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Technical Note

Evaluating gluteus maximus maximal voluntary isometric contractions for EMG normalization in male rugby players

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Abstract. [Purpose] The aim of this study was to determine the highest electromyography (EMG) amplitude of the gluteus maximus from closed and open kinetic gluteal maximal voluntary isometric contractions (MVICs). [Participants and Methods] Ten healthy male rugby players performed three MVIC techniques that included, in random order: single leg squat, prone hip extension and standing gluteal squeeze. EMG signals were recorded from the inferior and superior regions of gluteus maximus of the dominant leg, and were normalized to the prone hip extension. [Results] For statistical analysis the EMG of both gluteus maximus regions were pooled together. The standing gluteal squeeze revealed a significantly lower EMG compared to single leg squat and prone hip extension. However, there was no significant difference in gluteal EMG activity between single leg squat and prone hip extension. [Conclusion] There is no distinct advantage for either single leg squat or prone hip extension in eliciting maximum EMG activity. Future research should compare the present positions with other MVICs that are commonly prescribed or have been demonstrated to produce high EMG amplitudes.

Key words: Muscle activation, Prone hip extension, Single leg squat

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INTRODUCTION

Electromyography (EMG) normalization allows for comparison between muscle groups, tasks, participants and studies[1–3)]. Peak or mean EMG amplitude in an exercise or activity is used as a reference value to determine the EMG activity in a specific task, which is expressed as a percentage of the reference. The reference value is usually obtained from a maximal voluntary isometric contraction (MVIC)[1–3)].

Using an open chain kinetic exercise such as, prone hip extension with the hip at 0° extension and the knee flexed at 90° is a common MVIC technique to elicit gluteus maximus EMG activity[4, 5)]. Worrell et al.[3)] reported that when prone hip extension was performed with a fixed knee angle (90° flexion) at 0°, 30°, 60°, 90° of hip flexion, gluteus maximus activity decreased with increased hip flexion. From a prone position of 20° of hip extension, Kwon and Lee[6)] reported no significant difference in gluteus maximus activity (48–65% of MVIC) at 0°, 30°, 60°, 90° and 110°of knee flexion.

Other body procedures for assessing gluteus maximus activity have been performed from bilateral standing[2)] and unilateral squat[7)]. Recent research comparing the MVIC of a bent-knee (90° flexion) prone hip extension (0°) with that of a standing bilateral hip extension with external rotation (referred to as a gluteal squeeze) reported no difference in eliciting maximum EMG activity of the gluteus maximus[2)]. However, it is unclear whether different MVIC techniques can alter gluteus maximus activation for an athletic population that participates in a specific activity or task. Other possible sources of variation in

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gluteus maximus activation may arise from the type of exercise. For instance, prone hip extension is an open kinetic chain exercise in which the upper body is supported, while single the leg squat and bilateral standing gluteal squeeze are classified as closed kinetic chain exercises. Therefore, it is unclear whether the gluteus maximus can elicit greater or lesser EMG activity in open or closed kinetic chain exercises at the same joint angles during MVIC techniques.

The gluteus maximus has two distinct regions, superior and inferior and according to the literature the inferior gluteus maximus is primarily involved for hip extension, while the superior gluteus maximus is more involved for hip abduction[8]. To our knowledge only two studies have investigated the different regions of the gluteus maximus using a variety of MVIC techniques to elicit maximal EMG activity[2, 9]. Further, the aforementioned open chain kinetic technique may lack posture specificity, especially in sports such as rugby, where a single leg squat and bilateral standing gluteal squeeze may provide a better body orientation to resembling the sporting activity; especially if it is performed at a knee and hip angle that is known to optimize force production in rugby players. Currently, there is a lack of research examining gluteus maximus activity using different MVIC techniques in an athlete population such as, male rugby players.

Assessing the MVIC of various muscles and muscle groups are well documented for EMG normalization, but the ideal exercise to elicit the highest EMG amplitude for the gluteus maximus is yet to be established[9]. Various gluteus maximus exercises have been performed in various research studies with little attention devoted in determining which exercise elicits the highest activity. Additionally, the literature highlights the need to establish if open or closed kinetic chain MVIC techniques that executed at the same joint angles are capable of eliciting the greatest EMG activity in the inferior or superior gluteus maximus. Therefore, the aim of this study was to determine the activity of the gluteus maximus regions from three MVIC techniques of open (modified prone hip extension) and closed (modified standing gluteal squeeze, and single leg squat) kinetic exercises that are applicable to male rugby players. It is envisaged that the results of this study will assist the practitioner in selecting a gluteus maximus MVIC technique that elicits the highest EMG activity for a distinct sporting population.

