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The between-day reliability of peroneus longus EMG during walking

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Abstract

The peroneus longus (PL) is a rearfoot evertor, important in frontal plane foot motion. Studying PL function has been limited by previous electromyography (EMG) studies reporting poor between-day reliability. Due to its close proximity to adjacent muscles, EMG measures of PL may be susceptible to crosstalk, thus correct electrode placement is vital. The aim of this study was to use ultrasound to aid placement of small surface EMG electrodes and determine the between-day reliability of PL EMG in healthy participants' walking. Ten participants walked barefoot and shod at a controlled, self-selected speed. Six trials per condition, per session, were recorded over two days (mean (SD): 5 (3) days apart). The muscle belly was located using ultrasound. EMG was recorded with surface electrodes (Trigno™ Mini, Delsys, Inc.) at 2000 Hz. Amplitude was normalized to the peak per gait cycle and time normalized to the gait cycle. Reliability of discrete variables were primarily assessed with the standard error of measurement (SEM), plus the coefficient of multiple correlation (CMC),the coefficient of variation (CV) and the intra-class correlation coefficient (ICC). The pattern of the EMG profile was consistent. The SEM of peak amplitude was 4% (3-8%) and 3% (2-5%) for barefoot and shod respectively. For timing of the peak the SEM was 2% (1-3%) and 1% (1-2%) for barefoot and shod respectively. Low SEM of discrete variables suggests good reliability of PL EMG during walking supporting the future use of this protocol. Therefore activation of PL can be confidently studied in repeated-measures study designs.

Background

The peroneus longus (PL) is a rearfoot evertor and electromyography (EMG) studies have investigated its function. However, reliability is among the most important factors regarding measurement accuracy (Hopkins, 2000) and poor between-day reliability of PL has been reported during walking (Barn et al., 2012; Murley et al., 2010). In patients with rheumatoid arthritis (RA), for example, peak PL amplitude in the combined midstance/propulsion phase had an ICC of 0.03-0.19 and standard error of measurement (SEM) of 17-18% (Barn et al., 2012). If between-day reliability of PL EMG is indeed poor, then our ability to study normal and abnormal activation of PL, and intervention effects, will be limited.

Due to being close to adjacent muscles, EMG measures of PL are susceptible to crosstalk (Campanini et al., 2007). Shifting electrode position can change peak PL activation relative to the central location by up to 29% (SD=13%) (Campanini et al., 2007). Crosstalk from tibialis anterior (TA) particularly, could explain poor between-day reliability of PL surface EMG in the study by Barn and colleagues (2012) if electrodes were inadvertently placed closer to the TA during one session than another. With a small sample size (n=5), the mean difference between sessions would be particularly susceptible to extreme errors in electrode placement. Identifying the borders of the PL with prior ultrasound scanning may facilitate sensor placement. Additionally with small EMG sensors muscle borders can be more easily avoided. The small head (25 mm x 12 mm x 7 mm) of the Delsys Trigno™ Mini sensor (Fig. 1., Delsys, Inc., Boston, USA) makes it suitable for recording from muscles that are difficult to isolate and susceptible to crosstalk (Delsys). The presence of RA may also have added variability by influencing muscle function in the study by Barn et al (2012). The reliability of surface PL EMG in a healthy population is unknown.

Using fine-wire EMG (Murley et al., 2010) eliminates crosstalk, however intramuscular wire electrodes are potentially sensitive to their position relative to active motor units (Kadaba et al., 1985). Possible variation between sessions does not appear to be overcome by normalising to maximum voluntary contractions (MVCs) or dynamic normalisation to a self-selected fast walking speed (Murley et al., 2010). Performing an MVC possibly introduces error, particularly if participants are unfamiliar with performing maximal movements in the frontal plane. Participants may also not truly produce maximum effort if a forceful contraction causes discomfort with fine-wire in the muscle. Furthermore good reliability of PL EMG using surface

electrodes would be advantageous because fine-wire EMG is invasive and requires specialist skills and equipment.

Therefore the aim of this study was to use ultrasound to aid placement of small surface EMG electrodes and determine the between-day reliability of PL EMG in healthy participants' walking.

