A comparison of two gluteus maximus EMG maximum voluntary isometric contraction positions

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Background: The purpose of this study was to compare the peak electromyography (EMG) of the most commonly-used positions in the literature, the prone bent-leg (90º) hip extension against manual resistance applied to the distal thigh (PRONE), to a novel position, the standing glute squeeze (SQUEEZE). **Methods:** Surface EMG electrodes were placed on the upper and lower gluteus maximus of thirteen recreationally active females (age = 28.9 years; height = 164 cm; body mass = 58.2 kg), before three maximum voluntary isometric contraction (MVIC) trials for each position were obtained in a randomized, counterbalanced fashion. **Results:** No significant ($p \leq 0.05$) differences were observed between PRONE (upper: 91.94%; lower: 94.52%) and SQUEEZE (upper: 92.04%; lower: 85.12%) for both the upper and lower gluteus maximus. Neither the PRONE nor SQUEEZE was more effective between all subjects. **Conclusions:** In agreement with other studies, no single testing position is ideal for every participant. Therefore, it is recommended that investigators employ multiple MVIC positions, when possible, to ensure accuracy. Future research should investigate a variety of gluteus maximus MVIC positions in heterogeneous samples.

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Running Head: GMax MVIC

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ABSTRACT

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Conclusions: In agreement with other studies, no single testing position is ideal for every participant. Therefore, it is recommended that investigators employ multiple MVIC positions, when possible, to ensure accuracy. Future research should investigate a variety of gluteus maximus MVIC positions in heterogeneous samples.

INTRODUCTION

Maximum voluntary isometric contractions (MVIC) are often used to normalize electromyography (EMG) signals. It is important to employ an MVIC position that elicits the highest activation in order to increase the validity of EMG studies and decrease incidents of abnormally high normalized mean and peak EMG data. In order for accurate comparisons to be made between studies, it is also important for researchers to standardize MVIC positions, or at least use positions that elicit similar magnitudes of EMG activity. A number of MVIC positions have been used in the literature to assess the gluteus maximus (GM), including the Biering-Sorenson position (Cambridge et al. 2012; McGill et al. 2009), the prone straight leg hip extension position (Barton et al. 2014; Worrell et al. 2001), the prone bent leg position (Jakobsen et al. 2013; Youdas et al. 2013), the prone straight leg position with 70º of hip flexion (Simenz et al. 2012), and the standing bent leg position (Boudreau et al. 2009). The most commonly used position, however, is the prone bent-leg (90º) hip extension with manual resistance applied to the distal thigh (PRONE) (Choi et al. 2014; Emami et al. 2014; Hislop et al. 2013; Kang et al. 2013; Kendall et al. 1993; Oh et al. 2007).

A recent study by Simenz et al. (2012) that used a prone GM MVIC position in 70º of hip flexion, demonstrates the importance of standardizing MVIC positions across studies. Researchers have shown that the GM is activated to a much smaller degree at higher degrees of hip flexion and reaches a maximum at end range hip extension (Worrell et al. 2001). By employing an MVIC position that renders significantly lower EMG activity than those values that are truly maximal, the normalized data of Simenz et al. (2012) are most likely overestimated. For example, if the work of Worrell et al. (2001) is extrapolated, the MVIC position used by

Simenz would only elicit approximately 80% of true MVIC, translating into 25% greater mean and peak values when compared to the true MVIC position. The data reported by Simenz et al. (2012) therefore cannot be used for comparison with exercises in other studies that utilized alternative MVIC positions with smaller hip flexion angles, as the data would have overestimated how effectively the GM was activated. Therefore, it is apparent that researchers should only compare EMG data that utilize positions that render similar values.

