The effect of lower limb massage on EMG and force production of the knee extensors

Running Head: Neuromuscular recruitment and force production of massaged skeletal muscle

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ABSTRACT

Objectives: This study evaluated the effect of massage on force production and neuromuscular recruitment. **Methods:** Ten healthy male subjects performed isokinetic concentric contractions on the knee extensors at speeds of 60, 120, 180 and 240º.s^{-1}. These contractions were performed before and after a 30 minute intervention of either rest in the supine position or lower limb massage. Electromyography (EMG) and force data was captured during the contractions. **Results: The change in isokinetic mean force from pre to post intervention showed a significant decrease ($p<0.05$) at 60 º.s^{-1} and a trend for a decrease ($p=0.08$) at 120º.s^{-1} as a result of massage in comparison to passive rest.** However, there were no corresponding differences in any of the EMG data. A reduction in force production was shown at 60 º.s^{-1} with no corresponding alteration in neuromuscular activity. **Conclusion:** This suggests that **motor unit recruitment and muscle fibre conduction velocity are not responsible for the observed reductions in force. Although experimental confirmation is necessary, one possible suggestion is that massage may have induced force loss by influence on "muscle architecture".** However, it is possible that the differences were only found at 60 º.s^{-1} as it was the first contraction post massage. Further work is therefore needed on examining both muscle tension and architecture post massage and the duration of any massage effect.

Keywords: Massage, IEMG, MPFS, force, muscle architecture

INTRODUCTION

It has recently been shown that massage is mainly used in major sporting events for preparation before competition and recovery from events as opposed to treating specific problems [1]. However, the benefit of massage prior to performing a bout of high intensity exercise has recently been questioned [2]. Robertson et al [2] examined the effect of massage on recovery after subjects had completed 6 high intensity 30 second cycling bouts. This recovery was examined by a 30 second Wingate Anaerobic Test (WAT) performed 8 minutes after the intervention. The results showed a significantly lower fatigue index following the massage, however the authors proposed that this was probably as a result of a slightly lower peak power output generated. This would then suggest that the massage caused an impairment of peak power generation.

This evidence concurs with that of Goodwin [3] who showed a decrement in vertical jump performance following massage treatment. The author proposed that this decrement was as a result of reduced muscle stiffness and neural activation. This proposal is **plausible** as firstly, reduced muscle stiffness has been evidenced by a lengthening of massaged muscle [4 5]. This would then suggest that massage has a similar effect to that of stretching, which has recently been shown to result in a loss of force production when incorporated as part of a warm up [6]. Secondly, there is evidence to suggest that massage causes a decline in motor unit activation [7 8 9 10 11]. **However, these studies used H-reflex pre and post massage and whilst being a valid measure of motor unit activation, they are a different measure to the recording of**

surface electromyography (EMG) during a voluntary contraction. In addition none of these studies have related **a** decline in motor unit activation to any alteration in performance characteristics of the massaged muscle. **This would then suggest that more studies need to be performed in order to adequately apply them to an exercise and sporting context.**

To our knowledge no previous studies have examined the effect of massage on neuromuscular recruitment during concentric force production. Accordingly, we decided to examine the effects of massage on four different concentric contraction speeds (60, 120, 180 and 240º.s^{-1}) and capture EMG data simultaneously. As previous studies have showed a decrement in power after massage treatment we also decided to incorporate a standing vertical jump test with countermovement.

METHODS

Subjects

Ten healthy male (21.5 ± 0.5 years) subjects who were physically active on a regular basis volunteered for the study. The mean age (SD) of the subjects was 21.5 (0.5) years (range 20-24), mass 74.4 (11.3) kg (range 64-91). All subjects were given written information concerning the nature of the study and gave written informed consent prior to participation. The local Ethics of Research Committee approved this study.

Experimental Design

Subjects entered the laboratory on three separate occasions one week apart and at the same time of day. Two of these visits consisted of either a massage intervention or 30 minutes of rest in random order. Familiarisation was completed on the first visit to ensure all **subjects** knew the protocol and could satisfactorily perform maximal contractions at the differing speeds. Two days before the familiarisation visit, dietary intake (food and fluid) were recorded, this procedure was then replicated prior to the other two subsequent visits. Subjects were told to refrain from any heavy exercise during the 24 hours proceeding each test session. Upon arrival to the laboratory they were then questioned about their compliance with the dietary intake and exercise controls.

