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Innervation zone location of the biceps brachii, a comparison between genders and correlation with anthropometric measurements

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ABSTRACT

Avoiding the innervation zone (IZ) is important when collecting surface electromyographic data. The purposes of this study were threefold: (1) to examine the precision of two different techniques for expressing IZ location for the biceps brachii, (2) to compare these locations between men and women, and (3) to determine if IZ movement with changes in elbow joint angle is related to different anthropometric measures. Twenty-four subjects (mean ± SD ages = 21.8 ± 3.5 yr) performed isometric contractions of the right forearm flexors at each of three separate elbow joint angles (90°, 120°, and 150° between the arm and forearm). During each contraction, the location of the IZ for the biceps brachii was visually identified using a linear electrode array. These IZ locations were expressed in both absolute (i.e. as a distance (mm) from the acromion process) and relative (i.e. as a percentage of humerus length) terms. The results suggested that the estimations of IZ location were more precise when expressed in relative versus absolute terms, and were generally different for men and women. The shift in IZ location with changes in elbow joint angle was not, however, related to height, weight, or humerus length.

1. Introduction

One of the most important practical issues in surface electromyography (EMG) is determining proper positioning of the electrodes on the surface of the skin. Of particular importance when addressing the issue of electrode location is the innervation zone (IZ) of the muscle. The IZ is a collection of neuromuscular junctions that occupy a relatively small, localized region of a muscle (Masuda et al., 1985). Action potentials originate within this region and travel in opposite directions away from the IZ toward the tendonous regions. Previous studies have shown that when bipolar electrode arrangements were placed over or near the IZ, the absolute EMG amplitude values were lower (Farina et al., 2001; Piitulainen et al., 2008; Rainoldi et al., 2000), the frequency values were higher (Farina et al., 2001; Li and Sakamoto, 1996; Piitulainen et al., 2008; Roy et al., 1986), and conduction velocity estimates were unstable (Nielsen et al., 2008; Roy et al., 1986) when compared to electrode arrangements that were away from the IZ. Thus, it has been suggested (Farina et al., 2001; Nielsen et al., 2008; Piitulainen et al., 2008; Rainoldi et al., 2004; Rainoldi et al., 2000) that the IZ should be avoided when recording surface EMG signals.

A multichannel, linear electrode array has been recommended to non-invasively determine the location of the IZ (Merletti et al., 2003). The EMG channel from the array that demonstrates minimal amplitude and phase reversal is then used to estimate the location of the IZ (Merletti et al., 2003). However, the linear electrode array is a relatively new methodology. Thus, there are many surface EMG laboratories that do not have the necessary resources to record multiple surface EMG signals from a muscle. In these circumstances, it is important to be able to estimate the IZ location such that it can be avoided when positioning the electrodes.

Previous studies have also shown that the IZ moves with changes in joint angle. For instance Rainoldi et al. (2000), examined the effects of knee joint angle changes on the IZ locations for the vastus lateralis and vastus medialis muscles. The authors found that when the leg was extended over a 90° joint angle change (75°–165°, 180° = full extension of the leg), there were 1 cm proximal shifts in the IZ locations for both muscles. Martin and MacIsaac (2006) also examined IZ location movement with changes in joint angle. These authors (Martin and MacIsaac, 2006) reported a shift of up to 30 mm in IZ location for the biceps brachii with changes in elbow joint angle from 50° to 130° (180° = full extension of the arm). The results from these studies (Martin and MacIsaac, 2006; Rainoldi et al., 2000) suggested that perhaps the location of the IZ should be estimated separately for each joint angle being tested in the experimental protocol.

Additionally, it is unclear if the location of the IZ, or the distance that it moves with changes in joint angle, differs on a subject-by-subject basis. Specifically, it is possible that differences in height and/or limb length could cause the absolute location of the IZ (i.e. the distance of the IZ from an anatomical landmark) to differ between subjects. For example, a subject with a relatively long humerus length, and subsequently a long biceps brachii muscle,

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should have an IZ that is located further away from the acromion process than a subject with shorter limbs and muscle lengths. Therefore, it is possible that estimations of IZ locations could be made more precise (i.e. less inter-subject variability) by expressing them as a percentage of limb or muscle length.

Rainoldi et al. (2004) provided estimates of IZ locations for 13 different lower limb muscles. However, no studies have given a similar recommendation for IZ location for the biceps brachii. Thus, the purposes of this study were three fold: (1) to examine the precision of two different techniques for expressing IZ location for the biceps brachii, (2) to compare these locations between men and women, and (3) determine if IZ movement with changes in elbow joint angle is related to different anthropometric measures.

2. Methods

2.1. Subjects

Seventeen healthy men (mean ± SD age = 21.7 ± 4.1 yr; height 1.80 ± 0.09 m; mass 87.3 ± 16.6 kg) and seven healthy women (age = 21.9 ± 1.5 yr; height 1.61 ± 0.08 m; mass 57.0 ± 4.0 kg) volunteered to participate in this investigation. Each participant completed a pre-exercise health and exercise status questionnaire, which indicated no current or recent (within the past six months) neuromuscular or musculoskeletal problems specific to the shoulder, elbow, or wrist joints. The study was approved by the University Institutional Review Board for Human Subjects, and all participants signed an informed consent form prior to testing.

