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Authors: Peter Lawrenson, Alison Grimaldi, Kay Crossley, Paul Hodges, Bill Vicenzino, Adam Semciw

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Title

Short Communication:

Iliocapsularis: Technical application of fine-wire electromyography, and direction specific action during maximum voluntary isometric contractions.

Authors

1. Peter Lawrenson[1]
2. Dr Alison Grimaldi[1,2]
3. Professor Kay Crossley[1,3]
4. Professor Paul Hodges[1]
5. Professor Bill Vicenzino[1]
6. Dr Adam Semciw[1,3]

[1] The University of Queensland, School of Health & Rehabilitation Sciences, Brisbane, QLD 4072, Australia

[2] Physiotec Physiotherapy, 23 Weller Rd, Tarragindi, QLD 4121, Australia

[3] College of Science, Health and Engineering, School of Allied Health, La Trobe University, Melbourne, Victoria, Australia

Corresponding Author

Dr Adam Semciw,

a.semciw@uq.edu.au,

The University of Queensland, School of Health & Rehabilitation Sciences, Brisbane, QLD 4072, Australia

Highlights

- The first paper to describe insertion of intramuscular EMG into Iliocapsularis
- Establishes Iliocapsularis' electromyographic activity in isometric contractions
- Reinforces the hypothesised role of Iliocapsularis in retraction of the hip capsule

Abstract

The iliocapsularis muscle of the anterior hip may play an important role in hip function, but no electromyographic (EMG) recordings have been made. This muscle provides the most substantial muscular attachment to the anterior hip capsule and is hypothesised to have a dynamic role to limit capsular impingement and to augment joint stability. Current understanding of the function of iliocapsularis is based on limited cadaveric and radiographic studies. Located deep over the hip joint it would require intramuscular fine-wire EMG to evaluate its activity directly with limited cross-talk from overlying muscles. The primary aim of this study was to describe a new technique for insertion of intramuscular EMG electrodes into iliocapsularis and to report its activation during different directions of hip maximum voluntary isometric contraction (MVIC). Fifteen healthy volunteers (10 M, mean age (SD) 22 (2) years) who were free from hip pain were recruited for electrode insertion and to perform MVIC's in six directions at 0° and three directions at 90° of hip flexion. Intramuscular electrodes were successfully inserted into the iliocapsularis muscle with guidance from real-time ultrasound imaging. The greatest muscle activity occurred during resisted hip flexion at 90° (Median (IQR); 100.0 (1.2) % MVIC) and lowest activity during hip extension, 0° (0.5 (0.3) % MVIC). These findings have implications for our understanding of iliocapsularis' functional role. This paper provides the first report of intramuscular electrode insertion into iliocapsularis with guided technical instructions for future EMG investigations in other populations and tasks.

Keywords (up to 6 keywords)

Electromyography, Hip, Groin, Intramuscular, Hip Capsule,

Introduction:

Iliocapsularis is a small muscle, located deep over the anterior hip capsule [1-4]. It originates on the inferior border of the anterior-inferior iliac spine, although most fibres arise from an elongated attachment to the anterior capsule; inserting distally to the lesser trochanter [2-4].

The function of the iliocapsularis muscle remains unclear, as recordings of muscle activity have not been made. It has been suggested to actively stabilise the anterior hip, because of its orientation and substantial pericapsular attachment stretching over the anteromedial capsule [4-6]. This attachment (the largest of any deep hip muscle [6]) has also been proposed to limit impingement of the hip joint capsule between the femoral head and acetabulum by tensioning the anterior capsule in positions of hip flexion [2]. A role in hip stability has also been proposed, based on radiological and cadaveric studies that show larger iliocapsularis size in individuals with limited passive joint stability, compared to structurally normal hips [1, 3, 4].

Electromyography (EMG) enables recording of muscle activation, but no EMG studies of iliocapsularis have been undertaken, partly because of the technical challenges posed by its deep anatomical location and close proximity to the femoral neurovascular bundle [2, 7]. This study aimed to provide a guide for the insertion of a fine-wire EMG electrode to record iliocapsularis muscle activity, and study its activation during a series of maximum voluntary isometric contractions (MVIC). These outcomes supplement the anatomical and radiological literature on this muscle to further understand its potential functional role, and provide evidence of feasibility of EMG recordings for future studies in groups with hip pain/pathology.

