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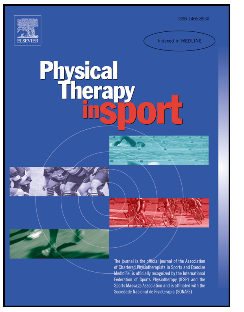

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ACTIVATION OF THE HIP ADDUCTOR MUSCLES VARIES DURING A SIMULATED WEIGHT-BEARING TASK

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ACTIVATION OF THE HIP ADDUCTOR MUSCLES VARIES DURING A SIMULATED WEIGHT-BEARING TASK

ABSTRACT

Objective: To investigate the pattern of muscle activation of the individual hip adductor muscles using a standardised simulated unilateral weight-bearing task.

Design: A repeated measures design.

Setting: Laboratory.

Participants: 20 healthy individuals (11 females, 9 males) participated in the study. Age ranged from 20 to 25 years.

Main Outcome Measurements: Surface electromyography recordings from adductor magnus and adductor longus muscles were taken at levels representing 10 to 50% of body weight during a simulated weight-bearing task. Electromyography (EMG) data were normalised to maximal voluntary isometric contraction.

Results: The adductor magnus was recruited at significantly higher levels than the adductor longus muscle during a simulated weight-bearing task performed across 10 to 50% of body weight ($p < 0.01$).

Conclusions: Adductor magnus and adductor longus muscles are recruited to different extents during a simulated weight-bearing task. This information should be considered when selecting exercises for management and prevention of groin strains. Closed chain exercises with weight-bearing through the lower limb are more likely to recruit the adductor magnus muscle over the adductor longus muscle.

Key Words: adductor magnus, adductor longus, weight-bearing

INTRODUCTION

Groin pain in athletes is a common musculoskeletal complaint. It occurs commonly in sports involving kicking, twisting, cutting and sprinting such as soccer, rugby, hockey and Australian Rules Football (Bradshaw, Bundy, & Falvey, 2008; Jansen, Mens, Backx, Kolfschoten, & Stam, 2008). Adductor-related groin pain has been reported to account for 58% of groin injuries in all sports and 69% of groin injuries in footballers (Holmich, 2007). The musculo-tendinous junction of the adductor longus muscle, is thought to be the structure most commonly involved (Renström, 1992). A twenty-year injury surveillance in the Australian Football League (AFL) recently reported that groin strains / osteitis pubis had the second highest incidence of all injuries, averaging 3.2 new injuries and 12.3 missed matches per club per season (Orchard, Seward, & Orchard, 2013). Whilst the majority of groin pain seen in athletes recovers quickly (within 3 weeks), the condition can become long-standing in nature and become difficult to treat. In these cases, there can be a relatively long period before athletes can return to full sports activity (Hölmich et al., 1999).

Both the management (treatment) and prevention of this condition are therefore important current goals in sports medicine. However, there is currently a lack of randomised trials evaluating exercise therapy for groin pain. Positive treatment outcomes for adductor groin injury in athletes have been reported by Hölmich et al., 1999. Using a program based on increasing strength, stability and co-ordination of the pelvic region and adductor muscles, 79% of athletes with long-standing adductor-related groin pain who underwent exercise therapy were able to resume sports at their pre- injury level. The median time to return to sport, however, was long, at 18.5 weeks (range 13 to 26). A more recent study using the same exercise regime was less effective, with 50 to 55% of athletes making a full return to sports (Weir et al., 2011). With respect to prevention of groin injury, a program based on these exercises was implemented in a large cluster-randomised trial including 1211 football players (Holmich, Larsen, Krogsgaard, & Gluud, 2010). The program consisted of six exercises including concentric and eccentric strength training of the adductor, abdominal and low-back muscles, combined with coordination and balance exercises. Although a reduction in groin injury was reported in this study, these results were not significant.

