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Evaluation of extensor digitorum brevis thickness in healthy subjects: A comparative analysis of nerve conduction studies and ultrasound scans

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HIGHLIGHTS

- Extensor digitorum brevis (EDB) thickness was closely associated with fibular nerve CMAP in healthy subjects.
- EDB thickness was greater in men compared to women and decreased significantly with age.
- Muscle thickness with ultrasound is a potentially useful measure of distal neuromuscular function.

ABSTRACT

Objectives: (1) To evaluate the relationship between the thickness and compound muscle action potential (CMAP) of the extensor digitorum brevis (EDB) muscle; (2) to obtain reference values for distal lower extremity muscle thickness as a possible measure of peripheral neuropathy; and (3) to evaluate various factors associated with unexplained EDB atrophy.
Methods: We measured the thickness of EDB, abductor hallucis brevis (AHB) and tibialis anterior (TA) muscles in 80 healthy volunteers with ultrasound and assessed EDB CMAP with fibular nerve stimulation. Two foot muscle-associated lifestyle factors were assessed and sociodemographic information was collected.
Results: A significant correlation was observed between the amplitude of the fibular nerve CMAP and EDB thickness. The thickness of each of the three muscles was greater in men compared to women. EDB thickness decreased significantly with age although the thicknesses of the AHB and TA muscles were not correlated with age.
Conclusions: EDB thickness was closely associated with fibular nerve CMAP but with less variation and differed among groups by age and sex; it was not associated with lifestyle factors.
Significance: The ability to obtain this measure painlessly with ultrasound and its low variation recommend it as a potentially useful complementary measure of distal neuromuscular function.

1. Introduction

Fibular nerve motor conduction studies recording from the extensor digitorum brevis (EDB) muscle are commonly performed in electrodiagnostic laboratories (Oh, 1998). These studies are useful for the diagnosis of polyneuropathies because the distal branches of the fibular nerve are commonly involved (Karsidag et al., 2005).

Ultrasound studies have demonstrated that the thickness of the EDB accurately reflects muscle volume (Ogawa et al., 2012). A prior study has shown that distal muscle thickness can reliably predict changes of the amplitude of compound muscle action potential (CMAP) in diabetic patients (Severinsen and Andersen, 2007). Another study showed reduced EDB thickness after injection of botulinum toxin was correlated to reduced CMAP (Hamjian and Walker, 1994). Small muscle thickness may therefore be a biologic marker of distal neuromuscular disease. In the present study, healthy Korean volunteers underwent a fibular nerve conduction study of the EDB, and ultrasound of the EDB, AHB, and TA muscles to establish reference values and to further investigate demographic and lifestyle factors influencing EDB thickness.

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2. Methods

2.1. Subjects

We recruited 80 healthy volunteers between 20 and 60 years of age through advertisements placed on bulletin boards. The participant pool consisted of an equal number of men ($n = 40$) and women ($n = 40$), with 10 men and 10 women from each age decade. Participants were excluded from the present study if they exhibited symptoms of a peripheral neuropathy, were diagnosed with a medical disease that could cause peripheral neuropathy (diabetes, renal failure, endocrine disorder, or systemic lupus erythematosus [SLE]), were abusers of alcohol, had been exposed to tuberculosis medication or an antineoplastic agent, and/or had a history of trauma or radiculopathy. The present study was approved by our institutional review board.

2.2. Methods

Sociodemographic data including age, sex, height, and weight were collected, and body mass index (BMI) was calculated using height and weight. Additionally, two lifestyle questions potentially associated with the atrophy of foot muscles were also asked, namely whether the participant usually wore comfortable casual shoes or dress shoes (high heel shoes for women) and whether the participant usually sat directly on a mat placed on the floor (Asian custom) or in a chair. Based on the answers to these questions, the participants were divided into three groups: benign lifestyle for the foot muscle (usually wears comfortable shoes and sits in a chair), intermediate lifestyle for the foot muscle (usually wears comfortable shoes or sits in a chair), and stressful lifestyle for the foot muscle (usually wears dress shoes and sits directly on the mat).

The present study assessed high-resolution ultrasound scans obtained using a Philips iU22 scanner (Philips Medical System; Bothell, WA, USA) with a 12 MHz linear array transducer. All measurements were performed by a single ultrasonographer with more than 2 years' experience in musculoskeletal ultrasound. Ultrasound scans of the bilateral EDB, AHB, and TA muscles were obtained while the participant was in a supine position (Fig. 1). We measured diameter with electronic calipers in cross-sectional views of the muscle. The diameter of each of the three muscles was measured at the location of maximum thickness (typically at the muscle's belly) with the transducer held perpendicular to the muscle with minimal pressure to obtain accurate measurements.

