

Isometric cervical extension force and dimensions of semispinalis capitis muscle

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Abstract—The anatomy of the human cervical region has a special complexity. Ultrasonography is a scanning technique, which has been successfully used to identify and measure the cervical muscle dimensions. The purpose of this study was to detect with the use of real-time ultrasonography the dimensional changes of the human semispinalis capitis muscle (SECM) during isometric cervical extension. Six junior ice hockey players took part in the study. We simultaneously measured the values of estimates, such as breadth or anteroposterior dimension (APD) and width or lateral dimension (LD), of the SECM cross-sectional area during isometric cervical extension at different maximum voluntary contraction (MVC) percent levels (0%, 20%, 40%, 60%, 80%, and 100%). The result of multiplication of the linear dimensions (APD \times LD), considered as the size of the SECM, increased ($p < 0.05$) with increasing the level of the cervical extension force. The correlation between muscle size and extension force of 100% MVC was $r = 0.79$ ($p = 0.05$). The ultrasonography method may be useful in evaluating the function of an individual cervical muscle.

Key words: *cervical, extension, force, size, ultrasonography.*

INTRODUCTION

The human cervical structure is a complex arrangement in which an important array of bones, soft tissues, and vital organs is collected in a closely packed area. Numerous small and large muscles act together to induce head and neck motion. The cervical muscles are also involved in many audiovisual reflexes, which is a complicated factor for routine assessment methods. The posterior cervical muscles extend mainly from the occiput to the thoracic and shoulder regions, and their functions are very important clinically. Among posterior cervical muscles, the semispinalis capitis muscle (SECM) has special physiological and mechanical characteristics in cervical extension [1].

The anatomical dimensions of human skeletal muscles have been used to study the function of the muscle with the use of scanning methods such as ultrasonography [2,3]. Real-time ultrasonography has been shown to be a highly valuable tool in the study of the relationship between muscle force and related muscle size [4–7].

In an ultrasonographic study, Ikai and Fukunaga detected a marked relationship between isometric arm flexion force and the cross-sectional area (CSA) of the arm flexor muscles [5]. They concluded that arm force is

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proportional to the CSA of the related muscles. In addition, they indicated that the CSA of the arm flexor muscles was 34 percent larger at 90° of the elbow flexion compared to the size of the muscle in full elbow extension. In their method, they measured the size of the muscle using ultrasonography while subjects were in a prone position with their arms held in water. Moreover, in the case of the relationship between quadriceps muscle size and knee extension force, the results have revealed a linear correlation between the two variables [7,8]. Another study reported a significant correlation between the quadriceps muscle CSA and the maximal isometric force of the knee extension in old men but not in young men [9]. In these studies, computed b-scanner ultrasonography had been applied to measure the size of the muscles. Later, a significant association between quadriceps muscle thickness and maximal isometric force of knee extensor muscles was reported in both males and females by using a real-time ultrasonography device [10].

Real-time b-mode ultrasound is a form of a scanning method in medical diagnosis and muscle research, by which the scan is dynamically visualized and continually updated. Real-time ultrasonography can easily screen the entire outline of the cervical muscles in the neck area [11,12], where numerous muscles of various sizes are collected in an impact area. With cervical muscle ultrasonography, the values of estimates, such as breadth or anteroposterior dimension (APD) and width or lateral dimension (LD), of the muscles can be measured. The high intertrial and intertester and test-retest reproducibility of the SECM size measurement has been reported in our previous study [12]. The results of our earlier studies and those of the back multifidus muscle study showed that the multiplied linear dimension ($MLD = APD \times LD$) correlated significantly with the CSA of the respective muscle [3,11–13]. So far, we have no studies estimating the individual spinal muscle dimensions simultaneously during contraction. In this study, we measured by using real-time ultrasonography the linear dimensions of the SECM before and during the measurement of the maximal isometric force of the cervical extension. The aim of this study was to quantify the size changes of the human SECM in relation to isometric voluntary contraction force.

METHODS

Subjects

Six male ice hockey players (aged 18 to 20) took part in this study. Characteristics of the subjects are presented in **Table 1**. They had participated in the Finnish national junior leagues and trained on the average six times a week during the last 2 years. All the procedures of this study were approved by the Ethical Committee of the University of Jyväskylä, Finland.

Subject's Position

Each of the subjects was in a sitting position while the head and neck were in a neutral position and the back in an erect position. The trunk was tightly fixed at the level of the iliac spine and the spine of scapula. Both hands were on the thighs, with knees extended, and the feet were resting on a footstool at the height of 15.0 cm. The load cell was against the occiput.

