Journal of Electromyography and Kinesiology 25 (2015) 667–674

Contents lists available at ScienceDirect

Journal of Electromyography and Kinesiology

journal homepage: www.elsevier.com/locate/jelekin

Reliability and fatigue characteristics of a standing hip isometric endurance protocol

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ARTICLE INFO

Article history:
Received 8 October 2014
Received in revised form 23 January 2015
Accepted 4 February 2015

Keywords:
Fatigue
Median frequency
Electromyography

ABSTRACT

Muscle fatigue is a common consideration when evaluating and rehabilitating athletic injuries. The presence of muscular fatigue has been previously determined by quantifying median frequency (MF) through a power spectral analysis on EMG signals collected throughout an endurance task. Research has not yet determined if a prolonged isometric test in a standing position generates muscular fatigue of the hip. The purpose of this study was to determine the reliability and fatigue characteristics of a standing hip isometric endurance test. Twenty healthy participants completed one 60-s Maximum Voluntary Isometric Contraction of standing hip flexion, extension, adduction, and abduction. MF of the participants' dominant limb rectus femoris (RF), biceps femoris (BF), gluteus maximus (GMax), gluteus medius (GMed) and adductor longus (ADD) was determined via surface electromyography during two sessions, 30-min apart. Reliability values ($ICC_{2,1}$) were moderate-to-excellent for all time intervals of each action ($Flexion_{RF}$: >0.80; $Extension_{BF}$: >0.89; $Extension_{GMax}$: >0.60; $Adduction_{ADD}$: >0.78; $Abduction_{GMed}$: >0.60) and MF significantly decreased over time for all actions. Results suggest the endurance test is a reliable technique to generate muscular fatigue for hip flexion, extension, adduction and abduction. It can be used as a time efficient fatigue protocol specific to the RF, BF, GMax, ADD and GMed.

1. Introduction

Fatigue has been collectively defined as an exercise-induced decrease in force production, or force-generating capacity associated with an increase in perceived effort necessary to maintain a desired force or action (Enoka and Duchateau, 2008; Kallenberg et al., 2007; Kent-Braun et al., 2002; Martin et al., 2010; Skurvydas et al., 2010; St Clair Gibson et al., 2001; Weir et al., 2006). Fatigue is commonly classified as an intrinsic risk factor for various injuries due to the associated effects from the decline in muscular strength, which in turn could decrease an athlete's functional performance and alter mechanics (Greig, 2008; Padua et al., 2006; Sangnier and Tourny-Chollet, 2007). The relationship between muscular strength and fatigue has been explored and one study determined that muscle strength accounts for approximately 25% of the variability of fatigue characteristics, indicating that individuals who vary in strength may respond differently to endurance tasks (Kent-Braun et al., 2002). Greig (2008) reported that eccentric hamstring peak torque was affected by exercise duration and concluded athletes may be at higher risk for strains and/or joint injuries during the latter part of a soccer game, depending on their level of fatigue. This lends support to the idea that fatigue influences muscular strength and injury risk, making it a risk factor worthy of further exploration.

The goal of a fatigue protocol is to develop either central fatigue or peripheral fatigue, with peripheral fatigue commonly referred to as intramuscular fatigue (Place et al., 2009; St Clair Gibson et al., 2001; Weir et al., 2006). In order to induce fatigue in the lower extremity, researchers have used various methods such as isokinetic (Sangnier and Tourny-Chollet, 2007), isometric (Katakura et al., 2011), sports-specific and treadmill protocols (Quammen et al., 2012; Weinhandl et al., 2011). These protocols are then used to detect eccentric, concentric or isometric strength differences and/or biomechanical changes in functional tasks such as running, cutting, jumping or landing before and after fatigue (Kallenberg et al., 2007; Katakura et al., 2011; Quammen et al., 2012; Sangnier and Tourny-Chollet, 2008; Weinhandl et al., 2011). Fatigue onset has been determined several ways through either task failure (Carcia et al., 2005; Quammen et al., 2012; Weinhandl et al., 2011), percent decline in strength (Carcia et al., 2005; Katakura et al., 2011; Sangnier and Tourny-Chollet, 2007),

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http://dx.doi.org/10.1016/j.jelekin.2015.02.003
1050-6411/

a fatigue ratio equation (Sangnier and Tourny-Chollet, 2007), 90% maximum age-calculated heart rate, VO_2max curve plateau, greater than 1.1 respiratory quotient (Quammen et al., 2012), significant increases in EMG amplitude or significant decreases in mean or median frequency (Jacobs et al., 2007; Kallenberg et al., 2007; Katakura et al., 2011).

Several studies have examined hip strength and endurance measures using maximal and sub-maximal isometric contractions and EMG analysis of muscle activity to quantify fatigue (Coorevits et al., 2008; Jacobs et al., 2005; Schmitz et al., 2002). Current assessments of hip muscle fatigue are performed in a seated, prone or side-lying position, depending on the muscle being tested (Coorevits et al., 2008; Jacobs et al., 2005, 2007; Schmitz et al., 2002). Although those positions control for the accessory movements associated with standing posture, most functional tasks are performed in a double or single-leg stance and involve various compensatory postural movements. Enoka and Duchateau (2008), described fatigue as task-dependent and suggested that changes in position could alter fatigue characteristics. This indicates that previous results associated with fatiguing the hip musculature in non-standing positions may not be interchangeable and may differ when the hip musculature is fatigued in a standing position. It has not been determined if a prolonged isometric fatigue test in a standing position is a reliable and potentially useful technique for generating hip musculature fatigue. Therefore, the purpose of the study was to determine the reliability and fatigue characteristics of a 60-s standing isometric protocol to generate muscular fatigue at the hip. We hypothesized that the test will produce good test–retest reliability measures and a significant decrease in median frequency, therefore demonstrating the onset of fatigue.

