


# Effect of instrument type and one-handed versus two-handed grips on force application during simulated instrument-assisted soft tissue mobilisation

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## ABSTRACT

**Objective** The purpose of this study was to examine whether the forces used by trained clinicians during a simulated instrument-assisted soft tissue mobilisation (IASTM) treatment varied across five different instruments during one-handed and two-handed IASTM grips.

**Methods** Nine athletic trainers who previously completed IASTM training and used the technique in professional practice were included in the study. A skin simulant was attached to a force plate and used to evaluate force production during a simulated IASTM treatment scenario. Peak ( $F_{\text{peak}}$ ) and mean ( $F_{\text{mean}}$ ) forces were recorded for both one-handed and two-handed grips for each participant across the five instruments. Data were analysed using separate 2 (grip type)  $\times$  5 (IASTM instrument) repeated measures analysis of variance for both  $F_{\text{peak}}$  and  $F_{\text{mean}}$ .

**Results** Data for  $F_{\text{peak}}$  demonstrated a significant main effect for grip type ( $F_{(1,8)}=46.39$ ,  $p<0.001$ ,  $\eta_p^2=0.34$ ), instrument ( $F_{(4,32)}=4.61$ ,  $p=0.005$ ,  $\eta_p^2=0.06$ ) and interaction ( $F_{(2,16)}=10.23$ ,  $p=0.001$ ,  $\eta_p^2=0.07$ ). For  $F_{\text{mean}}$ , there was also a statistically significant main effect for grip type ( $F_{(1,8)}=60.47$ ,  $p<0.001$ ,  $\eta_p^2=0.32$ ), instrument ( $F_{(4,32)}=4.03$ ,  $p=0.009$ ,  $\eta_p^2=0.06$ ) and interaction ( $F_{(2,19)}=7.92$ ,  $p=0.002$ ,  $\eta_p^2=0.06$ ).

**Conclusions** Clinicians produced greater IASTM forces when applying a two-handed grip than a one-handed grip. Instrument weight may matter less than instrument shape, size and bevelling for influencing force production as instrument length appears to influence force production when using one-handed or two-handed grips. Although the effects of IASTM force variation on patient outcomes remains unknown, these findings may be considered by clinicians when making instrument and grip choices.

## INTRODUCTION

Instrument-assisted soft tissue mobilisation (IASTM) is a therapeutic intervention commonly used to treat various soft tissue pathologies.<sup>1</sup> Clinicians may use IASTM to increase tissue healing response, mobilise

## WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Instrument-assisted soft tissue mobilisation (IASTM) is a common practice in sports medicine, yet data for the influence of instrument shape or grip type on force application is limited.

## WHAT THIS STUDY ADDS

⇒ Gripping instruments with two hands leads to a greater application of force.  
 ⇒ Clinicians produced different amounts of force depending on the instrument that was being used.  
 ⇒ Instrument weight may matter less than instrument shape, size and bevelling when considering the control of force application.

## HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The evidence for the amount of force used by trained clinicians across different instruments and grip types should guide future investigations when selecting treatment parameters for evaluating the efficacy of IASTM.

scar tissue, decrease tissue tension and enhance their ability to detect abnormalities in the soft tissue.<sup>1-4</sup> A wide variety of instruments with numerous variations (eg, manufacturer, materials (eg, steel, bone, stone), shape, size, weight) have been used by clinicians with different types of training and levels of clinical experience.<sup>2,5</sup> The wide variation of instrument designs and instrument application (eg, one hand or two hand grips) may influence the forces applied by clinicians during IASTM.<sup>5</sup>

Force application may be influenced by the size, shape, weight, edge bevel or texture of an instrument, which in turn may influence how clinicians grip or use an instrument during clinical practice. For example, instruments such as the RockBlades Mullet (RB) and



