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Original Research

The Relationship of Anticipatory Gluteus Medius Activity to Pelvic and Knee Stability in the Transition to Single-Leg Stance

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Abstract

Background: The knee abduction moment in a weight-bearing limb is an important risk factor of conditions such as patellofemoral pain and knee osteoarthritis. Excessive pelvic drop in single-leg stance can increase the knee abduction moment. The gluteus medius muscle is crucial to prevent pelvic drop and must be activated in anticipation of the transition from double-leg to single-leg stance.
Objective: To examine the relationship of anticipatory activity of the gluteus medius to pelvic drop and knee abduction moment.
Design: Observational, cross-sectional correlational study.
Setting: Research laboratory.
Participants: Twenty female adults (mean age 22.6 years, standard deviation 2.5) were recruited and fully participated. Participant selection was limited to healthy women who did not have a history of knee and ankle ligament injuries, any indication of knee, hip, and/or low back pain, and/or knowledge of the proper squat technique.
Methods: Participants performed 16 single-leg mini squats on their nondominant leg.
Main Outcome Measures: The onset and magnitude of anticipatory gluteus medius activity were measured in relation to toe-off of the dominant leg during the transition from double-leg to single-leg stance. Preplanned correlations between anticipatory gluteus medius onset and its activation magnitude, pelvic obliquity, and knee abduction moment were examined.
Results: The magnitude of anticipatory gluteus medius activity was significantly correlated with the knee abduction moment (r_s (18) $= -0.303$, $P < .001$) and pelvic obliquity (r_s (18) $= 0.361$, $P < .001$), whereas gluteus medius onset was not significantly correlated with either knee abduction moment or pelvic obliquity.
Conclusions: The amount of gluteus medius activity is more important for controlling knee and pelvic stability in the frontal plane than the onset of activation.

Introduction

Knee pain syndromes such as patellofemoral pain (PFP) and knee osteoarthritis (OA) are of growing importance in the health care community [1-3], especially in women, who have a higher incidence of these conditions compared with men [4,5]. These knee pain conditions have a negative impact on the overall health-related quality of life, as well as functional disability and associated health care costs [6-9]; therefore, preventing and treating these knee pain syndromes is important for improving public health and decreasing health care costs [10,11].

Internal knee abduction moments play a critical role in the development of PFP and knee OA [12,13]. Past research has found that persons with PFP exhibited a significantly greater knee abduction moment in the frontal plane during walking than did healthy persons [14]. In addition, greater knee abduction moments during walking have also been associated with the development of knee OA [15,16], and poor alignment at the knee can be considered an independent risk factor for the progression of knee OA [17].

Frontal plane pelvic motion may play an important role in changing knee abduction moments in a weight-bearing limb [12,18,19]. Pelvic rotation (frontal plane) toward or away from a support limb can change the location of the center of mass (COM) relative to the knee joint [12,19,20], thereby altering the knee abduction moment. Indeed, young adult women with PFP have been shown to experience more pelvic drop (ie, tilt of the pelvis toward the unsupporting leg) when compared with healthy persons [21]. It has also been suggested that knee OA could be accelerated by excessive pelvic drop [12]. To develop strategies for preventing excessive

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pelvic drop and subsequent increases of the knee abduction moment, previous research has focused on elucidating the role of the hip abductors in stabilizing frontal plane pelvic posture [22,23].

Because it has the largest physiological cross-sectional area among the hip abductors, the gluteus medius (GMED) mainly provides frontal plane pelvic stability [22,24,25]. Several studies have shown that persons with PFP have delayed onset of GMED activation compared with healthy persons [26-29]. Importantly, the authors of one of these studies reported that subjects with PFP showed both delayed GMED onset and increased knee abduction moment compared with healthy subjects [26], but the *relationship between* the onset of GMED and the increased knee abduction moment was not investigated. Given that an inevitable delay exists between the onset of muscle activity and force development of a muscle group [30], anticipatory activation of GMED appears crucial to control pelvic drop for the transition from single-leg to double-leg stance. It is important to elucidate how anticipatory GMED activation, in terms of onset timing and activation magnitude during a double-leg to single-leg support transition, controls frontal plane pelvic motion and the knee abduction moment. Knee disease and pain may alter the way someone moves, which then confounds the understanding of whether a change in movement caused the pain or if pain caused the change in movement; therefore, it is important to first investigate the neural control of a healthy, disease- and pain-free population to establish a normal pattern of control.

