

Investigation of The Acute Effects of Graston Technique on Muscle Mechanical Properties and Sportive Performance in Elite Female Handball Players with Isolated Gastrocnemius Tightness

İzole Gastroknemius Gerginliği Olan Elit Kadın Hentbolcularda Graston Tekniğinin Kas Mekanik Özelliklerine ve Sportif Performansa Akut Etkilerinin İncelenmesi

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ABSTRACT

This study aimed to investigate the acute effects of a single-session Graston Instrument-Assisted Soft Tissue Mobilization (IASTM) application on the mechanical properties of the gastrocnemius muscle and sport-specific performance outcomes in elite female handball players with isolated gastrocnemius tightness (IGT). Sixteen elite female handball players diagnosed with IGT according to the Silfverskiöld test participated in the study. Muscle tone, stiffness, and elasticity of the medial gastrocnemius were assessed using MyotonPRO. Ankle dorsiflexion range of motion was measured with a goniometer. Plantar flexor strength was evaluated using a handheld dynamometer. Vertical jump and agility performance were assessed via standardized field tests. All measurements were obtained immediately before and after a single 7-minute Graston intervention. Paired-sample analyses were performed to compare pre- and post-intervention values ($p < 0.05$). Significant post-intervention reductions were observed in muscle stiffness and tone, accompanied by an increase in elasticity ($p < 0.05$). Ankle dorsiflexion range of motion demonstrated a large improvement ($p < 0.001$). Plantar flexor strength, vertical jump height, and agility performance showed statistically significant improvements with small-to-moderate effect sizes ($p < 0.05$). A single-session Graston application acutely modifies passive muscle mechanical properties and improves ankle mobility in athletes with IGT. Although performance improvements were observed, their magnitude was smaller than the mobility changes, suggesting that acute IASTM effects primarily influence passive mechanical and mobility components.

Keywords: *Agility, Instrument-assisted soft tissue mobilization (IASTM), Isolated gastrocnemius tightness, Vertical jump*

Öz

Bu araştırmanın amacı, izole gastroknemius gerginliği (İGT) bulunan elit kadın hentbolcularda tek seanslık Graston (IASTM) uygulamasının gastroknemius kasının mekanik özellikleri ve spora özgü performans çıktıları üzerindeki akut etkilerini incelemektir. Silfverskiöld testi ile İGT tanısı konulan 16 elit kadın hentbolcu çalışmaya dahil edilmiştir. Medial gastroknemius kasına ait tonus, sertlik ve elastikiyet parametreleri MyotonPRO cihazı ile değerlendirilmiştir. Ayak bileği dorsifleksiyon hareket açıklığı gonyometre ile ölçülmüştür. Plantar fleksör kuvvet el dinamometresi ile belirlenmiştir. Dikey sıçrama ve çeviklik performansı standart saha testleri ile değerlendirilmiştir. Tüm ölçümler 7 dakikalık tek seans Graston uygulaması öncesinde ve hemen sonrasında alınmıştır. Ön-son karşılaştırmalar eşleştirilmiş örneklem analizleri ile yapılmıştır ($p < 0,05$). Uygulama sonrası kas sertliği ve tonusunda anlamlı azalma, elastikiyette ise artış gözlenmiştir ($p < 0,05$). Ayak bileği dorsifleksiyonunda büyük düzeyde artış saptanmıştır ($p < 0,001$). Plantar fleksör kuvvet, dikey sıçrama ve çeviklik performansında istatistiksel olarak anlamlı ancak küçük-orta düzeyde etki büyüklüğüne sahip iyileşmeler görülmüştür ($p < 0,05$). Tek seanslık Graston uygulaması, İGT bulunan sporcularda pasif kas mekanik özelliklerini ve ayak bileği mobilitesini akut olarak iyileştirmektedir. Performans çıktılarındaki gelişmeler daha sınırlı olup, akut IASTM etkilerinin öncelikle mobilite ve pasif mekanik bileşenlerde belirginleştiğini düşündürmektedir.

Anahtar Kelimeler: *Alet destekli yumuşak doku mobilizasyonu (IASTM), Çeviklik, Dikey sıçrama, İzole gastrocnemius gerginliği, MyotonPro*

INTRODUCTION

Handball is a high-paced competitive sport that requires advanced physical demands (Ziv and Lidor, 2010). The ability to achieve the desired performance in handball is influenced by the functionality of the lower extremities (Zebis and Bencke, 2018). One of the key structures responsible for the mobility of the lower extremities is the gastrocnemius muscle. The gastrocnemius is a superficial, biarticular muscle with two heads, situated in the posterior compartment of the lower leg, with its primary function being plantar flexion of the ankle (Bordoni and Varacallo, 2023). Due to intense usage, improper training models, or various traumas, structural abnormalities may develop in the gastrocnemius muscle among athletes. One of the most common structural disorders is isolated gastrocnemius tightness (IGT). IGT is considered critical in terms of sports injuries and performance and is also recognized as a prevalent disorder even in the general population (Chan et al., 2019; Kaneuchi et al., 2020; Knapik et al., 2019).

IGT, which arises as a result of gastrocnemius-soleus contracture, is a muscle dysfunction characterized by increased stiffness of the ankle joint in dorsiflexion (DF) (Huerta, 2014). Restrictions in DF caused by IGT can increase pressure on soft tissues during changing conditions and sudden movements in training and competitions, leading to a higher risk of injury and potential declines in sports performance (Endo and Sakamoto, 2014; Rezazadeh et al., 2017; Sarialioğlu and Başkan, 2023). Chronic muscle tightness also affects the viscoelastic properties of the muscle (Pawar et al., 2021; Yamauchi et al., 2016). Mechanical muscle properties such as muscle tone and stiffness are considered fundamental elements for maintaining efficient muscle contractions in terms of both function and energy (Masi and Hannon, 2008). A shortened and tight skeletal muscle may hinder potential force production, leading to increased muscle tone and stiffness. Increased tone and stiffness, in turn, can reduce movement efficiency and contribute to a higher risk of injuries (Brughelli and Cronin, 2007; Zhang et al., 2017).

