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Research paper

High-resistance strength training does not affect nerve cross sectional area – An ultrasound study

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A B S T R A C T

Objective: The aim was to study the effect of high-resistance strength training on peripheral nerve morphology, by examining properties of peripheral nerves as well as distal and proximal muscle thickness with ultrasound, comparing healthy individuals who perform and do not perform high-resistance strength training.

Methods: Neuromuscular ultrasound was used to examine cross sectional area (CSA) of the median and musculocutaneous nerves, and muscle thickness of the abductor pollicis brevis muscle, biceps brachii muscle, quadriceps muscle and extensor digitorum brevis muscle, in 44 healthy individuals, of whom 22 performed regular high-resistance strength training.

Results: No difference in nerve CSA was found between trained and untrained individuals although trained individuals had thicker biceps brachii muscles. The CSA of the median nerve in the forearm correlated with participants' height and was significantly larger in men than women.

Conclusions: In this cohort, CSA of the median and musculocutaneous nerves was not affected by strength training, whereas gender had a prominent effect both on CSA and muscle thickness.

Significance: This is the first study to examine the effect of high-resistance strength training on peripheral nerves with neuromuscular ultrasound.

1. Introduction

The application of ultrasound in the diagnostic evaluation of neuromuscular disorders is becoming increasingly common and important. Although the more traditional methods of electroneurography and electromyography are still routinely used as diagnostic tools for the nerve and the motor unit, ultrasound is a useful complement in yielding morphological information about the nerve and its surrounding tissues (Suk et al., 2013). Moreover, the structure of peripheral nerves may be affected by trauma and tumors, and the cross sectional area (CSA) is often affected by disorders such as carpal tunnel syndrome/entrapment and neuropathies (Hobson-Webb and Padua, 2016). Several ultrasound studies have evaluated peripheral nerve morphology in arms and legs, contributing reference values and examining the relationship between CSA and factors such as height, weight, age and body mass index (BMI) (Cartwright et al., 2008, 2013, Kerasnoudis et al., 2013, Qrimli et al., 2016).

It is well known that high-resistance strength training (HRST) causes changes in skeletal muscles (Jones and Rutherford, 1987, D'Antona et al., 2006, Folland and Williams, 2007, Seynnes et al., 2007), as well as adaptations of the central nervous system (Moritani and deVries, 1979, Yue and Cole, 1992, Zijdewind et al., 2003). Upper limb muscles gain a greater hypertrophy response to HRST than lower limb muscles (Wilmore, 1974, Cureton et al., 1988). Further, the hypertrophy response of arm muscles is greater in men than women (Kadi et al., 2000), most likely due to the fact that these muscles possess more androgen receptors. Women have approximately 60–80% of the muscle fiber area compared to men (Edwards et al., 1977), while elderly individuals have smaller muscles and fewer muscle fibers compared to younger individuals (Welle et al., 1996). Nevertheless, there is limited knowledge about if and how HRST affects the morphology of peripheral nerves. One previous study examined the skeletal muscle adaptation to

Abbreviations: APB, abductor pollicis brevis muscle; BMI, body mass index; CMAP, compound motor action potential; CSA, cross sectional area; EDB, extensor digitorum brevis muscle; HHD, hand-held dynamometer; HRST, high-resistance strength training.

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resistance training and found a greater increase in muscle thickness of arm muscles compared to leg muscles (Abe et al., 2000). Only one case study has examined the subacute effects of strenuous exercise on nerve remodeling with ultrasound, where both the CSA and the conduction velocity of several peripheral nerves, including the median nerve, were increased following a marathon (Kerasnoudis, 2016). If this holds true in a larger cohort, it could potentially cause misdiagnosis of neuropathy in individuals having completed strenuous exercise. To the authors' knowledge, no other study has assessed how strength training or cardiovascular exercise affects the appearance of peripheral nerves.

The aim of this study was to examine whether individuals who perform HRST on a regular basis have a larger CSA of peripheral nerves than individuals who do not perform HRST. Firstly, we hypothesized that the CSA of the median and musculocutaneous nerves would be larger in trained individuals compared to untrained individuals. Secondly, we hypothesized that trained individuals would have thicker biceps and quadriceps muscles than untrained individuals, and that men would have thicker muscles than women.