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EDGE Mobility System (EM) have a length and handle shape supportive of one-handed use. Other instruments, such as the Técnica Gavilán *Ala* (TG), Graston Technique *GT #5* (GT) and Fascial Abrasion Technique *FAT Stick* (FAT), are longer instruments that may be easier to apply with two-handed applications. Thus, there is potential for the amount of force applied during an IASTM intervention to vary by instrument and grip, which may influence therapeutic effects or patient perception of treatment effectiveness. Although a consensus on an ideal treatment force has not been reached, the amount of force used during treatment is a consideration for clinical application of IASTM.<sup>1 6 7</sup> Inconsistencies in outcomes from the IASTM literature may result from variations in research methodologies,<sup>1 2 4 5</sup> and variations across IASTM training courses.<sup>4 5</sup> The discrepancies between methodologies and techniques taught in training courses may be the basis for clinician-reported estimates ranging from lighter forces (ie, 500 g or less) to more substantial forces (ie, more than 500 g).<sup>4 5</sup>

The primary evidence guiding IASTM force application is found in animal studies examining the effects of IASTM application on tissue healing.<sup>8–10</sup> Consistent findings of increased fibroblastic healing (eg, recruitment, maturation) have been found with increased force application; thus, there may then be a relationship between the amount of force used in IASTM treatment and the amount of fibroblastic activity that is stimulated.<sup>8 9</sup> However, the study methodology included low IASTM forces (ie, 0.5–1.5 N; ~51 g to ~153 g) applied for short durations that may not replicate clinical practice well.<sup>8–10</sup> There is currently a limited number human trials that have reported lower levels of estimated force (ie, 208 g or 2.04 N).<sup>11</sup> Other studies quantifying the amount of force applied have used a wider range of forces (ie, 2.6–9.1 N) in human participants.<sup>12</sup> Simulated one-handed treatment scenarios on a force plate resulted in applied IASTM forces ranging from 2.6 to 14.0 N for average peak force and 1.6 to 10.0 N for average mean force across clinicians during one-handed IASTM grips.<sup>13</sup> Additionally, there is evidence for intraclinician reliability of applied IASTM forces for one-handed IASTM grips with the TG, FAT and RB.<sup>14</sup> While IASTM force reliability data for a two-handed grip was not identified in the literature, two-handed force data from a simulated treatment on a force plate was found: IASTM forces ranged from 1.1 to 21.3 N for average peak force and 0.9 to 15.3 N for average mean force across clinicians using the EM, RB, FAT, TG and GT instruments.<sup>15</sup> The variations in the range of forces reported by these studies across the aforementioned instruments requires further investigation into whether grip or instrument influenced force application.

The recent studies<sup>13–15</sup> on clinician applied IASTM forces during simulated treatment scenarios did not examine if IASTM forces vary across different IASTM instruments or whether one-handed or two-handed grips influence force application. The potential for force variation across IASTM instruments and one-handed or

two-handed stroke type would be valuable for informing clinical practice, literature interpretation and future research. Therefore, the purpose of this study was to examine the forces used by trained clinicians during simulated IASTM treatment across five different instruments during one-handed and two-handed IASTM applications. We had the following hypotheses for the study: (1) average peak and mean forces would be higher across all instruments for two-handed grips than one-handed grips and (2) use of longer/larger instruments (ie, TG, GT, FAT, RB) more supportive of two-handed application would result in higher peak and mean forces than smaller instruments (ie, EM) during two-handed grips.

## METHODS

The current study was part of a larger study. To be included in the study, participants had to complete at least one professional IASTM course instructed by a company that sells IASTM instruments and provides training for clinical use. Additionally, they had to use IASTM in professional clinical practice (ie, chiropractors, physical therapists, athletic trainers). The current study analysed a subsample of nine clinicians, which was intended to create a more homogeneous group for comparing the effect of instrument and grip. The included participants had completed an IASTM training course from at least one of the brands of instruments used in the study and had a similar professional background (ie, certified athletic trainers). Participants completed a demographic survey prior to the data collection in which they were asked about previous experience, current use of IASTM in their clinical practice, and details of past IASTM training (table 1). Although two of the participants reported rarely using IASTM in their current clinical practice, the removal of their data did not alter the results.

