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RELATIONSHIP BETWEEN ANTHROPOMETRIC AND ELECTROMYOGRAPHIC VARIABLES OF THE SCAPULAR MUSCLES

original paper
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ABSTRACT
Purpose. To determine the relationship between skinfolds and onset latency of scapular muscles in healthy young adults.
Methods. A cross-sectional study was carried out at the Biomechanics and Motor Control Laboratory of Saint Thomas University, Talca, Chile. Overall, 36 participants between 18 and 24 years of age were selected. The axillary, pectoral, and subscapular skinfolds were measured, as well as the electromyographic onset latency of the scapular muscles (serratus anterior and trapezius) when performing a voluntary arm abduction task. The Pearson correlation coefficient was used.
Results. There was a positive correlation between the axillary skinfold and the lower trapezius ($r = 0.51$, $p = 0.002$) and serratus anterior ($r = 0.53$, $p = 0.001$) muscle onset latencies, and also between the subscapular skinfold and the lower trapezius ($r = 0.38$, $p = 0.022$) and serratus anterior ($r = 0.73$, $p < 0.001$) muscle onset latencies.
Conclusions. During a voluntary abduction arm movement, a greater thickness of axillary and subscapular skinfolds is related to an increase in the lower trapezius and serratus anterior muscle onset latencies.
Key words: nutritional status, anthropometry, surface electromyography, shoulder

Introduction

Since 1975, obesity has seen a resounding increase worldwide. In 2016, 39% of adults presented as overweight and 13% were obese [1]. Considering these alterations is important to understand etiological factors of chronic diseases, including diabetes, cardiovascular diseases, and cancer [2]. In turn, shoulder problems were reported to be in the third place among musculoskeletal disorders and one of the main limitations in the activities of daily life [3].

The most widely used method for the classification of overweight and obesity is the body mass index (BMI), as it is easy to apply and reproduce [4]. Overweight and obesity are characterized by an accumulation of adipose tissue along the compartments of the human body, especially in the subcutaneous zone (80%) and the central region [5]. This leads to an increase in chronic inflammation, producing skeletal muscle disorders that alter the kinetics, kinematics, and neuromuscular activity of the whole body [6, 7]. In this context, the accumulation of fat has been considered as one of the factors that modify the electromyographic (EMG) record [8]. EMG allows to measure muscular electrical activity, and thus to register the electrical potential during muscular contractions through the expression of the amplitude, latency, and frequency of the EMG signal [8].

Among the methods to measure the central accumulation of fat are the waist circumference index, and subscapular (SB) and suprailiac skinfolds [9, 10]. While skinfold measurement is the most used method for determining the peripheral accumulation of fat in healthy people and athletes [9–11], it has been observed that the accumulation of subcutaneous fat generates alterations in the EMG record [8, 12], specifically

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a decrease of EMG amplitude [13]. Nordander et al. [13] observed a negative relationship between a greater amount of subcutaneous tissue in the arm region and EMG amplitude. On the other hand, some authors describe no relationship between skinfold measurement and muscle activity [14, 15]. De Vito et al. [14] did not note significant results when trying to determine whether adiposity influenced the coactivation of the biceps femoralis, vastus lateralis, and rectus femoralis during an isometric extension of the knee. Despite the above, there are no reports on the relationship of the skinfolds near the scapular region and the onset latency of scapular muscles.

In this context, there are no studies that evaluate the influence of adipose tissue accumulation on the onset latency, especially of muscles that are part of the axial skeleton. The variation of latency is an important indicator of neuromuscular control, as it allows estimation of the recruitment order of the muscles that stabilize and mobilize a joint [16–18]. In this sense, it is important to understand the relationship between skinfolds and the onset latency of the scapular muscles, as if there is a relationship, this would be a determining factor when evaluating, analysing, and interpreting the surface EMG record. Thus, the purpose of this study was to determine the relationship between the skinfolds and the onset latency of the scapular muscles in healthy young adults.

Material and methods

Participants

A cross-sectional study was carried out at the Biomechanics and Motor Control Laboratory of Saint Thomas University (Chile). Participants were selected as a non-probabilistic sample of a group of students of the Faculty of Health of Saint Thomas University. A total sample of 37 subjects was calculated on the basis of an alpha risk of 0.05, power (beta risk) of 0.05, Pearson correlation coefficient estimation of 0.6, and a dropout rate of 0.15. The participants included were males aged 18–24 years. In the sample recruitment, the following exclusion criteria were applied: (1) incomplete shoulder range of motion; (2) history of shoulder pain; (3) participation in overhead sports; (4) observable scapular dyskinesia; (5) history of trauma, dislocation, rotator cuff tear, deformities of the spine, root symptoms, and/or neurological diseases.