Since Worrell et al. (2001) found that full hip extension elicited the greatest amount of GM EMG activity, and this finding is corroborated by earlier work from Wheatley & Jahnke (1951) and Fischer & Houtz (1968), it is postulated that the most appropriate GM MVIC position is at full hip extension, or hip hyperextension. PRONE is currently the recommended position in several texts on muscle testing (Hislop et al. 2013; Kendall et al. 1993), although to the authors' knowledge, this position has not been compared to others in the literature. In order to correct for individual variation, some researchers have employed multiple MVIC positions. For example, McGill et al. (2009) used both the Biering-Sorenson and PRONE positions; whichever position elicited the greatest activity was used for normalization purposes. The authors, however, are unaware of any existing research that quantitatively compares GM MVIC positions.

The GM muscle appears to be segmented into at least two subdivisions, which may display different EMG activity in response to certain muscle actions. McAndrew et al. (2006) used a laser-based mechanomyographic (MMG) technique to measure the mean contraction time in six subdivisions of the GM, both in the sagittal plane (superior, middle, inferior) and in the frontal plane (medial and lateral). The superior region displayed the longest contraction time followed by the middle region and then the inferior region. On the basis of these findings, McAndrew et al. (2006) suggested that the superior region may contain more slow twitch fibers and be more involved in postural tasks compared to the inferior region, while the inferior region may contain more fast twitch fibers and be more involved in dynamic tasks. This is further substantiated by the work of Lyons et al. (1983) and Karlsson & Jonsson (1965), who found differences between upper (UGM) and lower (LGM) GM EMG during functional movement; for example, load acceptance during stair ambulation better targets the LGM (Lyons et al. 1983), while hip abduction better targets the UGM (Karlsson & Jonsson 1965).

Pilot data from our lab showed that some subjects were able to elicit greater EMG activity during a standing glute squeeze (SQUEEZE) when compared to PRONE, and this was especially true for the UGM. Given this observation and the findings articulated in previous paragraphs, the purpose of this investigation was to compare UGM and LGM EMG activity in PRONE versus SQUEEZE. Based on our pilot data, it was hypothesized that SQUEEZE would elicit greater UGM EMG activity, while PRONE would elicit greater LGM EMG activity.

METHODS

Subjects

Thirteen healthy women (age = 28.9 ± 5.1 years; height = 164 ± 6.3 cm; body mass = 58.2 ± 6.4 kg) with 7.0 ± 5.8 years of resistance training experience participated in this study. Inclusion criteria required subjects to be between 20 to 40 years of age and have at least 3 years of consistent resistance training experience. All subjects were healthy and free of any musculoskeletal or neuromuscular injuries, pain, or illnesses. Subjects completed an Informed

Consent form. Subjects were advised to refrain from training their lower body for 72 hours prior to testing. The study was approved by the Auckland University of Technology Ethics Committee (AUTEC Reference number 13/375).

Procedures

Subjects first performed a 10-minute general warm-up consisting of various dynamic stretches for the lower body musculature. Following warm-up, subjects practiced each testing position several times, until they felt comfortable with the technique. Subjects were asked to wear appropriate clothing for access to the EMG electrode placement sites. Before placing the electrodes on the skin, excess hair was removed with a razor, and skin was cleaned and abraded using an alcohol swab. After preparation, self-adhesive disposable silver/silver chloride pre-gelled dual snap surface bipolar electrodes (Noraxon Product #272, Noraxon USA Inc, Scottsdale, AZ) with a diameter of 1 centimeter (cm) and an inter-electrode distance of 2 cm were attached in parallel to the fibers of the right UGM and LGM, in concordance with the recommendations of Hermens et al. (1999) and Lyons et al. (1983). After the electrodes were secured, a quality check was performed to ensure EMG signal validity.

Following electrode placement, subjects completed three trials of PRONE then SQUEEZE, or vice versa. For example, if a subject was randomized to complete PRONE first, her testing order would be PRONE, SQUEEZE, rest, PRONE, SQUEEZE, rest, PRONE, SQUEEZE. Each contraction phase lasted 5 seconds, and each rest phase lasted 3 minutes. Randomization was counterbalanced so that half the subjects performed PRONE first and the other half performed

SQUEEZE first. In all MVIC positions, subjects were instructed to contract the GM "as hard as possible."