The study was conducted as a randomised cross-over study where IASTM trained clinicians completed simulated treatments on simulated tissue (Complex Tissue Model, Simulab Corporation, Seattle, Washington, USA) attached to a force plate (HE6×6, AMTI, Watertown, Massachusetts, USA) in a university biomechanics laboratory. The equipment was secured to a treatment table that allowed clinicians to perform the simulated treatment. The five instruments used were produced by different IASTM companies (figure 1): (1) RockBlades (RB; Durham, North Carolina, USA) Mullet (mass: 178 g); (2) Técnica Gavilán (TG; Tracy, California, USA) *Ala* (mass: 196 g); (3) FAT (Niagra Falls, Ontario, USA) *FAT Stick* (mass: 293 g); (4) EM (Lake View, New York, USA) *Edge Tool* (mass: 196 g); (5) Graston Technique (GT; Indianapolis, Indiana, USA) *GT #5* (mass: 156 g). Of note, training varies across companies: the TG and FAT approaches offer in-person training for healthcare professionals/students, the GT (eg, in-person, hybrid, online) and RB (eg, in-person, live webcast, DVD) trainings are offered in multiple formats, and EM training is available in multiple remote formats (ie, online course, Ebook,

**Table 1** Participant training and experience

Clinician	Manufacturer IASTM training completed	IASTM experience (years)	Frequency of IASTM use in current clinical practice
1	TG, RB	12	Rarely
2	TG	1	Frequently
3	TG	2	Frequently
4	TG, GT	6	Frequently
5	TG	9	Frequently
6	GT	4	Frequently
7	TG, GT, RB	10	Daily
8	TG	2	Rarely
9	TG	11	Frequently

GT, Graston Technique GT #5; IASTM, instrument-assisted soft tissue mobilisation; RB, RockBlades Mullet; TG, Técnica Gavilán Ala.

DVDs). Requirements and availability of instrument purchases also varies: the *FAT* sells certain instruments (eg, *FAT Tool*) to healthcare professionals only, while the *FAT Stick* is available for purchase online without any professional credential or training from the FIT Institute; RB and TG instruments could be purchased with professional IASTM training from the manufacturers or online (eg, Amazon, Alert Services) without professional healthcare or IASTM training required; EM instruments are also sold online (eg, Amazon) without a health professional or IASTM training requirement; and the GT instruments can only be purchased from the company by healthcare professionals who have completed GT training.

Each participant was provided the opportunity to practice applying sweeping strokes with both one-handed and two-handed grips for each tool on the skin simulant until the participant reported being comfortable with each instrument and grip. Participants were provided with the standardised treatment scenario. The instructions of the treatment scenario were that the participant

had already scanned the area and was now to apply five linear sweeping strokes for a patient with reported gastrocnemius tightness. The linear sweeping strokes were performed in a unidirectional and linear manner, while lifting off the skin simulant after each stroke. Although lifting the instrument between strokes may not be common practice, it was necessary to differentiate between strokes during the data analysis. Sweeping strokes may be considered similar to effleurage and thus use a relatively light force<sup>16</sup>; however, participants were not instructed on how much force to use during the simulated treatment and were instructed to apply this stroke in a manner consistent with their clinical practice for the provided treatment scenario.

Each clinician had training on applying this type of linear sweeping stroke within their professional IASTM training from either Técnica Gavilán, RockBlades or Graston Technique (table 1). Standardising to only a linear sweeping stroke was intended to limit the variation between different types of IASTM treatment strokes that are non-linear and thought to target deeper tissues which may result in greater treatment forces. Additionally, clinicians were able to use either the concave or convex side of the instrument for the TG and GT depending on what would best represent their clinical practice. Participants were not allowed to switch sides while data were being collected. The concave side of the EM and RB instruments were not used because this would have created multiple contact points on the skin simulant; the *FAT* instrument was applied on its only treatment edge. Instructions were not provided regarding the effort to replicate forces between instruments or grips. Instead, participants were only instructed to apply each instrument in a manner that the participant felt would replicate their application of the linear sweeping strokes in clinical practice for the provided treatment scenario.