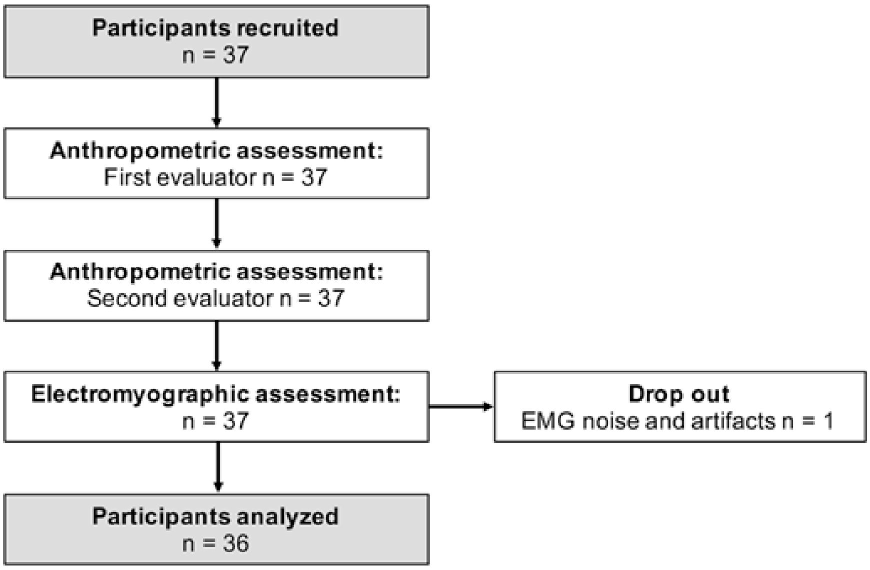
Instrumentation

Body weight was assessed with scales (Seca, Hamburg, Germany; 0.1 kg accuracy); standing height was measured by using a stadiometer (Seca, model 220, USA; 0.1 cm accuracy); and pectoral (PE), axillary (AX), tricipital, SB, ileocrestal, abdominal, and anterior thigh skinfolds were determined with a Lange calliper Model C-130 (Creative Health Products, Inc., Ann Arbor, MI, USA; 0.5 mm precision). Surface EMG and acceleration signals were acquired with a Delsys Trigno™ Wireless sEMG System and recorded with the Delsys EMGworks Acquisition 4.2.0 (Delsys Inc., Boston, MA, USA). The beginning and end of the arm raise task were determined with an accelerometer (Delsys Inc. Boston, MA, USA) on the anterior deltoid surface of the dominant arm [19]. The electrodes were made of silver (99%) and had an inter-electrode distance of 10 mm. The sEMG was sampled at 2000 Hz, amplified with a gain of 300, and filtered with a bandpass filter (fourth-order, Butterworth filter with frequencies between 20 and 450 Hz).

Procedures

The flow chart of the study procedures can be observed in Figure 1. Body weight, height, BMI, and cutaneous skinfolds were assessed. The skinfolds were measured on the participants' right side, in accordance with a protocol described by the International Society for the Advancement of Kinanthropometry (ISAK) [20]. Two certified ISAK level II evaluators performed the measurements. Each skinfold was measured twice by an evaluator (technical measurement error: 0.91%) and a third measurement was made by a different evaluator (technical measurement error: 0.89%). Then, the median of the 3 repetitions performed was selected. The percentage of body fat (%BF) was obtained by the Siri equation, where the body density considered was the one proposed in the Jackson and Pollock equation [21], as this equation was formulated on the basis of a sample from the general population aged 18–61 years, which is the closest to the sample included in the present investigation.