Fibular nerve conduction studies were performed using a Medelec Synergy electromyography (EMG) machine (Oxford Instrument Medical Ltd., Surrey, UK) according to standard methods (Oh, 1998). The fibular nerve was stimulated at the ankle and below fibular head. The amplitude of CMAP was measured from the positive peak to the negative peak (peak-to-peak). If the CMAP amplitude is higher with stimulation at below fibular head, fibular nerve was stimulated at a location posterior to the lateral malleolus to determine whether an accessory fibular nerve was present. The amplitude of the CMAP obtained following distal stimulation at the ankle was used to assess the correlation with the thickness of the EDB muscle. The surface temperature of the extremities was maintained between 32 and 34 °C using heat lamps or a thermal fan.

2.3. Statistical analysis

The correlations between fibular nerve CMAP amplitude and the thickness of each of the three muscles were assessed using Pearson's correlation coefficients. Additionally, correlation coefficients between the thicknesses of the three muscles and participants' height, weight, and BMI were calculated. Two-sample *t*-tests were used to compare muscle thickness between men and women, and a one-way analysis of variance (ANOVA) was used to compare the muscle thickness among the different age and lifestyle groups. To estimate the risk factors for EDB atrophy linear regression analysis was applied.

All analyses were performed using SPSS version 19.0 (SPSS Inc., Chicago, IL, USA). All data are presented as means ± standard deviation (SD), and a p-value <0.05 was considered statistically significant.

3. Results

The present study included 80 Korean healthy volunteers (40 men and 40 women) between 20 and 60 years of age (mean age: 39.5 ± 11.0 years). The mean height, weight, and BMI values were 167.1 ± 8.2 cm, 63.2 ± 10.0 kg, and 22.5 ± 2.3 kg/m^2, respectively. The amplitudes of the fibular nerve CMAP were 10.05 ± 3.47 (range 2.2–18.5) mV for the right side and 9.40 ± 3.31 (range 1.7–18.9) mV for the left side (Table 1), and the EDB muscle thicknesses were 5.93 ± 1.25 (range 3.2–9.2) mm for the right side and 6.03 ± 1.20 (range 3.4–9.9) mm for the left side. All muscles were easily visualized and measured with ultrasound. Table 1 shows the thicknesses of the TA and AHB muscles. The coefficient of variation (the standard deviation divided by the mean) of EDB muscle thickness ($R = 0.22$, $L = 0.20$) was much lower than that of the CMAP ($R = 0.35$, $L = 0.35$).

There were significant correlations between the CMAP and the EDB thickness on both sides (Fig. 2); the correlation coefficient (r) was 0.60 ($p < 0.001$) for the right side and 0.50 ($p < 0.001$) for the left side. In contrast, EDB CMAP was not significantly related to TA and AHB muscle thickness. The thickness of the EDB muscle was significantly greater in men compared with women and was significantly correlated with weight, height, and BMI (Tables 1 and 2). The same results were observed for the AHB and TA muscles. Although gender difference in muscle thickness decreased after adjustment of BMI, the difference was still significant in TA and there was a trend in EDB and AHB. Table 2 shows the CMAP amplitude of the fibular nerve and muscles thickness according to age and lifestyle. The older participants exhibited a significant decrease in CMAP amplitude and EDB thickness compared with the younger participants. Additionally, participants with a stressful foot lifestyle had a significantly thinner EDB compared with the benign and intermediate lifestyle groups. However, after adjustment of age and BMI, the lifestyle impact on EDB thickness disappeared. AHB and TA muscle thickness was not correlated with age or lifestyle.

4. Discussion

The primary finding of the present study was that EDB muscle thickness was closely related to the CMAP amplitude. Moreover, in normal subjects, the coefficient of variation of the EDB thickness was substantially lower than that of the CMAP. These findings suggest that EDB thickness measured by ultrasound is a relatively less variable measure of distal muscle biology than CMAP. Taken together with prior studies (Mohseny et al., 2015; Hamjian and Walker, 1994; Severinsen and Andersen, 2007) that have shown a relationship between the size of small distal muscles and function it is possible that EDB thickness could be useful in evaluating fibular nerve pathology.

The present study also determined normal reference values of muscle thickness (EDB, TA, and AHB) and demonstrated a relationship with gender and BMI on the thickness of all three muscles. A prior study has suggested a significant correlation between gender