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Original Article

Comparison of maximum voluntary isometric contraction of the biceps on various posture and respiration conditions for normalization of electromyography data

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Abstract. [Purpose] Maximum voluntary isometric contraction can increase the reliability of electromyography data by controlling respiration; however, many studies that use normalization of electromyography data fail to account for this. This study aims to check changes in maximum voluntary isometric contraction based on changes in posture and respiration conditions. [Subjects and Methods] Twenty-two healthy volunteers were included in this study. Using 22 healthy subjects, MVIC of the biceps brachii muscle was measured in three respiration conditions: (1) Maximum voluntary isometric contraction during inspiration after maximal expiration, (2) Maximum voluntary isometric contraction during expiration after maximal inspiration and (3) Maximum voluntary isometric contraction during the Valsalva maneuver. The subjects were in tested in standing and supine postures under all three respiration conditions. [Results] A significant difference was observed in the standing and supine postures based on the respiration condition. A significant difference was observed in the maximum voluntary isometric contraction during inspiration after maximal expiration and maximum voluntary isometric contraction during the Valsalva maneuver conditions when the subjects were in the supine posture. [Conclusion] It is necessary to apply the same respiration condition and the same posture to each subject when measuring Maximum voluntary isometric contraction for the normalization of electromyography data.

Key words: Biceps brachii, Maximum voluntary isometric contraction, Respiration

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INTRODUCTION

Maximum voluntary isometric contraction (MVIC) is a very important method with high reliability that is used to measure and evaluate muscle strength[1)]. Moreover, MVIC can be substituted for the normalization of electromyography (EMG) data, which is used to measure muscle conditions in many studies. As such, MVIC has become a very important standard in patient evaluation and studies involving muscle activity.

Although MVIC is the standard method used to evaluate muscle activation, it is measured in diverse ways due to intrinsic and extrinsic factors[2)]. Previous studies have reported that maximal isometric contraction differs according to the condition of the neighboring joint[3)], the time of day the measurement is obtained[4)], the location of the joint[5)], and the contraction of the synergic muscles[6)]. One study has reported muscle activity variability due to psychological impact, such as the subject's motivation[6)]. Moreover, athletes often use MVIC during training to strengthen their muscles in order to achieve better performance and to assist in recovery from injury[7, 8)].

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Table 1. Biceps muscle MVIC according to ventilation condition on stand and supine position

	$MVIC_I$	$MVIC_E$	$MVIC_V$
Stand posture*	456.4 ± 185.2	599.6 ± 259.9†	423.3 ± 198.0
Supine posture*	422.0 ± 186.5	679.9 ± 259.8†	502.7 ± 269.7

Unit: μV, p<0.05, Mean ± SD.
†Significant difference between expiration and inspiration.
$MVIC_I$: MVIC during inspiration after maximal expiration; $MVIC_E$: MVIC during expiration after maximal inspiration; $MVIC_V$: MVIC during Valsalva maneuver

Respiration is an important activity that increases the efficiency of resistance exercise and generates changes in muscles. Stabilizing the body trunk muscle by controlling the respiration condition (e.g., inspiration, expiration, or the Valsalva maneuver) can enhance the activity of limb muscles[9]. In particular, the Valsalva maneuver induces significant contraction power in the limb muscles when the spinal column is stabilized due to elevated intra-abdominal pressure[10]. However, the Valsalva maneuver elevates blood pressure and increases the load on the heart. Hence, it is difficult to use in subjects with cardiovascular system disease[11]. Moreover, an accurate method and mechanism is yet to be clarified, and the specific impact on the limbs is still unclear[12, 13]. Moreover, according to a recent study, higher MVIC activity was observed during expiration instead of during application of the Valsalva maneuver[9, 10]. As such, studies examining MVIC based on the type of respiration condition are continuously being conducted, and more research is needed.

Muscle activation of the lower limb muscles differs with the size of the base of support (BOS) and the height of the center of gravity (COG)[14]. That is, posture is closely related to the movement of muscles as humans cannot escape the force of gravity. However, studies examining MVIC have mainly focused on joint location and muscle length; very few studies have investigated the activation of the biceps brachii muscle on the change of posture.

Hence, three respiration conditions—inspiration, expiration, and the Valsalva maneuver—were applied in this present study to examine the MVIC of the biceps brachii muscle based on respiration condition and posture. Each respiration condition was tested with the subjects in standing posture and supine posture. By investigating the MVIC of the biceps brachii muscle based on the respiration condition and posture, this paper attempts to provide a more reliable standard posture and respiration method when measuring MVIC for the normalization of EMG data.

SUBJECTS AND METHODS

Twenty-two healthy volunteers (13 males, 9 females; age, 25.6 ± 2.4 years; age range 22–29 years; weight, 63.5 ± 10.48 kg; weight range, 47–88 kg; height, 169.8 ± 8.9 cm; height range, 158–187 cm) took part in the experiments. All of the subjects gave their written informed consent and the study was approved by our institutional review board.