Ultrasonography Measurements

We used a real-time ultrasonography apparatus (Aloka SDD-1400, Tokyo, Japan) to measure the linear dimensions of the SECM. After using a lubricant warm gel, we monitored the left SECM at the C3 level and then froze it as a reference picture on the left side of the screen. The right side of the screen was continuously active to monitor the size variation of the muscle. Linear dimensions (APD and LD) were measured perpendicular to each other as the maximum distance of the muscle outline from border to border from the ultrasound display screen. Shape ratio of the muscle was calculated as LD/APD .

Table 1.

The height, weight, and body mass index (BMI) of the studied subjects ($n = 6$).

Subjects (No.)	Height (cm)	Weight (kg)	BMI*
1	188.4	84.9	23.9
2	177.0	83.0	26.4
3	188.2	83.5	23.5
4	183.3	83.2	24.7
5	182.7	75.7	22.6
6	191.7	84.5	22.9

*BMI = weight/height²

Isometric Measurements

We applied a custom-designed force measurement apparatus to measure the force of the neck extensor muscles [14]. Subjects were instructed to perform three MVCs of neck extension (N), each lasting for 3 to 4 seconds with 5-minute intervals. The order of testing was similar for all subjects. All scanning processes started a few seconds before contraction and lasted to the end of the 100 percent MVC. We recorded muscle force curves using the DATAQ Instruments Codas data acquisition system. The images were recorded concurrently with a videotape recorder. We used the ORVO software (KIHU—Research Center, Jyväskylä, Finland) to synchronize between the muscle pictures and the muscle strength curve. The records were not accepted if the synchronization processes failed. We further displayed and analyzed the synchronized images and force values to evaluate the relationship between the average of the MLDs, LDs, APDs, and ratios of the muscle and the average of cervical extension force at 0, 20, 40, 60, 80, and 100 percent MVCs.

Statistical Analysis

The standard statistical methods were used to compute the means and standard deviations of the variables. We evaluated the reliability of the SECM dimension measurements and neck extension strength measurements at each force level by interclass correlation of coefficient (ICC), calculated from one-way analysis of variance (ANOVA) [15].

We used the Pearson's product moment and linear regression analysis to compute the correlation and association between the average values of linear dimen-

sions and the average values of MVCs at each force level. We then used the paired t-test to compare the difference between both the MLD and shape ratio of the SECM before contraction and during contraction. The statistical analysis was performed with the use of a statistical package for social science (SPSS) software (Windows version 6.1).

RESULTS

The mean ICCs were 0.91 and 0.94 for LD and APD, respectively, and 0.95 for MVC measurements in repeated measurements for all levels of MVC (18 times per subject). The descriptive characteristics of the SECM before and during contraction are shown in **Table 2**. The results of the paired t-test revealed that at maximal neck extension force, the MLD of the SECM increased and the shape ratio decreased significantly compared to the muscle at rest ($p < 0.05$, $p < 0.001$, respectively). **Figure 1** shows the ultrasonographic and schematic pictures of the SECM during contraction. The relationship between the mean values of the MLD of the SECM at a 0 and 100 percent level of the cervical extension force is presented in **Figure 2**.

The levels of the correlation between the MLD of the muscle measured in relaxation and the cervical extension force at 100 percent MVC was $r = 0.73$ ($p = 0.09$). The correlation between MLD and extension force, both measured at 100 percent MVC was $r = 0.79$ ($p = 0.05$). There was no correlation between shape ratio and each level of MVC of the cervical extension force.

Table 2.

Mean \pm SD (standard deviation) and range of cervical extension force, multiplied linear dimension (MLD), and shape ratio of semispinalis capitis muscle (SECM) at different levels of maximum voluntary contraction (MVC) of cervical extension ($n = 6$).

Variables	0% MVC	20% MVC	40% MVC	60% MVC	80% MVC	100% MVC
Extension Force (N)	—	66.2 \pm 5.7 57.8 – 76.5	132.0 \pm 11.6 117.7 – 153.0	199.4 \pm 17.1 176.5 – 229.5	265.0 \pm 22.5 235.4 – 306.0	332.3 \pm 29.7 291.3 – 382.5
MLD(cm^2)	2.22 \pm 0.33 1.56 – 3.30	2.66 \pm 0.54 1.56 – 2.71	2.68 \pm 0.51 1.68 – 3.45	2.77 \pm 0.57 1.80 – 3.53	2.96 \pm 0.64 1.86 – 3.88	3.51 \pm 0.59 2.26 – 4.46
Shape Ratio	5.64 \pm 0.93 4.35 – 7.69	4.23 \pm 1.01 2.88 – 4.04	3.88 \pm 0.89 2.44 – 6.21	3.67 \pm 0.87 2.35 – 5.08	3.60 \pm 0.64 2.69 – 4.70	3.36 \pm 0.56 2.71 – 4.49

