryan et al., 2014). However, there are studies that do not report any change (Jagers, Swank, Frost, & Lee, 2008; Dalrymple, Davis, Dwyer, & Moir, 2010; Popelka & Pivovarniček, 2018) or that report a reduction (Paradis et al., 2014) in the performance. These conflicting results are attributed to the lack of consensus in the literature on the critical variables that should be considered when designing an appropriate warm-up routine such as the intensity, volume, duration, and type of DS movements (Ryan et al., 2014). In addition, there are inconsistencies in defining stretching procedures. DS is often mistaken for other types of stretching such as ballistic stretching (Opplert & Babault, 2018).

It is widely accepted in the literature that DS improves performance if an increase in the core temperature is achieved. The rate of application of DS protocols should be sufficiently high to achieve an increase in the heart and metabolic rates, tissue oxygen and fuel transport, glycolysis and high energy phosphate degradation rates, and nerve contraction and muscle contraction rates (Fletcher, 2010). In the literature, there are various studies in which the speed of the protocols that increase the jump performance shows progression from slow to fast, slow to moderate, and moderate to fast, which combine slow and fast exercises and make comparison between fast and slow DS exercises (Opplert & Babault, 2018). Fletcher et al. (2010) have observed a

significant improvement in all jump tests (squat, depth, and counter movement jumps) in their study by comparing slow and fast DS protocols. Nevertheless, the slow DS group showed a significant improvement in the other jump tests except CMJ when compared to the control group. However, Vetter et al. (2007) have kept the speed of the DS protocol slow and constant in their study and were unable to produce a change in jump performance. This suggests that DS protocols at all speeds can produce performance improvements when advancing progressively, but high-speed dynamic exercises are a better choice to achieve the best performance. Therefore, medium and high intensity exercises were used for the DS protocol in our study. An increase in the performance was consistent with the results of other studies in the literature.

In addition to the speed of the DS protocol, the synergy between the lower extremity muscle groups and the duration of the protocol are also considered important for the physiological changes described above and to improve performance. However, when the previously published studies investigating the effect of DS on jump performance are examined, contradictory results are observed. In the study by Ryan et al. (2014), 26 recreationally active male participants were randomized into 3 different groups that performed 6 min and 12 min of DS. The DS program included the quadriceps, hamstring, hip extensor, flexor, adductor, abductor, and plantar flexor muscle groups. According to the results of the study, 6 min and 12 min DS performed after 5 min of jogging increased jump performance. Perrier et al. (2011) randomized participants into the control, static stretch (SS), and DS groups in their study of 21 active male subjects. The DS program included the quadriceps, hamstring, gluteal muscles, hip flexors, adductors, piriformis, obliques, and calf muscle groups. The DS group completed the DS protocol, which lasted for an average of 13.8 ± 1.7 min after completing a 5-min jogging phase, which increased jump performance. In their study of 21 healthy college students (13 females, 8 males), Clark et al. (2014) have evaluated the effect of SS and DS on CMJ peak power production by electromyography on the soleus muscle. The DS protocol consisted of 3 repetitions of DS exercises involving the contraction of the soleus muscle for 20 min resting for 30 s. As a result, DS decreased presynaptic inhibition and did not cause an increase in power production. However, Curry et al. (2009) have compared the efficacy of SS, DS, and mild aerobic activity in their study of 24 healthy, recreationally active but non-trained female subjects. A total of 24 participants were included in 3 groups, and the study lasted for 2 weeks. The DS protocol was a 10-min exercise program that engaged the quadriceps, hamstring, gluteal muscles, hip flexors, adductors, gastrocnemius and soleus muscles after a 5-min cycle ergometer. When the results were evaluated, it was observed that the DS group had a decrease in the jump performance after 5 min and 30 min. An observed decrease in the jump performance, although many muscle groups work together and DS exercises are performed, possibly occurred because the activity and training levels of the participants differed between the studies, and the study populations only consisted of women. For the DS group in our study, 14 active individuals (7 females, 7 males) were included. The DS program consisted of 10-min dynamic exercises targeting the whole body. After the 5-min jogging protocol, the evaluation showed an increase in the jump performance. Because this situation may provide a greater performance increase for the individuals who have the ability to produce higher strength (Needham, Morse, & Degens, 2009), it is also necessary to examine the physical activity levels of the groups, the weekly activity level in minutes, and the training type. It is necessary to separately compare the effectiveness of the same intervention in male and female individuals. Further studies are needed to determine the optimal stretching time following the DS protocol without fatigue, which has positive effects on muscle performance (Opplert & Babault, 2018).