Standing Jump Test

Upon reporting to the laboratory subjects were asked to perform a five-minute warm-up on the cycle ergometer at 70 revolutions per minute (RPM) with 100W load. **The subjects then performed 3 vertical jump tests from a standing position with arms fixed with counter-movement included.** These jump tests were then repeated immediately after the rest and massage intervention.

Muscle Function Tests

To normalise EMG recordings during isokinetic contractions it was first necessary to perform maximal isometric force output testing. The strength of the subjects' right knee extensors were measured on an isokinetic dynamometer (Kin-Com Chattanooga Group Inc., USA). Subjects sat on the dynamometer and their hips, thighs and upper bodies were firmly strapped to the seat. In this position their hip angle was at 100° angle of flexion. The right lower leg was then attached to the arm of the dynamometer at a level slightly above the lateral malleolus of the ankle joint and the axis of rotation of the dynamometer arm was aligned with the lateral femoral condyle. The dynamometer arm was then **set at a start and stop angle of 65 and 60º respectively** from full leg extension**, which mean that during an isometric setting, the lever arm automatically alternated between these two angles for each contraction**. Each subject performed four sub-maximal familiarisation contractions prior to performing two maximal MVC's; **the latter at 60° was used for normalisation of EMG data.** All subjects were encouraged verbally to exert maximal effort during both MVC's.

Following both the MVC **(pre-intervention)** and **after** 30 minutes of massage or rest **(post-intervention)**, **the subjects performed** isokinetic knee extensions at 60° per second, 120° per second, 180° per second and 240° per second. The subject performed one warm-up at each speed and **then** completed 3 maximal effort contractions at each of the speeds **(always starting with 60° per second and increasing to 240° per second)**. Subjects were instructed to exert effort as hard and as fast as possible on all contractions. 10 seconds of rest was given between each of the contractions and **1 minute between** the differing velocities and again the subjects were verbally encouraged to exert maximal effort. The lever arm was pushed back by the investigator so that only the concentric phase of the contractions was measured.

Massage

After the subjects performed the **pre-intervention** muscle function tests they then received either 30 minutes of passive rest (in the supine position) or massage in random crossover fashion for both visits. The massage was applied for 30 minutes in 7 minute 30 second segments to the back of each leg with the subject on the prone position on a standard treatment **couch**. The subject then assumed a supine position, and massage was also applied for the same duration on the anterior **aspect** of both legs. Table 1 shows the massage protocol followed during each 7 minute 30 second period. Most strokes were grade 1 or 2, but three grade 3 effleurage strokes, using a clenched fist, were applied in a centripetal direction to the left and right iliotibial band midway through the supine massage. All massage was administered by the same charted physiotherapist using a conventional bland mineral oil (40 ml contact medium was used per massage area).

Table 1 Massage protocol

Massage technique	**Description**	**Grade**
Stroking	whole hand, one and two handed centripetal and multidirectional	**4 strokes grade 1 (very light contact to give sedative effect), 2 strokes grade 2 (slightly firmer to produce minimal effect on superficial vessels)**
Effleurage	whole hand two handed and reinforced centripetal and centrifugal	**grades 1 (sufficient depth to influence onward flow of superficial vessels), 2 (affecting deeper vessels) and 3 (reinforced)**
Petrissage	Picking up – whole hand two handed v-shaped, centripetal and centrifugal	**grade 1 (sufficient to influence superficial vessels and on underlying structures compress superficial soft tissue) and 2 (sufficient to compress deep tissue on underlying structures and affect deeper tissue drainage)**
Wringing	whole hand two handed centripetal, centrifugal, multidirectional	**grade1 (same as Petrissage grade)**
Rolling	muscle rolling centripetal	**grade 2 (muscle rolling, lifting muscle tissue and affecting deeper structures)**

This protocol represents the procedures followed during each of the four 7 minute 30 second massage periods. All petrissage was interspersed with effleurage grade 2 in a centripetal direction. **Grading as described by Watt**[12]

EMG

Prior to maximal isometric strength testing on the Kin-Com isokinetic dynamometer, EMG dual electrodes (PNS Dual Element Electrode, Vermed, VT, USA) were attached to the subject's lower limb midway between the superior surface of the patella and the anterior superior iliac crest of the "belly" of the rectus femoris after preparing the skin as described previously [13]. The electrodes were linked to the BioPac EMG apparatus (Biopac Systems, USA) and host computer. The EMG data was automatically anti-aliased by the hardware (Biopac Systems, USA). Each activity was sampled at a 2000 Hz capture rate. This gave route mean square (RMS) of the EMG signal, giving a measure of the power of the signal, which was used for subsequent analyses. Recordings were taken on the second maximal isometric trial and for all the isokinetic contractions thus yielding a raw signal. MVC EMG data was recorded before the first set of isokinetic contractions for both conditions to ensure similar normalisation of EMG in both trials. The raw data were divided into 4 epochs which captured all the electrical activity recorded in each contraction. The first epoch included all data collected during the second MVC trial, and the remaining three epochs included data collected for the three maximal isokinetic contractions at each speed.