2.2. Isometric testing

The isometric testing was performed on a calibrated Biodex System 3 isokinetic dynamometer (Biodex Medical Systems, Inc., Shirley, NY). The participants were seated with restraining straps over the shoulders and waist, and the elbow was rested on a limb support pad so that the input axis of the dynamometer bisected the longitudinal axis of the shaft of the humerus in accordance with the manufacturer's instructions (Biodex, 1998). Each participant performed submaximal isometric contractions of the right forearm flexors at randomly ordered joint angles of 90°, 120°, and 150° between the arm and forearm. These submaximal contractions were 6 s in duration and used to provide EMG signals for finding the location of the IZ. The participants were instructed to provide an effort corresponding to approximately 50% of their perceived maximal voluntary contraction (MVC) during each contraction, and the location of the IZ was usually identified within three to five trials. Force was not directly measured; however, the dynamometer did guarantee the isometric nature of the effort by not permitting movement of the dynamometer lever arm. Two minutes of rest were allowed between all submaximal contractions, and after testing was completed at the first joint angle, the participant's forearm was moved to the next randomly ordered joint angle, and the testing was repeated.

2.3. EMG measurements

During each contraction, fifteen separate bipolar surface EMG signals were detected from the biceps brachii using a linear 16 electrode array and surface EMG16 data acquisition system (EMG16, LISiN-Prima Biomedical & Sport, Treviso, Italy). The skin over the belly of the biceps brachii was prepared prior to testing by shaving, careful abrading, and cleansing with rubbing alcohol. Conducting gel was then applied to the skin, three reference electrode straps were wrapped around the subject's wrist to reduce electromagnetic noise as much as possible (EMG16, 2006), and a 15-channel electrode array (1 × 1 mm prongs, 2.5 mm interelectrode distance, Ottino Bioelettronica, Torino, Italy) was placed over the belly and most prominent part of the muscle to find the location of the IZ. Specifically, the participant was asked to contract the forearm flexors at approximately 50% of his/her perceived MVC, and the location of the IZ was visually identified by the investigator as the EMG channel that demonstrated minimum amplitude and phase reversal (EMG16, 2006; Shiraishi et al., 1995; Tokunaga et al., 1998; Yamada et al., 1987). The IZ location was identified to the nearest 1.25 mm (half of the interelectrode distance). The 15-channel electrode array was then removed, and the location of the IZ at each joint angle was marked on the skin with a permanent marker. In a few cases in which two innervation zones were present, the one that most clearly showed minimum amplitude and phase reversal was marked. In the case of a wide IZ that occupied multiple channels, the middle of the IZ was used. An example of the linear electrode array and its resulting signals are shown in Fig. 1.

2.4. Anthropometric measurements

Humerus length (mm), height (m), mass (kg), and the three IZ locations were measured upon completion of the isometric testing. All measurements were taken with the subject in the standing position with their arm and forearm relaxed and hanging at their side. Humerus length was estimated as the distance from the

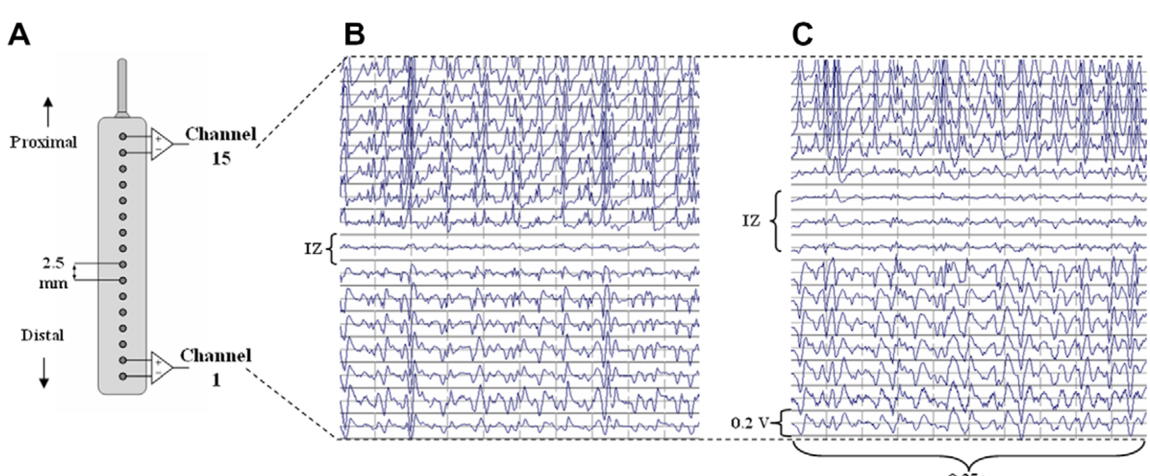

Fig. 1. (A) A representation of a linear electrode array, (B) an example of a narrow-band innervation zone (IZ), and (C) an example of a wide-band IZ. The two signals came from two separate subjects and show the between subject variability in IZ distribution. The wide-band could be due to either a wide IZ or due to multiple motor units that occupy different IZs in close proximity of each other being recruited at the same time.