For each clinician, instrument order was randomised, and this procedure was then repeated three times for each instrument totalling 15 strokes with each instrument and 75 IASTM strokes overall. These same procedures were completed approximately 24 hours later with



**Figure 1** Image of all instruments. EM, EDGE Mobility System Edge Tool; FAT, Fascial Abrasion Technique FAT Stick; GT, Graston Technique GT #5; RB, RockBlades Mullet; TG, Técnica Gavilán Ala.

one-handed linear sweeping strokes. NetForce software (V.3.5.3, AMTI, Watertown, Massachusetts, USA) was used to collect the force data at 500 Hz. The data were then exported to MATLAB (V.2019b, Natick, Massachusetts, USA) and filtered with a 10 Hz low-pass Butterworth filter.

## DATA ANALYSIS

Data for peak normal force ( $F_{\text{peak}}$ —calculated as the sum of maximum vertical forces for each stroke divided by the number of trials) and average normal force ( $F_{\text{mean}}$ —defined as the sum of mean vertical forces produced across the entire length of a single stroke and divided by the number of trials) were collected for analysis. Data were analysed using 2 (grip type (ie, one-handed or two-handed))  $\times$  5 (IASTM instrument), within-subjects, repeated measures analysis of variance (RM-ANOVA) to analyse the effect of grip type and instrument. Separate RM-ANOVAs were conducted for  $F_{\text{peak}}$  and  $F_{\text{mean}}$ ; Bonferroni adjustments for multiple comparisons were made for all follow-up pairwise comparisons. Alpha was set at  $p \leq 0.05$ . Partial eta squared values were interpreted as small ( $\eta_p^2 = 0.01$ ), medium ( $\eta_p^2 = 0.06$ ) and large ( $\eta_p^2 = 0.14$ ).<sup>17</sup> Cohen's  $d$  was calculated for pairwise comparisons and interpreted as small ( $d=0.2$ ), medium ( $d=0.5$ ) and large ( $d=0.8$ ).<sup>17</sup> Statistical analyses were performed with R V.3.6.2 (The R Foundation for Statistical Computing Platform, 2019).

## Patient and public involvement

Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

## RESULTS

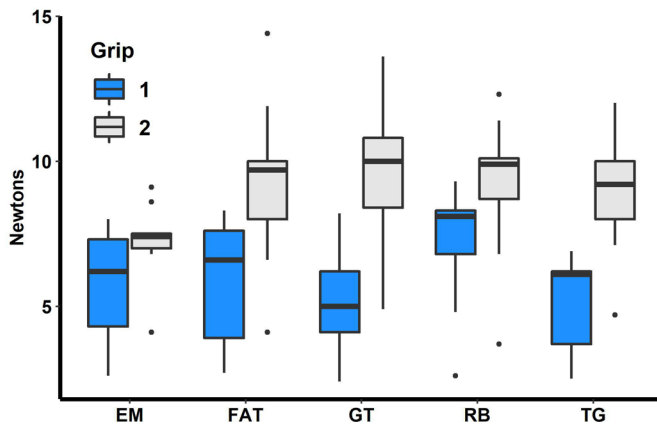
All nine participants who initiated study participation completed the study protocol. Shapiro-Wilk tests indicated that data were normally distributed for all instruments for both  $F_{\text{peak}}$  and  $F_{\text{mean}}$  data. The RM-ANOVA for  $F_{\text{peak}}$  demonstrated a significant main effect for grip type ( $F_{(1,8)}=46.39$ ,  $p < 0.001$ ,  $\eta_p^2 = 0.34$ ), instrument ( $F_{(4,32)}=4.61$ ,  $p=0.005$ ,  $\eta_p^2 = 0.06$ ) and interaction ( $F_{(2,16)}=10.23$ ,  $p=0.001$ ,  $\eta_p^2 = 0.07$ ). Post hoc comparisons indicated a statistically significant effect of grip type for four of the instruments (FAT:  $F_{(1,8)}=6.89$ ,  $p=0.01$ ,  $\eta_p^2 = 0.32$ ; TG:  $F_{(1,8)}=121.0$ ,  $p < 0.001$ ,  $\eta_p^2 = 0.52$ ; GT:  $F_{(1,8)}=66.7$ ,  $p < 0.001$ ,  $\eta_p^2 = 0.53$ ; RB:  $F_{(1,8)}=20.3$ ,  $p=0.01$ ,  $\eta_p^2 = 0.15$ ), but not the EM instrument ( $F_{(1,8)}=6.89$ ,  $p=0.15$ ,  $\eta_p^2 = 0.17$ ) for  $F_{\text{peak}}$ . Pairwise comparisons (table 2) revealed statistically significant differences for one-handed use between the RB and TG instruments ( $p=0.02$ ,  $d=1.03$ ) and the RB and GT instruments ( $p=0.04$ ,  $d=0.99$ ) for  $F_{\text{peak}}$ . One-handed grip post hoc  $F_{\text{peak}}$  differences did not reach statistical significance but presented with meaningful effect sizes between the following instruments (table 2): EM and RB ( $p=0.24$ ,  $d=0.67$ ) and FAT and RB ( $p=0.61$ ,  $d=0.55$ ). Statistically significant two-handed grip differences for  $F_{\text{peak}}$  occurred between the EM and two other instruments: TG ( $p=0.05$ ,  $d=0.96$ ) and RB ( $p=0.03$ ,  $d=0.89$ ), respectively. Two-handed grip post hoc  $F_{\text{peak}}$  differences that did not reach statistical significance but demonstrated meaningful effect sizes were found between the EM and two other instruments: FAT ( $p=0.23$ ,  $d=0.89$ ) and GT ( $p=0.06$ ,  $d=1.10$ ), respectively.