IGT can be alleviated through various conservative and invasive interventions aimed at reducing muscle tightness, restoring ankle DF, and improving functional mobility. Conservative approaches—such as stretching-based exercise models, eccentric loading programs, neuromuscular re-education, and soft tissue mobilization have been shown to effectively reduce gastrocnemius–soleus contracture and enhance lower-extremity kinematics (Chang et al., 1999; Chimera et al., 2010; Knapik et al., 2019). Among non-invasive treatment strategies, the Graston technique, a form of instrument-assisted soft tissue mobilization (IASTM), has gained prominence. The Graston technique involves the application of controlled mechanical loading to myofascial tissues using rigid instruments (Cheatham et al., 2016). It has been reported that this intervention may produce acute effects through mechanisms such as mechanical disruption of adhesions, alterations in fascial viscosity, increased local circulation, and modulation of afferent neural input. These effects may influence the viscoelastic behavior of the muscle–tendon unit, potentially reducing passive muscle stiffness, regulating muscle tone, and improving joint range of motion (Cheatham et al., 2016; Cheatham et al., 2019; Hammer, 2008). Due to these characteristics, Graston applications are recommended to enhance tissue compliance within the myofascial complex, improve function, and reduce hypomobility associated with skeletal muscle tightness (França et al., 2023; Itotani et al., 2021).

Previous studies have examined the acute effects of Graston/IASTM on ankle range of motion, performance, and/or gastrocnemius muscle properties in healthy or athletic populations (Lee et al., 2023; Sarialioğlu, 2024; Yana et al., 2025). However, evidence remains limited in athletes with clinically defined IGT and in studies that simultaneously evaluate muscle mechanical properties together with sport-specific performance outcomes. Accurate identification of IGT and understanding its potential neuromuscular and biomechanical implications are crucial for maintaining athlete health

and optimizing performance. Therefore, this study aimed to investigate the acute effects of Graston massage on muscle mechanical characteristics and sport-specific performance in elite female handball players presenting with IGT.

METHOD

Research Method: The study was designed as a quasi-experimental study. After completing a standardized warm-up protocol, all participants underwent the IGT assessment. Participants identified with IGT subsequently performed strength, vertical jump, and agility tests, with ten minutes of rest provided between each performance test. To eliminate the potential effects of the performance tests on the assessment parameters, a 24-hour rest period was given, and participants were instructed to avoid any physical activity during this time. On the second day, following the same warm-up protocol, participants underwent the IGT test and myotonometrical measurements, after which a Graston intervention was applied to both calf regions. All tests were repeated after the intervention in accordance with the pre-intervention protocol. To evaluate the effects of the intervention on joint range of motion, passive DF angles assessed with the knee in extension during the IGT test were additionally recorded before and after the intervention. The effects of the intervention on the measured parameters were statistically analyzed.

To enhance the reliability of the study and minimize biases, all performance tests were conducted by the same expert researcher, while all myotonometric measurements, IGT assessments, and Graston applications were performed by a different expert physiotherapist. The study data were analyzed by an independent researcher. The study was approved by the Giresun University Social Sciences, Science, and Engineering Research Ethics Committee with the decision numbered 09/09 dated 02.10.2024 and was carried out in accordance with the Helsinki Declaration and with signed consent forms obtained from the participants. The study was registered at clinicaltrials.gov on NCT06911580.

Participants: A total of 16 female handball players with IGT in at least one leg, with a mean age of 23.87 ± 4.09 years, voluntarily participated in the study.

Table 1

Demographic Information of the Participants

Variables	Mean \pm SD
Age (year)	23.87 \pm 4.09
Height (cm)	171.63 \pm 7.37
Body weight (kg)	62.00 \pm 6.22
Body mass index (kg/m ²)	21.01 \pm 1.00

Inclusion criteria: Athletes who had IGT in at least one leg, who were competing in the Turkish Women's Handball Super League during the current season, and who had been training at least 3 days per week for the past one year (excluding macrocycle breaks) were included in the study.

Exclusion criteria: Athletes with a history of serious injury, fracture, ligament or meniscus tear, or surgical intervention within the past one year; those who were in their menstrual period; those who had used pharmacological agents such as muscle relaxants within the previous 24 hours; and individuals who did not meet the inclusion criteria were excluded from the study.

Power analysis: The Sample size was determined using G*Power (version 3.1.9.2) software, based on right foot dorsiflexion (RDF) findings from the reference study. According to the a priori power analysis, assuming an alpha level of 0.05, statistical power of 0.95, and a large effect size ($d_z = 1.02$), a minimum of 13 participants was determined to be sufficient for the study (Zhang et al., 2020).

Warm-up: All participants completed a standardized warm-up protocol lasting a total of 15 minutes to ensure physiological readiness and to minimize the risk of injury during subsequent assessments. The warm-up began with 5 minutes of continuous running at a self-selected moderate intensity to gradually elevate heart rate and increase body temperature. This was followed by 5 minutes of short sprint activities, designed to activate the neuromuscular system and prepare the lower extremities for high-intensity movements. Finally, participants performed 5 minutes of dynamic stretching exercises targeting the major muscle groups of the lower extremities, with emphasis on the ankle, knee, and hip joints, in order to enhance joint mobility and muscle elasticity. The warm-up protocol was applied uniformly to all participants under supervision to ensure consistency across testing sessions.

