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Research article

The Acute Effects of Theragun™ Percussive Therapy on Viscoelastic Tissue Dynamics and Hamstring Group Range of Motion

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Abstract

Handheld percussive therapy (PT) massage guns have seen a rapid rise in use and with-it increased attention within injury prevention and sport performance settings. Early studies have proposed beneficial effects upon range of motion (ROM), however the mechanism behind these increases remains unreported. This study aimed to determine the influence of a minimal frequency PT dose upon ROM and myotonometry outcomes. Twenty participants (N = 20; 13 males and 7 females, height 1.78cm ± 9.62; weight 77.35kg ± 8.46) participants were allocated to either a PT group receiving 2 x 60-seconds (plus 30-seconds rest) via a Theragun™ Pro4 to the hamstrings covering a standardised 20 lengths from proximal to distal via the standard ball attachment at 1 bar of pressure or a control group (CON) of 2-minutes 30-seconds passive supine rest. Pre and post intervention outcomes were measured for ROM via passive straight leg raise (PSLR) and tissue dynamics via MyotonPro (Tone, Stiffness, Elasticity, Relaxation Time). Results showed significant within-group increases ($p < 0.0001$, ηp^2 0.656, +11.4%) in ROM following PT and between group difference against CON ($P < 0.026$). Significant within-group differences in stiffness ($p < 0.016$, ηp^2 0.144, -6%), tone ($p < 0.003$, ηp^2 0.213, +2%) and relaxation time ($p < 0.002$, ηp^2 0.232, +6.3%) were also reported following PT. No significant difference was reported in elasticity ($P > 0.05$) or any other between group outcomes. PT therapy can provide an acute increase in hamstring group ROM following a resultant decrease in tissue stiffness.

Key words: Theragun™, flexibility, tissue stiffness, vibration.

Introduction

Recent advancements in handheld vibration device technology have resulted in a rapid rise in use amongst both athletic populations and soft tissue therapists (Macaulay et al., 2019). These developments have provided users with affordable, self-applied and accessible means to create vibratory influences to superficial dermal tissues through a percussive application in order to assist their performance, recovery and well-being (Konrad et al., 2020; García-Sillero et al., 2021). This method of treatment has since been termed Percussive therapy (PT) and defined as the rapid and repetitive application of pressure applied perpendicular to the body evoking both physiological and neurological responses (Theragun, 2020). Stemming from the origins of tapotement massage (Coats, 1994) and a rationale consistent with mechanical vibration (Cerciello et al., 2016) through which the triggering of cutaneous reflexes elicits vasodilatory responses, percussive therapy devices provide a mechanical oscillation to dermal tissues at frequencies between 5 to 60Hz causing the tissues beneath to vibrate (Rauch 2009). PT has been used in the treatment of soft tissue to elicit benefits in pain relief, increase blood flow (Macaulay et al., 2019), decreased symptoms associated with post exercise muscle soreness, increase range of motion (ROM) (Trainer et al., 2022), and inhibition of the Golgi reflex (García-Sillero et al., 2021).

Recent investigations (Guzman et al., 2018; Konrad et al., 2020; Hernandez, 2020) have proposed beneficial effects from such handheld devices on ROM with large magnitude acute effects on ankle dorsiflexion (Konrad et al., 2020); and significant increases in hip flexors and extensors, knee flexors (Guzman et al., 2018), plantar flexors (Hernandez, 2020), and shoulder internal rotators (Trainer et al., 2022). Suggested insights into the possible mechanism behind these ROM effects were offered through reductions in muscle thickness when no change or a decrease in muscle soreness response occurred following PT (Trainer et al., 2022). Muscle thickness is viewed as the distance between the superficial and deep tendon aponeurosis which is acknowledged as an indirect measure of strength and important factor influencing muscle's function (Fridén and Leiber, 2001; Moreau et al., 2010). Other indicators of a muscle's function include parameters determined by muscle myotonometry such as muscle tone, elasticity and stiffness. Muscle tone is referred to as the mechanical tension of the muscle regardless of its conscious contraction (Loturco et al., 2015; Agyapong et al., 2016), and is reflective of a muscle's recovery following a mechanical stimulus or influence. Muscle elasticity represents a muscles ability to return to its resting state upon cessation of external stimuli or load affecting a muscle (Wheeler et al., 2015) and reflects the state of blood circulation during muscular work. During periods of contraction muscle cells receive a constant supply of blood while during its accompanied relaxation phase blood can flow steadily meaning muscle tissue has to restore its natural state over a short period (Mustalampi et al., 2012). Muscle elasticity is characterised by logarithmic decrement of oscillations, i.e., the coefficient of elasticity. It has been noted that the higher the logarithmic decrement of damped oscillations, the lower a muscle's elasticity (Aird et al., 2012). Muscle stiffness refers to the ability of a muscle to resist the deforming forces being imparted, with higher levels of muscle stiffness resulting in the antagonist muscle receiving higher loads to maintain appropriate strength distribution. This results in an increase in energy demand to perform move-