Then, we proceeded to locate the electrodes on the muscles: anterior deltoid, electrode placed in the width of a distal finger and anterior to the acromion; upper trapezius, electrode placed 50% in the line from the acromion to the vertebral column in vertebra C7; middle trapezius, electrode placed 50% between the medial border of the scapula and the spine, at the level of T3; lower trapezius, electrode placed at 2/3 in



EMG – electromyography

Figure 1. Flow chart of the study procedures

the line from the trigonum spinea to T8. These procedures were performed in accordance with the SENIAM recommendations [12]. In the case of the serratus anterior, the procedure was based on a previous investigation [22]. The electrodes were placed in the muscular belly in the mid-AX line of the right side on the fifth rib. Then, the participants performed stretching exercises of the glenohumeral and scapular muscles. Subsequently, they performed a voluntary arm abduction task. This consists of an elevation of the arm in the scapular plane at the rhythm of a cycle of abduction and adduction in 4 seconds, as this speed of movement is considered slow or standard [23]. Before the test, the participants were instructed to reproduce the movement speed following the rhythm established by a metrometer, and they practised the movement twice. Overall, 3 trials were performed, and each considered 3 arm elevations (abduction and adduction cycle). In each trial, the second elevation of the arm was selected; these were averaged for the subsequent analysis.

Statistical analysis

The statistical software SPSS 23.0 for Windows (SPSS Inc., Chicago) was used. The mean, standard deviation, and 95% confidence interval of the skinfold variables and onset latency of each scapular muscle were calculated. In addition, the normal distribution was checked by using the Kolmogorov-Smirnov test. The Pearson correlation coefficient, or *r*, was used to determine the correlation between BMI, %BF, and each skinfold (AX, PE, and SB) and the onset latency of each scapular muscle (upper trapezius, middle trapezius, lower trapezius, and serratus anterior). A Pearson correlation coefficient of 0–0.4 was considered weak; 0.41–0.7, moderate; and 0.71–1.0, strong. The level of significance for all statistical tests was 0.05.

Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Southern Centre Ethics Committee of Santo Tomás University, Chile.

Informed consent

Informed consent has been obtained from all individuals included in this study.

Results

The basic characteristics of the sample are shown in Table 1. One participant was not included in the analysis because their EMG signals presented with excessive noise and artifacts. Therefore, the following results consider 36 subjects. The Kolmogorov-Smirnov test results showed that all of the variables were normally distributed ($p < 0.05$). The Pearson correlation coefficient and significant correlations between scapular muscles and BMI, %BF, and skinfolds are shown in Table 2. Significant relationships were observed between the AX skinfold and lower trapezius ($r = 0.51$,

Table 1. Basic characteristics of the sample

Characteristics	Mean	Median	Standard deviation	95% confidence interval	25th percentile	50th percentile	75th percentile
Age (years)	22.4	22.0	1.9	21.7–23.0	21.0	22.0	23.0
Height (m)	1.74	1.74	0.05	1.72–1.76	1.69	1.74	1.78
Weight (kg)	76.6	76.0	10.5	73.1–80.1	67.4	76.0	82.2
Body mass index (kg/m^2)	25.2	24.9	3.2	24.1–26.3	23.1	24.9	26.8
Body fat (%)	18.2	18.7	3.5	17.1–19.4	15.8	18.7	20.6
Axillary skinfold thickness (mm)	16.6	16.3	3.8	15.3–17.9	13.6	16.3	19.5
Pectoral skinfold thickness (mm)	13.4	13.0	3.4	12.3–14.6	10.7	13.0	16.0
Subscapular skinfold thickness (mm)	23.0	23.0	3.6	21.8–24.2	19.3	23.0	25.0
Upper trapezius onset latency (ms)	–38.4	–45.5	40.5	from –51.9 to –24.9	–72.3	–45.5	–16.2
Middle trapezius onset latency (ms)	–27.1	–34.7	76.9	from –52.7 to –1.4	–89.7	–34.7	48.3
Lower trapezius onset latency (ms)	–29.0	–13.5	62.5	from –49.9 to –8.2	–90.5	–13.5	27.3
Serratus anterior onset latency (ms)	–16.8	–13.5	72.6	from –41.0 to 7.3	–67.9	–23.6	51.8

Table 2. Correlation between skinfold thickness and scapular muscles onset latencies

Parameter	Upper trapezius		Middle trapezius		Lower trapezius		Serratus anterior	
	r	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Body mass index	–0.41	0.070	–0.11	0.509	0.10	0.548	0.23	0.170
Body fat (%)	–0.05	0.737	0.01	0.909	0.24	0.150	0.27	0.102
Axillary skinfold	–0.13	0.436	0.29	0.080	0.51	0.002	0.53	0.001
Pectoral skinfold	–0.12	0.464	0.11	0.511	0.22	0.181	0.27	0.105
Subscapular skinfold	–0.17	0.291	0.29	0.079	0.38	0.022	0.73	< 0.001

p = 0.002) and serratus anterior (r = 0.51, p = 0.53) onset latency, with moderate correlation in both cases. Other significant relationships were found between the SB skinfold and lower trapezius (r = 0.38, p = 0.022) and serratus anterior (r = 0.73, p < 0.001) onset latency, with a strong correlation in the latter case.