IGT Assessment: IGT was determined using the Silfverskiöld test under standardized conditions. All measurements were performed by the same experienced physiotherapist to ensure consistency. Participants were positioned supine on a treatment table with the subtalar joint maintained in a neutral position to minimize compensatory pronation. Passive ankle DF was measured using a standard universal goniometer, with the axis aligned over the lateral malleolus, the stationary arm aligned with the fibular shaft, and the moving arm aligned with the fifth metatarsal. DF was first assessed with the knee fully extended and subsequently with the knee flexed to 90°, while ensuring that no excessive force was applied beyond the point of firm end-feel. Three measurements were taken in each position, and the average value was recorded for analysis. IGT was defined as $\leq 5^\circ$ of passive DF with the knee extended and $\geq 15^\circ$ of DF with the knee flexed, consistent with previously established criteria (DiGiovanni et al., 2002; Johanson et al., 2008; Liyanarachi et al., 2021). Participants meeting these criteria in at least one limb were classified as having IGT (Figure 1).

Figure 1

Silfverskiöld Test (Goniometric Measurements with the Knee Joint in Full Extension and with the Knee Joint in 90° Flexion)



Assessment of Muscle Mechanical Properties: The MyotonPRO muscle palpation device was used to evaluate muscle mechanical properties. MyotonPRO is a portable, non-invasive device with established reliability and objectivity in assessing muscle mechanical properties. The device consists of a body and a probe. The probe applies mechanical pressure to the surface, generating a rapid deformation through a mechanical impulse. This deformation induces damped natural oscillations in the soft tissue, which are recorded by an accelerometer. The device then provides numerical values

for muscle tone, stiffness, and elasticity, calculated using logarithmic formulas (Aird et al., 2012; Bohlen et al., 2022; García-Santamaría et al., 2024).

During the application, the participant was positioned supine on a treatment table. To ensure the most relaxed position of the muscle, a small cushion was placed under the tibia, to support the ankle. Following the device protocol, three impulses were applied to the reference point of the medial gastrocnemius using the probe. The results were recorded in three parameters: frequency, dynamic stiffness, and decrement. All measurements were performed by the same physiotherapist (Figure 2).

Figure 2

Evaluation of Medial Gastrocnemius Mechanical Properties



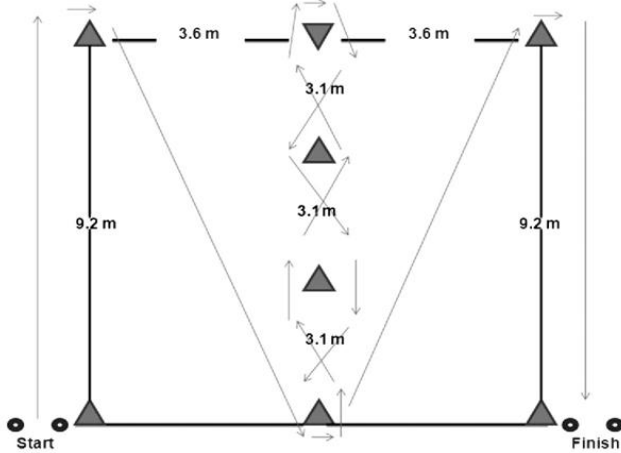
Strength Measurement: Strength measurement was performed on the calf muscle group. The Activforce Digital Dynamometer, which has been reported to have a high level of reliability, was used for this assessment (Karagiannopoulos et al., 2022). The device was fixed to the wall at foot level, and the participant, lying in a supine position, was instructed to apply maximum plantar flexion force against it. To prevent any backward movement that could affect the measurement, support was provided to the participant at the shoulder region during the test.

Agility Test: Agility performance was assessed using the Illinois Agility Test. The Illinois Agility Test has been reported in the literature as a valid and reliable field-based assessment for evaluating agility performance in athletic populations (Hachana et al., 2013; Raya et al., 2013). During the test, a photocell-based electronic timing system with a precision of 0.01 seconds and infrared timing gates positioned at a height of 1 meter were used. Each participant performed three trials, and the best performance time was included in the analysis.

The test was conducted on a flat, non-slippery surface in accordance with the standardized test protocol. Upon the starting command, the participant sprinted 9.20 m from the marked starting area, turned around, and returned to the starting line. After returning to the starting line, the participant completed the agility course by sprinting two additional 9.20 m distances, weaving in and out between four markers (Figure 3).

Figure 3

Illinois Agility Test (Hachana et al., 2013)



Vertical Jump Test: Vertical jump performance was assessed using a Smart Speed electronic jump mat (Fusion Sport, Australia) via a countermovement jump with arm swing. The arm swing technique was selected as a deliberate methodological choice to better reflect sport-specific, in-game jumping mechanics. Participants stood on the jump mat with their feet shoulder-width apart. From a self-selected countermovement depth, athletes performed a maximal vertical jump using natural arm movement and landed back on the mat. Three valid trials were performed with 3-second rest intervals, and the highest jump height (cm) was recorded. Trials involving knee flexion during the flight phase were considered invalid and repeated (Driller et al., 2017; Heishman et al., 2019).

Graston Application: The application was performed using Graston Technique® (GT) instruments. The participant was positioned prone on the treatment table with the knee slightly flexed. A small amount of lubricating gel was applied to the gastrosoleus complex and the calcaneal tendon. Sweeping strokes were applied in a downward direction over the gastrocnemius heads for one minute using the GT-5 instrument. From the second to the fourth minute, the GT-5 instrument was applied in an upward direction to ensure coverage of both the gastrocnemius and soleus muscles. Subsequently, the GT-2 instrument was used to perform one minute of downward and one minute of upward sweeping strokes over the calcaneal tendon. Following this, the GT-3 instrument was used to apply short, perpendicular strokes to the medial and lateral aspects of the calcaneal tendon, with 30 seconds allocated to each side. The total application duration was approximately 7 minutes (Palmer et al., 2017).

