Physical Therapy in Sport 15 (2014) 39–46

Contents lists available at SciVerse ScienceDirect

Physical Therapy in Sport

journal homepage: www.elsevier.com/ptsp

Original research

Gluteal muscle activation during the isometric phase of squatting exercises with and without a Swiss ball

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ARTICLE INFO

Article history:
Received 18 November 2011
Received in revised form
22 February 2013
Accepted 27 February 2013

Keywords:
Electromyography
Gluteal
Hip
Squat
Swiss ball

ABSTRACT

Objectives: Growing evidence supports hip muscle activation and strengthening exercise prescription to prevent and treat various lower limb injuries. Common prescriptions include single-legged and double-legged squatting, with and without a Swiss ball. We aimed to establish the effect of varying forms of squatting exercises on gluteal muscle activation.
Design and setting: Observational laboratory study.
Participants: Nineteen (11 male) healthy participants (28.4 +/− 2.7 years old) were compared using one-way repeated measures analysis of variance.
Main outcome measures: Surface electromyography (EMG) measures of gluteus medius (GMed) and gluteus maximus (GMax) during the isometric phase of single-legged and double-legged squatting, with and without a Swiss ball.
Results: A greater percentage of maximal voluntary contraction (%MVC) during single-legged squatting was found compared to double-legged squatting for GMed (42 versus 9%MVC, $p < 0.001$) and GMax (35 versus 14%MVC, $p < 0.001$). Additionally, the Swiss ball increased GMax activity (42 versus 35%MVC, $p = 0.026$) and demonstrated a trend toward increased GMed activity (46 versus 42%MVC, $p = 0.075$) during the single-legged squat.
Conclusions: These results indicate single-legged squatting may be more appropriate than double-legged squatting to facilitate strength gains of GMed and GMax. Additionally, the Swiss ball may be a useful adjunct to target gluteal muscle strengthening during single-legged squatting.

1. Introduction

Lower limb strength training is an important intervention in the treatment and prevention of many lower limb conditions. Recently, hip muscle retraining has been proposed as a vital consideration during any knee injury rehabilitation program (Powers, 2010). This concept has come to the forefront of research and clinical practice in light of reported cross-sectional links between gluteal muscle weakness and knee pathologies, including patellofemoral pain (PFP) (Prins & van der Wurff, 2009) and iliotibial band friction syndrome (ITBFS) (Fredericson, Cookingham, Chaudhari, Dowdell, Oestreicher, & Sahrmann, 2000). Gluteal weakness is thought to contribute to greater hip adduction and internal rotation, and dynamic knee valgus movements during functional activity, and subsequently increased stress to the patellofemoral joint (PFJ) and iliotibial band (ITB) (Powers, 2010). Supporting this theory, excessive hip adduction was reported to be the strongest biomechanical predictor of ITBFS development in female runners (Noehren, Davis, & Hamill, 2007). Although lacking prospective evidence, greater hip adduction and/or internal rotation has also been reported to exist in some cross-sectional studies evaluating individuals with PFPS (Dierks, Manal, Hamill, & Davis, 2008; Noehren, Pohl, Sanchez, Cunningham, & Lattermann, 2012; Souza & Powers, 2009; Willson & Davis, 2008).

Evidence to support the effectiveness of including gluteal muscle strengthening in the management of both PFP (Avraham et al., 2007; Boling, Bolgla, Mattacola, Uhl, & Hosey, 2006; Dolak, Silkman, Medina McKeon, Hosey, Lattermann, & Uhl, 2011; Ferber, Kendall, & Farr, 2011; Fukuda, Rossetto, Magalhaes, Bryk, Lucareli, & de Almeida Aparecida Carvalho, 2010; Khayambashi, Mohammadkhani, Ghaznavi, Lyle, & Powers, 2012; Nakagawa, Muniz, Baldon Rde, Dias Maciel, de Menezes Reiff, & Serrao, 2008) and ITBFS (Beers, Ryan, Kasubuchi,

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http://dx.doi.org/10.1016/j.ptsp.2013.02.006

Fraser, & Taunton, 2008; Fredericson et al., 2000) continues to grow. Additionally, many of the improvements in pain and function reported in these studies were also correlated with increased gluteal muscle strength (Beers et al., 2008; Dolak et al., 2011; Ferber et al., 2011; Fredericson et al., 2000; Khayambashi et al., 2012). In view of this, identification of the most appropriate exercises to enhance activation of this musculature is needed.

Many exercise programs targeting rehabilitation of the knee incorporate squatting based exercises. This is based on the premise that the squatting motion replicates everyday functional activity such as stair descent, sit to stand, running and hopping. Additionally, squatting based exercises will incorporate strengthening of the entire lower limb including the gluteal musculature. Depending on the functional level of the individual, squat exercises can be completed in either double or single limb stance.