The adductors include the pectineus, adductor magnus, adductor longus, adductor brevis and gracilis. Although all termed “adductors,” individual muscles from the group may have different functional roles. The adductors are required to work under both closed chain (for example, in the stance leg, with the axial compressive forces from gravity) and open chain conditions (for example, during kicking, where movement occurs in the absence of axial compression through the limb). The most obvious differences in function have been reported between the adductor magnus and adductor longus muscles. Whether the adductor longus is more active during open or closed chain exercises is controversial. This muscle which originates on the pubis and attaches to the middle third of the linea aspera of the femur, functions primarily in adduction of the femur (Moore & Dalley, 2006). A number of functional EMG studies have reported peak levels of muscle recruitment in adductor longus during the open chain, swing phase of gait (Green & Morris, 1970; Lyons, Perry, Gronley, Barnes, & Antonelli, 1983; Perry & Burnfield, 2010). After performance of a kicking task, a greater change in signal intensity has been reported in the adductor longus of the kicking leg, compared to the adductor magnus, with a reversal of this pattern for the stance leg (Baczkowski, Marks, Silberstein, & Schneider-Kolsky, 2006). Two recent studies, however, have reported conflicting information, with increased activation in the adductor longus evident during both open (Delmore, Laudner, & Torry, 2014) and closed (Serner et al., 2014) chain exercise, however, as adductor magnus was not included in these studies, no comparisons were able to be made.

Evidence on the function of the adductor magnus muscle is more consistent. This muscle is the largest of the adductor group, comprising up to 63% of the mass of the adductor volume (Takizawa, Suzuki, Ito, Fujimiya, & Uchiyama, 2014) and has both an extensor portion originating on the ischial tuberosity and an adductor portion, originating on the pubic ramus (Bardeen, 1907). In a study of functional tasks, the adductor magnus muscle was found to be most active in the particular components of these tasks which involved weight-bearing, such as sit to stand (Green & Morris, 1970) and walking up stairs (Lyons et al., 1983). Furthermore, during normal gait, peak activity has been documented in the adductor magnus of the “stance leg” during the initial contact and loading phases of ambulation, (Green & Morris, 1970; Lyons et al., 1983; Perry & Burnfield, 2010). Results from bed-rest studies have also provided an insight into adductor muscle function in healthy populations. After 56 days of bed-rest, the greatest amounts of muscle atrophy have been reported in the adductor magnus muscle, followed by the adductor longus, with no significant atrophy of the adductor brevis (Belavý et al., 2009; Miokovic et al., 2014). Together, this information suggests that although the adductor muscles may act as synergists, they may function differently depending on the demands of the task.

It would seem that while progress has been made, there is a need for a better understanding of both the mechanisms underlying adductor related groin pain and the rationale for selection of exercises for the management and prevention of this condition. Examining the roles and functions of the individual adductor muscles in more detail could provide a basis for the refinement of the selection of prevention exercises currently in use. The main purpose of this study was therefore to investigate the individual adductor muscles and quantify their activation patterns during a simulated, unilateral, weight-bearing task in normal subjects who did not have groin strains. Based on previous research, it was anticipated that the adductor magnus would be more active in the simulated weight-bearing task than the adductor longus muscle.

METHODS

Participants

A convenience sample of 20 healthy individuals (11 females, 9 males) from the university population, ranging in age from 20 to 25 years volunteered for the study. All individuals provided informed written consent prior to the commencement of the study. Ethical clearance was obtained from the University of Queensland Research and Postgraduate Studies Human Ethics Committee, School of Health and Rehabilitation Sciences. Individuals were excluded from the study if they had a history of adductor muscle dysfunction, spinal or hip joint surgery, low back pain or sacro-iliac joint pain, musculoskeletal abnormalities of the spine, pelvis or lower limbs, had a medical condition affecting the musculoskeletal system, or were undertaking intensive training more than 3 times per week. Participants were also excluded if pain was experienced during the testing procedures.

Procedure

Figure 1 illustrates the unilateral simulated weight-bearing task (modified leg press) that participants performed. The unilateral simulated weight-bearing task has been described in detail in previous publications (Hides, et al., 2009; Hides, Wong, Wilson, Belavý, & Richardson, 2007; Hyde, Stanton, & Hides, 2012), however, in brief, a foot plate with a force transducer was designed to allow a static leg-press action in lying. This was used to simulate different levels of weight-bearing in the sagittal plane as occurs when the body is upright. The participant was positioned in supine on a moving platform with the heel of the test leg against a fixed foot plate, the hip in 45 degrees of flexion and the knee in 90 degrees of flexion (Lovell, Blanch, & Barnes, 2012). A brace worn over the shoulders and back provided a longitudinal compressive force, similar to gravity, but without the variable of balance. The shoulder brace was connected to a strain gauge bridge amplifier (model: AST-500, Amalgamated Instruments Co Pty Ltd, Hornsby, Australia) and a footplate that was attached to a Picolog ADC-16 analog–digital converter (Amalgamated Instruments Co Pty Ltd, Hornsby, Australia). A video monitor was positioned directly above the participant in the line of sight and displayed the force output (LabVIEW7.1, National Instruments Corporation, Austin, Texas, USA).