Methods

Ten healthy participants (two male, eight female), mean (SD) age of 28 (4) years, body height of 1.69 (0.07) m, body mass of 67.13 (9.22) kg walked barefoot and shod in standardized shoes at a self-selected walking speed. Six good trials were recorded per condition in a session, and two sessions were performed over two days, a mean (SD) of 5 (3) days apart. Three-dimensional kinematics and kinetics were recorded simultaneously with EMG through Qualysis Track Manager Software (QTM, version 2.13, Qualysis, Gothenburg, Sweden) in order to normalise EMG to the gait cycle. Reflective markers were placed on anatomical landmarks to track three dimensional movement using 15 infra-red cameras (Oqus 400, Qualysis, Gothenburg, Sweden). Ground reaction force data was recorded using two AMTI force plates (OR6, USA, Type: BP400600, dimensions: 600mm x 400mm). The study conformed to the Declaration of Helsinki and was granted approval by the University of Salford ethics panel and informed consent was obtained per subject.

EMG sensor placement

Firstly approximate sensor location was found on the right leg using the Surface Electromyography for the Non-Invasive Assessment of Muscles (SENIAM) guidelines (Hermens et al., 2000). Specifically, participants laid supine and the lateral malleolus and the fibula head were marked. A third mark was made at 25% of the distance from the fibula head to the lateral malleolus. Secondly the muscle belly of PL was scanned in the transverse plane level with the middle mark using ultrasound at 5-8 MHz (Linear 60 mm probe, Echo Blaster 128 CEXT, Telemed Medical Systems, Milan, Italy). The ultrasound probe was coated in water soluble gel. A blunt metal stick was placed under the probe to gently apply pressure to the skin, to visualise deformation in the ultrasound image level with the two borders of the muscle in turn (Fig. 2.). The probe was removed and a mark was made by the stick with a surgical marker. The marks were typically within ~1 cm of the SENIAM placement in the longitudinal direction, but often more anterior/posterior of the line between the fibula head and malleolus depending on the individual. Marks from session one were not visible in session two. Skin was cleaned of

gel and wiped with an alcohol wipe. The sensing head of a Trigno™ Mini was then affixed between the two marks orientated in the longitudinal direction of the shank and PL muscle fibres. The main sensor of the Trigno™ Mini was affixed over the tibia. Tape was fixed over the sensing head and cable to minimise potential movement artefact. The EMG signal was tested by everting while standing on the left leg. If unsatisfactory the sensor was removed, the location wiped and the sensor reapplied.

Analysis

Marker data were collected, identified and labelled with QTM software (V.2.13, Qualysis AB, Sweden) and then further processed and analysed in Visual 3D (V.6, C-Motion, Inc., USA). Walking speed was controlled in processing using mean stride time. Trials with stride time outside mean±5% were excluded.

A 75 ms window was used to calculate the route mean squared (RMS) EMG from each trial and averaged across all included gait cycles. The RMS signals were exported to ASCII files after normalisation to the gait cycle for further analysis in MATLAB (R2016b). Amplitude was normalized to the peak of each gait cycle and then averaged across trials for each condition. Our previous work found peak normalisation superior to normalising to MVCs in shank muscles for reducing variability (Onmanee, 2016).

Statistics

The SEM is advocated for reliability studies because it is easy to interpret as it is expressed in the units of measurement itself and unaffected by the range of the measurement (Atkinson and Nevill, 1998; Baker and McGinley, 2013; Deschamps et al., 2011; McGinley et al., 2009). Although the intra-class correlation coefficient (ICC) depends on sample heterogeneity (Atkinson and Nevill, 1998; Baker and McGinley, 2013; Hopkins, 2000) and the coefficient of multiple correlation (CMC) depends on the range of the data (McGinley et al., 2009), both are commonly used (Barn et al., 2012; McGinley et al., 2009; Murley et al., 2010). The (ICC (3,1)) and CMC were calculated in order to compare to other reliability studies and because reporting multiple reliability statistics is recommended (Atkinson and Nevill, 1998; Luiz and Szklo, 2005).

The CMC was calculated to compare the average PL EMG profile between sessions using Microsoft Excel. The (ICC (3,1)) and SEM ($SD\Delta/\sqrt{2}$) for the peak and timing of the peak were calculated using a freely downloadable Microsoft Excel spreadsheet for consecutive pairwise

analysis (Hopkins, 2015). The CV was calculated as: (SEM/Grand mean)*100 (Batterham and George, 2003; Hopkins, 2000).

