



Gender, side to side and BMI differences in long thoracic nerve conduction velocity: A novel technique

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ABSTRACT

Objectives: The purpose of this study was to describe a new technique to record long thoracic nerve conduction velocity through the axilla as well as to assist in establishing normative values for latency and amplitude of the long thoracic nerve and to evaluate side to side, gender and BMI differences.

Methods: 26 healthy subjects (12 males/14 females) participated in the study with data collected bilaterally resulting in 52 limbs studied. Surface recording was over the serratus anterior muscle with the recording electrode located on the rib closest to a distance within a standardized range of 22–24 cm distal to the acromion. Stimulation was delivered at the mid axillary line, then again in the supraclavicular region. A caliper was used to measure the distance between the two stimulation sites in order to calculate the nerve conduction velocity.

Results: The normal value (mean + 2 SD) for distal latency is <2.7 msec, while the normal value for velocity (mean – 2 SD) is >61.0 m/s. Absolute amplitude values were not calculated. Side to side difference normal values for distal latency, amplitude and velocity are 0.7 msec, 70.3% and 8.5% respectively. A two way analysis of variance (ANOVA) revealed a significant gender and BMI difference in both distal (0.02) and proximal amplitude (0.05) means. There was no significant interaction between gender and BMI for latency or velocity values for either stimulation site.

Conclusions: The distal latency values are not significantly different from those reported previously, however long thoracic nerve conduction velocity has not been described before and would be an appropriate way to monitor velocity through the proximal portions of the brachial plexus. Men who qualified as overweight with a BMI greater than 25 demonstrated a larger amplitude when compared with average weight men and women. In contrast women with BMI greater than 25 demonstrated a much smaller amplitude when compared with overweight men and average weight men and women.

Significance: Absolute amplitude normal values are not reported as BMI may impact the ability to record an accurate amplitude for both men and women. Long thoracic nerve conduction velocity and latency appear to be more reliable measures.

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1. Introduction

The long thoracic nerve arises proximally from the anterior primary rami of C5,6,7 and often times pierces the middle scalene muscle before descending in the mid-axillary line at an oblique angle superficial to the serratus anterior muscle which it supplies (Hester et al. 2000, Moore et al. 2013). The C5 and C6 components may join and travel together through the scalene muscles before the C7 component joins more distally at the level of the first rib

anterior to the scalene muscles (Olamakin and Karl 2016, Tubbs et al. 2006). Long thoracic nerve injuries can occur due to pressure from backpacks or may occur idiopathically, (Olamakin and Karl 2016) following thoracic surgeries (Belmonte et al. 2014, Krasna and Guillermo 2006) or with trauma due to the superficial location of the long thoracic nerve (Olamakin and Karl 2016). Sports related injuries have been reported related to football, bowling, gymnastics, soccer and hockey (Martin and Fish 2008). Repeated weight lifting and throwing have also been reported to produce long thoracic nerve compression at the level of the middle scalene (Nath et al. 2007). Hester et al. (2000) describes a fascial sling which may entrap the long thoracic nerve at the level of the brachial plexus as the long thoracic nerve travels with the plexus through the axillary sheath (Olamakin and Karl 2016) or again at the level

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of the second rib, while [Laulan et al. \(2011\)](#) report that the long thoracic nerve may be compressed under branches of the thoracodorsal artery. Clinically, patients with long thoracic neuropathy often complain of an ache in the shoulder and scapular region with medial border scapular winging during overhead activities due to serratus anterior weakness in the presence of the unopposed action of the trapezius and the rhomboids ([Martin and Fish 2008](#), [Olamakin and Karl 2016](#)). Persistent serratus anterior weakness from long thoracic injury can result in long term shoulder dysfunction and pain ([Olamakin and Karl 2016](#)).

Long thoracic nerve conduction studies are typically used to assess neuropathic involvement and have been described in several ways using both surface and needle recording electrodes and with both axillary and supraclavicular stimulation. [Kaplan \(1980\)](#) described supraclavicular stimulation with monopolar needle recording from the serratus anterior muscle in 25 subjects. [Seror \(2006\)](#) describes surface recording over the 7th or 8th digitation of the serratus anterior muscle with axillary stimulation and needle recording in the 6th or 7th digitation of the serratus anterior muscle with supraclavicular stimulation in 44 cases. [DePalma et al. \(2005\)](#) examined 15 subjects and described surface recording using a disposable ring electrode placement over the digitations of the serratus anterior muscle vertically beginning at the level of the nipple line with axillary stimulation. Both [Seror \(2006\)](#) and [DePalma et al. \(2005\)](#) describe a large standard deviation relative to the mean values for surface recorded amplitudes indicating that long thoracic amplitude responses may have a degree of variability.