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ments (Amiri-Khorasani and Kellis., 2015). The opposite response to this whereby a decrease in muscle stiffness results in reduced antagonist resistance also applies. Collectively these interactions of muscle tone, elasticity and stiffness ensures joint stability when movement is performed. These variables are viewed as influential in maintaining joint stability in the presence of unexpected disturbances and loading (Maharaj et al., 2016; Bryanton and Bilodeau, 2016). “Optimal” tissue stiffness remains a much-debated variable from its association to lowered overuse injury risk (Butler et al., 2003; Williams et al., 2004) to its positive correlation with muscular performance (Bojsen-Møller et al., 2005). While high levels of stiffness have been reported with increased risk of injuries attributed to higher musculoskeletal loading on bony structures, levels deemed too low are also attributed to permitting excessive joint motion resulting in increased risk of soft tissue injuries (Butler et al., 2003, Lim and Park, 2019). Previous research has examined the influence of similar therapeutic adjuncts (foam rollers) evidencing reductions in tissue stiffness but with no effects (positive or negative) on performance variables (Wilke et al., 2019, Baumgart et al., 2019, Morales-Artacho et al., 2017). To date there remains a paucity of evidence examining or understanding of the use of handheld percussive guns, their effects and the implications associated with these effects. This study aims to examine the acute effects of percussive therapy on ROM at the hip and its associated influence upon tissue dynamics determined via myotonometry. This research hypothesised that percussive therapy would result in acute changes in myotonometry and range of motion outcomes.

Methods

Participants

Twenty participants (self-declaring as meeting current UK recommended activity guidelines) (Department of Health and Social Care, 2019) providing two datum points each (N = 20; 13 males height 1.81cm ± 4.55; weight 83.31kg ± 8.46 and 7 females, height 1.74cm ± 7.29; weight 70.43kg ± 4.96) were recruited from the University of Northampton. Each participant provided data sets for both limbs increasing the overall data pool analysed. Exclusions included participants under 18-years of age, those with known contraindications to percussive therapy (Deep vein thrombosis, peripheral vascular disease. bleeding disorders, cardiac, liver, or kidney disease, skin rash, open wounds or local inflammation), ongoing or recent lower injury (within 3 months prior) or a prior passive straight leg raise (PSLR) range of motion greater than 120^0.

Study design

A single-blind, independent subject design was used to collect data where participants were randomly allocated (via random number generator) to either a percussive therapy (PT) or control (CON) groups. Baseline measurements were recorded prior to group allocation and subsequent intervention. To minimise bias participants were blinded to viewing of the PSLR and all outcome results recorded. Due to the vibratory nature of the percussive therapy intervenetion, it was not possible to blind participants from the application of the intervention itself. Ethical approval was granted by the Faculty of Arts, Sciences and Technology Ethics Committee at the University of Northampton with the study completed in accordance with the Declaration of Helsinki.

Procedure

Upon volunteering. Participants were provided with a participant information sheet, PAR-Q and informed consent forms. Participants attended the laboratories at the University of Northampton for initial screening for contraindication to PT, PSLR (>120°) and familiarisation to the PT intervention. On completion, participants returned (minimum 7-days post familiarisation) for a single testing session. Initial baseline measures for muscular stiffness within the hamstrings were taken via a myomechanographic device (MyotonPro, Myoton AS, Tallinn Estonia). This device determines the mechanical oscillation of tissue provoked following a defined mechanical impact. Following a perpendicular preload of 0.18N to the skin, five repeated mechanical impacts (15ms) of 0.4N were imparted on to the targeted tissue. Measurements for Tone (Hz); Stiffness (N/m); Elasticity and Mechanical Stress Relaxation Time (ms) were recorded. With patients lying prone, application of the device was applied to the Bicep Femoris at a surface marked location halfway between the ischial tuberosity and head of fibula along the line of the Bicep Femoris (see Figure 1). Palpation and surface marking of this location was performed by a single primary investigator for consistency. The same investigator then performed the PSLR assessment using an Easy Angle digital goniometer (EA, Meloq©, Stockholm, Sweden) fixed to the lower limb aligned to the lateral malleolus and head of fibula. Zero degrees (0°) was set with limb full extended and resting parallel to the bed (see Figure 2). With the contralateral limb strapped to the bed, the limb was passively raised into hip flexion with an extended knee until a fixed point of resistance was encountered. At this point the ROM was recorded from the Easy Angle (see Figure 3).