Methods

Ethical approval was obtained from the University Human Ethics Committee (2013001448) to recruit 15 healthy adults (10 men, mean age (SD) 22 (2) years), with no prior history of hip pain or known pathology. Participants provided informed consent.

Teflon coated, stainless steel wires were prepared as described by Basmajian and Stecko [8] and passed through a 23 gauge hypodermic needle. The needle and wire lengths were 7 and 20 cm, respectively.

The insertion procedure was developed based on cadaveric observation, imaging [2] and anatomical studies [3, 5]. B-mode ultrasound imaging was used to guide the needle insertion. A linear transducer (7-10MHz) (LogIQV2, GE Medical Systems Co. Ltd, China) was placed in the transverse plane anteriorly over the hip, bisecting iliocapsularis (Fig. 1A). Colour Doppler imaging was used to visualise the femoral artery (Fig. 1B), medial to iliocapsularis. With the participant in supine, the location of the insertion site in relation to the transducer was marked (Fig. 1A), and ultrasound imaging was used to guide the needle lateral to the femoral artery, through the sartorius and iliacus muscles, and into iliocapsularis (Fig. 1C). An insertion path passing medial to lateral, through iliacus was considered as the most appropriate, to avoid the tendon of rectus femoris, which lies superior and lateral to Iliocapsularis (Fig. 1C).

After needle removal, the wires were secured to the skin and connected to a Trigno™ Wireless EMG System (Delsys Inc., Boston, USA). Once the quality of recordings was confirmed with gentle isometric hip flexion contractions, two repetitions of MVICs were performed with strong verbal encouragement into six different movement directions with the hip in a position of anatomical neutral. Three contractions were also performed in 90° hip flexion (Table 1). Participants increased the contraction force over 2s then maintained maximal exertion for 3s, with resistance provided manually, with a belt or a solid foam block (Table 1). The order of contraction directions was block randomised based on the plane of movement, with participants resting for 30s between repetitions and 60s between trials.

Raw EMG was collected using a Trigno™ Wireless EMG System (CMRR>80 dB@60Hz; gain – 1000x; bandpass filter - 20–900Hz). Data were sampled at 2000Hz and processed using customised LabVIEW software (National Instruments, Austin Texas USA). DC off-set was removed; then high-pass filtered (4^{th} order Butterworth, 50Hz, no phase lag), rectified and low pass filtered (4^{th} order Butterworth, 6Hz, no phase lag) to create a linear envelope. The mean amplitude of the middle 1-s was recorded for each trial and the highest value from each movement direction analysed.

To evaluate potential differences in EMG amplitude between force directions, EMG data were normalised to the highest amplitude across all directions (%Peak). Differences between MVIC's were assessed using Friedman's repeated measures ANOVA (α=0.05), with Bonferroni adjusted post-hoc tests performed using the Wilcoxon signed-rank test (α=0.0014) to identify which paired movement directions differed. Non-parametric statistics were used because of non-normally distributed data, which could not be transformed because data were skewed in opposite directions.

Results

Intramuscular electrode placement was tolerated well with no adverse events. One male participant inadvertently removed the electrode from the muscle while changing body position, prior to the EMG recording. Greatest activity from the remaining 14 participants (9 male, 22 (2) years) was recorded during hip flexion with the hip flexed to 90° (median (IQR); (100.0 (1.2) %Peak) and lowest was recorded with hip extension in prone (0.5 (0.3) %Peak) (Fig. 2A). There was a significant difference in EMG activity across movement directions ($X^2(8)$ =92.375, df=8, p<0.001). Fig. 2B illustrates results of pairwise comparisons. In anatomical neutral, flexion has greater amplitude than extension; abduction is greater than adduction; while there is no difference in rotation. In 90° hip flexion, external rotation activity is greater than internal rotation; and hip flexion activity is greater at 90° than in anatomical neutral.

Discussion

This study developed a safe method for insertion of intramuscular EMG electrodes into iliocapsularis and demonstrated the first EMG recordings of this muscle. EMG amplitude was highest during isometric flexion in 90° of hip flexion and lowest during hip extension. EMG amplitude was variable between participants during hip flexion in neutral (0°), abduction and external rotation (90°) (Fig. 2A). Taken together with the attachment of iliocapsularis to the hip joint capsule and its small cross-sectional area, this data would be consistent with a local action on the joint capsule rather than significant contribution to hip torque [9]. As out of plane force generation was discouraged through feedback (contractions were redone if judged out of plane), the observed variability implies some potential inter-individual differences in recruitment of the muscle. Iliocapsularis EMG amplitude was consistently low during internal rotation and adduction, which suggests a limited role during force generation in these directions.