Participants were instructed to push through the heel whilst maintaining a stable position of the lower back. The video monitor displayed a standardised force ramp that progressively increased from 0% to 50% of the participant's body weight over a 10 second period, see Figure 2. Participants were instructed that their effort produced by pushing on the foot plate would be displayed on the monitor along with the standardised force ramp. They were required to try to match the ramp with their effort as closely as possible in terms of force and speed (see figure 2). One familiarisation trial followed by four test trials was performed by each participant. Thirty seconds rest was provided between each trial. Verbal feedback regarding lower back movement when performing the task was provided and participants were encouraged to minimise this movement.

During the unilateral simulated weight-bearing task, surface electromyography recordings from the adductor magnus (AM) and adductor longus (AL) muscles were taken at levels representing 10 to 50% of body weight (MR 01B system, AMLAB, Amsterdam). Recordings were performed using bipolar silver/silver chloride surface electrodes (ConMedCorporation Dignostic ECG Electrodes). Skin preparation of the electrode site consisted of shaving the area, fine sandpapering and cleaning with alcohol. Resistance for each electrode was measured with an ohmmeter to ensure resistance was below 5kOhms. For measurement of AM the electrode was placed half-way between the pubic tubercle and the medial femoral epicondyle over the bulk of the adductor muscles. For the AL muscle the electrode was placed four fingerbreadths distal to pubic tubercle over the bulk of the adductor muscles (Delagi & Perotto, 1980). A ground electrode was placed on the ipsilateral anterior superior iliac spine. EMG data were amplified (x5000), band-pass filtered between 10 and 480 Hz and sampled at 1000Hz.

EMG activity was normalised to maximal isometric contraction. To perform the maximal isometric contractions, participants were positioned in supine with the test limb in a neutral hip position in the frontal plane. A strap was placed around the ankle of the test leg, and a strain gauge (model: AST-500, Amalgamated Instruments Co Pty Ltd, Hornsby, Australia) was attached between the ankle strap and a stable metal. Stabilisation was provided to the contralateral anterior superior iliac spine and ankle. Three maximal isometric contraction of hip adduction were performed. Each contraction was performed for six seconds and thirty seconds of rest was provided between each contraction. Participants were instructed to pull the test leg against the ankle strap in the direction toward the midline as hard as possible without bending or rotating through the hip or bending the knee. EMG activity of AM and AL muscles was recorded during each contraction.

<u>Data management</u>

LabVIEW7.1 (National Instruments Corporation, Austin TX) was used for analysis of EMG data. From the maximum isometric contractions of hip adduction, for each muscle the root mean square (RMS) for each of the

three trials was calculated and the two highest efforts were averaged. This value was used to normalise EMG data of test trials. EMG data from the familiarisation trial was eliminated as this was considered a practice trial. As some participants showed signs of fatigue (less ability to match the standardised force ramp) by the fourth test trial, the data for this trial was not included in the analysis. From the three remaining trials, the two 'best' trials were used for analysis. The 'best' trials were identified as those in which the participant's effort differed least from the standardised ramp that they were instructed to follow. To do this, the difference between the participant effort and standardised ramp was calculated and the standard deviation of these differences around zero was determined. The two trials with the lowest standard deviations were considered the 'best' trials for that participant. For the two best trials the average RMS value was calculated at the points in time when the participant was pushing against 10%, 20%, 30%, 40% and 50% of their body weight. The RMS values for each percentage body weight were calculated at one second intervals around these time points and normalised to the value obtained from the maximum isometric hip adduction contractions.