Figure 1. Surface marked measurement via Myoton Pro.

Participants then received either PT (n = 13) via the Theragun^{TM} Pro G4 or CON (n = 7) interventions. PT was applied to the hamstrings by a single, trained investigator in a linear manner applied between origin and insertion at a rate of 1750 percussions per minute (PPM) or 29 Hz. Participants received 2 sets of treatment each lasting 1 minute with (plus 30-seconds rest) covering a standardised 20 lengths from proximal to distal utilising the standard ball attachment at 1 bar of pressure (as indicated by the device screen). CON interventions consisted of 2-minutes 30-seconds passive supine rest. All outcome measures for muscle stiffness and PSLR were immediately repeated as per baseline. This entire process was then repeated for the contralateral limb. To minimise the risk of order effect influencing results the order of limb application was also randomised. The contralateral limb was measured only as means to increase the data pool as the study aims were not to investigate comparative limb effects no separate limb analyses were conducted.

Figure 2. Zero setting of Easy Angle Goniometer – PSLR start point.

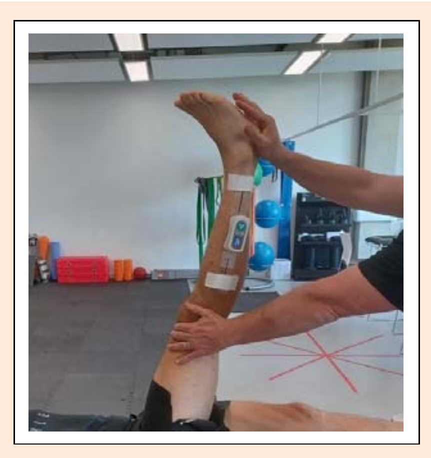

Figure 3. PSLR measurement via Easy Angle Goniometer.

Data analysis

All statistical analyses were conducted via SPSS 26.0 utilising a significance level of $p \leq 0.05$ for all acceptances. Following screening for normal distribution via Shapiro-Wilks ($p > 0.05$), a two-way mixed model ANOVA was conducted with Bonferroni post hoc tests used to assess changes within and between the interventions. Sphericity was checked via the Mauchly's test and where required the degrees of freedom adjusted using the Greenhouse-Geisser correction. Effect sizes were calculated using the partial eta-squared (η_P^2) with ≥0.01 indicating small, ≥0.059 medium and ≥0.138 large effects (Richardson, 2011). Post-hoc power analysis was then completed using G-Power 3.1 for all statistically significant findings.

Results

Descriptive results for all outcomes obtained are presented in Table 1.

ROM (°)

Significant within group differences were reported in ROM (F, 1, 38) 12.76 p = 0.001, ηp^2 0.251 with associated interaction effect by condition (F1, 38) 42.23 p = 0.0001, ηp^2 0.526. Pairwise comparisons revealed significant increases in ROM following PT pre to post (p = 0.0001, ηp^2 0.656, +11.4%) with statistical power calculated for the pairwise comparison at 0.07 for the PT group, while no statistical increase was observed in the CON ROM (p > 0.05, ηp^2 0.080, -3.6%). Pairwise comparisons also revealed significant between group differences only post intervention (p = 0.026).

Tone (Hz)

There were no significant differences identified for TONE (F, 1, 38) 2.97 p = 0.093 but significant difference was seen with associated interaction effect by condition (F, 1, 38) 4.29 p = 0.045. Pairwise comparison revealed significant increase in TONE (Hz) in PT from pre to post (p = 0.003, ηp^2 0.213, +2%) with statistical power calculated for the pairwise comparison at 0.02 for the PT group, while no statistical difference was reported in CON (p > 0.05, ηp^2 0.001). No differences were reported between the groups at either pre or post time points (p > 0.05).