The aim of this study was to examine the relationship of anticipatory GMED activity with frontal plane pelvic motion and knee abduction moment. This correlation was measured when participants transitioned from double-leg to single-leg support while performing a single-leg mini squat. Anticipatory GMED activity was defined as activity prior to toe-off of the nonsupporting leg. We hypothesized that an earlier onset and greater magnitude of the anticipatory GMED activity of the supporting leg would be significantly correlated with decreased pelvic drop and reduced knee abduction moment of the same leg.

Methods

Participants

Participants in this study were 20 healthy women between the ages of 18 and 39 years (mean, 22.6 years; standard deviation [SD], 2.5). Because pain, injuries, and knowledge of movement mechanics may modify the movement pattern of the participants, participant selection was limited to healthy women who did not have a history of knee and ankle ligament injuries, any indication of current knee, hip, and/or low back pain, and/or knowledge of the proper squat technique. Eligibility to participate was determined through a prescreening questionnaire. This research protocol was reviewed and approved by the institutional research ethics board. Informed consent was obtained before beginning the testing protocol for all participants.

Instrumentation

Leg dominance was identified using a Modified Waterloo Footedness Questionnaire [31]. Participants rated which leg they most often used for object manipulation tasks (the dominant leg), as well as for providing support (the nondominant leg). Three-dimensional (3D) kinematic data from the pelvis and lower limbs were collected using a motion capture system (Vicon Motion Systems, Los Angeles, CA), and ground reaction forces (GRFs) were measured using force platforms under each foot (OR6; Advanced Mechanical Technology, Inc, Watertown, MA) while the participants performed single-leg mini squats (SLMS). Kinematic data and GRF data were collected at a sampling rate of 100 and 2000 Hz, respectively. An SLMS is a commonly used clinical screening tool for assessing frontal plane pelvic and knee movement during weight bearing that is functionally similar to stair negotiation [32]. Furthermore, the quality of SLMS performance can reliably represent the functional quality of GMED activation [33]. To perform the SLMS, participants first transitioned from double-leg to single-leg standing, and then lowered their body by flexing their hip, knee, and ankle (Figure 1). Surface electromyography (EMG; 2400GT2, Noraxon Inc, Scottsdale, AZ), sampled at 2000 Hz, was used to record the muscle activity of the GMED [34,35] during the movement.

Testing Protocol

An initial 60-second quiet standing trial was collected to obtain baseline EMG values. Participants then performed a total of 32 SLMS. Movement speed was standardized using the beat of a metronome set at 80 beats per minute: At the first beat, the participant lifted her toe off the force platform to make the transition from

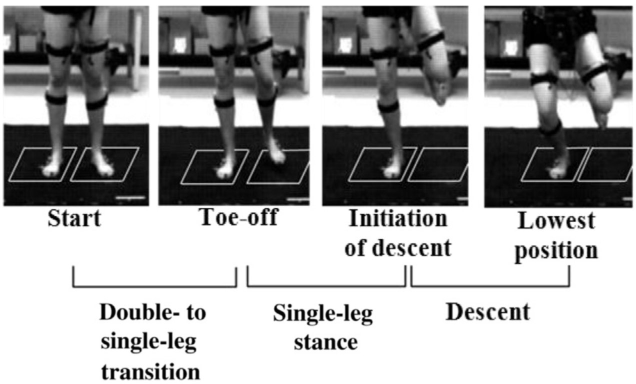

Figure 1. Sequential movement events.

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