PARTICIPANTS AND METHODS

Ten healthy representative male rugby players (mean ± standard deviation; age 20.4 ± 2.7 yrs; height 184.8 ± 6.6 cm; body mass 97.2 ± 13.0 kg) volunteered for the study. The dominant leg was assessed from which, eight participants indicated they were right leg dominant. This was defined by the leg they use to kick a rugby ball maximum distance. Ethical approval was granted by the University Human Ethics Committee and written informed consent was obtained from participants.

Every participant performed, in a random order, three MVIC techniques to activate gluteus maximus: modified prone hip extension (PHE); standing bilateral hip extension known as the standing gluteal squeeze (SGS); and single leg squat (SLS). Three repetitions of each MVIC technique were each held for 4 sec and separated by 2 mins rest. Participants were verbally encouraged during each MVIC. The EMG trace was visually assessed by the lead researcher to ensure the signal was from muscle and not, for example, artifact. The MVIC technique of PHE, SGS and SLS in the sagittal plane were set to a knee angle of ~60° of flexion and hip angle of ~60° of flexion. For PHE and SLS the frontal and transverse planes of the hip were set a 0°. All joint angles were measured by the lead researcher using a manual goniometer. The knee and hip angles were selected to optimize force production for rugby players[10–12].

Prone hip extension is a common MVIC technique to elicit gluteus maximus EMG activity[4, 5]. Participants were instructed to position their upper body prone on a massage table. A strap was placed across the distal posterior thigh and attached to the base of the massage table (Fig. 1a). Participants were instructed to maximally extend the hip while the strap provided resistance.

The single leg squat was selected because of its theorized application to rugby. For SLS, the core muscles that stabilize the lumbar spine allow maximum contraction of the gluteus maximus without causing increased lumbar spine movement[13]. It is hypothesized that stabilizing the lumbar spine allows the force closure of the sacroiliac joint to produce optimum force and maximum activity of the gluteus maximus[4]. Using a hydraulic squat machine (AeroStrength Hydraulic Fitness Equipment, Durango, Co., USA) participants placed their dominant foot in the middle of the platform and positioned both shoulders under the padding of the squat machine (Fig. 1b). The knee and hip angles were then measured and the squat machine was locked into place. Participants were cued to contract the gluteus maximus while pushing their heel into the platform as forcefully as possible.

The standing gluteal squeeze has been described elsewhere[2]. Although joint angles were not reported by Contreras et al.[2], their illustration indicates that both knee and hip angles were set at 0°. For the current study the SGS was modified to ensure that sagittal knee angle and hip angles were comparable between the three MVIC techniques. Participants stood with their feet slightly wider than shoulder width apart with hips externally rotated by placing the right foot at the 2 o'clock position and the left foot at the 10 o'clock position. Participants were then instructed to squeeze their gluteals forcefully, while attempting to externally rotate their hips (Fig. 1c).

Prior to surface electrode placement the area was shaved, gently abraded and cleaned with isopropyl alcohol. To maximize the ability to detect the target muscle's signal the surface electrodes were placed parallel to the fibers of the superior and inferior gluteus maximus. The electrodes were placed at an inter-electrode distance of 20 mm and were secured with medical tape to prevent movement. The surface electrodes (pre-gelled Ag-AgCl; Ambu, Ballerup, Denmark) for the superior gluteus maximus were placed superior and lateral to the midpoint of a line drawn between the posterior superior iliac spine and the