Stiffness (N/m)

Significant within group differences reported in STIFFNESS (F, 1, 38) 2.97 p = 0.043 ηp^2 0.073. Pairwise comparison revealed significant reductions in STIFFNESS from pre to post PT (p = 0.016 ηp^2 0.144, -6%) with statistical power calculated for the pairwise comparison at 0.04 for the PT group, while no statistical differences were seen in the CON group (p > 0.05, ηp^2 0.002, <1%). No significant differences were reported between groups either pre or post intervention (p > 0.05).

Table 1. Mean, standard deviation and effect size for ROM, muscle tone, stiffness, elasticity, and relaxation time.

	Mean and Standard Deviation (±)				
	Conditions				
	PT Pre	PT Post	CON Pre	CON Post	Effect Size (ηp^2)
ROM (°)	88.76 ± 23.46	98.84 ± 25.03*	84.21 ± 15.05	81.28 ± 17.66**	0.656
Tone (Hz)	1.28 ± 0.25	1.30 ± 0.19*	1.20 ± 0.12	1.18 ± 0.19	0.213
Stiffness (S) (N/m)	265.15 ± 54.08	249.65 ± 38.78*	261.21 ± 53.45	258.85 ± 62.34	0.144
Elasticity	1.28 ± 0.25	1.30 ± 0.19	1.20 ± 0.12	1.18 ± 0.20	n/a
Relaxation Time (ms)	19.97± 3.50	21.25 ± 3.09*	19.78 ± 3.53	19.73 ± 3.50	0.232

*Indicating statistical significance within group. ** Indicating statistical difference between groups.

Elasticity

No significant within groups difference reported in ELASTICITY (F, 1, 38) 0.36 $p > 0.05$, ηp^2 0.001, or with interaction by condition (F, 1, 38) 0.54 $p = 0.464$, ηp^2 0.014. No significant differences between groups were noted at either time points ($p > 0.05$).

Mechanical stress relaxation time (ms)

No significant difference was reported in RELAXATION time (F1,38) 3.70, $p = 0.062$, ηp^2 0.089, but significant differences were reported with interaction effect by condition (F1,38) 4.33, $p = 0.044$, ηp^2 0.102. Pairwise comparison revealed a significant increase in RELAXATION time from pre to post PT ($p = 0.002$, ηp^2 0.232, +6.3%) with statistical power calculated for the pairwise comparison at 0.02, with no statistically significant change in CON from pre to post ($p > 0.05$, ηp^2 0.0001). Between group analysis revealed no significant differences in relaxation at either time point ($p > 0.05$).

Discussion

The aim of this investigation was to investigate the acute effects of handheld percussive therapy on hip ROM and examine any concurrent alterations in tissue dynamics. Findings illustrate significant increases within-group in the intervention group for ROM, Tone, Elasticity and Relaxation Time, with a significant decrease in Muscle Stiffness following percussive therapy. Furthermore, PT elicited a significantly greater ROM (+11.4%) compared to a control (passive rest) (-3.6%), however no significant between group differences were observed on myotonometry outcomes. The investigative hypothesis was therefore accepted. These findings suggest that PT offers a means of significantly altering short term ROM that may be the resultant of reduced stiffness within the tissue. To date it appears that no study to date has investigated the effects of PT on tissue dynamics determined via myotonometry. Results appear consistent with previous findings demonstrating the positive, large effects size of PT on ROM (Konrad et al., 2020; Hernandez, 2020; Trainer et al. 2022). These previous studies have all utilised higher frequency settings (40 - 53Hz) offered within the different devices used at treatment durations of 5-minutes. This current investigation offers evidence demonstrating that similar ROM gains can be generated from much lower frequency settings (1750rpm / 29Hz). It is therefore proposed that users of PT devices seeking ROM benefits can utilise frequency settings aligned to comfort and personal preference. Furthermore, the ROM effects were generated within a shorter application time (total treatment time 2-minutes) compared to the previous 5-minute intervention adopted in the past studies (Konrad et al., 2020; Hernandez, 2020; Trainer et al., 2022). Notable limitations within the previous research are observed in the lack of standardisation in speed of movement of the device and (or) pressure applied through the device. The current investigation utilised the improvements in technological development of the Theragun™ Pro G4 to maintain both a consistent pressure (applied to its minimum dosage) and metronomically paced speed of movement to improve the standardisation and repeatability in the treatment application. This proposed notion of user comfort is aligned with previous findings in which positive ROM outcomes were only observed in patients who reporting a reduction in soreness sensation post PT (Trainer et al., 2022). From this it was hypothesised that the frequency at which the PT devices compressed the muscles could over-stimulate non-nociceptive impulses to the muscles blocking the nociceptive impulses. Where the blocking of these nociceptive impulses is proposed to result in a relaxation effect inhibiting muscle guarding, users of PT with highly sensitive nociceptive fibres could find the resulting treatment increase soreness and muscle guarding. Additionally, percussive and vibratory devices have been reported to strongly influence afferent discharge within muscle spindles and fast adapting mechanoreceptors (Constantino et al., 2017), with resultant improvements in pressure pain threshold associated following it application (Jonker, 2019). Therefore, improvements in pain tolerance to stretch may explain the attained increases in ROM reported.