Figure 4

Graston Application



Statistical Analysis: The SPSS 25.0 software package was used for data analysis. Initially, the normality of the data was assessed using skewness–kurtosis values and the Shapiro–Wilk normality test. Although the Shapiro–Wilk test indicated statistically significant deviations from normality for some pre-intervention parameters of the left gastrocnemius muscle ($p < 0.05$), the skewness and kurtosis values for both stiffness (S: skewness = 1.066, kurtosis = 1.019) and elasticity decrement (D: skewness = -0.691, kurtosis = -0.353) were within acceptable limits, indicating an approximately normal distribution (George and Mallery, 2010). It has been reported that normality tests such as the Shapiro–Wilk test are highly sensitive to sample size, and even minor deviations may yield statistically significant results (Field, 2024; Razali and Wah, 2011). Considering the robustness of parametric tests to minor violations of the normality assumption, parametric statistical procedures were deemed appropriate. Accordingly, a paired t-test was applied to evaluate pre- and post-intervention changes. Statistical significance was set at $p < 0.05$. Effect sizes were calculated using Cohen’s d and interpreted as small ($d \geq 0.2$), medium ($d \geq 0.5$), and large ($d \geq 0.8$) (Cohen, 1992).

Table 2*Normality Test (Skewness–Kurtosis Values and the Shapiro–Wilk Normality Test)*

Muscle mechanical properties parameters					Ankle DF and performance parameters					
Parameters		Skewness ($\bar{x} \pm SE$)	Kurtosis ($\bar{x} \pm SE$)	Shapiro- Wilk (p value)	Parameters	Skewness ($\bar{x} \pm SE$)	Kurtosis ($\bar{x} \pm SE$)	Shapiro- Wilk (p value)		
RG	F	Pre-A	0.39±0.56	-0.44±1.09	0.894	RDF	Pre-A	-0.50±0.56	-0.42±1.09	0.489
		Post-A	0.19±0.56	-0.70±1.09	0.866		Post-A	0.90±0.56	1.34±1.09	0.446
	S	Pre-A	0.31±0.56	-0.27±1.09	0.979	LDF	Pre-A	-0.25±0.56	-1.10±1.09	0.123
		Post-A	0.26±0.56	-0.50±1.09	0.706		Post-A	-0.07±0.56	-0.97±1.09	0.456
	D	Pre-A	0.09±0.56	-0.07±1.09	0.950	RS	Pre-A	0.81±0.56	0.74±1.09	0.386
		Post-A	-0.63±0.56	-0.26±1.09	0.313		Post-A	0.23±0.56	-1.12±1.09	0.379
LG	F	Pre-A	0.92±0.56	-0.05±1.09	0.062	LS	Pre-A	0.39±0.56	-0.16±1.09	0.776
		Post-A	-0.05±0.56	-0.56±1.09	0.752		Post-A	0.22±0.56	-1.00±1.09	0.655
	S	Pre-A	1.07±0.56	1.02±1.09	0.044*	VJ	Pre-A	0.48±0.56	0.28±1.09	0.529
		Post-A	0.77±0.56	-0.23±1.09	0.103		Post-A	0.43±0.56	0.26±1.09	0.724
	D	Pre-A	-0.70±0.56	-0.35±1.09	0.044*	A	Pre-A	0.54±0.56	-0.15±1.09	0.678
		Post-A	0.12±0.56	-0.98±1.09	0.625		Post-A	0.56±0.56	-0.23±1.09	0.738

Abbreviation: Pre-A: before application, Post-A: after application, RG: right gastrocnemius, LG: left gastrocnemius, F: frequency, SE: standard error, S: stiffness, D: decrement, DF: dorsiflexion, RDF: right dorsiflexion, LDF: left dorsiflexion, RS: right strength, LS: left strength, VJ: vertical jump, A: agility.

RESULTS**Table 3***Muscle Mechanical Properties Before and After Application*

Parameters		Pre-A ($\bar{x} \pm SD$)	Post-A ($\bar{x} \pm SD$)	t	p	d
RG	F	13.29±1.06	12.88±0.93	2.347	0.033*	0.520
	S	225.94±30.31	211.44±25.32	3.056	0.008*	0.707
	D	1.21±0.16	1.16±0.16	1.383	0.187	0.312
LG	F	13.44±1.14	12.91±0.82	3.203	0.006*	0.409
	S	231.06±34.07	209.94±21.62	3.866	0.002*	0.515
	D	1.23±0.20	1.13±0.17	2.746	0.015*	0.375

Abbreviation: Pre-A: before application, Post-A: after application, RG: right gastrocnemius, LG: left gastrocnemius, F: frequency, SD: standard deviation, S: stiffness, D: decrement, t: t value, p: p value, d: Cohen’s d. P-values are from paired t-test. * $p < 0.05$; ** $p < 0.01$.

When Table 3 is examined, it is observed that after the application, all parameters showed a significant change in the left gastrocnemius, while in the right gastrocnemius, the F and S parameters exhibited a significant change ($p<0.05$), whereas the D parameter showed no change ($p>0.05$).

Table 4

Ankle DF and Performance Parameters After the Application.

Parameters	Pre-A ($\bar{x}\pm SD$)	Post-A ($\bar{x}\pm SD$)	t	p	d
RDF	1.44±2.63	5.81±3.69	-4.010	0.001**	1.328
LDF	-0.13±6.18	7.94±5.76	-6.451	0.001**	1.349
RS	517.74±117.55	587.99±117.75	-2.899	0.011*	0.597
LS	507.14±110.82	565.33±101.09	-2.580	0.022*	0.547
VJ	35.44±5.88	36.78±5.57	-4.817	0.001**	0.238
A	17.47±1.01	17.26±0.93	3.244	0.016*	0.216

Abbreviation: Pre-A: before application, Post-A: after application, RDF: right dorsiflexion, LDF: left dorsiflexion, RS: right strength, LS: left strength, SD: standard deviation, VJ: vertical jump, A: agility, t: t value; p: p value; d: Cohen's d, P-values are from paired t-test. * $p<0.05$; ** $p<0.01$.