MLD = APD \times LD

Shape ratio = LD/APD

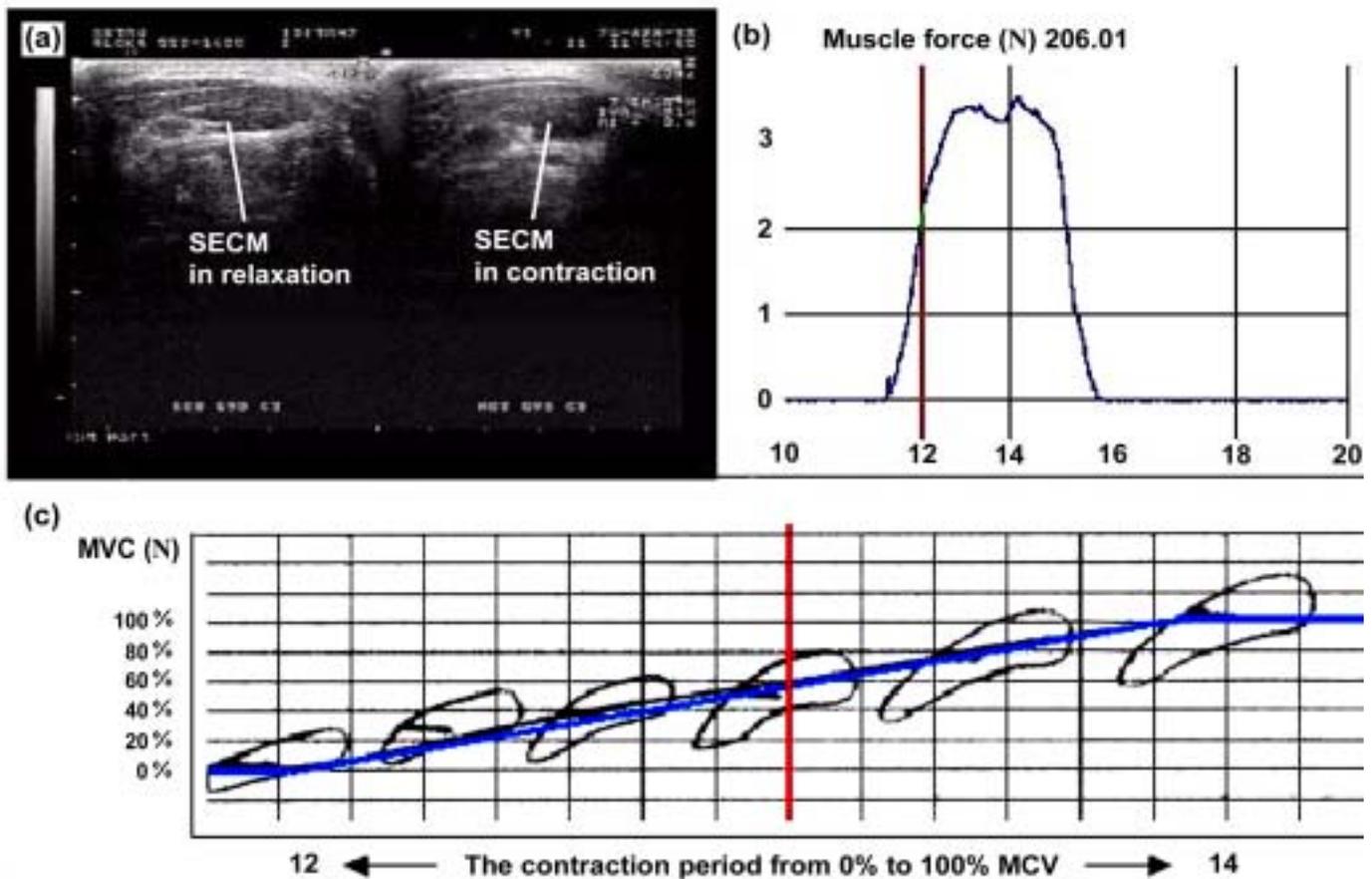


Figure 1.

Ultrasonographic (a) and schematic (c) pictures of semispinalis capitis muscle (SECM) of a subject before contraction and during contraction and (b) isometric neck extension curve from 0% to 100% of maximum voluntary contraction (MVC).

