Journal of Electromyography and Kinesiology 21 (2011) 411–417

Contents lists available at ScienceDirect

Journal of Electromyography and Kinesiology

journal homepage: www.elsevier.com/locate/jelekin

Voluntary and automatic recruitment of superficial and deep abdominal muscles in adults with and without cystic fibrosis

A. Taillon-Hobson [a,e,*], S. Aaron [b], L. McLean [c], M. Bilodeau [a,d,e]

[a] School of Human Kinetics, University of Ottawa, Ottawa, Ontario, Canada
[b] Division Head, Respiratory Medicine, Ottawa Hospital, Ottawa, Ontario, Canada
[c] School of Rehabilitation Therapy, Queens University, Kingston, Ontario, Canada
[d] School of Rehabilitation Sciences, University of Ottawa, Ottawa, Ontario, Canada
[e] Élisabeth Bruyère Research Institute, Ottawa, Ontario, Canada

ARTICLE INFO

Article history:
Received 7 September 2010
Received in revised form 25 February 2011
Accepted 28 February 2011

Keywords:
Abdominal muscles
Cystic fibrosis
Surface EMG

ABSTRACT

Recruitment patterns of the superficial and deep abdominal muscles have been well documented in the general population, but not in a group of individuals with a chronic cough, such as individuals with cystic fibrosis (CF), which may alter the recruitment patterns between the abdominal muscles. Therefore the two objectives of this study were (1) to identify whether recruitment of the superficial and deep abdominal muscles during abdominal hollowing (AH) and unilateral leg load (ULL) tasks differed between individuals with CF and a non-CF control group (C); and (2) to compare the muscle activity between the superficial and deep abdominal muscles across these tasks. *Methods*: Twenty-eight participants (14 with CF and 14 controls) performed (i) AH in supine at three target pressures of a pressure biofeedback unit (PBU) and (ii) a right-sided ULL. Surface electromyography (EMG) of the abdominal muscles was recorded and the amplitude of the signal was normalized to a maximum value (% max). *Results*: A 3-way repeated measures ANOVA showed a muscle × task interaction during the AH, but no between group differences. Bonferonni post hoc tests on pooled data showed the deep abdominal muscles to be significantly more active than the superficial muscles. A 2-way repeated measure ANOVA indicated no group differences during the ULL. *Discussion*: The results of this study demonstrate that adults with stable CF do not recruit their abdominal muscles differently from healthy control subjects during the AH and the ULL tasks. This suggests that coughing is not a risk factor for developing abdominal muscles imbalances in adults with cystic fibrosis.

1. Introduction

The study of abdominal muscle recruitment has gained much interest in the last two decades. Once considered to be recruited as a group (DeTroyer et al., 1990), the abdominal muscles are now recognized to act concertedly yet independently to control the body's centre of mass during postural perturbations (Cresswell et al., 1992; Cresswell, 1993), create axial trunk movements (Urquhart et al., 2005a,b), support respiration (Abe et al., 1996; Misuri et al., 1997; Hodges and Gandevia, 2000b), and control intra-abdominal pressure (Cresswell et al., 1994; Hodges and Gandevia, 2000a). These studies have revealed intricate motor recruitment patterns between the superficial (rectus abdominis (RA), external obliquus (EO)) and the deep (internal obliquus (IO), transversus abdominis (TrA)) abdominal muscle layers, according to the task.

Tasks requiring voluntary and simultaneous activation of the abdominal muscles include trunk flexion, trunk rotation (Williams et al., 1999; Urquhart et al., 2005b) and abdominal bracing (isometric contraction of all the abdominal wall muscles) (Vera-Garcia et al., 2007). Sequential and independent voluntary recruitment of these muscles can become very skilled, as evidenced by the recruitment activity of the RA and the EO in eastern-style belly dancing (Moreside et al., 2008). The standard exercise used to demonstrate the independence of recruitment of the superficial from the deeper layer of abdominal muscles is the abdominal hollowing (AH) exercise. It requires the independent activation of the deep and superficial abdominal muscle layers (Jull et al., 1993; Hodges et al., 1999; Hides et al., 2000, 2006; Urquhart et al., 2005b) and is performed by "drawing-in" of the umbilicus, up and towards the spine. When performed using a pressure biofeedback unit (PBU) to grade the intensity of effort, this exercise highlights the differential activation of the abdominal muscle layers. There is preferential recruitment of the TrA muscle (and to some degree the lower fibers of the IO muscle) at lower target pressures of 42 mmHg to 45 mmHg, while the RA and the EO remain relatively

* Corresponding author at: School of Human Kinetics, University of Ottawa, Ottawa, Ontario, Canada.
E-mail address: atail026@uottawa.ca (A. Taillon-Hobson).

1050-6411/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jelekin.2011.02.006

silent. Higher target pressures of 50 mmHg or 55 mmHg require greater activity of the IO, EO and RA muscles (O'Sullivan et al., 1997; Allison et al., 1998). During the AH maneuver, use of the superficial abdominal muscles during low PBU pressures is considered a substitution pattern (Hides et al., 2000) and indicative of abdominal muscle imbalance, where there is overactivity of the superficial muscles and slower onset in the recruitment of the deep muscles (Comerford and Mottram, 2001). Altered patterns of recruitment of the superficial and deep abdominal muscles are not generally present in the normal population, but have been found in people with non-specific mechanical low back pain (Hodges and Richardson, 1996; Hodges et al., 1999), mechanical low back pain due to spondylolysis/spondilolisthesis (O'Sullivan et al., 1997), and experimentally-induced hypercapnia (Hodges et al., 1997). It has also been suggested that overuse of the superficial abdominal muscles may cause imbalance in the recruitment activity of the superficial and deep abdominal muscles (Sarhmann, 2002). Since coughing requires high levels of activity of the abdominal muscles, chronic coughing could be considered as a task which overuses these muscles, and may therefore cause imbalances of the recruitment activity between the RA, the EO, and the IO/TrA. If this is the case, such differences could be identified using surface electromyography.

