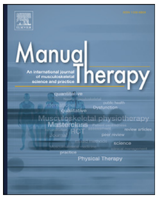
Musculoskeletal Science and Practice xxx (2017) 1–6

Contents lists available at ScienceDirect

Musculoskeletal Science and Practice

journal homepage: https://www.journals.elsevier.com/musculoskeletal-science-and-practice



Technical and measurement report

Influence of stretching velocity on musculotendinous stiffness of the hamstrings during passive straight-leg raise assessments

Ty B. Palmer [a], [*], Nathaniel D.M. Jenkins [b], Brennan J. Thompson [c], Joel T. Cramer [d]

[a] Department of Kinesiology and Sport Management, Texas Tech University, Lubbock, TX, United States
[b] Department of Health and Human Performance, Oklahoma State University, Stillwater, OK, United States
[c] Department of Kinesiology and Health Science, Utah State University, Logan, UT, United States
[d] Department of Nutrition and Health Sciences, University of Nebraska-Lincoln, Lincoln, NE, United States

ARTICLE INFO

Article history:
Received 4 July 2016
Received in revised form
29 December 2016
Accepted 30 December 2016

Keywords:
Stretch reflex
Electromyography
Portable
Range of motion

ABSTRACT

Background: Recently, passive musculotendinous stiffness (MTS) has been assessed manually in the field; however, when conducting these types of assessments, the stretching velocity must be controlled to avoid eliciting the stretch reflex, which can be observed by increased electromyographic (EMG) amplitude of the stretched muscles and greater resistive torque (indicating the assessment is no longer passive).
Objective: To examine the effects of slow, medium, and fast stretching velocities during manually-applied passive straight-leg raise (SLR) assessments on hamstrings MTS and EMG amplitude characteristics.
Study design: Crossover study.
Methods: Twenty-three healthy, young adults underwent passive, manually-applied SLR assessments performed by the primary investigator at slow, medium, and fast stretching velocities. During each SLR, MTS and EMG amplitude were determined at 4 common joint angles (θ) separated by 5° during the final common 15° of range of motion for each participant.
Results: The average stretching velocities were 7, 11, and $18^\circ \cdot s^{-1}$ for the slow, medium, and fast SLRs. There were no velocity-related differences for MTS ($P = 0.489$) or EMG amplitude ($P = 0.924$). MTS increased ($P < 0.001$) with joint angle ($\theta_1 < \theta_2 < \theta_3 < \theta_4$); however, EMG amplitude remained unchanged ($P = 0.885$) across the range of motion.
Conclusions: Although velocity discrepancies have been identified as a potential threat to the validity of passive MTS measurements obtained with manual SLR techniques, the present findings suggest that the SLR at any of the velocities tested in our study ($7–18^\circ \cdot s^{-1}$) did not elicit a detectible stretch reflex, and thereby may be appropriate for examining MTS.

1. Introduction

Passive musculotendinous stiffness (MTS) is a measure of the mechanical properties of the muscle-tendon unit (MTU) and is typically calculated as the slope of the angle-torque curve recorded during passive stretch (Herda et al., 2011). Greater MTS values of the hamstrings measured during a straight-leg raise (SLR) can be found in patients with low back pain (Tafazzoli and Lamontagne, 1996), and the use of a SLR to assess hamstrings flexibility is regarded as a potentially important test for predicting sport-related injuries (Witvrouw et al., 2003). In the laboratory, the utilization of an isokinetic dynamometer during a SLR at a constant velocity may provide an objective, quantitative measurement of MTS (Marshall et al., 2009). However, isokinetic dynamometers are too cumbersome and immobile for assessing MTS in the field (Chen et al., 2001). The need for a manual technique to quantify MTS in applied settings has been suggested and subsequently implemented by previous authors that have used portable, hand-held devices during SLR testing (Palmer et al., 2013, 2014). However, unlike the slow constant-velocity stretch of an isokinetic dynamometer (i.e. $5^\circ \cdot s^{-1}$), modest increases in stretch velocity (i.e. ~$5–20^\circ \cdot s^{-1}$) can occur during these types of manual assessments,

---

[*] Corresponding author. Department of Kinesiology and Sport Management, Texas Tech University, Lubbock, TX, 79409, United States.
E-mail address: ty.palmer@ttu.edu (T.B. Palmer).

http://dx.doi.org/10.1016/j.msksp.2016.12.018
2468-7812/

Please cite this article in press as: Palmer, T.B., et al., Influence of stretching velocity on musculotendinous stiffness of the hamstrings during passive straight-leg raise assessments, Musculoskeletal Science and Practice (2017), http://dx.doi.org/10.1016/j.msksp.2016.12.018

which could elicit the stretch reflex, causing contamination of the passive stiffness measurements (by eliciting active force production and passive tension), and possibly affecting the capacity of the SLR as a diagnostic tool to identify individuals with tight hamstrings (Palmer et al., 2015). In addition, greater movement velocities accompanied by increased stiffness and electromyographic (EMG) activity have been suggested to be more likely to cause muscle injury during stretch (McNair et al., 2002). Consequently, knowledge of the potential velocity variations in MTS and EMG characteristics during a SLR may provide researchers and clinicians with precise guidance on the prescription of stretching speeds to enhance the safety and results of hamstrings stretching interventions for persons with shorter and stiffer muscles.