DISCUSSION

A few reports in the literature indicate the association between muscle size and force [5,10,16]. In these studies, muscle size has been measured at rest and compared to the 100 percent MVC of the related force.

The relationship between muscle force and muscle size may lose the applicability in clinical investigation, particularly when pain and reflex inhibition restrict the muscle contraction and force executions [17]. In addition, in some clinical muscle evaluations, like in myopathic patients, muscle force may decrease because of alterations in the morphology of contractile and noncontractile tissues. In these cases, the larger muscle size does not necessarily indicate larger muscle force.

One possible way to determine the actual relationship between muscle size and muscle force may be to

measure muscle function during contraction. The echo amplitude of the quadriceps muscle during contraction has been measured to evaluate the muscle function [18]. Hicks et al. revealed a significant decrease in echo amplitude of the quadriceps muscle during MVC of knee extension [18]. In this regard, further information has been reported in an ultrasonographic study of the vastus lateralis muscle at rest and during MVC of the knee extension [19]. It was indicated that during MVC, the angle between intramuscular echogenic fascia increased significantly, and muscle length decreased largely compared to the relaxation period. Moreover, a marked decrease in fiber angulation of the human vastus lateralis and vastus intermedius muscles from full extension (muscle shortening) to full flexion (stretching) has been demonstrated [20]. Likewise, the physical dimensions of the muscle vary when the muscle is shortened or

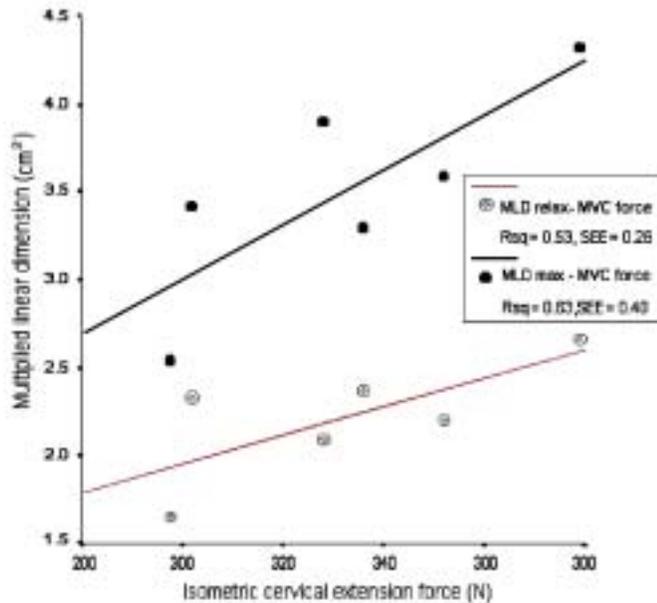


Figure 2.

Relationship between maximal cervical extension force (100% MVC) and multiplied linear dimension (MLD) of SECM measured before contraction (MLD relax) and during maximum voluntary contraction (MLD max). $R_{sq} = R^2$ and SEE = standard error of estimation.

stretched [5]. In our earlier study, MLD of the SECM was shown to enlarge while subjects were keeping the weight of their heads in a prone position [21]. We also found a significant correlation between MLD of the SECM measured at rest and 100 percent MVC of the cervical extension force ($r = 0.82$, $p < 0.001$). In our earlier study, we were not able to make the synchronization between muscle size and muscle force and, consequently, to estimate the SECM size at different submaximal levels of MVC percent [21].

In this present pilot study, we quantified the LD and APD of the SECM from the relaxation period to the maximum level of the cervical extension force. The MLD of the SECM appeared to be proportionate to muscle force at 100 percent MVC. The results of the MLD and shape ratio parameters depicted in **Table 2** and **Figure 1** showed a clear trend of increasing with increasing MVC percent, but only the highest and lowest levels were statistically significant. The inability to identify small changes as statically significant may be a result of the small sample size in this pilot study.

Evaluation of the SECM dimensions appeared to be particularly suitable during muscle contraction. The measurement of the physical dimensions of the SECM is a

quick and simple method compared to the measurement of the cross-sectional area by planimetry. Information on the physiological and anatomical characteristics of the muscle can help clinicians to understand the muscle dysfunction in patients.

The simultaneous measurement of muscle force and muscle size can be of special importance in gaining a lucid understanding of the action of the muscles in such a complex structure as the cervical spine. Monitoring muscle contraction in vivo with ultrasonography can be a novel method for reeducating or training the selected muscle [22]. During muscle contraction, subjects can see the alteration of their muscle outlined on the screen and reinforced by means of visual feedback. Further studies are required regarding applications of the technique of ultrasonography in the biomechanical research, physiotherapy, and rehabilitation fields.

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