INTRODUCTION

The ability of an individual to generate maximal quadriceps torque is dependent mainly upon motor unit activation characteristics. This assessment can often be considered invalid should its reproducibility be in question. Furthermore, the median frequency (MF) of sampled EMG signals during maximal voluntary efforts is inherently variable both within and between multiple trials. The purpose of the present investigation was to assess MF variability and reliability of the quadriceps during multiple trials of maximal voluntary efforts. A second purpose of this study was to examine MF differences between the 3 superficial portions of the quadriceps femoris muscles.

PROCEDURES

Subjects for this study consisted of 30 healthy male and female volunteers (mean age=23.1±2.2 yr, mean hgt=170.8±9.8 cm, mean wgt=68.8±13.2 kg). Motor unit activation variability and reliability, as well as muscle differences in MF, were assessed in all subjects during 3 maximal isometric voluntary contractions. Isometric torque was measured on the Biodex System II Isokinetic Dynamometer while subjects were in a comfortable, upright seated position. The subjects were secured using thigh, pelvic and torso straps in order to minimize extraneous body movements. Gravity correction was obtained by measuring the torque exerted on the dynamometer resistance adapter with the knee in a relaxed state at full knee extension. During the contractions, each subject folded their arms and was given verbal encouragement and visual feedback from a computer monitor in an attempt to achieve a maximal torque level. Once the knee of each subject was fixed at a 60 deg flexion angle, 2-3 sub-maximal followed by 2-3 maximal contractions for familiarization purposes were performed. Subjects were then asked to contract their quadriceps as hard as they could and to sustain the contraction for 5 sec. This contraction was repeated 2 more times with a minimal rest of 2 min in between each contraction.

Motor unit activation was assessed via the frequency spectrum for the vastus medialis (VM), vastus lateralis (VL), and rectus femoris (RF) muscles. Pre-amplified bipolar circular surface electrodes (Ag/AgCl) was placed on pre-determined areas of each muscle with a fixed inter-electrode distance (center to center) of 2 cm. The reference electrode was placed over the medial shaft of the tibia. EMG activity was collected at 1000 Hertz (CMRR = 87 dB at 60 Hertz, input impedance of >25 Mohms at dc) with a gain of 10K. The signals collected within the first and last second of each 5 sec MVC was not used for analysis. A power spectral analysis was then performed on the resultant 3 sec window for each muscle. A fast Fourier transformation of 512 points (Hanning window processing) was
performed on 11 consecutive, 512 msec segments, overlapping each other by half their length (256 msec), for each 3 second contraction. The MF was determined from each of the 11 overlapping windows. The mean and standard deviation (SD) of the 11 windows during each contraction was then calculated, for each muscle. These 2 values were then used for statistical analyses.

To determine reliability of the MF (mean and SD), intraclass correlation (ICC-2,1) coefficients were calculated for each muscle across the 3 trials. The standard errors of measurement (SEMs) and 95% confidence intervals (CI) were then calculated and subsequently expressed in units of each variable to estimate the expected trial-by-trial variability range for MF. To assess any muscle or trial differences or interactions, a 2 factor ANOVA with repeated measures was performed on the calculated mean values from the 11 overlapping windows. In order to evaluate differences in MF variability, a 2 factor ANOVA was also performed on the calculated SD from the 11 overlapping windows. Analysis of the SD in this manner was based mainly upon the assumption that these data display ratio characteristics. Therefore, trial-to-trial variability differences that may be inherent to this method of using overlapping windows to average MF could be determined. All tests of significance were performed at an alpha of p<0.05.

RESULTS AND DISCUSSION

The mean absolute torque level (+SD) for each of the 3 MVCs were as follows: MVC₁ – 214.3±63.3 N•m, MVC₂ – 218.9±62.6 N•m, and MVC₃ – 218.8± 63.4 N•m. The calculated ICC between the 3 MVC’s was 0.98, and the SEM was 8.9 N•m (4.1% of the mean). The 95% CI for the SEM value was found to be 3.4%-4.8%. The results from this study demonstrated a significant muscle main effect for the mean MF across the 3 MVCs (F₂,₅₈=66.5, p<0.05). Specifically, pair-wise contrasts showed that MF was highest for the VL (157.9±23.9 Hz), followed by the RF (120.2±19.9 Hz) and VM (105.7±21.4 Hz) muscles. The results also demonstrated that the variability associated with calculating an average MF from a series of overlapping windows was different among the 3 muscles (muscle main effect: F₂,₅₈=8.0, p=0.001). Pair-wise contrasts revealed that variability was highest for the VL (10.4±3.4 Hz) followed by both the VM (8.0±4.2 Hz) and RF (7.8±3.6 Hz). Variability for the latter 2 muscles was not significantly different.

Reliability for the calculated MF mean for the 11 windows was found to be high (ICC= 0.85-0.96) with relatively low SEMs (4.2-8.3 Hz) and 95% CIs. Conversely, reliability of the SD of the 11 overlapping windows was found to be low (ICC=0.13 – 0.45) with relatively high SEMs (2.7-3.3 Hz) and CIs. The findings from this study demonstrates that inter-trial MF reliability for the superficial quadriceps muscles is high, while within-trial variability measures display low inter-trial reliability estimates. These findings also show higher MF for the VL than the other 2 muscles, and higher MF for the RF than the VM muscle.

SUMMARY

The surface EMG signal sampled from the quadriceps muscles during maximal effort contractions can be considered “quasi-random” in nature. High and low reliability estimates for between trial MF mean and variability, respectively, supports this contention. Furthermore, relatively higher MF observed for the VL suggests that future inquiry focus on a possible adaptation response of this muscle as a result of habitual reliance during daily activities.