ELSEVIER

Physiotherapy 99 (2013) 78–83

Physiotherapy

Trunk muscle activity while lifting objects of unexpected weight

Masahiro Watanabe [a], Koji Kaneoka [b,*], Yu Okubo [b], Itsuo Shiina [c], Masaki Tatsumura [d], Shumpei Miyakawa [a]

[a] *Department of Sports Medicine, Graduate School of Comprehensive Human Sciences, University of Tsukuba, Ibaraki, Japan*
[b] *Faculty of Sport Sciences, Waseda University, 2-579-15 Mikajima, Tokorozawa, Saitama 359-1192, Japan*
[c] *Mito Kyodo General Hospital, Department of Orthopaedic Surgery, Ibaraki, Japan*
[d] *Ichihara Hospital, Department of Orthopaedic Surgery, Ibaraki, Japan*

Abstract

Objective To determine trunk muscle activity when lifting an object of greater weight than expected, which may contribute to the development of low back pain.
Design Electromyographic evaluation of trunk muscle activity.
Setting University of Tsukuba, Spine laboratory.
Participants Eleven healthy men with a mean age of 24 (SD 2) years.
Interventions Trunk muscle activity was measured when subjects lifted an object with their right arm in immediate response to a light stimulus. Surface and wire electrodes were used to measure the activity of the rectus abdominis, external oblique and erector spinae muscles, and the transversus abdominis and lumbar multifidus muscles, respectively. The lifting tests were performed in three different settings: lifting an expected 1-kg object, lifting an unexpected 4-kg object (erroneously expected to weigh 1 kg), and lifting an expected 4-kg object.
Main outcome measures The muscle activity induced when subjects lifted objects of different weights was compared by calculating the root mean square (RMS) of muscle activity at rest and % maximum voluntary contraction.
Results When the subjects were aware of the weight of the object to be lifted, the activity of the external oblique, transversus abdominis, erector spinae and lumbar multifidus muscles increased immediately after lifting. When the subjects were not aware of the weight of the object to be lifted, the increase in muscle activity was delayed ($P < 0.05$).
Conclusions Trunk muscles may not be able to function appropriately when individuals lift an object that is much heavier than expected.

Keywords: Electromyography; Trunk muscles; Estimate; Feedforward; Low back pain; Rehabilitation

Introduction

Low back pain is one of the most common physical complaints worldwide. To address this problem, guidelines for the clinical evaluation of low back pain have been established in various countries [1]. To the authors' knowledge, a number of these guidelines have not specified any evaluation and treatment methods from the standpoint of physical therapy, and no definitive statements have been made on the function of the trunk muscles, which play an important role in lifting.

Activity of the trunk muscles, especially the deep-seated muscles, is essential to control trunk stability [2,3], and feedforward control of the trunk muscles occurs prior to any movement [4]. It has been reported that an individual changes the response of the trunk muscles depending on the weight of the object to be lifted, in order to control trunk stability [5]. However, various physical factors, such as delayed contraction of the transversus abdominis muscles (the deep-seated trunk muscles) and attenuated muscle activity of the back muscles [6], and psychological factors, such as fear-avoidance [7], have potential effects on chronic low back pain.

The causes of back pain include lifting objects that are heavier than expected and unintentional behaviour [8,9]. Although the mechanism of muscular control of the unstable trunk can be predicted, the reaction of the trunk muscles to unpredicted loads has received little attention. A previous

* Corresponding author. Tel.: +81 429 476 958; fax: +81 429 476 958.
E-mail address: kaneoka@waseda.jp (K. Kaneoka).

0031-9406/$ – see front matter
doi:10.1016/j.physio.2011.09.005

study reported that activity of the trunk muscles, especially the back muscles, occurs when an object is lifted with one hand [10], but few studies have reported on the reactions of the trunk muscles when a subject lifts an object that is heavier than expected.

Against this background, this comparative study investigated the effects of expectation of an object's weight on trunk muscle activity using surface electrodes and wire electrodes.