Results

Mean (SD) of PL peak amplitude (% of peak per gait cycle) was 90 (4) on day 1 and 92 (3) on day 2 when barefoot and 87 (7) on day 1 and 91 (3) on day 2 when shod. The timing of initial PL activation (% of the gait cycle) was 44 (2) on both days when barefoot and 45 (3) on day 1 and 44 (2) on day 2 when shod.

The EMG profiles of PL were repeatable in both barefoot and shod (Fig. 3.), with very good CMCs (0.91 and 0.88 respectively). Reliability of discrete variables was moderate to very good for PL for all statistics except the ICC for peak amplitude. For barefoot, reliability was generally moderate for the peak (SEM: 3% (2-5), ICC: 0.23 (-0.33-0.67), CV: 3%) and very good for the timing of the peak (SEM: 1% (1-2) of gait cycle, ICC: 0.85 (0.52-0.96), CV: 2%). Similarly for shod, reliability was moderate for the peak (SEM: 4% (3-8), ICC: 0.44 (0-0.82), CV: 5%) and very good for the timing of the peak (SEM: 2% (1-3) of gait cycle, ICC: 0.72 (0.20-0.92), CV: 3%).

Discussion

The aim of this study was to determine the reliability of PL EMG in walking. The PL EMG profile and discrete variables were repeatable, supporting the future use of this protocol.

The between-day reliability of discrete EMG variables in PL was more reliable in our study than in the study by Barn et al. (2012). In the previous study the SEM (95% CI) for peak amplitude in early stance was 19% (-53, 51) and 12% (-27, 40) for barefoot and shod respectively. Low reliability might be expected in early stance if crosstalk with TA was present because there is high levels of TA activity in this phase. Considering the peak in the combined midstance/propulsion phase, when PL is most active, the SEM for peak amplitude was 17% and 18% for barefoot and shod respectively in the previous study, but only 3% and 4% in our study. The SEM of the time of peak in the combined midstance/propulsion phase was 8% and 9% in the previous study and 1% and 2% in the present study for barefoot and shod respectively.

The greater between-day reliability in the combined midstance/propulsion phase in the present study versus the earlier study may be due to differences in power, study populations, and/or normalisation. Barn et al. (2012) acknowledged the limitation of a sample size of five, due to

the challenge of recruiting RA patients. They also suggested that RA may have contributed to the variability in both raw and normalised EMG signals. Fluctuations in inflammatory cytokines can influence muscle function and subsequent EMG recordings and variability in MVCs may have been an issue as differences in joint tenderness between days may affect the capacity to perform an MVC (Barn et al., 2012). A limitation of our study is that only healthy participants were tested, thus reliability of this approach with patients is unknown.

The ICC (3,1) for peak PL amplitude in barefoot walking in our study 0.23 (-0.33-0.67) was worse than the ICC (2,1) of peak PL amplitude in the midstance/propulsion phase during barefoot walking in the earlier study using fine-wire: 0.53 (0.17–0.77) and 0.52 (0.15–0.76) for MVC and sub-maximum normalisation respectively (Murley et al., 2010). However in the study by Murley et al. (2010) a systematic bias (% mean difference) of 7.7% existed between sessions for peak amplitude in the combined midstance/propulsion phase using sub-maximum normalisation. The difference in mean of peak amplitude in the present study while barefoot was only 2% and the SEM 3% (2-5) and CV (3%) were low despite poor reliability according to the ICC. The ICC (3,1) of 0.85 (0.52-0.96) in our study for time of peak amplitude barefoot was superior to time of peak in midstance in the earlier study ICC (2,1): 0.58 (0.27–0.78). Differences between the studies may be due to differences between fine-wire and surface EMG. Repeatability is similar in soleus, TA and medial gastrocnemius for surface and fine-wire EMG (Bogey et al., 2000; Onmanee, 2016). However it is unknown if these results apply to PL because motor units could be distributed differently in PL and if a different number of active motor units are recorded from between sessions then this could affect between-day reliability (Onmanee, 2016). Nonetheless the present protocol is less invasive than fine-wire EMG.

In conclusion, the PL EMG profile was repeatable between sessions during barefoot and shod walking. Good reliability was also demonstrated for the majority of statistical measures of reliability for peak PL amplitude and time of peak amplitude. Therefore activation of PL can be confidently studied in repeated-measures study designs like interventions using this protocol.

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Declaration of conflicting of interests

The manuscript was prepared by J.R. The preparation of the manuscript was primarily supervised by C.N. All authors were involved in the drafting and approving of the manuscript. C.N. owns equity in a company that manufactures foot orthoses. Other authors have no conflicts of interest to declare.