The RM-ANOVA for  $F_{\text{mean}}$  data indicated a statistically significant main effect for grip type ( $F_{(1,8)}=60.47$ ,  $p < 0.001$ ,  $\eta_p^2 = 0.32$ ), instrument ( $F_{(4,32)}=4.03$ ,  $p=0.009$ ,  $\eta_p^2 = 0.06$ ) and interaction ( $F_{(2,19)}=7.92$ ,  $p=0.002$ ,  $\eta_p^2 = 0.06$ ). Post hoc tests for  $F_{\text{mean}}$  revealed a statistically significant effect

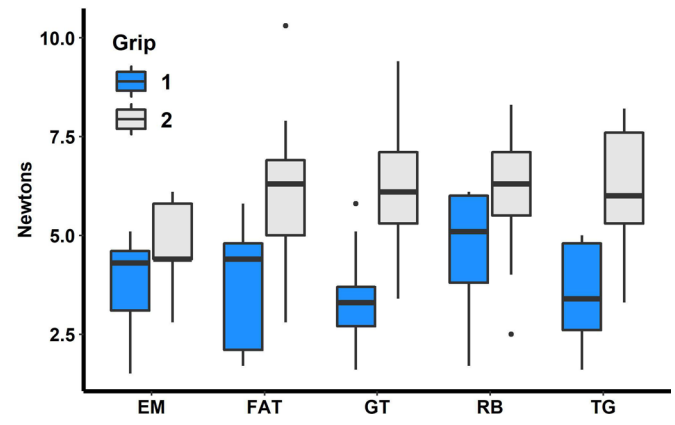
**Table 2** Results of pairwise comparisons

Comparison	One hand				Two hand			
	Mean forces		Peak forces		Mean forces		Peak forces	
	P value	Cohen's d	P value	Cohen's d	P value	Cohen's d	P value	Cohen's d
Edge-FAT	1	0.13	1	0.08	0.32	0.93	0.23	0.89
Edge-Gavilan	1	0.21	0.81	0.35	0.18	0.89	0.05	0.96
Edge-Graston	1	0.18	1	0.32	0.16	1.07	0.06	1.10
Edge-RockBlade	0.27	0.72	0.24	0.67	0.07	0.84	0.03	0.89
FAT-Gavilan	0.93	0.32	0.46	0.42	1	0.14	1	0.10
FAT-Graston	1	0.31	1	0.39	1	0.01	1	0.06
FAT-RockBlade	0.87	0.55	0.61	0.55	1	0.16	1	0.08
Gavilan-Graston	1	0.01	1	0.02	1	0.16	1	0.18
Gavilan-RockBlade	0.07	0.92	0.02	1.03	1	0.02	1	0.01
Graston-RockBlade	0.14	0.89	0.04	0.99	1	0.17	1	0.15

FAT, Fascial Abrasion Technique.