Pourcho, Sellon [2] proposed that iliocapsularis activity tensions the anterior capsule to avoid synovial impingement between the neck/head of femur and the acetabulum. It would follow that Iliocapsularis EMG activity should be greater into positions of possible impingement (hip flexion). Our observed highest EMG amplitude during flexion with the hip at 90° flexion supports this proposal.

Iliocapsularis has also been hypothesised to stabilise the hip anteriorly [3, 4, 9] and activity was expected during hip extension to support the capsule [5] and limit anterior translation of the femoral head [1]. Inactivity in iliocapsularis during maximal isometric hip extension, did not support this hypothesis, but does not exclude its potential role as an active stabiliser in other positions, dynamic tasks or populations with compromised passive stability.

A potential limitation of this study is assessor bias in judging the plane of movement. This may affect the validity of direction specific muscle activity, but reflects previously used methods [10-12].

Here we provide the first description of insertion of intramuscular EMG electrodes into the iliocapsularis muscle. We confirm viability of the approach, describes technical guidelines for future EMG investigations, and provide insight into the functional role of this muscle in different directions of isometric hip force. The high EMG amplitude during hip flexion, particularly with the hip flexed to 90°, supports the hypothesised role of iliocapsularis to draw the hip joint capsule anteriorly when the hip approaches positions of impingement. Further investigation is required to challenge this hypothesis in populations with pathology involving the anterior capsule, such as femoroacetabular impingement, and in tasks with the potential for capsular impingement such a squatting.

Conflict of Interest Statement

The authors have no affiliations or interests that would present as a conflict of interest or allow for any bias in the preparation and reporting of this study.

