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Feasibility study of detecting surface electromyograms in severely obese patients

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ABSTRACT

The aims of this study were to examine if surface EMG signals can be detected from the quadriceps femoris muscle of severely obese patients and to investigate if differences exist in quadriceps force and myoelectric manifestations of fatigue between obese patients and lean controls.

Fourteen severely obese patients (body mass index, BMI, mean ± SD: 44.9 ± 6.3 kg/m^2) and fourteen healthy controls (BMI: 23.7 ± 2.5 kg/m^2) were studied. The vastus medialis and lateralis of the dominant thigh were concurrently investigated during voluntary isometric contractions (10-s long at submaximal and maximal intensities and intermittent submaximal contractions until exhaustion) and sustained (120-s long) electrically elicited contractions.

We found that the detection of surface EMG signals from the quadriceps is feasible also in severely obese subjects presenting increased thickness of the subcutaneous fat tissue. In addition, we confirmed and extended previous findings showing that the volume conductor properties determine the amplitude and spectral features of the detected surface EMG signals: the lower the subcutaneous tissue thickness, the higher the amplitude and mean frequency estimates. Further, we found no differences in the mechanical and myoelectric manifestations of fatigue during intermittent voluntary and sustained electrically elicited contractions between obese patients and lean controls.

1. Introduction

In the last 20 years, the detection of surface electromyographic (EMG) signals made outstanding progress in the non-invasive investigation of the neuromuscular system. Surface EMG signal analysis has been adopted in physiological studies to investigate motor unit recruitment strategies and discharge properties (Merletti et al., 2008), myoelectric manifestations of fatigue (Botter et al., 2009; Farina et al., 2004a; Merletti et al., 1990), spinal reflexes (Türker, 2010), muscle architecture and posture (Merletti et al., 2010), and exercise-related muscle damage (Hedayatpour et al., 2009; Piitulainen et al., 2011). However, the technique has also been applied to the investigation of numerous pathological conditions, including neck (Falla and Farina, 2008) and low back pain (Jacobs et al., 2011), fibromyalgia (Casale and Rainoldi, 2011), carpal tunnel syndrome (Rainoldi et al., 2008), temporomandibular disorders (Castroflorio et al., 2008), neurological disorders such as motor neuron diseases, neuropathies, myopathies (Drost et al., 2006), involuntary muscle phenomena such as fasciculations (Kleine et al., 2012), cramps (Minetto et al., 2011), and tremor (Dideriksen et al., 2011). Surprisingly, no surface EMG studies have been performed in obese patients, even if obesity is frequently characterized by increased fatigability and reduced motor performance, especially in the highest degree of disorder that is known as severe obesity or morbid obesity. The reason for the lack of surface EMG investigations of neuromuscular function in obese patients is that myoelectric signal quality is negatively affected by the thickness of the subcutaneous fat. In fact, when surface EMG signals are detected, the motor units and the recording electrodes are separated by biological tissue that can be regarded as a passive volume conductor. The volume conductor properties largely determine the features of the detected surface EMG signals, in terms of their signal amplitude and also in terms of frequency content (Kuiken et al., 2003; Farina et al., 2002, 2004b; Lowery et al., 2004; Roeleveld et al., 1997; Staudenmann et al., 2010).

Complementary to surface EMG detection, neuromuscular investigation can also be performed through analysis of force and mechanical manifestations of fatigue during voluntary and/or electrically elicited contractions. A number of studies have quantified

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muscle strength and physical performance in obese patients, showing that they exhibit greater absolute force (Hulens et al., 2001; Lafortuna et al., 2005; Maffiuletti et al., 2007) and comparable (Blimkie et al., 1989; Rolland et al., 2004) or reduced relative force (adjusted for body mass) (Abdelmoula et al., 2012; Hulens et al., 2001; Maffiuletti et al., 2007) compared to lean controls. However, only two studies have investigated the fatigue profiles in obese patients: adult obese patients showed greater quadriceps fatigability in voluntary contractions and comparable quadriceps fatigability in electrically elicited contractions with respect to adult lean subjects (Maffiuletti et al., 2007), while no differences in mechanical manifestations of fatigue during either voluntary or electrically elicited contractions of the quadriceps have been observed between obese and non-obese adolescents (Maffiuletti et al., 2008).

In this study, we detected surface EMG signals from the quadriceps femoris muscle of obese and lean subjects during non-fatiguing and fatiguing contractions. The aims were to examine if surface EMG signals can be detected from the quadriceps muscle of severely obese patients and to investigate if differences exist in quadriceps force and myoelectric manifestations of fatigue between obese patients and lean controls. To achieve the latter goal, surface EMG signals were detected during two different fatiguing protocols: voluntary intermittent exercise and stimulated sustained exercise. The two contraction modalities have been selected because of their differences in muscle energetics. In fact, intermittent exercise may rely predominantly on aerobic energy supply, while stimulated sustained exercise relies almost exclusively on the anaerobic energy supply (Russ et al., 2002).