<u>Statistical analysis</u>

Consistency of EMG data across the two 'best' trials was determined using two procedures. First, correlations to examine the similarity in the rank order of the RMS values across trials for corresponding percentages of body weight and second, repeated measure analysis of variance (ANOVA) to examine the similarity in the RMS values across the two best trials for each muscle. Separate ANOVAs for each muscle were conducted with repeated measure of the two 'best' trials and the five percentages of body weight

A repeated measure ANOVA with Type III sums of squares model was performed (SPSS 18.0) with repeated measures factors of muscle (adductor longus, adductor magnus) and percentage body weight (10, 20, 30, 40 50), and a between subject factor of gender. The alpha level was set at 0.05. Means and 95% confidence intervals for each muscle across the five percentages of body weight during the ramp were also calculated.
One female study participant who undertook intensive daily athletic training during the testing period was excluded from analyses, leaving 19 cases for analysis.

RESULTS

Consistency

The analyses indicated high consistency between the two trials across each of the body weight percentages for both muscles. For AM correlations (r) were 0.96, 0.97, 0.98, 0.98 and 0.97 respectively across the 10-50% body weight. For AL correlations (r) were 0.69, 0.87, 0.88, 0.93 and 0.95 respectively across the 10-50% body weight. The ANOVA for each muscle indicated no statistically significant effect for trial (AM: $F = 0.1$, $p = 0.80$, AL: $F = 0.7$, $p = 0.42$) and no interaction effect between trial and body weight (AM: $F = 1.1$, $p = 0.36$, AL: $F = 0.9$, $p = 0.46$).

Adductor magnus and adductor longus activation during the simulated weight-bearing task

The repeated measures ANOVA indicated significant main effects for muscle ($F = 24.8$, $p < 0.001$) and percentage body weight ($F = 32.0$, $p < 0.001$), and a significant interaction effect between muscle and percentage body weight ($F = 16.1p < 0.001$). Paired contrasts (repeated design) of the interaction effect indicated that the activation level of AM was significantly higher for each respective increase in percentage body weight compared with AL which showed no significant change in activation level. This is indicated in Figure 3 as a divergence in mean activation levels across body weight for the two muscles. There were no statistically significant effects involving gender (all $p > 0.05$).

DISCUSSION

The main result of this study was that a standardised simulated weight-bearing task reliably produced different activation of the adductor magnus and adductor longus muscle. During the weight-bearing task employed in the current study, the adductor magnus muscle was recruited to the equivalent of the maximal levels produced during a maximally resisted isometric, open chain adduction task. In contrast, the adductor longus muscle was recruited to only one-quarter of its possible maximum. Significant changes in EMG activity levels for adductor magnus occurred during the ramp task at low body weight percentages, with significant differences in muscle activity between the two adductor muscles also detected at low percentages of body weight.

The apparatus used in this study allowed examination of the effects of graduated weight bearing on two adductor muscles. The task required a slow and controlled increase in weight bearing up to 50% of body weight, on one leg, which is the load supported by an individual limb during normal upright stance. However, it should be noted that this task was performed in the absence of gravity, and balance was not required, making this task less demanding than in real life. Even so, the results showed that slow, controlled weight-bearing through the heel with the hip, knee and ankle in good alignment recruited the adductor magnus muscle to a greater extent than the adductor longus muscle across all levels of percentage body weight tested.

The greater activation of adductor magnus compared to adductor longus in this study are supported by findings from a number of functional studies which have also reported greater activity in this muscle during tasks involving loading of the limb (Green & Morris, 1970; Lyons et al., 1983; Perry & Burnfield, 2010). In addition, data from recent bed-rest studies concur with findings from this study, with greater muscle volume loss reported in the adductor magnus compared to the adductor longus (Belavý et al., 2009; Miokovic et al., 2014). As bed-rest removes the load of gravity on the joints normally present in upright functional activity, the opposite effects to increasing functional weight-bearing load would be expected. Furthermore, due to its ability to both adduct and extend the hip, it is not unreasonable to expect increased adductor magnus activity during tasks involving weight-bearing, to assist with stabilisation of the hip.