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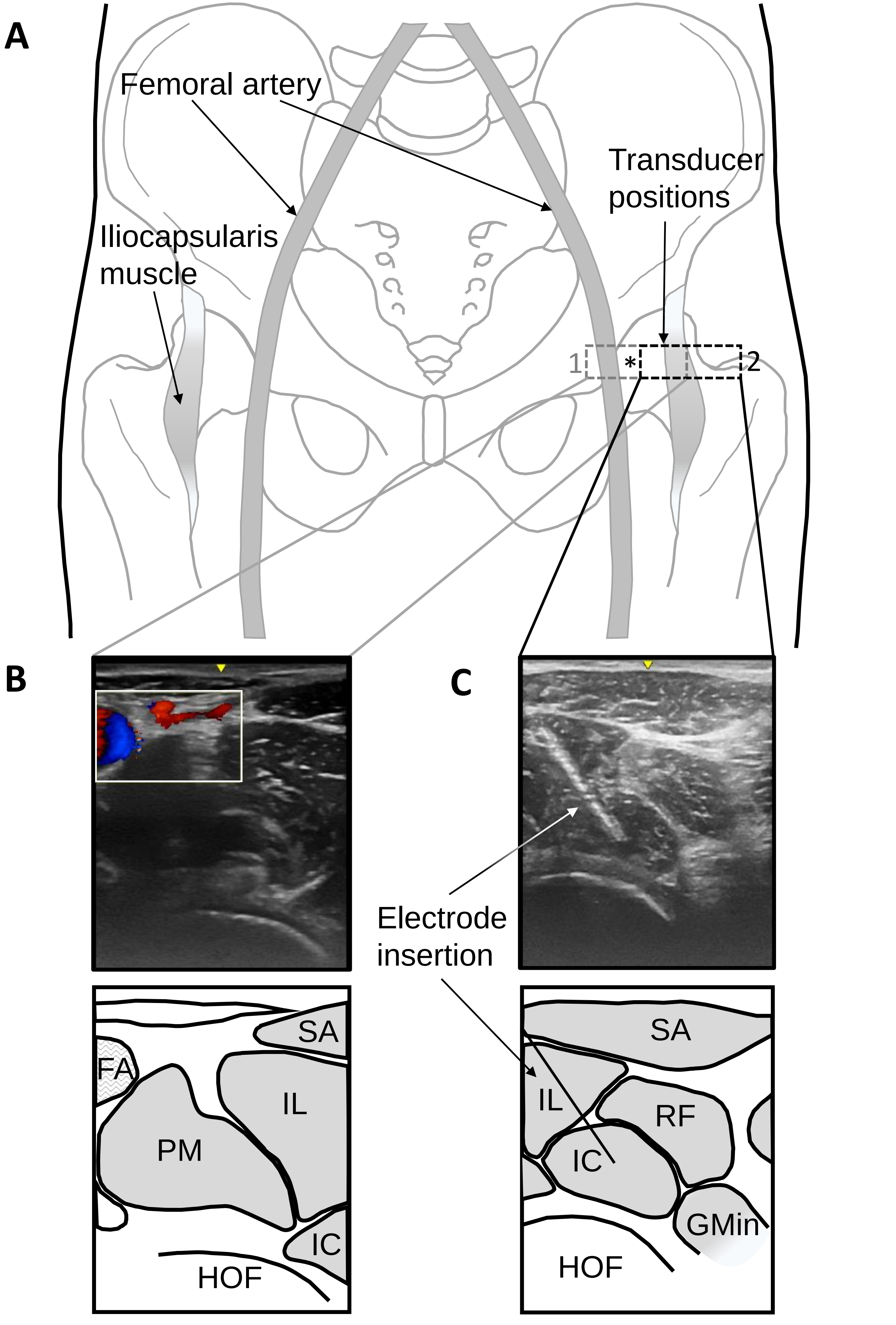
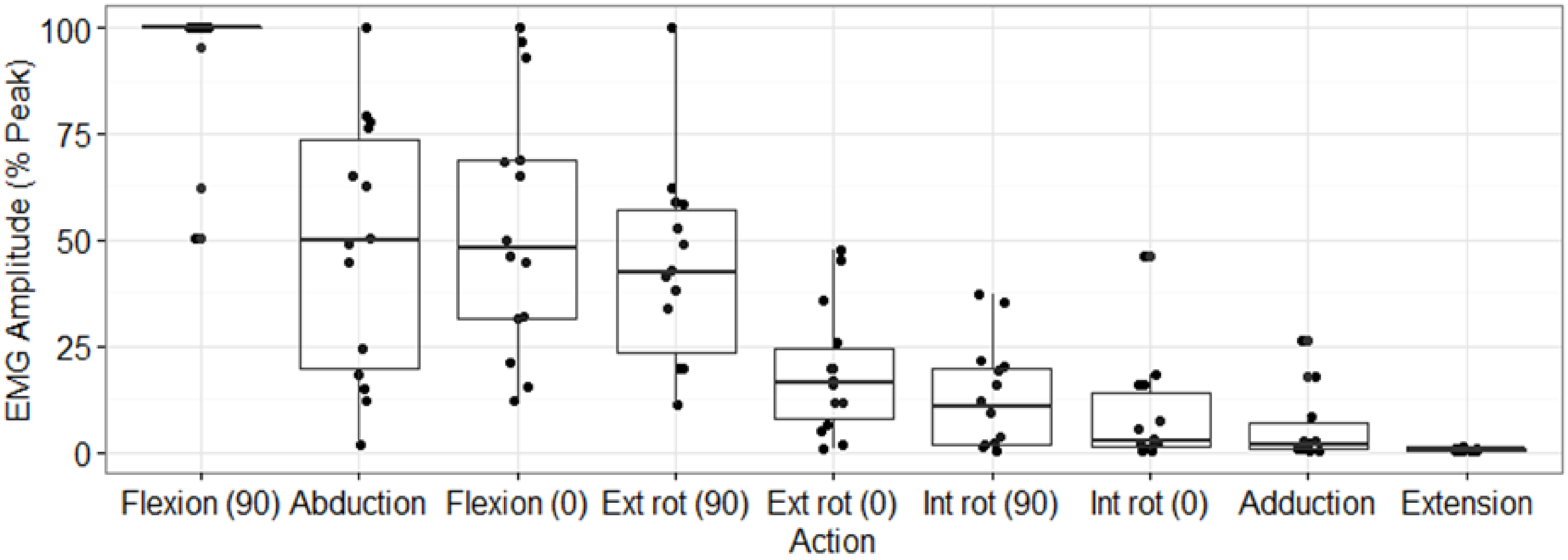
Fig. 1. (A) Anatomy of the iliocapsularis muscle and its location on the anterior aspect of the hip. The location of the ultrasound transducer for both position 1 and position 2 are shown (dashed rectangle) along with the location of the site for electrode insertion (*). (B) Cross-sectional view in the transverse plane of the ultrasound transducer (position 1) to identify the femoral artery using colour doppler imaging(solid white rectangle). The lower panel highlights the location of the femoral artery in relation to iliocapsularis and other muscles of the anterior hip. (C) Position 2 of the ultrasound transducer which was used to guide the electrode insertion. The needle passed through sartorius, iliacus and into iliocapsularis. The lower panel highlights the position of rectus femoris and other muscles surrounding iliocapsularis during insertion. Abbreviations; FA, femoral artery; GMin, gluteus minimus; HOF, head of femur; IC, iliocapsularis; IL, iliacus; PM, psoas major; RF, rectus femoris; SA, sartorius.