2. Methods

A cross-sectional study with test re-test design was used to assess the reliability and fatigue characteristics of a standing hip isometric endurance test to generate muscle fatigue in four directions (flexion, extension, abduction, and adduction) with neutral hip joint position. Median frequency (MF), interpreted as the rate of conduction of muscle fibers, was used to quantify fatigue based on the theory that decreases in MF represent fatigue of fast twitch motor units (higher frequency) while retaining slow twitch motor units (lower frequency) to sustain activity (De Luca, 1983). MF was examined from the EMG signal of the primary muscle(s) of each hip action (Flexion = Rectus femoris [Flexion_{RF}]; Extension = Biceps femoris [Extension_{BF}], Gluteus Maximus [Extension_{GMax}]; Adduction = Adductor longus [Adduction_{ADD}]; Abduction = Gluteus Medius [Abduction_{GMed}]) for each 15 s time interval of each trial through a power spectral analysis. Measures of normalized torque were collected for each action and used as a secondary measurement of the fatigue characteristics.

2.1. Participants

Twenty healthy male and female recreationally active individuals (10 male, 10 female; age = 25.2 ± 3.3 years; height = 175.1 ± 11.6 cm; mass = 70.6 ± 15.4 kg) volunteered to participate in a single session of testing. Participants were included if they participated in physical activity for at least 30 min, three times per week. Activity limitation was assessed via the Disablement in the Physically Active Scale (DPAS) (Vela and Denegar, 2010). All participants scored below 12 (1.8 ± 3.20) indicating no significant self-reported activity limitations (Vela and Denegar, 2010). Exclusionary criteria included a history of any lower extremity injury at the time of testing or within 4 months prior to testing, and surgery to the hip, knee or ankle within the last two years. All participants signed a written informed consent form that was approved by the Institutional Review Board.

2.2. Instrumentation

An isokinetic dynamometer (Primus RS, BTE Technologies, Hanover, MD) was used to apply isometric resistance and measure torque during the hip isometric endurance tests. Surface EMG data was collected synchronously with the torque data using a DelSys Bagnoli system (DelSys Inc., Boston, MA) at 1000 Hz. Each participant's skin was shaved, abraded and cleaned with alcohol in preparation of electrode placement. Single differential surface electrodes with 1-cm interelectrode distance were placed over the muscle bellies of the rectus femoris (RF), biceps femoris (BF), gluteus maximus (GMax), adductor longus (ADD), and gluteus medius (GMed). BF, GMax and GMed electrodes were placed between the innervation zone and distal attachment as described by Rainoldi et al. (2004). Electrode sites were verified with manual muscle testing to ensure the electrodes were running parallel to the muscle fibers (Norcross et al., 2010; Sakamoto et al., 2009; Schmitz et al., 2002). One reference electrode was placed on the ipsilateral clavicle. The same investigator performed all electrode preparation, placement and verification.

2.3. Procedures

The participants completed two sessions of testing within the same day, with a thirty-minute rest period between sessions. Each testing session included one endurance test per motion. Prior to testing, participants completed the DPAS questionnaire to determine any activity limitations and if no major limitation existed anthropometric measures were recorded. Surface EMG electrodes were then applied after an 8-min pre-determined warm-up that included a five-minute stationary bike and self-stretching of the hip musculature. Once electrode placement was verified, the participants were asked to stand as still and relaxed as possible and five seconds of resting muscle activity were recorded. The action order for the endurance test was counterbalanced for all participants to eliminate an order effect. The same counterbalanced order was used for the second session. The test limb for all participants was the dominant limb, defined as the preferred limb to kick a ball.

2.4. Endurance testing

Prior to endurance testing, all participants completed three, five-second MVIC trials for each motion to normalize the EMG and torque collected over the endurance trial. Thirty seconds of rest was given after the normalization trials followed by one practice endurance trial at sub maximum effort for up to 30-s for familiarization of the endurance test. Following one minute of rest after the practice trial, a maximal effort 60-s endurance test trial was performed. Each participant was given two minutes of non-weight bearing rest after each test trial before continuing to the next motion.

Participants were asked to stand shoulder width apart and the lower 1/3 of the test shank was attached to the distal arm of the dynamometer, 5-cm proximal to the medial malleolus with the use of an ankle cinch strap (Kollock et al., 2010). The stance foot for all female participants was placed on top of a piece of carpet an inch high to aid in clearing the test leg when performing the test (Fig. 1). We determined the need of the carpet during pilot testing in order for the heel of the test limb to not make contact with the ground and for the female's iliosacral joint to stay horizontally aligned throughout the test. The males did not require such adjustment and could clear the heel of the test limb from the ground