Muscle activation was measured in standing posture and supine posture: shoulder flexion 0°, elbow flexion 90°. The subjects performed the following three respiration conditions: (1) MVIC during inspiration after maximal expiration ($MVIC_I$), (2) MVIC during expiration after maximal inspiration ($MVIC_E$), and (3) MVIC during Valsalva maneuver ($MVIC_V$). Each respiration condition was applied randomly to each subject. To ensure the objectivity of the data, the measurements were taken three times under each condition, and the average values were used in the statistical analysis. Each MVIC was held for five seconds. The muscle activation data for the middle three seconds, excluding the first second and the last second, were recorded and averaged for the analysis. To prevent fatigue, the participants took a three-minute break after each five-second MVIC interval.

Surface EMG (MyoSystem TM DTS, Noraxon Inc., USA) was used, and a surface electrode (IWC-DTS and 9113A-DTS, Noraxon Inc., USA), consisting of three electrodes (Positive-Ground-Negative), was used to measure the activation of the biceps brachii muscle on the dominant side. The surface electrode was attached relative to the Surface Electromyography for the Non-Invasive Assessment of Muscles (SENIAM). The frequency of the EMG signal was set to 20–500 Hz and the sampling frequency was 1,024 Hz. Depilation was performed using a razor on the attaching sites; the horny substance was removed with sandpaper. To gather accurate EMG data, the electrodes were attached after the sites were cleaned with an alcohol swab.

The measured data was analyzed using paired sample t-test and Statistical Package for the Social Sciences (SPSS) (version 12.0) for Windows in order to compare the muscle activations at the two different postures. Repeated-measures one-way analysis of variance (ANOVA) with factor tasks was used to compare the muscle contractions during the three different types of respiration conditions: $MVIC_I$, $MVIC_E$, and $MVIC_V$. When necessary, the post-hoc Sheffe's test was used to analyze the significant differences among the various types of respiration conditions. The level of significance was set at $p \leq 0.05$.

RESULTS

Table 1 shows the MVIC results for each respiration condition based on the standing and supine postures. Significant differences in the relative MVIC for the biceps brachii muscle were observed for the three respiration conditions in the stand-

Table 2. Biceps muscle MVIC according to each posture on three ventilation condition

	Stand posture	Supine posture
$MVIC_I$	456.4 ± 185.2	422.0 ± 186.5
$MVIC_E$*	599.6 ± 259.9	679.9 ± 259.8
$MVIC_V$*	423.3 ± 198.0	502.7 ± 269.7

Unit: μV, p<0.05, Mean ± SD

ing posture ($p<0.05$) (Table 1). The post-hoc test found statistically significant differences between $MVIC_E$ and $MVIC_I$ for the standing posture. Significant differences in the relative MVIC for the biceps brachii muscle were observed for the three respiration conditions for the supine posture ($p<0.05$) (Table 1). The post-hoc test found statistically significant differences between $MVIC_E$ and $MVIC_I$ for the supine posture.

Table 2 shows the MVIC results for each posture based on the three respiration conditions. Significant differences in $MVIC_E$, and $MVIC_V$ were observed between the standing posture and the supine posture ($p<0.05$) (Table 2).

DISCUSSION

This study measured the MVIC of the biceps brachii muscle under three respiration conditions, $MVIC_I$, $MVIC_E$, and $MVIC_V$, and two posture conditions, standing and supine postures, in order to examine the impact of respiration condition and posture on the MVIC of the upper limb muscles. The study results indicated strong muscle activity for $MVIC_E$ in comparison to the other respiration conditions. This result can be attributed to the fact that the movement direction of body trunk acted as a substitution for an action against a specific resistance, since the movement direction of the body trunk during inspiration is the same as the contraction direction of the biceps brachii muscle. That is, the resistance that can induce MVIC caused compensation due to the power of trunk extension and rib elevation that is identical to the action direction of the biceps brachii muscle. This phenomenon is believed to be identical in the standing posture and the supine posture.

Moreover, $MVIC_E$ and $MVIC_V$ showed strong muscle activity in the supine posture. It is conjectured that the high activity of $MVIC_E$ and $MVIC_V$ in the supine posture is due to the contraction of muscle in a more stable posture than is possible in the standing posture as expiration and the Valsalva maneuver make the rib cage move in a caudal direction. These results are consistent with the findings in previous literature that reported the impact of posture stability on muscle activation of the limbs[15].

These results imply that the MVIC activity of the biceps brachii muscle is significantly influenced by the respiration condition and posture.

Hence, in the case of measuring MVIC for the normalization of EMG data, the results from previous studies, including studies on joint location and the use of synergic muscles, as well studies on respiration performed on a daily basis, should be equally applied first. Moreover, the change of posture should be considered in addition to the respiration condition. The MVIC measurement should be conducted in an identical posture by controlling the location and movement of the neighboring joint and the body trunk. It is conjectured that the reliability of EMG data normalization must be increased by measuring MVIC after equalizing these conditions.

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