Raw EMG signals were collected at 2000 Hz by a Myotrace 400 EMG unit (Noraxon USA Inc, Scottsdale, AZ). Data was sent in real time to a computer via Bluetooth and recorded and analyzed by MyoResearch 3.6 Clinical Applications software (Noraxon USA, Inc., Scottsdale, AZ). A 10-500 Hz bandpass filter was applied to EMG data. Signals of all MVIC trials were full-wave rectified and smoothed with a root mean square (RMS) algorithm with a 100 ms window. Maximal peak EMG values over a 1000 ms window were then used to normalize peak EMG signals obtained during each MVIC trial (Vera-Garcia et al. 2010).

<u>Statistical Analysis</u>

Paired samples *t*-tests were performed after checking normality using Shapiro-Wilk test in Stata 13 (StataCorp LP, College Station, TX). Alpha was set *a priori* at 0.05 for significance. Effect sizes (ES) were calculated by Cohen's *d* using the formula $d = \frac{M_d}{s_d}$, where s_d is the standard deviation of differences (Becker 1988; Morris 2007; Smith & Beretvas 2009). This method is slightly different than the traditional method of calculating Cohen's *d*, as it calculates the within-subject effect-size rather than group or between-subject effect size. ES were defined as small (0.20-0.49), moderate (0.50-0.79), and large (≥ 0.80) (Cohen 1988). Confidence intervals (95% CI) for each ES were also calculated.

RESULTS

The normalized peak EMG for the different exercises and GM sections can be observed in Table 1. In terms of the UGM comparison, no significant differences were observed in the peak EMG for both exercises (ES = 0.005; 95% CI = −0.599 – 0.609; t(12) = 0.018; p = 0.986). With regards to the LGM, a small ES was observed (−0.412; 95% CI = −0.102 – 0.193) between the two positions; however, this outcome may have been due to chance alone (t(12) = −1.485; p = 0.164).

Table 1
Group mean ± SD of normalized peak EMG amplitudes.

	PRONE	**SQUEEZE**
UGM	91.94 ± 11.64	92.04 ± 11.30
LGM	94.52 ± 13.59	85.12 ± 12.64

UGM = upper gluteus maximus; LGM = lower gluteus maximus

DISCUSSION

The purpose of this investigation was to compare a novel GM MVIC position, SQUEEZE, to the current gold standard, PRONE. Our hypotheses were rejected, as there were no statistically significant differences between the two positions tested (Table 1). However, despite no statistically significant differences, the peak EMG values for the LGM were approximately 9% higher for the PRONE compared to the SQUEEZE. Consequently, if the SQUEEZE test were used for normalization, it would render approximately 10% higher mean and peak EMG values compared to the PRONE test. Therefore, although not statistically significant, the findings could be considered practically meaningful. Furthermore, these data show a large amount of individual variation (Table 2), which has been previously described by McGill (1990) and Vera-Garcia et al. (2010) for other muscles.

Table 2
Number of subjects (percentage of subjects (%)) which each MVIC technique resulted in the greatest peak EMG amplitude.

	PRONE	SQUEEZE
UGM	7 (53.85)	6 (46.15)
LGM	10 (76.92)	3 (23.08)