**Figure 2** Boxplots comparing  $F_{peak}$  between instruments with one and two hands. EM, EDGE Mobility System Edge Tool; FAT, Fascial Abrasion Technique FAT Stick; GT, Graston Technique GT #5; RB, RockBlades Mullet; TG, Técnica Gavilán Ala.



**Figure 3** Boxplots comparing  $F_{mean}$  between instruments with one and two hands. EM, EDGE Mobility System Edge Tool; FAT, Fascial Abrasion Technique FAT Stick; GT, Graston Technique GT #5; RB, RockBlades Mullet; TG, Técnica Gavilán Ala.

of grip type for four of the instruments (FAT:  $F_{(1,8)}=6.15$ ,  $p=0.005$ ,  $\eta_p^2=0.33$ ; TG:  $F_{(1,8)}=133.0$ ,  $p<0.001$ ,  $\eta_p^2=0.45$ ; GT:  $F_{(1,8)}=91.0$ ,  $p<0.001$ ,  $\eta_p^2=0.48$ ; RB:  $F_{(1,8)}=15.4$ ,  $p=0.02$ ,  $\eta_p^2=0.14$ ), but not the EM instrument ( $F_{(1,8)}=6.15$ ,  $p=0.19$ ,  $\eta_p^2=0.18$ ). One-handed grip pairwise comparisons (table 2) for  $F_{mean}$  did not identify any statistically significant differences between instruments; however, meaningful effect sizes were identified between the RB instrument and the other four instruments: GT ( $p=0.14$ ,  $d=0.89$ ), TG ( $p=0.07$ ,  $d=0.92$ ), FAT ( $p=0.87$ ;  $d=0.55$ ) and EM ( $p=0.27$ ,  $d=0.72$ ), respectively. Two-handed grip pairwise comparisons (table 2) for  $F_{mean}$  did not identify any statistically significant differences between instruments; however, meaningful effect sizes were identified between the EM instrument and the other four instruments: GT ( $p=0.16$ ,  $d=1.07$ ), TG ( $p=0.18$ ,  $d=0.89$ ), FAT ( $p=0.32$ ;  $d=0.93$ ) and RB ( $p=0.07$ ,  $d=0.84$ ), respectively.

## DISCUSSION

Evidence-based guidelines for IASTM application are lacking and little is known about how IASTM forces may vary during IASTM treatments when different grips, strokes or instruments are used. Thus, the purpose of this study was to examine the  $F_{peak}$  and  $F_{mean}$  forces used by IASTM trained clinicians during a simulated IASTM treatment to determine how forces were influenced by

differences in instruments and grip type (ie, one handed or two handed). Our results provide insight into how forces may differ with IASTM treatment when clinicians use different grip types or instruments and support our hypotheses: (1) that average peak and mean forces were higher across all instruments for two-handed grips than one-handed grips and (2) use of longer/larger instruments (ie, TG, GT, FAT, RB) resulted in higher peak and mean forces than smaller instruments (ie, EM) during two-handed grips.

Survey responses<sup>2 5</sup> have indicated many clinicians consider the amount of force applied when using IASTM in clinical practice. Most respondents estimated that they applied a moderate force (ie, 250–500g; 2.45–4.90 N) during treatment, but responses were not reported as to whether that force varied when using different grip types or instruments.<sup>5</sup> Our data (table 3) indicate two-handed  $F_{peak}$  and  $F_{mean}$  values averaged for all participants exceeds the previously reported moderate force range; similarly, one-handed  $F_{peak}$  values also exceeded that range, while  $F_{mean}$  values trended towards the upper boundaries of that range. Thus, clinicians may be producing more force than estimated during IASTM, with potentially greater underestimation occurring when two-handed grips are being performed. Further, we found meaningful differences in  $F_{peak}$  (figure 2) and  $F_{mean}$  (figure 3) values for two-handed and one-handed grips, which suggests more