Prior published long thoracic nerve conduction normative studies have not evaluated side to side, gender or BMI differences. The purpose of this study is to describe long thoracic motor nerve conduction velocity through the axilla and to assist in the establishment of long thoracic nerve normative values for latency and amplitude using surface recording. This study also aims to identify if there are significant side to side, gender or BMI differences in a temperature controlled setting.

2. Methods

Twenty-six participants aged 22–30 years old (mean age 23.8 ± 1.8 years of age) were recruited from Belmont University to participate in the study. The mean BMI \pm SD and (range) for all participants was 24.6 ± 2.9 (18.8–31.7). The mean BMI for the females was 23.0 ± 1.9 (18.8–26.7) and for the males was 26.5 ± 2.7 (23.9–31.7). The subjects were tested bilaterally for a total of 52 limbs (24 male and 28 female) studied. Temperature was monitored and remained above 32 degrees Celsius for all participants.

The participants were positioned supine with the arm abducted 90 degrees at the shoulder and a standard re-usable bar recording electrode was taped in a vertical position with the active electrode affixed to the closest rib to a distance of 23 cm distal to the acromion measured along the anterior aspect of the thorax and positioned 2–4 cm anterior to the mid-axillary line. The active electrode was relocated to a rib within a range of 22–24 cm distal to the acromion if necessary to gain a clear initial negative deflection from baseline and if relocation anteriorly along the rib also did not produce a clear initial negative deflection. The reference electrode was 2 cm inferior to the recording electrode, and a ground electrode was placed on the acromion ([Fig. 1](#)). A supramaximal stimulus was then delivered in the supraclavicular ([Fig. 2](#)) and again in the axillary region along the mid-axillary line. A caliper was used to measure the distance between the two stimulation sites and all measurements were taken with the shoulder in 90 degrees of abduction.

The amplitude, latency and nerve conduction velocity values were recorded with a Cadwell Wave EMG machine (Kennewick



Fig. 1. Positioning and establishing recording electrode location. A tape measure was used to measure a distance of 23 cm distal to the acromion and 2–4 cm anterior to the mid axillary line over the serratus anterior muscle fibers. The active component of a standard bar electrode was affixed to the rib nearest to the 23 cm location and repositioned if a clear initial negative deflection from baseline could not be achieved within a range of 22–24 cm from the acromion.

WA). The mean, standard error of the mean and standard deviation as well as mean difference between sides were calculated. Normal ranges were calculated to include upper and lower limits of normal for all parameters assessed using the mean \pm 2 SD and a mean side to side difference \pm 2 SD. A two-way analysis of variance (ANOVA) was used to analyze gender and BMI differences. Significance was set at $P \leq 0.05$. Data were analyzed using SPSS (Statistical Package for the Social Sciences, version 22.0, SPSS Inc., Chicago, IL).

Institutional Ethics Committee approval was obtained for procedures on human subjects and written informed consent was obtained from each subject. This study complied with the 2013 Declaration of Helsinki. Subjects were tested bilaterally and each side was considered a separate participant in establishing group mean values, such that there were 52 limbs included.

3. Results

Subjects were tested bilaterally and each side was considered a separate participant in establishing group mean values, such that there were 52 limbs included. The group mean \pm standard deviation (SD) values are as follows: distal latency 2.1 ± 0.3 msec, distal amplitude 3.4 ± 2.2 mV, proximal amplitude 2.9 ± 2.3 mV and velocity 65.8 ± 2.2 m/s. See [Table 1](#) for both overall and gender specific means and SD values. [Fig. 3](#) depicts a long thoracic waveform.

Absolute normal values were established as a mean \pm 2 standard deviations for latency and velocity. The normal value for distal latency is <2.7 msec, while the normal value for velocity is >61.0 m/s. Absolute normal amplitude values were not calculated. Side to side difference was calculated as a mean difference \pm 2 SD between sides to establish an upper limit of normal variability between sides. See [Table 2](#).

A Two-Way ANOVA revealed significant gender and BMI differences in the distal (0.02) and proximal amplitudes (0.05) only. Average weight men and women had similar amplitude values. However, the men with a BMI over 25 (overweight) demonstrated larger amplitudes when compared with average weight men and women. In contrast, overweight women with a BMI over 25 demonstrated a smaller amplitude when compared with average weight men and women. See [Table 3](#). There was no significant BMI or gender interaction for latency or velocity values.

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