The spectrum of the frequency for each epoch of data collected during the cycle ride was assessed using the raw EMG data by using a fast Fourier transformation algorithm. The analyses for frequency spectrum were restricted to frequencies of the 5-500 Hz range, due to the EMG signal content consisting mostly of noise when it is outside of this bandwidth. The frequency spectrum from each epoch of data was compared with that derived from the MVC, and the amount of spectral compression was estimated. This technique was performed as described by Lowery et al. [8], which is a modification of the work of Lo Conte and Merletti [9] and Merletti and Lo Conte [10]. The spectrum of the raw signal of each epoch was obtained and the normalised cumulative power at each frequency was calculated for each epoch. The shift in percentile frequency was then examined (i.e. at 0%...50%...100% of the total cumulative). The percentile shift was then estimated by calculating the mean shift in all percentile frequencies throughout the mid-frequency range (ie. 5-500 Hz). This method has been suggested as a more accurate estimate of spectral compression than median frequency analyses, which uses single value of (50th) percentile frequency [11]. This change in mean percentile frequency (MPFS) data was used for subsequent analyses.

Statistical analysis

A two-way ANOVA for repeated measures was used to evaluate statistical significance of all the variables measured. Significance was accepted at $P \leq 0.05$. All data are expressed as means ± SD.

RESULTS

Force

There was a significant ($p<0.05$) difference in the decline in isokinetic mean force **pre to post intervention** for the massage condition during the $60°.s^{-1}$ contraction speed **only,** as well as a trend ($p=0.08$) for a decline in isokinetic mean force for **the contraction at** $120°.s^{-1}$ (Figure 1). No significant differences were observed for the subsequent 180 and $240°.s^{-1}$ contractions and **no significant decline in force was observed pre to post passive rest intervention** (Figure 1). However, there was a **significantly** ($p<0.05$) **greater** absolute mean force pre intervention for the massage **trial** and a highly significant ($p<0.01$) decline in force from $60º.s^{-1}$ through to $240.s^{-1}$, without any interaction effect **in all assessments** (Figure 2). After the intervention there was no difference **in absolute force production** between the **massage and passive rest trials**, but a similar highly significant ($p<0.01$) drop off in force was shown for both **trials** as the contraction velocity increased.

EMG

There were no differences observed in both EMG RMS **(Figure 3)** and MPFS **(Figure 4)** for 60, 120, 180 and $240º.s^{-1}$ and between the two conditions, despite a reduction in force decrement for $60º.s^{-1}$ contraction during the massage condition.

Vertical Jump

Despite a slight non significant reduction in jump height post intervention, there were no differences between the massage and rest conditions (Figure 5).

Subjective response

All subjects reported that their legs felt “light” after receiving the massage treatment, therefore perceived greater effort during the isokinetic contractions.

DISCUSSION

A **greater** decrement in force production **was observed pre to post** massage treatment at the 60º.s^{-1} contraction, with a **near significant decrement** at 120º.s^{-1} and no **decrement** in the remaining contractions (180 and 240º.s^{-1}) **compared with the passive rest**. There was no corresponding alteration in motor unit recruitment and firing rate for these slow contractions which is shown by the unchanged RMS and MPFS data.

We hypothesised that **any** decline in force would coincide with a similar rate of decline in both motor unit recruitment and firing rate [14]. This would be as a direct result of smaller and fewer motor units being recruited displaying a reduced RMS [15] [16] [17]. A reduced MPFS may also have been hypothesised as a result of reduced drive from the CNS and/or an accumulation of metabolites lowering the pH of the muscle resulting in slowed conduction velocity [18] [19] which slows down the firing rate. Therefore, unchanged RMS and MPFS data suggests that mechanisms other than neuromuscular recruitment must be responsible for this decrement in force. **Alternatively, it could be suggested that there should have been an increase in neural recruitment to compensate for the impaired force generating capacity following massage treatment: Particularly when it is clear to see from Figure 3 there was a large amount of recruitment reserve available for all of the contractions. However, when additional motor units are recruited for example during submaximal fatigue, this would be dependent on afferent receptors signalling the CNS to increase the force [20]. As the**

protocol used in this study used concentric only isokinetic maximal non fatiguing contractions, there would be minimal involvement of afferent receptors to modulate motor unit recruitment.