**Table 3** Average forces for each instrument and grip

Grip	Force	Edge	FAT	Gavilan	Graston	RockBlade
1	Fpeak	5.8±1.9	5.9±2.1	5.1±1.7	5.2±1.7	7.1±2.2
	Fmean	3.7±1.3	3.9±1.5	4.3±1.3	3.4±1.3	4.7±1.5
2	Fpeak	7.2±1.4	9.3±3.0	9.0±2.3	9.4±2.5	9.1±2.6
	Fmean	4.7±1.0	6.3±2.1	6.0±1.7	6.3±1.8	6.0±1.8

FAT, Fascial Abrasion Technique.

force is being used when two-handed grips are being applied compared with one-handed grips.

Other researchers<sup>12</sup> have quantified two-handed grip forces used by a single clinician on human gastrocnemius muscle tissue, reporting 4.68–9.07 N (495.58–924.88 g) and 2.63–4.47 N (268.19–455.81 g) for  $F_{\text{peak}}$  and  $F_{\text{mean}}$ , respectively. An IASTM intervention session (three sets of seven strokes in proximal and distal directions over 7–8 min across four treatment sections) with these forces did not produce significant changes in inflammatory markers, passive musculotendinous stiffness, passive ROM or maximum voluntary contraction peak torque in healthy participants.<sup>12</sup> Our  $F_{\text{peak}}$  and  $F_{\text{mean}}$  values overlapped with these ranges across all instruments and grip types. Currently, little is known about how these applied forces or the variation of these forces throughout treatment influences patient outcomes. Researchers examining an enzyme induced tendinitis model in rats reported that 1.5 N (~153 g) of force significantly increased fibroblast proliferation compared with 1 N (~102 g),<sup>8</sup> while larger forces (ie, 250–300 g; 2.45–2.94 N) increased vascular perfusion and accelerated ligament healing in rats with induced MCL injury.<sup>9 10</sup> However, the implications of findings in animal models should be viewed with caution given challenges in translating these findings to clinical practice given study methodology (eg, instrument size, enzyme induced tendinitis, tissue properties) that would not occur in practice. Therefore, research is needed to determine how different force levels or force variations influence healing in human trials or improve patient outcomes. Until then, clinicians may want to consider therapeutic goals and how force application may theoretically affect these goals, while considering how applying one-handed or two-handed grips may influence IASTM force application to guide IASTM intervention decisions.

Another factor to consider is how instrument properties (eg, weight, bevel, texture) may influence IASTM application and subsequent force production. We found significant differences across instruments for both one-handed and two-handed IASTM applications in our study (tables 2 and 3). As hypothesised, the longer/larger instruments (ie, FAT, GT, TG and RB) resulted in higher  $F_{\text{peak}}$  and  $F_{\text{mean}}$  values than the shorter/smaller (ie, EM) instrument when a two-handed grip was applied. The heaviest instrument (ie, FAT), however, did not result in substantially higher force application for  $F_{\text{peak}}$  and  $F_{\text{mean}}$  with a two-handed grip. Similarly, our results seem to suggest that, on average, edge bevelling and instrument texture differences between the longer/larger instruments did not result in meaningful differences in  $F_{\text{peak}}$  and  $F_{\text{mean}}$  values between these instruments (tables 2 and 3). For example, the bevelling on the treatment edge of the FAT instrument is flatter, the bevelling on the TG and GT is sharper, and on the RB the treatment edge is more round. Additionally, the added texture on the FAT instrument is coarser than the smoother TG, GT and RB surfaces. A potential explanation for the findings is that the longer/larger instruments provide ample

control during a two-handed grip allowing clinicians to provide similar IASTM forces during IASTM application, while a smaller instrument (ie, EM) may create gripping or control challenges that result in lighter IASTM force application in the same scenario.