Foam Roller

Although there are studies reporting that FR intervention does not change jump performance during the warm-up phase (Behara & Jacobson, 2017; Baumgart et al., 2019; Healey, Hatfield, Blanpied, Dorfman, & Riebe, 2014; Hodgson, Lima, Low, & Behm, 2018), some studies have reported an increase (Giovannelli et al., 2018; Peacock, Krein, Silver, Sanders, & Von Carlowitz, 2014). These conflicting results may be due to two reasons. The first reason is the lack of consensus on clinical standards for evaluation, intervention, and application dose (Cheatham & Stull, 2018). In addition, there is no consensus on the optimal FR intervention, including the type and intensity of FR used, technical treatment parameters, applied pressure, and cadence. The second reason is related to the change in muscle stiffness (Pruyn, Watsford, & Murphy, 2014). FR can particularly affect connective tissue and fascia properties, especially water content and muscle stiffness (Schleip & Müller, 2013). Because tissue composition (e.g., skin, fat, connective tissue) is differently affected during FR administration, muscle stiffness may also vary in different proportions, which results in different outcomes (Baumgart et al., 2019).

As a result of traction and compression generated with FR, the connective tissue and fascia lose water, and tension is reduced. The rehydration rate peaks 3–4 h after the mechanical stress application. In the *in vitro* model evaluation, this is called the sponge effect. During the FR application, the soft tissue is squeezed like a sponge; then, the movement between different fascia layers is wetted by the released liquid. Different results can be obtained *in vivo* compared to *in vitro* (Giovannelli et al., 2018; Schleip & Müller, 2013). Therefore, in their studies on cost-running and lower extremity muscle strength after FR application, Giovannelli et al. (2018) have suggested the use of activities such as jumping with stretch-shortening cycles that require explosive force; although this approach is not recommended because the acute effect of using FR adversely affects running

endurance. Jumping performance was sustained immediately after the application and for up to 3 h. The results of our study were similar to the acute effects of this study. The FR intervention time is also important for muscle performance. Short application time (<30 s) does not have a significant effect on performance. Therefore, it is recommended to apply FR for a longer period of time, especially for large muscle groups (Giovanelli et al., 2018). Junker et al. (2019) have evaluated the application duration of the participants who were included in the FR group twice a week for 8 weeks as 3 sets of 50 s (a total of 150 s) for each of the calf, quadriceps, hamstring, iliotibial band, and gluteal muscles. Although there was an increase in ROM for this program, there was no accompanying increase in balance and muscle performance. Similarly, Hodgson et al. (2018) have shown that the 4-week FR training, which was applied to the hamstring and quadriceps muscles in both groups that received FR as 4 sets of 30 s for 3 or 6 times a week made no contribution to jump performance and quadriceps strength. Healey et al. (2014) have compared FR with plank exercise groups. FR application was performed on the quadriceps, hamstrings, calves, latissimus dorsi, and rhomboid muscles for 30s; after the application, there was no improvement in VJP, isometric squat strength, and participant agility in the immediate evaluation. Behara et al. (2017) have compared DS and FR interventions by performing a 1-min FR application to each of the gluteus maximus, quadriceps, hamstring, and calf muscles, followed by continuing the application for 8 min bilaterally. After the application, the hip ROM, knee isometric torque, and vertical jump strength and speed were evaluated. According to the results, while hip flexibility increased in both groups, there was no change in performance. In the application protocol of our study, each case received 1 set of FR for 180 s, and jump performance improved. This suggests that it may be more beneficial to conduct the applications without dividing them into sets and perform them for a longer duration.

Graston Technique®

The results of the studies examining the effect of IASTM on jump performance are contradictory. There are studies that suggest no change in performance (MacDonald, Baker, & Cheatham, 2016), and there are other studies reporting an increase in the performance (Stroiney, Mokris, Hanna, & Ranney, 2020; Kim, Lee & Sung Hyun You, 2018; Rhyu, Han, & Rhi, 2018). We think that this discrepancy is due to the lack of standardization in factors such as the instruments used, number of muscles on which the application is performed, application duration and follow-up period, and the use of SS or non-SS. The treatment protocol recommended by GT includes examination, warm-up, IASTM treatment, post-treatment stretching, strengthening and, if necessary, ice application (Carey-Loghmani, Schrader, & Hammer, 2014; Kim, Lee & Sung Hyun You, 2018; Cheatham, Baker, & Kreiswirth, 2019; Hammer, 2008). Stroiney et al. (2020) have studied the effect of the stick roller and the Técnica Gavilán® brand IASTM treatment on the jump and 40-yard sprint performance of 49 physically active college students. After the participants were warmed up with an ergometer for 5 min, treatments were applied to the triceps surae, hamstring, and quadriceps muscles in both groups and on both legs. The administration procedure lasted for a total of 4.5 min in both groups. In the FR group, each case received application for 1.5 min. SS was not applied to the muscles after the application. The application protocol of the GT® group included 1.5 min of passive lengthening and 1.5 min of active movement after each case was given GT® for 1.5 min. The results of the study showed that the stick roller was more effective in the jump performance. Sprint performance did not change in either group. In our study, unlike the results of Stroiney et al. (2020), there was a significant increase in jump performance in both the FR and GT® groups. The differences between the two results can be explained as follows. Although the use of passive stretching and exercise after GT® was present in the described application concept (Carey-Loghmani, Schrader, & Hammer, 2014; Kim, Lee & Sung Hyun You, 2018; Cheatham, Baker, & Kreiswirth, 2019; Hammer, 2008), it is known that SS applied before performance measurements reduces muscle strength production (Opplert & Babault, 2018). Thus, passive lengthening after GT® application may have led to this result. This suggests that further investigations are needed to determine whether static stress during the GT® application protocol should be given just before the performance assessment.