When Table 4 was examined, it was seen that there was a significant change in all parameters after the application ($p<0.05$).

DISCUSSION

In this study, the acute effects of a single-session Graston application on the passive mechanical properties of the gastrocnemius muscle and sport-specific performance outcomes were investigated in elite female handball players with IGT. The findings demonstrated that following the intervention, the passive mechanical behavior of the gastrocnemius demonstrated a shift toward reduced muscle tone and stiffness, accompanied by increased elasticity. In parallel, improvements were observed in ankle DF range of motion and certain performance outcomes. However, the magnitude of the effects varied across variables: DF exhibited a very large effect size, changes in muscle mechanical properties and plantar flexion strength were of moderate magnitude, whereas agility and vertical jump performance, despite reaching statistical significance, showed small effect sizes (Table 3, Table 4). These results suggest that the acute effects of IASTM may primarily manifest in mobility and passive mechanical components, while their translation into performance outcomes may depend on task-specific demands.

The most prominent finding in terms of effect size was the post-intervention increase in DF. This improvement may be associated with an acute reduction in the passive stretch resistance of the gastrocnemius. Increased passive stiffness and reduced stretch tolerance related to IGT have been reported as key factors limiting DF range of motion (DiGiovanni et al., 2002; Hoang et al., 2007). It has also been suggested that the Graston technique may improve joint range of motion by addressing myofascial restrictions associated with chronic tightness (Bush et al., 2020; Palmer et al., 2017). In the present study, the mechanical pressure and shear forces applied through Graston may have facilitated local tissue mobilization within the muscle–fascia complex, thereby acutely modifying viscoelastic behavior. The observed reduction in tone and stiffness likely reflects decreased passive resistance at rest, allowing lower opposing force during a stretch and, consequently, a greater DF angle. In addition to mechanical effects, IASTM may also induce neurophysiological responses. Previous studies have emphasized that deep mechanical stimulation may modulate afferent input via mechanoreceptors, potentially increasing stretch tolerance and reducing protective reflex activity (Bialosky et

al., 2009; Ge et al., 2017). Collectively, these mechanisms provide a biomechanically plausible explanation for the marked increase in DF observed after a single session.

The post-intervention changes observed in muscle mechanical properties may be interpreted, within the context of IGT, as a reduction in mechanical resistance opposing joint motion. Previous research has shown that chronic muscle tightness can increase muscle spindle sensitivity and elevate resting muscle tone, potentially leading to greater stiffness and reduced elasticity (Ganguly et al., 2021; Lettner et al., 2024; Mense and Masi, 2010). The Graston technique has been reported to facilitate myofascial relaxation and modulate neural activation and local circulation (França et al., 2023; Itotani et al., 2021). In the present study, the observed decrease in tone and stiffness, together with increased elasticity, may be associated with reduced spindle sensitivity and alleviation of myofascial tension. However, the mechanical response was not symmetrical between sides. This asymmetry may be explained by differences in baseline mechanical profiles, dominant limb usage patterns, or the severity of IGT. Therefore, changes in muscle mechanics should be interpreted as context-dependent rather than uniform responses.

A moderate increase in plantar flexion strength was observed bilaterally following the intervention. This finding suggests that improvements in DF and passive muscle mechanics were partially reflected in functional output. Previous research indicates that force production is closely related to the optimal length–tension relationship of the muscle and that chronic tightness may disrupt this relationship (Komi, 2000; Pawar et al., 2021; Zhang et al., 2017). Manipulative approaches such as the Graston technique have been reported to induce mechanical and neuromuscular adaptations within the muscle–tendon complex (Cheatham et al., 2016; Cheatham et al., 2019). In the present study, the increased DF range may have allowed the gastrocnemius to operate closer to a more favorable length–tension position, thereby optimizing force production. Additionally, reduced passive stiffness may have lowered internal resistance components during contraction, contributing to greater net force output. However, the moderate magnitude of strength gains suggests that the acute intervention likely enhanced the efficiency of existing neuromuscular capacity rather than directly increasing maximal capacity.

Although changes in vertical jump and agility performance reached statistical significance, the observed effect sizes were small. These performance components depend not only on the functional capacity of the calf muscles and ankle joint but also on multi-joint coordination involving the hip–knee–ankle complex, eccentric–concentric transition velocity, and motor control strategies (Chen et al., 2025; Markovic and Mikulic, 2010; Sarvestan and Fakhraei Rad, 2025; Sheppard and Young, 2006). Therefore, acute improvements in mobility and passive mechanical properties may have limited transfer to multi-joint, highly coordinated tasks in which the central nervous system contribution is more prominent. From a biomechanical perspective, it is not unexpected that a single-session localized myofascial intervention would not produce large-scale enhancements in such complex performance tasks. Accordingly, the observed improvements in performance outcomes may be more closely associated with gains in mobility and localized force production rather than global neuromuscular adaptation.

When the findings are considered overall, it should be noted that the physiological components emphasized in this study were not directly measured, and the interpretations were made based on possible mechanisms grounded in the existing literature. Nevertheless, the partially coherent pattern of the findings supports the theory proposed by Bialosky et al. (2009), which suggests that mechanical forces applied through manual therapy may initiate a series of neurophysiological responses in the peripheral and central nervous systems, and that the combined effects of biomechanical and neurological mechanisms may contribute to the observed outcomes.

CONCLUSION

This study demonstrates that a single-session Graston application in elite female handball players with IGT produced acute reductions in muscle tone and stiffness, accompanied by a marked increase in ankle DF. Moderate improvements were observed in plantar flexion strength, whereas changes in vertical jump and agility were limited and of small magnitude. These findings indicate that IASTM primarily influences passive mechanical and mobility-related components, with more constrained and task-dependent transfer to complex performance outcomes. However, considering the limitations of the study, further evidence is required to draw definitive conclusions and to confirm the generalizability of the findings.