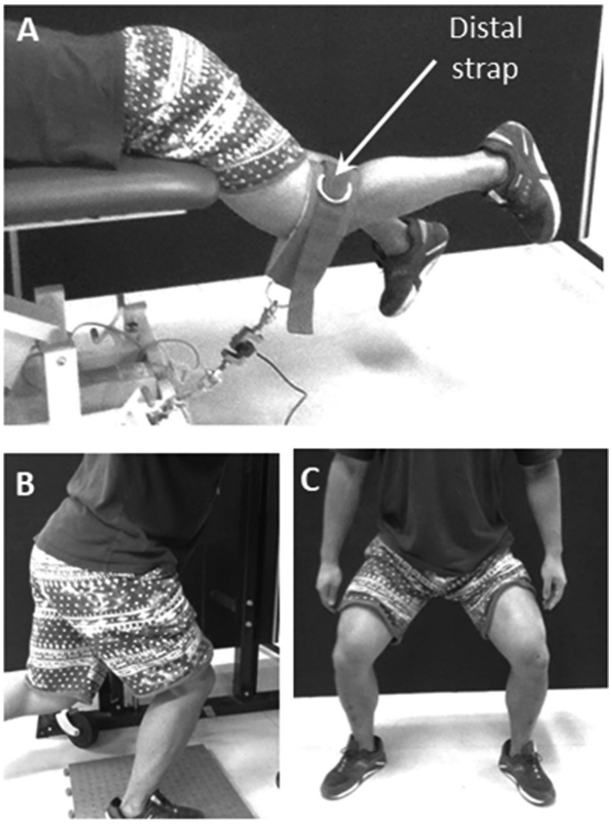

Fig. 1. A-Prone hop extension; B-Single leg squat; C-Standing gluteal squeeze. Knee angle ~60° of flexion.

posterior greater trochanter. The surface electrodes for the inferior portion of the gluteus maximus were placed inferior and medial to the midpoint of the same line, such that, they were 2.5 to 5.0 cm above the gluteal fold[9]. For eight participants the surface electrodes were placed on the right limb, and for the two participants who were left leg dominant, electrodes were placed on the left gluteus maximus.

The electrodes were connected to wireless EMG sensors that were pre-amplified at a gain of 400. A first order high pass filter with a 10 Hz ± 10% cut-off and 500 Hz low pass filter were applied. The sensors were securely fastened to the muscle sites with medical adhesive tape. Raw EMG signals were sampled at 3,000 Hz and synchronized with video capture (Logitech C920 HD Pro Webcam, NSW, Australia), which was used to identify the MVIC files. The EMG signals were transmitted telemetrically in real-time to a PC interface-receiver (Telemyo DTS, Noraxon, Scottsdale, AZ, USA). Using a data acquisition system (MyoResearch XP Master, version 1.07.1, Noraxon, Scottsdale, AZ, USA) the raw EMG data were rectified and smoothed over 100 ms (root mean square algorithm).

Using a data acquisition system (MyoResearch XP Master, version 1.07.1, Noraxon, Scottsdale, AZ, USA) a 1-second window located the highest EMG from the three 4-second MVIC repetitions of PHE, SLS and SGS. The use of 1-second window to determining the highest mean EMG of an MVIC is a prescribed method for normalization[5, 14]. An algorithm from the acquisition system identified the portion of the highest EMG signal from the three trials of PHE, SLS and SGS. Of the ten participants, seven recorded having the highest EMG from PHE and three recorded having the highest EMG from SLS. Given that the majority of participants elicited the highest EMG from PHE; it was decided to use PHE as the reference for normalization. The highest mean EMG 1-second window from PHE was used as the normalization reference that was applied to the 1-second window of the highest EMG trial of PHE, SLS and SGS.

For statistical analyses, initially a two-way repeated measure (MVIC techniques x glutei sites) analysis of variance (ANOVA) was used to evaluate EMG activity of the superior and inferior gluteus maximus of the dominant leg. This revealed no main effect of the glutei sites (p=0.372), and no interaction (p=0.834), therefore superior and inferior gluteus maximus were pooled for the remaining analyses using a one-way repeated measure ANOVA design. The magnitudes of change were calculated as effect size (ES) and categorized from the following criteria: 0.0 trivial; 0.2 small; 0.6 moderate; 1.2 large; and 2.0 very large[15]. All statistical analyses was computed using SPSS for Windows (version 24.0, IBM, NY, USA). If a significant value was observed, post-hoc pairwise comparisons were performed using the Bonferroni adjustment. The level of significance was set at $p \leq 0.05$ and the values reported were mean ± standard deviation.

Table 1. Mean ± SD of normalized EMG amplitude of pooled GM from the three MVIC techniques

EMG	SLS	PHE	SGS †
EMG amplitude GM (%)	88.8 ± 15.5	100 ± 0	51.6 ± 14.5

GM: Gluteus maximus superior and inferior; SLS: Single leg squat; PHE: Prone hip extension; SGS: Standing gluteal squeeze. †p<0.01 compared to SLS and PHE.