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a) b)

Fig. 1. Delsys Trigno™ Mini sensor to scale, shown a) from above and b) the electrodes on the underside

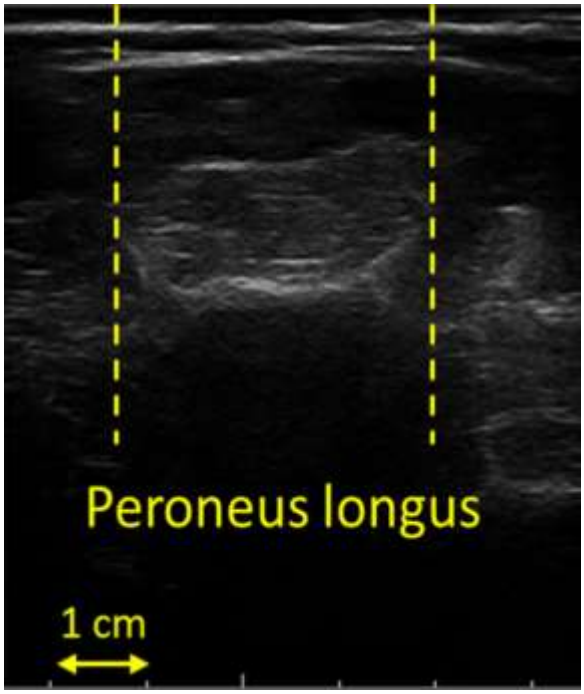

Fig. 2. Ultrasound image of the peroneus longus in the transverse plane, dashed lines indicate the borders of the PL muscle

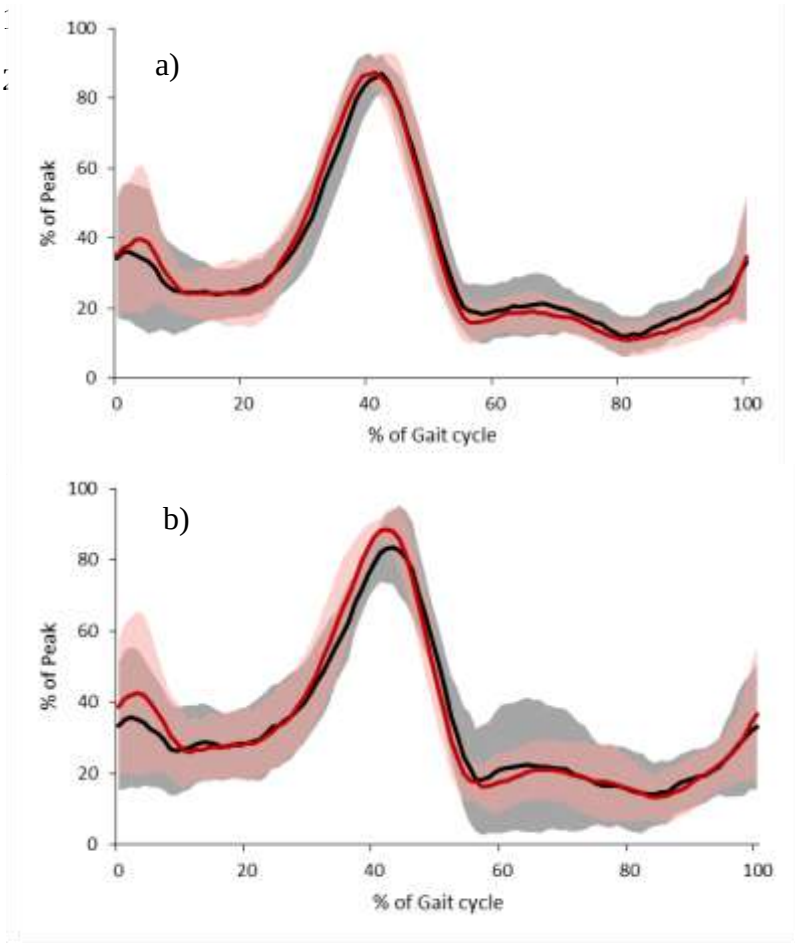

Fig. 3. Peroneus longus EMG average profiles ± SD expressed as a percentage of the gait cycle in a) barefoot and b) shoes. Day 1: black lines and Day 2: red lines