Limitations: The first limitation of this study is its quasi-experimental design without a control or sham group. This limits the ability to attribute the observed changes exclusively to the intervention. Particularly for performance parameters that demonstrated small effect sizes, the potential influence of familiarization effects, motivational factors, or measurement-related variability cannot be excluded. The second limitation concerns the sample size. Although the sample size was deemed sufficient based on power analysis, the limited number of participants restricts the generalizability of the findings. Additionally, the small sample size did not allow for subgroup analyses or relational modeling between variables. Therefore, the potential causal or associative link between changes in muscle mechanical properties and performance outcomes could not be directly tested. The third limitation is that only acute effects were evaluated. The persistence of the observed mechanical and functional changes following IASTM, whether repeated applications may produce cumulative effects, and their long-term influence on performance or injury risk remain unknown. The fourth limitation is the absence of direct assessment of neurophysiological mediating mechanisms, which restricts the ability to test the underlying mechanisms of the observed changes. Finally, the evaluation of multiple outcome variables increases the possibility that some significant findings may have occurred by chance; therefore, caution is warranted, particularly when interpreting parameters with small effect sizes.

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Author Contribution:

1. **Nihat SARIALIOĞLU:** Concept/Idea, Design, Data Collection and Processing, Analysis and Interpretation, Literature Review, Manuscript Writing
2. **Rıdvan TÜRKERİ:** Data Collection and Processing, Literature Review, Manuscript Writing
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REFERENCES

1. **Aird, L., Samuel, D., and Stokes, M. (2012).** Quadriceps muscle tone, elasticity and stiffness in older males: reliability and symmetry using the MyotonPRO. *Archives of Gerontology and Geriatrics*, 55(2), e31-e39. <https://doi.org/10.1016/j.archger.2012.03.005>
2. **Bialosky, J. E., Bishop, M. D., Price, D. D., Robinson, M. E., and George, S. Z. (2009).** The mechanisms of manual therapy in the treatment of musculoskeletal pain: a comprehensive model. *Manual Therapy*, 14(5), 531-538. <https://doi.org/10.1016/j.math.2008.09.001>
3. **Bohlen, L., Schwarze, J., Richter, J., Gietl, B., Lazarov, C., Kopyakova, A., ... and Schmidt, T. (2022).** Effect of osteopathic techniques on human resting muscle tone in healthy subjects using myotonometry: a factorial randomized trial. *Scientific Reports*, 12(1), 16953. <https://doi.org/10.1038/s41598-022-20452-9>
4. **Bordoni, B., and Varacallo, M. (2023).** Gastrocnemius muscle. In StatPearls. StatPearls Publishing.
5. **Brughelli, M., and Cronin, J. (2007).** Altering the length-tension relationship with eccentric exercise: implications for performance and injury. *Sports Medicine*, 37, 807-826.
6. **Bush, H. M., Stanek, J. M., Wooldridge, J. D., Stephens, S. L., and Barrack, J. S. (2020).** Comparison of the Graston technique® with instrument-assisted soft tissue mobilization for increasing dorsiflexion range of motion. *Journal of Sport Rehabilitation*, 30(4), 587-594. <https://doi.org/10.1123/jsr.2019-0397>
7. **Chan, O., Malhotra, K., Buraimoh, O., Cullen, N., Welck, M., Goldberg, A., and Singh, D. (2019).** Gastrocnemius tightness: a population based observational study. *Foot and Ankle Surgery*, 25(4), 517-522. <https://doi.org/10.1016/j.fas.2018.04.002>
8. **Chang, Y. W., Su, F. C., Wu, H. W., and An, K. N. (1999).** Optimum length of muscle contraction. *Clinical Biomechanics*, 14(8), 537-542. [https://doi.org/10.1016/S0268-0033\(99\)00014-5](https://doi.org/10.1016/S0268-0033(99)00014-5)
9. **Cheatham, S. W., Lee, M., Cain, M., and Baker, R. (2016).** The efficacy of instrument assisted soft tissue mobilization: a systematic review. *The Journal of the Canadian Chiropractic Association*, 60(3), 200-211
10. **Cheatham, S. W., Baker, R., and Kreiswirth, E. (2019).** Instrument assisted soft-tissue mobilization: a commentary on clinical practice guidelines for rehabilitation professionals. *International Journal of Sports Physical Therapy*, 14(4), 670-682. <https://doi.org/10.26603/ijsp20190670>
11. **Chen, B., Deng, L., Liu, Y., Deng, X., and Yuan, X. (2025).** The effect of integrative neuromuscular training on enhancing athletic performance: a systematic review and meta-analysis. *Life*, 15(8), 1183-1205. <https://doi.org/10.3390/life15081183>
12. **Chimera, N. J., Castro, M., and Manal, K. (2010).** Function and strength following gastrocnemius recession for isolated gastrocnemius contracture. *Foot and Ankle International*, 31(5), 377-384. <https://doi.org/10.3113/FAL2010.0377>
13. **Cohen, J. (1992).** A power primer. *Psychological Bulletin*, 112(1), 155-159. <https://doi.org/10.1037/0033-2909.112.1.155>
14. **DiGiovanni, C. W., Kuo, R., Tejwani, N., Price, R., Hansen Jr, S. T., Cziernecki, J., and Sangeorzan, B. J. (2002).** Isolated gastrocnemius tightness. *The Journal of Bone and Joint Surgery*, 84(6), 962-970.
15. **Driller, M., Mackay, K., Mills, B., and Tavares, F. (2017).** Tissue flossing on ankle range of motion, jump and sprint performance: A follow-up study. *Physical Therapy in Sport*, 28, 29-33. <https://doi.org/10.1016/j.ptsp.2017.08.081>
16. **Endo, Y., and Sakamoto, M. (2014).** Relationship between lower extremity tightness and star excursion balance test performance in junior high school baseball players. *Journal of Physical Therapy Science*, 26(5), 661-663. <https://doi.org/10.1589/jpts.26.661>
17. **Field, A. (2024).** Discovering statistics using IBM SPSS statistics. *Sage*.
18. **França, M.E.D., dos Santos Amorim, M., Sinhorim, L., Santos, G. M., and do Nascimento, I. B. (2023).** Myofascial release strategies and technique recommendations for athletic performance: A systematic review. *Journal of Bodywork and Movement Therapies*, 36, 30-37. <https://doi.org/10.1016/j.jbmt.2023.04.085>
19. **Ganguly, J., Kulshreshtha, D., Almotiri, M., and Jog, M. (2021).** Muscle tone physiology and abnormalities. *Toxins*, 13(4), 282. <https://doi.org/10.3390/toxins13040282>
20. **García-Santamaría, A., Abelairas-Gómez, C., Carrera, S., Padrón-Cabo, A., and Rey, E. (2024).** Effects of maturation on myotonometric parameters and their predictors of athletic performance in elite youth soccer players. *Scientific Reports*, 14(1), 12287. <https://doi.org/10.1038/s41598-024-63224-3>
21. **Ge, W., Roth, E., and Sansone, A. (2017).** A quasi-experimental study on the effects of instrument assisted soft tissue mobilization on mechanosensitive neurons. *Journal of Physical Therapy Science*, 29(4), 654-657. <https://doi.org/10.1589/jpts.29.654>
22. **George, D., and Mallery, P. (2010).** SPSS for Windows Step by Step: A Simple Guide and Reference, 17.0 Update (10th ed.). Pearson.
23. **Hachana, Y., Chaabène, H., Nabli, M. A., Attia, A., Moulhi, J., Farhat, N., and Elloumi, M. (2013).** Test-retest reliability, criterion-related validity, and minimal detectable change of the Illinois agility test in male team sport athletes. *The Journal of Strength and Conditioning Research*, 27(10), 2752-2759.