RESULTS

Mauchly's test was performed and sphericity was not violated. The results revealed that the EMG gluteal activity of SGS (51.6%) was significantly lower ($p<0.01$), compared to SLS (88.8%, ES=1.32) and PHE (100%, ES=2.85). However, there was no significant difference ($p>0.05$) in EMG activity between SLS and PHE (ES=0.50) (Table 1).

DISCUSSION

The objective of this study was to determine the EMG activity of the gluteus maximus regions from three different MVIC techniques. We found that there was no significant difference between the inferior and superior gluteus maximus, thus both muscles were pooled for further analyses. Previous research has reported that when hip abduction and/or external rotation is included into lower-limb exercises the superior gluteus maximus generates greater EMG activity compared to inferior gluteus maximus[9)]. In SGS the hip was externally rotated and the expectation was that superior gluteus maximus would elicit a higher level of activation than PHE and SLS. However, SGS may require additional external resistance to achieve this.

The findings of this study indicate that when the angle of knee and hip was set at approximately 60° of flexion, EMG gluteal activity of SLS and PHE was significantly higher compared to SGS. The gluteus maximus EMG from SGS revealed 52% MVIC, which was less than 85–92% MVIC reported by Contreras et al[2)]. The SGS was performed using ~60° of hip flexion, in this study. In contrast, the hips were extended in the investigation by Contreras et al.[2)], which may explain why the current SGS exercise failed to elicit the same level of gluteal EMG. In PHE, it has been reported if hip flexion is increased gluteal activity decreases[3)]; however, if knee flexion is increased there is little change in gluteus maximus activity[6)]. Thus, it is plausible that increasing hip flexion for SGS may be more counterproductive than increasing knee flexion in eliciting the highest gluteus maximus activity. Further investigation is required to confirm this hypothesis.

There was no significant difference in gluteus maximus EMG activity between the PHE and SLS. This indicates that the body orientation of prone (PHE) versus upright (SLS) had little influence on gluteus maximus EMG activity when the knee and hip angles were the same. Similarly, there seems to be no effect related to support of the upper body, this is corroborated by previous research that reported no difference in gluteus maximus activity when the upper body or lower body were fixed when performing isometric horizontal back extension[16)]. However, the two techniques of PHE and SLS, do differ from each other. The SLS is a closed kinetic chain (CKC) exercise while PHE is an open kinetic chain (OKC) exercise. Typically, OKCs are single joint exercises, which may be helpful for targeting specific muscles or muscle groups. However, in attempting to elicit maximum EMG activity there appeared to be no distinct advantage using a CKC for this population of rugby players compared to an OKC exercise. Based on the current findings the PHE technique is able to elicit gluteal EMG activity similar to that of SLS. Therefore, further research is required to determine whether other specific rugby activities involving hip extension such as, scrummaging should be used to obtain MVIC reference value of gluteal EMG activity or whether these can be equivalently achieved with the techniques in the current study and the standard.

The current study had some limitations, which need to be discussed briefly. Firstly, the interpretation of the data is limited by the small sample size and although it is comparable to other research[2)], larger studies are required to increase its generalizability. Secondly, further investigation is required to compare the current MVIC techniques to a standard version of PHE (hip=0°, knee=90°) and SGS to determine the highest MVIC EMG activity. Thirdly, there is a possibility that EMG cross-talk may have occurred although the pairs of electrodes for the gluteal sites were placed in close proximity, which is likely to have reduced the magnitude of the crosstalk. However, the electrode may have reduced the breadth and depth of muscle activity detection; the gluteus maximus may have more adipose tissue than other areas, which may decrease the validity and/or reliability of signal detection. Fourthly, the joint angle of the SLS was selected because of its ability to optimize force production in rugby players; however, the standard MVIC position of PHE was not assessed and SGS was modified to allow comparable joint angles to be used across the three MVIC techniques.

In conclusion, SLS is a functionally relevant position for rugby that may be considered as an alternative to the PHE performed in this study. Adopting greater hip flexion in SGS is ineffective in eliciting the greatest gluteal activity in comparison to the present PHE and SLS techniques. Future research should compare the present positions with other MVIC techniques that are commonly prescribed or have been demonstrated to produce high EMG amplitudes.

Conflict of interest

None.

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