Compared to double-legged squatting, single-legged squatting is thought to increase the reliance on the gluteal musculature resulting from a greater challenge to pelvic stability and increased hip adduction torques (Distefano, Blackburn, Marshall, & Padua, 2009; Hewitt, Myer, & Ford, 2006; Powers, 2010). Distefano et al. (2009) recently evaluated gluteus medius (GMed) and gluteus maximus (GMax) muscle activity using surface electromyography (EMG) in 21 healthy individuals during 12 different rehabilitation exercises. From these exercises, single-legged squatting was found to produce the greatest level of gluteus maximus EMG activity, and second greatest level of gluteus medius EMG activity of all the exercises performed (Distefano et al., 2009). Additionally, Ayotte, Stetts, Keenan, and Greenway (2007) have reported that a single-legged wall squatting task produces significantly greater levels of GMed and GMax activity than three alternative step-up tasks. However, superiority of single limb stance over double limb stance for facilitating gluteal muscle activity during squatting cannot be established from this research (Ayotte et al., 2007; Distefano et al., 2009), since neither study evaluated double-legged squatting.

During squatting exercise prescription, the Swiss ball is frequently used to create instability and hence facilitate greater muscle activation. The rationale for using a Swiss ball during rehabilitation exercise is to place greater neuromuscular control demands on the musculoskeletal system (Escamilla et al., 2010). Therefore, any potential muscle activation or strength gains may be enhanced. However, there is currently limited evidence to support the efficacy of using a Swiss ball to increase muscle activity in the lower extremity. Wahl and Behm (2008) reported that standing on a Swiss ball significantly increased soleus, biceps femoris and rectus femoris muscle activity compared to a stable surface. However, Marshall and Murphy (2006) reported the addition of a Swiss ball behind the back during the completion of a double-legged squatting exercise did not alter either vastus lateralis or biceps femoris muscle activity. Additionally, Behm and Anderson (Behm, Anderson, & Curnew, 2002) reported that sitting on a Swiss ball compared to a stable surface did not change muscle activity of the ankle plantar flexors, and actually decreased quadriceps muscle activity during resisted isometric contractions. There does not appear to be any previous research which has evaluated the efficacy of using a Swiss ball to facilitate gluteal muscle activity during single- or double-legged squatting.

The aims of this study were to (i) compare gluteal muscle activity between completion of a single-legged squat and a double-legged squat during an isometric hold; and (ii) evaluate the influence of using a Swiss ball on gluteal muscle activity during a single-legged and double-legged squat. It was hypothesised that gluteal muscle activity would be increased by moving from a double to single-legged stance during squatting and with the addition of a Swiss ball in both stances.

2. Methods

2.1. Participants

Using convenience sampling, nineteen healthy university students (11 male, 8 female), without history of lower back or lower limb pathology volunteered for the study. Participants' mean age, height and weight were 28.4 years (SD = 2.7), 172.4 cm (SD = 5.8) and 67.8 kg (SD = 10.4), respectively. Ethical approval was obtained from Queen Mary Research Ethics Committee, University of London, and all participants gave written informed consent. Data collection for comparison between the conditions took place for each participant during a single data collection session. Additionally, 10 participants were asked to return one week later in order to establish the reliability of the testing protocol.

2.2. Electromyographic data collection

Gluteus medius (GMed), and gluteus maximus (GMax) muscle activity was collected using disposable, self-adhesive Ag/AgCl Noraxon surface electrodes fixed 20 mm apart over each muscle (parallel to muscle fibre orientation) on the participant's dominant side. Surface electrode preparation and placement followed the recommendations of the SENIAM project (SENIAM, 2011). Data from each surface electrode was collected via a telemetric EMG system (Noraxon TeleMyo 2400 G2, Arizona, USA). Surface EMG signals were sampled at 1500 Hz, amplified and bandpassed filtered between 10 and 500 Hz and sent wirelessly via a PCMCIA card (Cisco Systems Inc., San Jose, CA, USA) to the data acquisition computer. Raw data was then transferred to MATLAB (v2009a, Mathworks, Natwick, MA, USA), where it was rectified and smoothed using a 100 epoch running mean method for visualisation. The mean amplitude of unsmoothed rectified data was used for analysis.

Prior to each testing session (on the same day), participants' maximal voluntary contraction (MVC) for each muscle was obtained using resisted isometric contractions so that data could be normalised. Maximal isometric hip abduction for both the GMed and GMax were performed against gravity and manual resistance using standard clinical testing methods as outlined by Hislop, Montgomery, Connelly, and Daniels (1995) and utilised by Norcross, Blackburn, and Goerger (2010). Participants lay on their side with hips and knees in neutral and the hip in 10° abduction to establish MVC for GMed. GMax was evaluated with participants lying prone with their hips extended 10°. During each isometric contraction, participants were instructed to gradually increase their force to maximum over 2 s, maintain a static hold for 5 s, and gradually decrease force to rest over 2 s. Data collected during the 5-s static hold phase were analysed. Prior to each task, subjects were allowed 1 attempt in order to familiarise themselves with the action to be performed. The same examiner applied manual resistance during the tasks. Each task involved 3 repetitions with 1 min rest, and the maximum of the three was recorded for further analysis.

2.3. Exercise procedure

All participants performed a 5-min warm-up period of brisk walking, and the MVC tasks prior to completion of the squatting exercises. Both double and single-legged squatting exercises were completed with and without a 55 cm diameter Swiss ball in a random order. Each exercise was performed 3 times with a 30-s rest allowed between repetitions. Participants were allowed 1 practice before 3 repetitions were recorded. Feedback was given throughout each exercise regarding body alignment and speed of movement.