24. **Hammer, W. I. (2008).** The effect of mechanical load on degenerated soft tissue. *Journal of Bodywork and Movement Therapies*, 12(3), 246-256. <https://doi.org/10.1016/j.jbmt.2008.03.007>
25. **Heishman, A., Brown, B., Daub, B., Miller, R., Freitas, E., and Bembem, M. (2019).** The influence of countermovement jump protocol on reactive strength index modified and flight time: contraction time in collegiate basketball players. *Sports*, 7(2), 37-48. <https://doi.org/10.3390/sports7020037>
26. **Hoang, P. D., Herbert, R. D., Todd, G., Gorman, R. B., and Gandevia, S. C. (2007).** Passive mechanical properties of human gastrocnemius muscle-tendon units, muscle fascicles and tendons in vivo. *Journal of Experimental Biology*, 210(23), 4159-4168. <https://doi.org/10.1242/jeb.002204>
27. **Huerta J. P. (2014).** The effects of the gastrocnemius on the plantar fascia. *Foot and Ankle Clinics of North America*, 19, 701-718. <https://doi.org/10.1016/j.fcl.2014.08.011>
28. **Itotani, K., Kawahata, K., Takashima, W., Mita, W., Minematsu, H., and Fujita, H. (2021).** Myofascial release of the hamstrings improves physical performance-A study of young adults. *Healthcare*, 9(6), 674-681. <https://doi.org/10.3390/healthcare9060674>
29. **Johanson, M., Baer, J., Hovermale, H., and Phouthavong, P. (2008).** Subtalar joint position during gastrocnemius stretching and ankle dorsiflexion range of motion. *Journal of Athletic Training*, 43, 172-178. <https://doi.org/10.4085/1062-6050-43.2.172>
30. **Kaneuchi, Y., Ootoshi, K. I., Hakozaki, M., Watanabe, K., and Konno, S. I. (2020).** Talipes equinus deformity caused by fibrous gastrocnemius muscle contracture after direct contusion in football players: report of two cases. *The Journal of Foot and Ankle Surgery*, 59(4), 816-820. <https://doi.org/10.1053/j.jfas.2019.10.004>
31. **Karagiannopoulos, C., Griech, S., and Leggin, B. (2022).** Reliability and validity of the ActivForce Digital Dynamometer in assessing shoulder muscle force across different user experience levels. *International Journal of Sports Physical Therapy*, 17(4), 669-676 <https://doi.org/10.26603/001c.35577>
32. **Knapiak, D. M., LaTulip, S., Salata, M. J., Voos, J. E., and Liu, R. W. (2019).** Impact of routine gastrocnemius stretching on ankle dorsiflexion flexibility and injury rates in high school basketball athletes. *Orthopaedic Journal of Sports Medicine*, 7(4), 2325967119836774. <https://doi.org/10.1177/2325967119836774>
33. **Komi, P. V. (2000).** Stretch-shortening cycle: a powerful model to study normal and fatigued muscle. *Journal of Biomechanics*, 33(10), 1197-1206. [https://doi.org/10.1016/S0021-9290\(00\)00064-6](https://doi.org/10.1016/S0021-9290(00)00064-6)
34. **Lee, H., Kwon, M., Kim, J., Kim, H., Lee, E., and Choi, W. (2023).** Immediate effect between graston technique and self-myofascial release technique on calf muscle function and walking of young adults: a cross-sectional study. *Physical Therapy Rehabilitation Science*, 12(4), 514-521. <https://doi.org/10.14474/ptrs.2023.12.4.514>
35. **Lettner, J., Królikowska, A., Ramadanov, N., Oleksy, L., Hakam, H. T., Becker, R., and Prill, R. (2024).** Evaluating the reliability of MyotonPro in assessing muscle properties: A Systematic review of diagnostic test accuracy. *Medicina*, 60(6), 851-880. <https://doi.org/10.3390/medicina60060851>
36. **Liyanarachi, S., Hulleberg, G., and Foss, O. A. (2021).** Is gastrocnemius tightness a normal finding in children?: A cross-sectional study of 204 norwegian schoolchildren. *The Journal of Bone and Joint Surgery*, 103(20), 1872-1879. <http://doi.org/10.2106/JBJS.20.01273>
37. **Masi, A. T., and Hannon, J. C. (2008).** Human resting muscle tone (HRMT): narrative introduction and modern concepts. *Journal of Bodywork and Movement Therapies*, 12(4), 320-332. <https://doi.org/10.1016/j.jbmt.2008.05.007>
38. **Markovic, G., and Mikulic, P. (2010).** Neuro-musculoskeletal and performance adaptations to lower-extremity plyometric training. *Sports Medicine*, 40(10), 859-895.
39. **Mense, S., and Masi, A. T. (2010).** Increased muscle tone as a cause of muscle pain. In S. Mense and A. T. Masi (Eds.), *Muscle pain: Understanding the mechanisms* (pp. 207-249). Springer. https://doi.org/10.1007/978-3-540-85021-2_6
40. **Palmer, T. G., Kohn, M., and Miko, S. (2017).** The effect of Graston massage therapy on talocrural joint range of motion. *International Journal of Athletic Therapy and Training*, 22(3), 66-75. <https://doi.org/10.1123/ijatt.2015-0096>
41. **Pawar, A., Phansopkar, P., Gachake, A., Mandhane, K., Jain, R., and Vaidya, S. (2021).** A review on impact of lower extremity muscle length. *Journal of Pharmaceutical Research International* 33(35A), 158-164. <https://doi.org/10.9734/JPRI/2021/v33i35A31885>
42. **Raya, M. A., Gailey, R. S., Gaunaud, I. A., Jayne, D. M., Campbell, S. M., Gagne, E., and Tucker, C. (2013).** Comparison of three agility tests with male servicemembers: Edgren side step test, T-test, and illinois agility test. *Journal of Rehabilitation Research and Development*, 50(7), 951-960. <http://doi.org/10.1682/JRRD.2012.05.0096>
43. **Razali, N. M., and Wah, Y. B. (2011).** Power comparisons of shapiro-wilk, kolmogorov-smirnov, lilliefors and anderson-darling tests. *Journal of Statistical Modeling and Analytics*, 2(1), 21-33.
44. **Rezazadeh, F., Shojaeddin, S. S., Ebrahimi, I., Barati, A. H., and Farahmand, F. (2017).** Kinematic and kinetic features of normal level walking in athletes with tightness of gastrocnemius-soleus complex: more than a sagittal plane alteration. *Medical Journal of Tabriz University of Medical Sciences*, 39(4), 42-52.