Interestingly, significant changes in EMG activity levels of the adductor magnus and between the two adductor muscles were detected at low body weight percentages. In addition to the data from functional studies, findings from a study by Takizawa et al., (2014) may provide another possible explanation for this. This study suggested that based on differences between muscle architecture and innervation, adductor magnus may be divided into four portions. Takizawa et al., (2014), reported that surface electrodes would likely detect signals from the most proximal part of the adductor magnus, proposed to be related to stability of the hip compared to the deeper, more distal sections, which according to this study are better suited to movement of the pelvis. One other interesting finding of this study was the greater than 100% activation of adductor magnus during the simulated weight-bearing task at higher body weight percentages. For the purposes of normalisation of the EMG data, maximal hip adductor strength was measured during a standardised, open chain, hip adduction task in supine lying, however, it is possible that adductor magnus may not have been recruited maximally in this task. The greater than 100% recruitment of adductor magnus during the ramp task may be reflective of the increased muscle activity required for stabilisation of the pelvis during weight-bearing, which may not be necessary during an open chain task.

The findings of the current study may have implications for exercise selection for the management and prevention of groin strains. If the aim of exercise therapy is to increase recruitment of the adductor magnus muscle, weight-bearing exercise with good alignment of the lower limb would be an appropriate strategy. In addition, the results of this study demonstrate that there is not a requirement to increase load (lift weights) to maximally recruit this muscle. Weight-bearing, closed-chain exercise, would not however, be an optimal choice if the aim was to preferentially increase recruitment of the adductor longus muscle.

The next logical extension of this work would be to repeat this study in athletes with groin pain to see if their pattern of muscle recruitment differs to that of people without pathology or painful symptoms. The simulated weight-bearing test has been performed in both athletic and non- athletic populations with low back pain (Hides et al., 2009; Hyde, Stanton, & Hides, 2012). Results showed that those with low back pain tended to over-recruit the trunk muscles in an attempt to stiffen the spine when compared with non-symptomatic individuals, which represented a less than optimal strategy. Comparison of test results between those with and without groin pain in the future may potentially help to deepen our understanding of different strategies of adductor muscle recruitment patterns adopted by athletes with this condition. In addition, future research could consider including the hip flexors and abductors in their investigation to provide a more holistic picture of the function of the hip muscles during weight-bearing and non-weight bearing tasks.

There are some limitations which should be considered when interpreting the findings of the current study. Using surface EMG, we were unable to investigate the role of adductor brevis or deep fibres of adductor magnus due to their anatomical locations deep in the medial thigh. Future studies could consider investigating the function of these muscles with the use of fine wire EMG, or imaging modalities such as FMRI. Although the current study employed strategies at data collection to minimise the potential for cross-talk (i.e. electrode sensor location, appropriate electrode size, inter-electrode distance), the possibility that cross-talk occurred cannot be completely excluded. Lastly, the sample size of this study was modest (n = 19) and may limit the generalisability of the results. It should be considered however, that this was a pilot investigation and as such, the results of the current study may be used to provide a more accurate estimation of the sample size required for future studies.

In conclusion, the simulated weight-bearing task performed in this study resulted in a different pattern of muscle recruitment in the adductor magnus and adductor longus. Weight-bearing, closed chain exercises are more likely to recruit the adductor magnus over the adductor longus muscle. This information is important for clinicians and may help improve their rational for exercise selection for the management and prevention of groin strains.

Ethical Approval: University of Queensland, Research and Postgraduate Studies Human Ethics Committee, School of Health and Rehabilitation Sciences – This committee does not issue reference numbers.