The purpose of this study was to compare the recruitment patterns of the superficial and deep abdominal muscles between individuals with stable cystic fibrosis and individuals without CF.

The specific objectives of this study were twofold. The first objective was to identify differences between individuals with stable CF and an age and gender matched non-CF control group (C) in the recruitment of the superficial and deep abdominal muscles during the abdominal hollowing (AH) exercise and during the automatic activity of a unilateral leg load (ULL). The second objective was to compare the relative levels of muscle activation between the superficial and deep abdominal muscles during the AH tasks and the ULL task.

Given that the evidence in the literature suggests a dominance of the superficial abdominal muscles and a decrease in the recruitment of the deeper abdominal muscles during abdominal muscle imbalances, four hypotheses were investigated in this study. These were: individuals with CF would demonstrate (i) higher EMG activity of their superficial abdominal muscles during the AH exercise as compared to the control group and (ii) lower EMG activity of the deep abdominal muscle group during the AH exercise as compared to the control group (iii) higher EMG muscle amplitudes in the superficial abdominal muscles when performing the ULL and (iv) lower EMG amplitudes in the deep abdominal muscles when compared to the control group.

2. Materials and methods

2.1. Sample and recruitment

Fourteen individuals with stable CF (9 women and 5 men) and 14 healthy control subjects (8 women and 6 men) participated in the study. None of the participants had a previous history of stress urinary incontinence, chronic low back pain in the previous six months, or any previous experience with abdominal muscle training or "core strengthening" such as is participating in Pilates® or Yoga. All were in good general health. The participants with stable CF were not included if they had experienced any fever or malaise, change in sputum color or quantity, tiredness, or increase in cough frequency during the week prior to testing. Participants with a neurological disease, a respiratory disease other than cystic fibrosis, or abdominal pain were also not included. All participants signed a written consent form approved by the Ethics Boards of Bruyère Continuing Care, the Ottawa Hospital, and the University of Ottawa. Control subjects were recruited via poster advertisements, and the CF participants were recruited through the Cystic Fibrosis Clinic at the Ottawa Hospital, Ottawa, Ontario, Canada. All participants completed the Leicester Cough Questionnaire (LCQ) (Birring et al., 2003) which was used as an indirect measure of coughing habits as well as to confirm that the CF participants were chronic coughers and that the control group were not chronic-coughers.

2.2. Instrumentation

Surface electromyographic (EMG) signals were obtained using four Delsys differential surface electrodes (DE 2.1 Bagnoli System, Delsys™, Baltimore, Maryland, USA) which were taped to the skin overlying the abdominal muscles, on the right side of the body. The signals were amplified, filtered (band-pass filter 10–1000 Hz, CMRR 92 dB at 60 Hz) digitized at a sampling rate of 1000 Hz using a 1401digital/analog acquisition card (Cambridge Electronic Design Ltd., England) and stored on a personal computer. Data were processed using Spike 2 version 5.6™. The intensity of 40 mmHg on the pressure biofeedback unit (PBU) (Chattanooga model, BP Medical Supplies, USA) was used to confirm that the participants maintained their lumbar spine in a neutral position during the instruction phase. Increasing the PBU intensities served as motor targets during the three AH tasks.

2.3. Procedures

Surface electrodes were positioned and oriented parallel to the muscle fibers over the right abdominal muscles (Ng et al., 1998). The skin was prepared by rubbing with water and shaving the area when necessary. Conductive gel was applied to the electrodes and these were taped to the skin using Delsys™ 2-slot adhesive skin interface tape (Delsys, Baltimore, MD, USA) and further secured using hypoallergenic tape. The following anatomic locations were used for electrode placement: upper fibers of RA (RA-UP) centered 7 cm inferior and 3 cm lateral to the xyphoid process, middle fibers of RA (RA-MID) centered 3 cm lateral to the umbilicus, EO centered 13 cm lateral to the umbilicus, and IO and TrA (IO/TrA) centered 3 cm medial and inferior to the right anterior superior iliac spine (ASIS). These positions have been used previously (O'Sullivan et al., 1997; Allison et al., 1998) and considered valid for measuring deep abdominal muscle function (McGill et al., 1996). A reference electrode was placed over the left ASIS.

Each participant was first asked to perform submaximal and maximal voluntary contractions (subMVCs and MVCs, respectively), as well as a double straight leg raise (dSLR) to serve as normalization conditions for each muscle group. For a given muscle, the maximum EMG amplitude from any of these contractions was then used to normalize the EMG amplitude for the AH and ULL tasks. The subMVCs were performed in crooklying (lying supine, with the head in mid-line resting on two pillows, the hips and knees flexed to 60°) with the arms crossed over the chest and hands reaching to the opposite shoulders. The following physiological movements were performed: trunk flexion (targeting RA-UP and RA-MID) consisting of raising the head and thorax until the inferior angles of the scapulae lifted off the plinth; trunk left rotation (targeting EO) repeating the same movement as for trunk flexion but adding trunk rotation to the left once the inferior angle of the left scapula was off the plinth; and trunk right rotation (targeting the IO/TrA), repeating the movement as for trunk flexion but adding right trunk rotation and focusing on pushing the right scapula to the floor once the right inferior angle of the scapula had lifted off the plinth (McGill et al., 1996). All contractions were