Jumping is a movement that requires several muscle groups to work together. It is thought that the effect of IASTM application on various muscle groups contributing to movement instead of an isolated muscle will cause a higher increase in the performance. In our study, the application was performed on the hamstring, triceps surae muscles, and plantar fascia; both myofascial release groups showed an increase in the performance. In MacDonald et al. (2016), 48 physically active individuals were divided into 3 groups. In group 1 (the quadriceps muscles) and in group 2 (the triceps surae muscles) received a Técnica Gavilán® brand IASTM treatment. The third group was regarded as the control group. Jumping performance was evaluated after the participants were warmed up with an ergometer for 5 min in all groups. After IASTM was bilaterally applied to the selected muscle group for 3 min, jump performance was reevaluated. Thus, according to initial measurements and contrary to our study, no significant difference was observed between the groups in vertical jump height, peak power, and peak speed parameters. Because jumping movement occurs owing to the participation of various muscles that simultaneously work together and with the same power balance, the insignificance of results of the application of IASTM indicates the necessity of intervening in all muscle groups at the same time.

In studies with IASTM, there is a need for a standardization regarding the frequency and dose of administration. In the literature, the recommended dosage and frequency of administration are defined as

follows. When GT® was compared with light, medium, and hard applications, it was observed that the hardest application increased fibroblastic activity. Considering the collagen loadability and inflammatory process, applications can be given to the same area twice a week with 3-intervals. Three to five minutes of local area treatment (e.g., shoulder) is the appropriate duration for 8–10 min of combined treatment zones. It is suitable to do 1–3 repetitions with 30-s stretching. The conservative treatment program should focus on collagen synthesis, maturation, and strength; in chronic conditions, the treatment should continue for 4–6 weeks (Hammer, 2008). Rhyu et al. (2018) have reported that 40 healthy basketball players were treated with GT® 6 times a week during 8 weeks, each session lasting for 40 min (10 min of warm-up, 30 min of GT® and exercise), which resulted in a significant improvement in active ROM, functional fitness and flexibility, and isokinetic strength measurements. However, Kim et al. (2018) have conducted a study on 40 male football players; the outcomes after IASTM application were analyzed in various aspects including physical fitness, isokinetic strength, and fatigue. Participants were divided into two groups as IASTM and control, and jump performance was evaluated. Participants were enrolled in a training program (10-min warm-up, 40-min IASTM and exercise, 10-min cooling) for a total of 60 min 5 times a week for 12 weeks. According to the results of the study, the training program resulted in decreased fatigue, increased muscle strength, and improved performance. Both studies, although administered more frequently than the recommended dose, gave positive results when evaluated in terms of their outcomes. In our study, there was a significant improvement in the jump performance as a result of bilateral administration and single application. Although the immediate effect may improve performance, such as long-term post-treatment outcomes, new/further studies are needed to examine the continuity of long-term performance improvement and to work within the recommended dose limits. The studies in the literature vary in terms of the applied doses, treatment duration, and location of administration, and there is no standard of dosage for treatment. Therefore, the optimum performance increase should be standardized in terms of application regions and dosages.

Conclusions

On the basis of our results and contrary to the conflicting results in the literature, we recommend to use any DS, FR, and GT® to improve VJP during the warm-up period. Our results showed the importance of dosing, combining muscle groups to be administered, and explaining the intervention to the participants. Although all 3 interventions provided a statistically significant increase in jump performance, the needs of the participant should be also considered. If the participant does not need myofascial loosening because of a specific disorder, such as facial adhesion, DS can be preferred because it requires less equipment, mimics movement, and increases muscle contractility.

Conflicts of interests: The authors declare no conflicts of interest.

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