Subjects and methods

Subjects

Eleven adult men without low back pain were enrolled in the study {mean age 24 [standard deviation (SD) 2] years, mean height 172.1 (SD 6.6) cm, mean weight 67.2 (SD 7.9) kg, all right-handed, mean length of right arm 71.8 (SD 5.1) cm}. The exclusion criteria included a history of lumbar spine disorders, neurological disorders and/or spinal surgery.

This study was conducted in the presence of an orthopaedic surgeon and was approved by the Ethics Committee of the Waseda University Faculty of Sport Sciences. All subjects gave informed consent to participate.

Tests

Each test commenced with the subject sitting on a stool in an erect posture, with the soles of his feet in contact with the floor. The knee and hip joints were flexed at 90°. The right arm grasped an object on a table, and the left arm hung naturally against the side of the body. Each subject was instructed to lift an object from the table up to eye level with his right arm, with the elbow straight, in response to a light stimulus (lifting test). The five steps of the test procedure were performed sequentially (Table 1).

The materials used in the lifting test were 1 kg of sand and 4 kg of lead. These materials were placed in identical containers to make it impossible to distinguish between them based on external appearance.

Table 1
The five test steps.

(1) Recognising a 1-kg object	The subject lifted an object weighing 1 kg, as expected, 10 times to achieve familiarisation with the 1-kg weight. The repetitive trials allowed the subjects to learn the most appropriate way to lift the object.
(2) Lifting the expected 1-kg object and measuring muscle activity	An object identical to that used in Step 1 in external appearance and weight was placed on the table, and muscle activity was measured when the subject lifted the object (one session). A sensor was placed between the table and the object to immediately detect the removal of the object from the table, generating an electromyographic signal.
(3) Lifting the unexpected 4-kg object and measuring muscle activity	An object that looked identical to that used in Step 1 but which differed in weight (4 kg) was placed on the table, and muscle activity was measured when the subject lifted the object. The subject had not been aware of a difference in weight between this object and that used in Step 1.
(4) Recognising a 4-kg object	The subject lifted a 4-kg object placed on the table 10 times to achieve familiarisation with the 4-kg weight.
(5) Lifting the expected 4-kg object and measuring muscle activity	An object identical to that used in Step 4 was placed on the table, and muscle activity was measured when the subject lifted the object.

Electromyography

The activity of 10 muscle types was measured, including the right and left rectus abdominis, external oblique, transversus abdominis, lumbar multifidus and erector spinae muscles. The electromyographic (EMG) signals of the bilateral transversus abdominis and lumbar multifidus muscles were recorded using fine-wire bipolar electrodes fabricated from two strands of urethane-coated stainless steel wire (diameter 0.05 mm; Unique Medical Co Ltd, Tokyo, Japan). The fine wire was threaded into hypodermic needles (23 gauge × 60 mm) with 2 mm of urethane cut off, and the tips were bent back to form 1- and 2-mm hooks. Wire electrodes were sterilised in an autoclave (HighClave HVE-50; Hirayama Manufacturing Corp, Saitama, Japan) at 121 °C for 20 minutes. The electrodes were inserted into the bilateral transversus abdominis (approximately midway between the rib cage and the iliac crest) [11] and lumbar multifidus (approximately 2 cm lateral to the L5 spinous process) [12] muscles under the guidance of ultrasound imaging. Once the electrodes reached the target muscle, it was stimulated electrically and muscle contraction was confirmed visually by ultrasound imaging.

Before the surface electrodes were attached, the skin was rubbed with a skin abrasive and alcohol to reduce skin impedance to a level below 2 kΩ. Pairs of disposable Ag/AgCl surface electrodes (Vitrode F-150S; Nihon Kohden Corporation, Tokyo, Japan) were attached bilaterally, parallel to the muscle fibres, with a centre-to-centre distance of 2 cm, to the rectus abdominis (3 cm lateral to the umbilicus) [13–15], external oblique (midway between the costal margin of the ribs), iliac crest (approximately 45° to the horizontal) [15,16] and erector spinae (3 cm lateral to the L3 spinous process) [14,17] muscles. A reference electrode was placed over the sternum.

Tests on maximum voluntary contraction

For normalisation of the EMG data, a maximum voluntary contraction (MVC) test was performed on the individual