UGM = upper gluteus maximus; LGM = lower gluteus maximus

There are several kinematic and kinetic differences between PRONE and SQUEEZE, any of which may have affected our results, either individually or in combination. During PRONE, the knee is bent to 90º, whereas during SQUEEZE, the knees are fully extended. Previous research has shown that GM EMG activity during hip extension is greater with the knees flexed than when extended, presumably resulting from a greater reliance upon the GM for hip extension due to decreased hamstrings length (Kwon & Lee 2013). On the other hand, extended knees allow for greater hip extension range of motion compared to flexed knees, thereby shortening the gluteal fibers to a greater extent (Van Dillen et al. 2000) and leading to a greater amount of GM EMG activity (Worrell et al. 2001). In addition, PRONE involved primarily hip hyperextension since the pelvis was fixed, whereas SQUEEZE appeared to involve a combination of hip extension and posterior pelvic tilt. Although posterior pelvic tilt mimics hip extension (Neumann 2010), it is unclear how each of these kinematic variables might affect GM EMG activity individually. To our knowledge, no study to date has investigated GM EMG activity with varying combinations of hip extension and posterior pelvic tilt during MVIC actions. Moreover, PRONE is an open kinetic chain maneuver with the torso stabilized onto a bench, whereas SQUEEZE is a closed kinetic chain maneuver performed in a standing position. Stensdotter et al. (2003) investigated the EMG activity of the quadriceps muscle group during open kinetic chain and closed kinetic chain positions during MVIC actions and reported significant differences in EMG amplitude. The rectus femoris displayed greater EMG activity during open kinetic chain maneuvers while the vastus medialis displayed greater EMG activity during closed kinetic chain maneuvers. It is therefore hard to predict whether the GM would inherently display greater or lesser EMG activity during either open or closed kinetic chain maneuvers. Finally, PRONE required manual resistance, whereas SQUEEZE relied upon anatomical structures surrounding the hip to provide resistance against hip extension. Whether this factor has any effect on EMG activity recorded in a muscle is unclear, as the authors are unaware of any previous investigations into the effect of squeezing a muscle whereby range of motion is limited by anatomical structures on EMG activity rather than against external resistance.

This investigation was subject to several important limitations. Firstly, although we observed what may have been a practically important difference between the MVIC positions, this difference was not found to be statistically significant, which suggests that our initial estimates for the appropriate sample size may have been too small. Secondly, there were several kinematic differences between the two positions that were explored (PRONE and SQUEEZE), including different pelvic, hip, and knee joint angles. There were also kinetic differences between the two positions, in that PRONE was an open kinetic chain maneuver and SQUEEZE was a closed kinetic chain maneuver. Moreover, PRONE used external resistance and SQUEEZE utilized oppositional torques produced by internal, anatomical structures. These multiple differences make it difficult to assess whether our results arose from a combination of biomechanical factors acting in opposing directions, heterogeneity, or genuinely no difference between the conditions. Thirdly, we only compared two MVIC positions, and it is feasible that other positions might result in superior or inferior levels of EMG activity. Fourthly, we only investigated two subdivisions of the GM muscle and there are indications that there may be others, from proximal-to-distal, medial-to-lateral, and superficial-to deep. Furthermore, our statistical analysis was not designed to assess whether there was a difference between the EMG activity of the UGM and LGM during either MVIC position and therefore this remains uncertain.

Conclusions

Although these data are inconclusive as to which position is superior, they do provide insight as to the complexity of MVIC positions for the GM. More specifically, due to the large individual variations (Table 2), it is recommended that multiple MVIC positions be utilized to ensure that the greatest possible EMG amplitude be the divisor during normalization. These recommendations are well in line with other studies, which have utilized or recommended multiple MVIC positions (McGill et al. 2009; Vera-Garcia et al. 2010). Future research should use heterogeneous samples, such as athletic males, and also test more positions, such as the Biering-Sorenson position, quadruped hip extension position, and top hip thrust position (Contreras et al. 2011), each with manual resistance, along with the tall kneeling position.

Competing Interests

The authors claim no conflicts of interest.

Author Contributions

BC designed the experiment, carried out data collection, and drafted the manuscript.

ADV helped design the experiment, assisted with data collection, performed statistical analyses, and helped draft the manuscript.

BJS assisted with experimental design, data interpretation, and manuscript preparation.

CB assisted with data interpretation and manuscript preparation.

JC assisted with experiment design and manuscript preparation.

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