Although the effects of stretch velocity on passive resistive properties have been examined extensively for computer-controlled passive movements using an isokinetic dynamometer (Gajdosik et al., 2005; Nordez et al., 2008, 2009; Rabita et al., 2005), fewer studies have examined such effects for manually-applied passive movements using portable, hand-held devices. To examine the validity of hand-held dynamometers for the assessment of spastic hypertonia, Lamontagne et al. (1998) and Boiteau et al. (1995) evaluated the resistive forces generated by patients with spasticity at low (i.e. ~5–10$^\circ \cdot s^{-1}$) and relatively high (i.e. ~180–190$^\circ \cdot s^{-1}$) stretch velocities. The authors reported significant velocity-related effects; however, they did not examine the effects of lower, more physiological-based variations in velocity across 3 different speeds (i.e., slow, medium, and fast), nor did they perform testing in healthy individuals. Moreover, because the data used in these studies were limited to muscles surrounding the ankle (Boiteau et al., 1995; Lamontagne et al., 1998), it remains unclear whether potential velocity-related differences exist in MTS for other muscles, such as the hamstrings as assessed during a SLR. Therefore, the purpose of the present study was to examine the influence of stretching velocity on the hamstrings EMG and MTS characteristics measured during manually-applied passive SLR assessments.

2. Methods

2.1. Participants

Twelve healthy men (mean ± SD age = 23 ± 4 yr; mass = 79 ± 11 kg; height = 179 ± 6 cm) and 11 healthy women (age = 19 ± 1 yr; mass = 70 ± 16 kg; height = 166 ± 6 cm) volunteered for this investigation. This study was approved by the university's institutional review board for human subject's research, and all participants signed and completed an informed consent document and health history questionnaire.

2.2. Procedures

Each participant visited the laboratory two times, separated by 2–3 days. During the first visit, participants were familiarized with the testing procedures by performing several manual straight-leg raise (mSLR) assessment trials. For each of these trials, hip joint range of motion (ROM) measurements were taken to ensure participants could achieve the full ROM necessary for the study. To qualify, participants needed to achieve at least 15° of hip flexion from the starting point of the mSLR assessments, which was a hip joint angle of 20° above the horizontal plane. Based on this criterion, of the 23 participants, all were able to achieve the full ROM. During the second visit, participants completed six mSLR assessments involving two assessments at each condition which included slow, medium, and fast stretching velocities. The order of the slow, medium, and fast stretching assessments was randomized and the mean of the two assessments for each velocity for MTS and EMG amplitude was calculated at each joint angle and used for all subsequent analyses.

2.3. Assessment of passive musculotendinous stiffness

Passive MTS of the posterior hip and thigh muscles was examined using an mSLR technique as described previously (Palmer et al., 2013), which consisted of the primary investigator applying resistance against a load cell (LCHD-250, Omega Engineering, Inc., Bridgeport, NJ) positioned immediately posterior to the heel while the limb was moved toward the head at a slow, medium, or fast stretching velocity (Fig. 1). These velocities were controlled by having the investigator count silently (i.e., “one thousand one,” “one thousand two,” and so on) (Lamontagne et al., 1998) so that the movement times for an 80° ROM which was the average ROM of the participants during the familiarization trial, would be approximately 12, 7, and 4 s for the slow (5–7$^\circ \cdot s^{-1}$), medium (10–12$^\circ \cdot s^{-1}$), and fast (18–20$^\circ \cdot s^{-1}$) mSLRs, respectively (because 7$^\circ \cdot s^{-1}$ has previously been classified as a relatively slow, mSLR stretch velocity (Palmer et al., 2013), we classified 18–20$^\circ \cdot s^{-1}$ as a comparatively fast stretch velocity for this particular technique). The movement times for participants with ROM values that were higher or lower than the average ROM were adjusted accordingly so as to keep the stretching velocities consistent between participants. For each mSLR assessment, the knee was braced in full-extension, and the ankle was immobilized in a neutral 90° position (between foot and leg) with a custom-made cast that was fixed around the foot and held with straps above the ankle and over the toes and metatarsals. An electrogoniometer (TSD130B; Biopac Systems, Inc., Santa Barbara, CA) was used to measure the hip joint angle. The distal endblock of the electrogoniometer was aligned with the femur and attached directly to a tight elastic garment worn by each participant. The proximal endblock was attached to a stationary beam that was aligned with the participant's trunk. During the mSLR, participants laid in a supine position with restraining straps placed over the left unstretched thigh and ankle. All mSLR assessments were performed on the right leg to the point of discomfort, but not pain as indicated by the participant, which was regarded as the maximum ROM, at which point the leg was then immediately returned to the baseline position.

2.4. Surface electromyography

Surface EMG was recorded for the biceps femoris from bipolar pre-amplified electrodes (TSD150B; Biopac Systems, Inc., Santa Barbara, CA) with a fixed center-to-center interelectrode distance of 20 mm and a gain of 350. The electrodes were taped directly to the skin and were placed at 50% of the distance between the ischial tuberosity and the lateral epicondyle of the tibia. The electrode placements were based on the recommendations of Hermens et al. (2000). To decrease the interelectrode impedance, the skin was cleansed with isopropyl alcohol before electrode placement. A single pregelled disposable electrode (Ag–AgCl, Quinton Quick Prep; Quinton Instruments Co., Bothell, WA) was placed on the palmar side of the right wrist to serve as a reference electrode.

EMG amplitude values were calculated with a root-mean square (rms) function for 200-ms epochs corresponding to each whole-number degree during the ROM. According to the procedures of Herda et al. (2011), EMG amplitude baseline noise values were subtracted from the EMG amplitude values recorded during the passive mSLR assessments. Furthermore, the corrected EMG amplitude values (μVrms) were normalized to the corresponding pre-stretch isometric maximal voluntary contractions (MVC) peak

Please cite this article in press as: Palmer, T.B., et al., Influence of stretching velocity on musculotendinous stiffness of the hamstrings during passive straight-leg raise assessments, Musculoskeletal Science and Practice (2017), http://dx.doi.org/10.1016/j.msksp.2016.12.018