Fig. 2. (A) Box (median, interquartile range and range) and scatter plot illustrating amplitude (%Peak) of iliocapsularis EMG across all movement directions. (B) Post-hoc pair-wise comparisons, Bonferroni (* - P<0.0014). Flexion (90) - flexion at 90°; Abduction - abduction at 0°; Flexion (0) - flexion at 0°; Ext rot (90) - external rotation with hip at 90° flexion; Ext rot (0) - external rotation with hip at 0° flexion; Int rot (90) - internal rotation with hip at 90° flexion; Int rot (0) - internal rotation with hip at 0° flexion; Adduction - adduction at 0°; Extension - extension at 0°.


A
Femoral artery
Transducer positions
Iliocapsularis muscle
1
*
2
B
C
Electrode insertion
SA
FA
IL
PM
IC
HOF
SA
IL
RF
IC
GMin
HOF

A



B

	Flexion (90)	Abduction	Flexion (0)	Ext rot (90)	Ext rot (0)	Int rot (90)	Int rot (0)	Adduction	Extension
Flexion (90)		0.0017	0.0017	0.0017	0.0001*	0.0001*	0.0001*	0.0001*	0.0001*
Abduction			0.6698	0.7148	0.0198	0.0004*	0.0001*	0.0001*	0.0001*
Flexion (0)				0.3333	0.0001*	0.0002*	0.0001*	0.0001*	0.0001*
Ext rot (90)					0.0004*	0.0001*	0.0001*	0.0001*	0.0001*
Ext rot (0)						0.2166	0.1040	0.0203	0.0001*
Int rot (90)							0.1989	0.2166	0.0001*
Int rot (0)								0.9849	0.0005*
Adduction									0.0027
Extension									

Table 1.

Testing parameters for maximal voluntary contractions of Iliocapsularis

DIRECTION OF FORCE	POSITION	METHOD OF RESISTANCE
FLEXION	Sitting (hip 90 flexion)	Resistance applied by therapist, 5cm proximal to the superior edge of the patella
	Supine, anatomical neutral	Resistance applied by therapist, 5cm proximal to the superior edge of the patella
EXTENSION	Prone, anatomical neutral	Resistance applied by therapist, 5cm proximal to the knee joint line, at the posterior thigh
INTERNAL ROTATION	Sitting (hip 90 flexion)	Resistance applied by therapist, 5 cm proximal to the lateral malleolus
	Supine, (hip at anatomical neutral, knee 90 flexion)	Resistance applied by therapist, 5 cm proximal to the malleolus
EXTERNAL ROTATION	Sitting (hip 90 flexion)	Resistance applied by therapist, 5 cm proximal to the medial malleolus
	Supine, (hip at anatomical neutral, knee 90 flexion)	Resistance applied by therapist, 5 cm proximal to the medial malleolus
ABDUCTION	Side lying, anatomical neutral	Resistance against seat belt, 5cm proximal to the lateral knee joint line
ADDUCTION	Side Lying, anatomical neutral	Resistance against foam block, 5cm proximal to the medial knee joint line

NB: TWO TRIALS WERE PERFORMED PER DIRECTION WITH 30S REST BETWEEN REPETITIONS. PARAMETERS FOR MVIC'S WERE ADAPTED FROM PREVIOUSLY PUBLISHED TECHNIQUES [10-12] TO MINIMISE RISK OF COMPROMISING THE ELECTRODE INSERTION SITE THROUGH UNNECESSARY POSITIONAL CHANGES.