Funding: Nil

Conflict of Interest: All authors have no conflict of interest to declare

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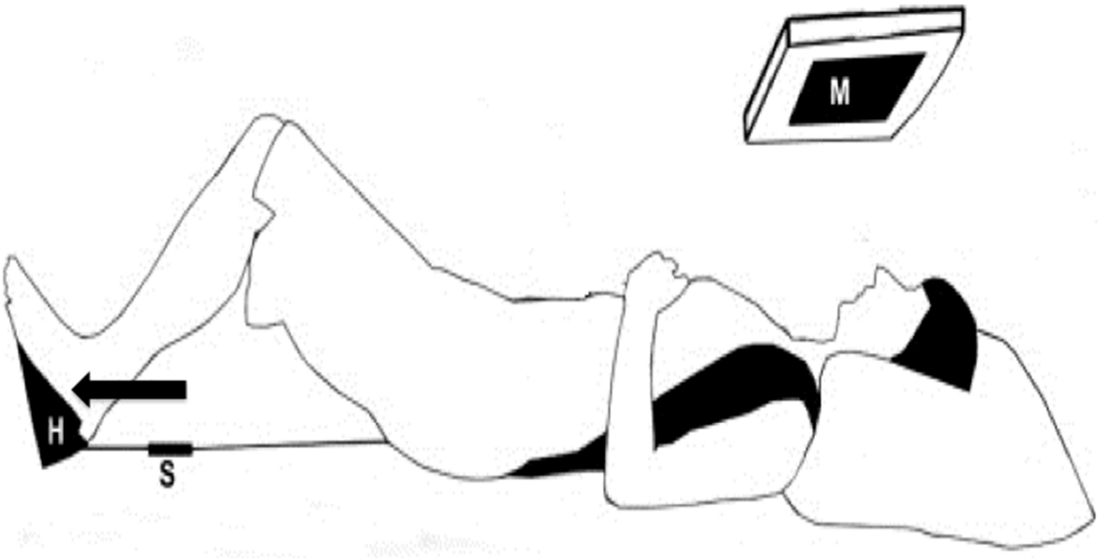
FIGURE LEGENDS

Figure 1. The unilateral, simulated, weight-bearing task. The unilateral simulated weight-bearing task (modified leg press) was conducted with the participant lying supine on a moving platform, with the foot supported at the heel (H). A monitor (M) was placed in the subject's field of view to provide feedback on force output as the subject pressed through their heel. Shoulder straps over both shoulders, which restrained cephalad movement, were connected to the foot support via a strain gauge (S), which measured loading levels.

Figure 2. Representation of display on screen during performance of the simulated weight-bearing task