45. Sarılioğlu, N., and Başkan, A. H. (2023). Kadın futbolcularda ayak bileği eklem hareket açıklıklarının statik ve dinamik denge ile ilişkisi. *Journal of Global Sport and Education Research*, 6(1), 30-41. <https://doi.org/10.55142/jogser.1202419>
46. Sarılioğlu, N. (2024). Acute effects of myofascial release on foot mobility and performance in basketball players with hypomobile feet—a randomized controlled trial. *Life*, 14(11), 1404-1419. <https://doi.org/10.3390/life14111404>
47. Sarvestan, J., and Fakhraei Rad, N. (2025). Lower limb joint coordination and coordination variability during landing: a scoping review. *Applied Sciences*, 15(9), 5118-5143. <https://doi.org/10.3390/app15095118>
48. Sheppard, J. M., and Young, W. B. (2006). Agility literature review: Classifications, training and testing. *Journal of Sports Sciences*, 24(9), 919-932. <https://doi.org/10.1080/02640410500457109>
49. Yamauchi, T., Hasegawa, S., Nakamura, M., Nishishita, S., Yanase, K., Fujita, K., ... and Ichihashi, N. (2016). Effects of two stretching methods on shoulder range of motion and muscle stiffness in baseball players with posterior shoulder tightness: a randomized controlled trial. *Journal of Shoulder and Elbow Surgery*, 25(9), 1395-1403. <https://doi.org/10.1016/j.jse.2016.04.025>
50. Yana, M., Farhoomand, B., and Güneş, M. (2025). Acute effects of instrument-assisted soft tissue mobilization on the flexibility, strength, vertical jump, and dynamic balance performances of the plantar flexor muscle in professional football players. *Journal of Bodywork and Movement Therapies*, 42, 1079-1084. <https://doi.org/10.1016/j.jbmt.2025.03.003>
51. Zebis, M. K., and Bencke, J. (2018). Biomechanical aspects in handball: Lower limb. *Handball Sports Medicine: Basic Science, Injury Management and Return to Sport*, 61-68. https://doi.org/10.1007/978-3-662-55892-8_5
52. Zhang, Q., Trama, R., Fouré, A., and Hautier, C. A. (2020). The immediate effects of self-myofascial release on flexibility, jump performance and dynamic balance ability. *Journal of Human Kinetics*, 75, 139-148. <https://doi.org/10.2478/hukin-2020-0043>
53. Zhang, Z. J., Ng, G. Y. F., Lee, W. C., and Fu, S. N. (2017). Increase in passive muscle tension of the quadriceps muscle heads in jumping athletes with patellar tendinopathy. *Scandinavian Journal of Medicine and Science in Sports*, 27(10), 1099-1104. <https://doi.org/10.1111/sms.12749>
54. Ziv, G., and Lidor, R. (2010). Vertical jump in female and male basketball players—A review of observational and experimental studies. *Journal of Science and Medicine in Sport*, 13(3), 332-339. <https://doi.org/10.1016/j.jsams.2009.02.009>