Discussion

The results of this study indicate a positive and significant correlation between skinfolds and scapular muscle onset latencies during a voluntary abduction arm task. Specifically, an increase in the onset latency of the lower trapezius and serratus anterior muscles versus a greater thickness of the SB and AX skinfolds was observed. To our knowledge, there are no previous studies that relate skinfolds to the EMG latency of the scapulothoracic musculature, so this research would be the first record on the subject.

Surface EMG analysis has shown great variation among subjects even when performing exactly the same motor task [24]. It has been established that the increase of the thickness of a skinfold affects the EMG signal registration, contaminated by crosstalk, acting as a spatial filter, and decreasing its selectivity [8, 12, 13, 25]. This is reflected in the decrease in amplitude and frequency, considered the most studied EMG variables [13, 26]. The literature indicates that a higher subcutaneous fat content increases the distance between muscle and electrode, attenuating the record of the action potential [26]. The presence of this fat content not only attenuates the signal but also contaminates it by picking up signals from the neighbouring motor units [26]. Another phenomenon described is the cancellation effect, which attenuates the EMG signal through the interaction of the positive and negative phases of the action potential emitted by the motor unit, cancelling each other out and reducing the information captured by the electrode [27].

On the other hand, some authors mention that there is no relationship between skinfold thickness and muscle activity [14, 15]. They did not observe significant results when trying to determine whether adiposity influenced coactivation of the femoral biceps, vastus lateralis, and rectus femoris during the isometric extension of the knee. On the other hand, previous studies have suggested that a higher BMI decreases resistance to fatigue [28, 29] and affects the development of motor tasks [30]. This is because the greater fat content around the muscle has a close relationship with the infiltration of fat in the muscle fibres [5], which favours inflammation and impairs muscular mechanical efficiency [31, 32]. In turn, fatigue affects motor control and the order of recruitment of the scapular muscles during an arm raise task [17]. Therefore, it is important to know the muscle performance prior to the EMG evaluation, since fatigue affects the onset latency and muscle recruitment order. Despite the above evidence, none of these authors specifically refers to the influence of the skinfolds on the onset latency of the scapular muscles.

It is known that the recruitment order of the scapular muscles varies depending on the characteristics of the motor task. For example, during an arm raise, a specific scapular recruitment order is observed [19]. There is an activation pattern from proximal to distal, involving the scapular and spinal stabilizers (serratus anterior and lower trapezius) before the arm mobilizers (anterior deltoid) and the rotator cuff during an arm movement [19, 24, 33]. In this context, our findings indicate that a greater skinfold will cause a delay in the onset latency of the scapular muscles, and therefore an alteration of motor control and performance during an arm raise task. These results should be considered during procedures of acquiring and processing EMG signals in sports science. In addition, fitness professionals should respect the effect of subcutaneous and intramuscular fat of the scapular and shoulder muscles, which can influence muscle metabolic performance in laboratory and field tests.

Within the limitations of this study, the recruitment of only men and the convenience selection criteria of the participants could increase the type I error of the investigation. On the other hand, the measurement of skinfolds is a dependent measurement of the evaluator and expresses an estimate of the subcutaneous fat content and, indirectly, the intramuscular fat. Therefore, it would be useful to carry out future investigations that would relate the skinfolds, the muscular cross-sectional area, and the muscular fat infiltration by means of magnetic resonance imaging and the EMG record.

Conclusions

During a voluntary abduction arm movement, the presence of a greater AX and SB skinfold is related to an increase in lower trapezius and serratus anterior onset latencies. The increase in onset latency may be a consequence of a combination of physical factors (EMG signal attenuation) and metabolic factors (muscle fat infiltration). In this context, the study contributes to the understanding that a greater skinfold influences the objectivity and clinical reliability of the EMG latency registry, this being important for a correct diagnostic approach that leads to optimal rehabilitation. In accordance with the results of this study and previous reports, we asked if there was an optimal percentage of subcutaneous adiposity for a reliable EMG record.

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Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

The authors state no conflict of interest.

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