2. Material and methods

2.1. Subjects

This study was performed at the Department of Clinical Neurophysiology, Uppsala University Hospital, between April and June 2016. Participants who had previously participated in a study on the use of compound motor action potential (CMAP) as a neurophysiological parameter for HRST (Molin and Punga, 2016) were asked to participate in this follow-up study. For the previous study, participants were divided into two groups based on training regimen: (1) the "trained group", consisting of individuals who reported performing HRST $\geq$ two times per week for at least one year, and (2), the "untrained group", which consisted of participants who reported no strength or cardiovascular training at all or who reported cardiovascular training but no HRST. Exclusion criteria were a family history of neurological disorders, use of muscle relaxant medication or symptoms of muscle fatigue. For this study, the criterion for remaining in the trained group was that the training intensity was *not less* than when participating in the previous study. To stay in the untrained group, participants had to confirm that they had not started performing HRST. Height and weight were once again noted to update these values from the previous study.

CMAP amplitude and area were assessed with motor neurography, with stimulation of the median, musculocutaneous, femoral and peroneal nerves, with recordings of the abductor pollicis brevis, muscle, biceps brachii muscle, rectus femoris muscle and extensor digitorum brevis muscle. The isometric muscle strength of these muscles was assessed with a hand-held dynamometer. Full details on the methods are available in the original article (Molin and Punga, 2016).

The study was approved by the Uppsala Ethical Review Board (Case No. 2014/430), performed in accordance with the ethical standards of the ICMJE and conformed to the recommendations of the Declaration of Helsinki. All participants signed a written informed consent form before participating in the study.

2.2. Ultrasound examination

The ultrasound examinations were performed with a stationary ultrasound device (LOGIQ S8; GE Healthcare). Measurements were performed by either C.J.M., J.W. or biomedical technicians at the Neurophysiology clinic at Uppsala University Hospital. C.J.M. participated in all evaluations in order to gain uniform judgments.

Three nerve sites were chosen for examination: median nerve at the wrist, just proximal to the carpal ligament; median nerve in the forearm, 12 cm proximal to the carpal ligament; and musculocutaneous nerve at the axillary fossa, in the crest between the biceps and deltoid muscle. The probe was adjusted so that it was perpendicular to the nerve. The CSA was measured with the tracer tool, measuring just inside the epineurium. At each predetermined measurement level, we aimed to assess the largest CSA. Three consecutive images and measurements were recorded, and the mean value of these three measurements was used for analysis. Usually there were only minimal differences between the three measurements. The largest CSA was chosen, since this is the parameter commonly used in clinical practice when evaluating neuropathies.

The thickness of four muscles was also measured: the abductor pollicis brevis (APB) muscle, the biceps muscle, the quadriceps muscle and the extensor digitorum brevis (EDB) muscle. Subjects lay supine with muscles relaxed during the examination. The APB and biceps muscle were examined with the forearm supine. The APB muscle was examined with the probe perpendicular to the first metacarpal bone, and was measured from the superficial fascia down to the tendon of the flexor pollicis longus muscle. The biceps muscle was measured approximately two thirds of the distance from the acromion to the elbow crease, and the quadriceps muscle was measured approximately in the middle between the anterior superior iliac spine and the proximal edge of the patella. For all muscles, measurements were taken at the thickest part of the muscle belly. In order to obtain a correct muscle thickness, the transducer was held against the skin with minimal pressure, with a visible layer of ultrasound gel between the transducer and the skin on the ultrasound image, i.e. the transducer had no direct contact with the skin. The largest measured diameter was recorded. Once again, three consecutive images and measurements were performed, and the mean was calculated. The measurements of the biceps brachii muscle also included the brachialis muscle, since the muscle belly was measured from the superficial part of the fascia, down to the part of the fascia adjacent to the humerus. The measurements of the APB muscle also included the superficial head of the flexor pollicis brevis muscle. For the quadriceps muscle, the vastus intermedius muscle belly and the rectus femoris muscle belly were measured individually. The values were then added together in order to obtain a total value of the quadriceps muscle thickness. Unless participants reported sensory or motor symptoms in the right-side extremities, the right arm and leg were examined. For the median nerve, APB and EDB muscles, an L8-18i MHz linear-array transducer was used. For the musculocutaneous nerve, biceps and quadriceps muscles, a ML6-15 MHz linear-array transducer was used. Participants were sitting up during examination of the median nerve and the APB muscle and lay supine with extended legs during examination of the biceps muscle, musculocutaneous nerve, quadriceps muscle and EDB muscle. When measuring the musculocutaneous nerve, participants were asked to place their right hand behind their head while laying supine, in order to expose the crest between the biceps and the deltoid muscle. Participants who reported symptoms of carpal tunnel syndrome (numbness, paresthesias, tingling) were excluded from the examination of the median nerve at the wrist. No participant reported symptoms or showed any signs of any other peripheral neurological disorder.

2.3. Statistical analysis

Statistical analysis was performed with R version 3.2.4 (R Core Team, 2016). A two-tailed independent *t*-test was performed to compare parametric data between the trained vs. the untrained group, and between men and women. Correlation analysis between CSA and age, height and weight was performed with