Myotonometry stiffness findings shows consistency with alternative self-applied soft tissue adjuncts (foam rolling) (Baumgart et al., 2019) and classical soft tissue therapy (Eriksson et al., 2015) however the current investigation is both the first to report the wider Myoton Pro outcomes. The reduction of stiffness offers a possible explanation for the increased ROM concurrently seen. A variety of proposed mechanism have previously been offered for this effect including the softening of tissue from the variety of mechanical forces (compression, vibration, tension, torsion, or shear) imparting increased tissue pliability (Imtiyaz et al., 2014), thixotropic effects (Behm and Wilke, 2019), increases in tissue temperature and the breaking of resting cross-bridges (Eriksson et al., 2015).

Previous findings have suggested that reduced stiffness levels may decrease injury risk (Messier et al., 2018). However contradictory to this, tissue stiffness was deemed to be not important in the development of ankle and knee injuries amongst runners (Davis and Gruber, 2021). It also appears unclear as to the performance benefits created by reduced stiffness values, with positive correlations reported between increased stiffness of the vastus lateralis and improved jump performance (Bojsen-Møller et al., 2005). Based on these conflicting stand points surrounding "optimal stiffness", the value of reducing stiffness level following the application of PT remain unclear, with further investigation examining performance measures warranted.

Further myotonometry outcomes evidencing increases in tone, elasticity and relaxation time appear form a consistent mechanical pattern following PT. It has been proposed that these responses could be explained through increases in local blood flow where small increases in intramuscular volume can lead to as much as a 50% increase in passive muscle tension (Sleboda et al., 2019). This higher level of resistance experienced because of increased blood flow would offer explanation for the slower Elasticity and Relaxation Time outcome. These findings demonstrate PT to be consistent with other forms of manual therapy (such as manipulative therapy and soft tissue therapies) in generating localised blood flow post application

(Matsuda et al., 2022; Mori et al., 2004). Generating improvements in localised blood flow within working tissue has been associated with improvements in both performance and health related outcomes from which five-minutes of manipulative and soft tissue therapies have been shown to significantly influence blood flow to the trapezius muscle in patients with neck stiffness (Matsuda et al., 2022) and lumbar region in comparison to passive rest during lumbar loading exercise (Mori et al., 2004). Vibration based interventions have also demonstrated increase in lower limb blood flow following 10-minutes of stimulation between 10 - 30Hz. With similar frequency and treatment applications PT may offer an alternative self-applied treatment mode to establish similar effects. While this hypothesised increased blood flow is supported by previous evidence, it proposes that further investigation supported with imagery-based measures be conducted to provide greater clarity of this response and determine whether any changes in circulation occur at cutaneous or muscular tissue levels. Finally, further application of the MyotonPro across different tissue types may be of benefit as the data generated is specific to the site of its application and therefore tissue changes cannot be assumed to occur consistently. This could for example include application upon tendinous tissue or subcutaneous adipose tissue. These tissue variants may demonstrate different responses to the measure, such as impedance to the mechanical vibration and amplitude of both the PT and myotonometry. Further investigation may therefore examine the influence of percussive therapy upon multiple tissue types.

Conclusion

This study aimed to examine the effect of percussive massage therapy via handheld massage gun on muscle ROM and tissue dynamics. Results suggest that PT can significantly increase hamstring group ROM by inducing a significant reduction in tissue stiffness levels. Associated alterations in tissue tone, elasticity and relaxation time can be attributed to increases in localised blood flow. Therefore, if the objective is to increase ROM and reduce tissue stiffness levels, PT can be recommended.

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Key points

- Handheld Percussive Therapy can provide moderate effect size acute increases in range of motion.
- Handheld Percussive Therapy can elicit acute reductions in tissue stiffness.
- Changes in tissue tone, elasticity and relaxation time following handheld Percussive Therapy are likely associated with acute changes in localised blood flow.

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