Figure 3. Display of means and 95% confidence intervals for Adductor Magnus and Adductor Longus at the five percentages of body weight during the simulated weight-bearing task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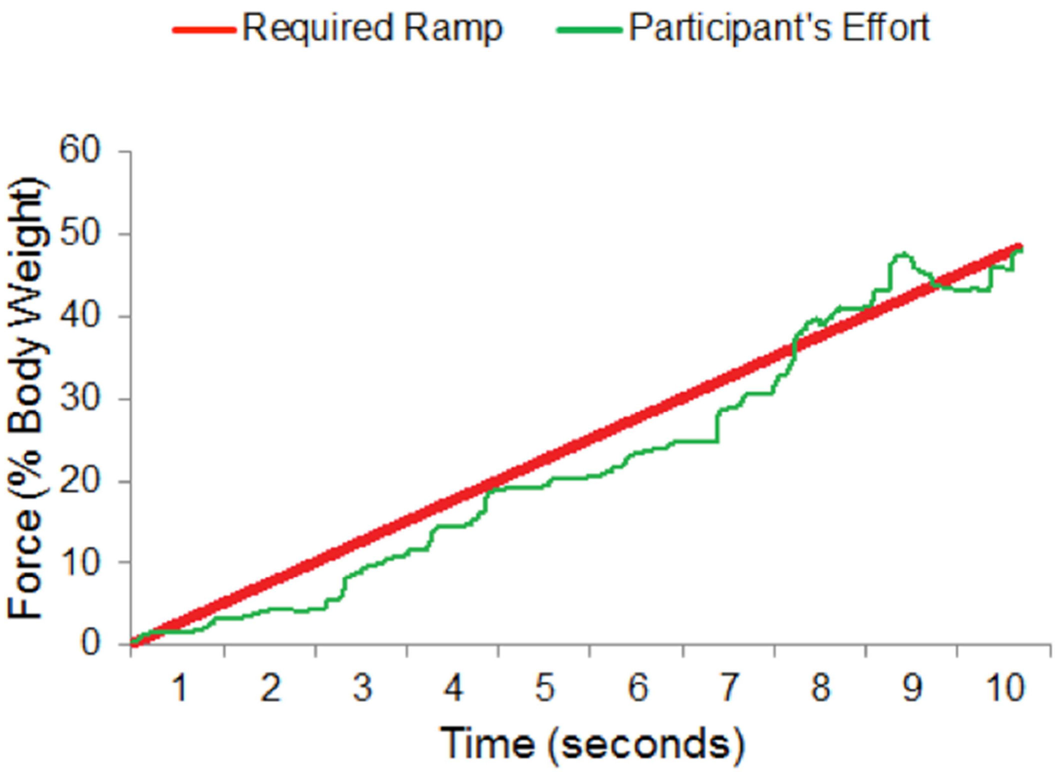
Required Ramp
Participant's Effort
Force (% Body Weight)
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30
40
50
60
1
2
3
4
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6
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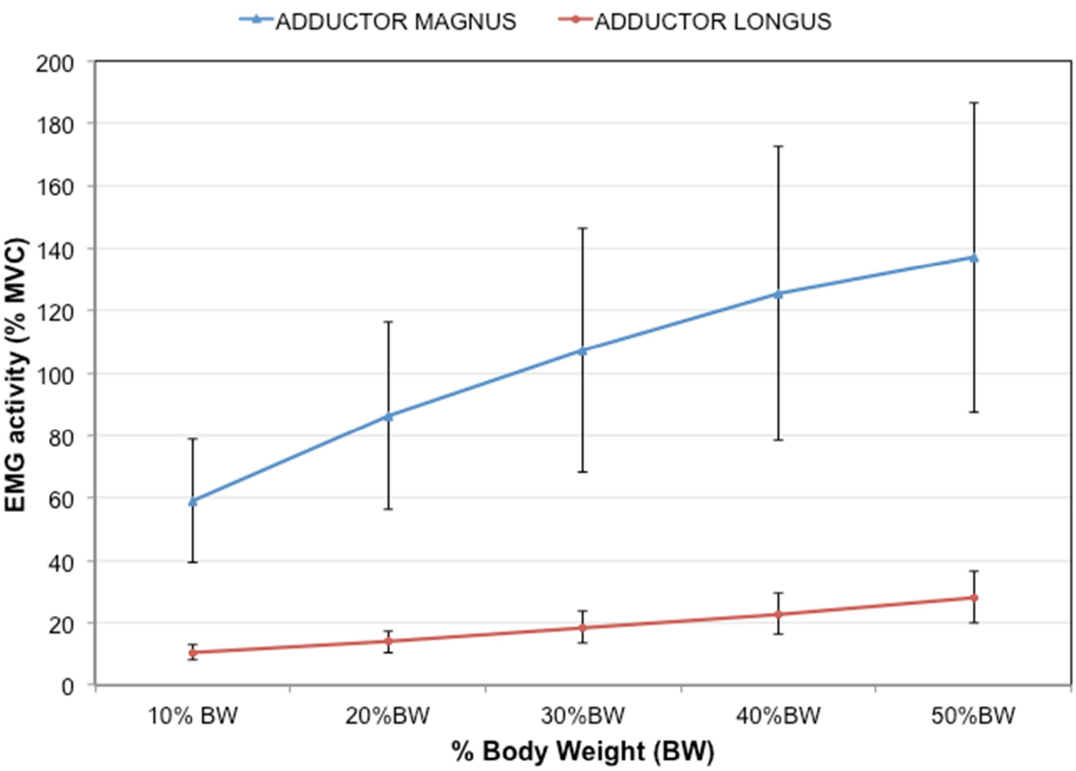
8
9
10
Time (seconds)


ADDUCTOR MAGNUS
ADDUCTOR LONGUS
EMG activity (% MVC)
0
20
40
60
80
100
120
140
160
180
200
10% BW
20%BW
30%BW
40%BW
50%BW
% Body Weight (BW)

HIGHLIGHTS

ACTIVATION OF THE HIP ADDUCTOR MUSCLES VARIES DURING A SIMULATED WEIGHT-BEARING TASK

- A simulated weight-bearing task recruits the hip adductor muscles differently
- Adductor magnus activity is greater than adductor longus in simulated weight-bearing
- Increased adductor magnus activity occurs with increased levels of weight-bearing
- Closed chain, weight-bearing exercise is more likely to recruit adductor magnus

ACTIVATION OF THE HIP ADDUCTOR MUSCLES VARIES DURING A SIMULATED WEIGHT-BEARING TASK

This study was approved by the University of Queensland, Research and Postgraduate Studies Human Ethics Committee, School of Health and Rehabilitation Sciences. This committee does not issue reference numbers.