2. Methods

2.1. Subjects

Fourteen severely obese patients (body mass index >35 kg/m^2) volunteered to participate in the study. They were admitted at the Italian Institute of Auxology (Piancavallo, Italy) for a 3-week integrated body mass reduction program and were tested at the beginning of the treatment. None of the patients had symptoms or signs referable to overt cardiovascular, respiratory or orthopaedic disease contraindicating the execution of the neuromuscular tests.

Fourteen age- and sex-matched lean controls were also tested. Age, anthropometrical and body composition data of the two subject groups are summarized in Table 1.

Each participant received a detailed explanation of the study and gave written informed consent prior to participation. The study conformed with the guidelines in the Declaration of Helsinki and was approved by the Ethics Committee of the Istituto Auxologico Italiano, Milan, Italy.

2.2. Measures

2.2.1. Bioelectric impedance analysis

It was adopted to assess whole body fat-free mass and fat mass. It was performed in the early morning after an overnight fast, according to a conventional standard technique (Lukaski et al., 1986). Subjects were asked not to drink within 4 h of the test, to empty their urinary bladder at least 30 min before the analysis, and to remain in the supine position for 5 min before the acquisition. The electrodes were placed on the right wrist and ankle of the subjects while lying comfortably supine in a bed with the limbs abducted from the body. Whole-body resistance to an applied current (at 1, 5, 10, 50 and 100 kHz, 0.8 mA) was measured with a tetrapolar device (Human IM, Dietosystem, Milan, Italy). Fat-free mass was calculated with the specific equations derived by Gray et al. (1989).

2.2.2. Surface EMG detection

Three bipolar EMG signals were detected during electrically elicited contraction of the vasti with linear adhesive arrays of four electrodes (1 mm thick, 3 mm long, and 10 mm apart, LISiN, Torino – Spes Medica, Battipaglia, Italy). In order to synchronize the stimulation and the M-wave acquisition, the trigger signal of the stimulator was sampled at 2048 samples/s per channel, digitalized, and stored. The stimulation artefact was removed by offline blanking of 3 ms (Mandrile et al., 2003), starting from the rising edge of each trigger pulse.

Monopolar EMG signals were detected during voluntary contractions of the vasti with linear adhesive arrays of eight electrodes (1 mm thick, 3 mm long, and 5 mm apart, LISiN, Torino – Spes Medica, Battipaglia, Italy). The reference electrode was placed at the ankle.

Before placement of the arrays, the skin was lightly abraded with abrasive paste (EVERI; Spes Medica, Battipaglia, Italy). To assure proper electrode-skin contact, 20 µl of conductive gel was inserted into the electrode cavities of the arrays with a gel dispenser (Multipette Plus; Eppendorf AG, Hamburg, Germany). The surface EMG signals were amplified (128-channel surface EMG amplifier, EMG-USB, LISiN – OT Bioelettronica, Torino, Italy), bandpass filtered (3-dB bandwidth, 10–750 Hz), sampled at 2048 samples/s per channel, converted to digital data (12 bit A/D converter), displayed in real time, and stored on a disk of a personal computer.

2.2.3. Stimulation technique

Stimulation was provided by a programmable neuromuscular stimulator (LISiN, Torino, Italy) equipped with a hybrid output stage to combine the features of a constant-current stimulator during the stimulus with the benefits of a closed-loop zero constant-voltage output after the stimulus (which quickly drives to zero the voltage on the load with low output impedance, allowing a fast discharge of the electrode-skin capacitances to reduce artifact amplitude and duration). Two adhesive stimulation electrodes (35 × 45 mm; Spes Medica, Battipaglia, Italy) were placed over the skin above the muscle (bipolar stimulation). For each stimulation burst, biphasic symmetric rectangular pulses (500-µs duration each) were delivered at the maximal current intensity, identified as follows: M-waves were monitored as the muscle was stimulated at 2 Hz with current pulses of increasing intensity. The stimulation intensity was increased until the M-wave peak amplitude reached

Table 1
Age, anthropometrical and body composition data of the two groups of obese patients ($n = 14$) and lean controls ($n = 14$). Values are mean ± SD.

	Obese ($n = 14$)	Lean ($n = 14$)	P value
Age (years)	37.4 ± 8.8	35.0 ± 12.7	0.6
Weight (kg)	119.0 ± 16.2	68.3 ± 8.8	<0.001
Height (cm)	162.1 ± 9.4	170.0 ± 6.2	<0.001
Body mass index (kg/m^2)	44.9 ± 6.3	23.7 ± 2.5	<0.001
Fat-free mass (kg)	56.4 ± 12.0	51.2 ± 9.7	0.2
Fat mass (kg)	61.5 ± 13.1	17.1 ± 5.4	<0.001
Subcutaneous tissue thickness (mm): vastus lateralis	18.2 ± 9.2	6.6 ± 2.9	<0.001
Subcutaneous tissue thickness (mm): vastus medialis	16.8 ± 9.8	5.7 ± 2.9	<0.001