The one-handed grip application results also suggest instrument type influences force production. As was found in the two-handed grip data, use of the heaviest instrument (ie, FAT) did not result in substantially higher force application for  $F_{\text{peak}}$  and  $F_{\text{mean}}$  during a one-handed grip. Similarly, it is also not surprising that  $F_{\text{peak}}$  and  $F_{\text{mean}}$  values for longer/larger instruments (ie, FAT, GT, TG) were reduced with a one-handed grip: these instruments can become more challenging to control with a one-handed sweeping stroke because force is applied several inches away from the instrument grip (ie, gripping the instrument at an end vs the centre of the instrument). This hypothesis may be supported by the one-handed grip RB instrument findings: statistically greater  $F_{\text{peak}}$  and  $F_{\text{mean}}$  values during a one-handed stroke were found when the RB instrument was used compared with the other four instruments (tables 2 and 3). The RB instrument was categorised as a larger/longer instrument given its shape and size. The RB instrument, however, is not as long as the other instruments (ie, FAT, GT, TG) and the RB instrument is also moulded to allow a one-handed grip directly over the site of treatment like the EM instrument. Unlike the EM instrument, however, the RB instrument has a more tapered/rounded edge. It could be hypothesised that clinicians produced more force when applying a one-handed grip with the RB instrument because the instrument provided enhanced control to produce force due to its design, while also providing less tissue feedback due to the rounded edge bevel. Thus, sharper bevelled edges (ie, TG, GT), or flat edges (ie, EM, FAT) may have provided more tactile feedback from the tissue through the instrument which resulted in less force. Our findings also provide support to suggest that  $F_{\text{peak}}$  and  $F_{\text{mean}}$  ranges may be narrower across one-handed and two-handed grips when using the RB instrument compared with the other four instruments. Future research is warranted to confirm this finding and to determine if patient outcomes improve when IASTM forces are provided in a narrower, more consistent range.

Our study is not without limitations relevant for consideration in clinical practice and future research. First, we are unable to assert whether the statistical differences in force between the instruments, or different grips, may be related to a clinically important difference. The simulated patient scenario was standardised (eg, one table height, one stroke type) with a scenario (eg, simulated tissue, strokes applied in a unilateral direction) that does not fully replicate clinical practice. Clinician IASTM force generation may be influenced based on body position of the patient or clinician and our simulated scenario is not representative of all clinical practice scenarios. Although we limited our sample to athletic trainers with similar training backgrounds, clinician variability for experience,

frequency of IASTM use in practice and a lack of familiarity with some of the instruments may have influenced force production. Additionally, we used a single IASTM stroke (ie, linear sweeping stroke) and many of these instruments are applied with multiple stroke types. Further, several of the IASTM manufacturers produce multiple instruments designed for different purposes and situations (ie, concave vs convex sides). Participant selection of the concave or convex sides may have varied for the TG and GT and this may have influenced force production; however, it was deemed more important to capture how the instrument may be used in practice by the individual clinician for assessing differences that would best replicate clinical practice given study limitations. Additionally, the use of a within-subjects statistical design did not account for between subject differences.

Finally, our sample size and use of conservative Bonferroni adjustments to correct for familywise error rate with follow-up comparisons increases the risk of a type II error in identifying between instrument differences<sup>18</sup>; however, we attempted to address this concern by reporting and interpreting standardised effect sizes to examine between instrument differences. Future research is needed to determine how IASTM force influences treatment outcomes and how these forces vary across the wide range of instruments and treatment scenarios. Additionally, further research could help elucidate how IASTM training differences, treatment goals and perceived clinician feedback—from the instrument or a patient— influences force application and patient outcomes.

## CONCLUSION

We examined the effect of instrument type and grip type on IASTM force production, and our findings suggest clinicians will produce greater force when applying a two-handed grip than a one-handed grip. Our findings also provide insight into how instrument type may influence force production in both one-handed and two-handed IASTM grips. Our findings suggest instrument weight may matter less than instrument shape, size and beveling; further, instrument length will likely influence force production when using one-handed or two-handed grips. The findings of this study may guide clinicians regarding IASTM force production when treating with one or two hands, as well as when treating with different instruments.

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