Previous evidence suggests that both acute and chronic effects of massage will result in a lengthening of massaged muscle [4 5]. Consequently, the length tension relationship may have been affected in this study resulting in a reduced force output [21 22 23 24]. Furthermore, it has been suggested that when skeletal muscle is lengthened, the amount of prospective actin / myosin cross-bridges declines [25] thus resulting in a loss of force, without a corresponding reduction in neural activation [25]. This suggests that **a possible** cause of this **greater** reduction in force **following massage** is from an alteration in muscle architecture as opposed to any alteration in motor unit recruitment or firing rate.

Interestingly, in our study the standing vertical jump data remained unchanged between the two conditions. **This could be due to the fact that the contraction velocity used in a vertical jump is going to be closer to 240°per second as opposed to 60° per second, therefore resulting in less impairment as a result of the massage which is also shown in the isokinetic contractions in this study. Contrary to our findings Goodwin [3] did show a decrement in vertical jump height when performing the same jump test. However, in that study the author combined both massage with stretch which may have resulted in greater lengthening of the muscles than just massage alone.**

Alternatively, the significant reduction in force after the massage treatment could be as a result of a higher force production shown before the massage treatment. However, if this was the only explanation for this occurrence then we would expect to also see significant reduction in force for all the contraction velocities as opposed to just 60º.s^{-1}. However, the higher force pre massage is none the less an interesting observation; **it is unclear why this occurred given the pre-testing controls for exercise, diet and time of day**, but a possible explanation is an anticipatory response to receiving a massage.

Furthermore, it is possible that the force decrement was only observed at 60 º.s^{-1} as it was the first contraction post massage, and the effect of the massage on all subsequent contractions **to be performed** diminished as a result of time or prior contraction. A similar response has also been shown at slow contraction velocities post stretch [26]. However, Hinds et al [27] performed contractions pre and post massage at one contraction speed of 240º.s^{-1} and showed no decrement in force production. The combination of data from these studies suggests that massage only effects force production at the slow contraction velocities. A logical explanation for this originates from the force-velocity relationship as described by Hill [28] which clearly shows that faster velocities produce less force as also demonstrated in this study. According to Spurway [29] skeletal muscle will shorten fastest under the lighter loads, therefore at the slow velocities there is slower shortening resulting in a greater force generating capacity, therefore the chances of observing an effect from massage will be greater at the slower velocities. This would result in a greater impairment of force production after massage as the muscle has been lengthened and has a reduced ability to shorten sufficiently in order to produce the necessary force output.

In conclusion, this study has shown that lower limb massage **appears to** produce a reduction in force during concentric isoknetic contractions of the knee extensors at 60º.s^{-1}, without any force alterations at higher contraction velocities. We propose that this alteration is not as a result of altered neuromuscular recruitment, rather from a possible change in muscle architecture affecting the length tension relationship. Further work, however is still needed on examining both muscle tension and architecture post massage and consideration **needs to be** given to the duration of any massage effect.

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FIGURE TITLES

Figure 1

Mean (SD) change in isokinetic mean force following passive rest and massage interventions for both rest and massage conditions. A significant (*$p<0.05$) and a trend (†$p=0.08$) for a decrement in decrease of force for the massage condition was shown at 60 and $120^{\circ}.s^{-1}$ respectively.

Figure 2

Mean (SD) isokinetic force pre intervention for both rest and massage conditions. A highly significant (**$p<0.01$) reduction in force was shown for both groups as the contraction velocity increased, whilst a significantly (*$p<0.05$) higher amount of force was produced by the massage group.

Figure 3

Mean (SD) EMG amplitude (RMS) values normalised as a % of MVC for both pre and post of massage and rest conditions at a contraction speed 60 $^{o}.s^{-1}$. No significant differences were shown between any of the values

Figure 4.

EMG frequency (MPFS) values normalized against MVC for both pre and post of massage and rest conditions at a contraction speed 60 º.s^{-1}. No significant differences were shown between any of the values

Figure 5.

Mean (SD) change in vertical jump performance after passive rest and massage interventions.

Information Box

'What is already known on this topic'

Massage is widely used by sportspersons in preparation for competition; however the perceived performance benefits and physiological mechanisms for this treatment are not fully understood.

'What this study adds'.

Immediately after receiving massage treatment force production will be reduced at the slower contraction velocities which is not caused by an alteration in neuromuscular recruitment