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Biomechanical analysis of low back load when sneezing

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ABSTRACT

Background: Although sneezing is known to induce low back pain, there is no objective data of the load generated when sneezing. Moreover, the approaches often recommended for reducing low back pain, such as leaning with both hands against a wall, are not supported by objective evidence.

Methods: Participants were 12 healthy young men (mean age 23.25 ± 1.54 years) with no history of spinal column pain or low back pain. Measurements were taken using a three-dimensional motion capture system and surface electromyograms in three experimental conditions: normal for sneezing, characterized by forward trunk inclination; stand, in which the body was deliberately maintained in an upright posture when sneezing; and table, in which the participants leaned with both hands on a table when sneezing. We analyzed and compared the intervertebral disk compressive force, low back moment, ground reaction force, trunk inclination angle, and co-contraction of the rectus abdominis and erector spinae muscles in the three conditions.

Findings: The intervertebral disk compressive force and ground reaction force were significantly lower in the stand and table conditions than in the normal condition. The co-contraction index value was significantly higher in the stand condition than in the normal and table conditions.

Interpretation: When sneezing, body posture in the stand or table condition can reduce load on the low back compared with body posture in the normal sneezing condition. Thus, placing both hands on a table or otherwise maintaining an upright body posture appears to be beneficial for reducing low back load when sneezing.

1. Introduction

Low back pain (LBP) is a common and major health problem, which can have sizeable socioeconomic impacts due to substantial direct and indirect social costs associated with LBP-related disability and loss of work [1,2]. In fact, most adults at some point in their lives experience some degree of LBP, of which approximately 85–90% of cases are classified as non-specific LBP [3,4]. In some instances, LBP is characterized as recurrent [5,6]. A recent report in Japan suggested that the lifetime prevalence of LBP was as high as 83% and the 4-week prevalence was 36%, making it the fifth-most common reason for medical consultation among outpatients [7].

Various factors can cause acute onset of non-specific LBP, including lifting and bending [8], and strategies for reducing low back load during such actions have been investigated from a biomechanical viewpoint using indicators for low back load such as the low back moment (LBM) and intervertebral disk compressive force (CF) in the lower back [9,10]. In clinical practice, sneezing is often reported to aggravate LBP. Indeed, Walker et al. reported sneezing to be an indicator of mechanical LBP [11], and Vroomen et al. [12] observed that 33% (40/122) of patients with LBP radiating in the leg but without radicular syndrome felt more pain on coughing, sneezing, or straining.

Sneezing occurs frequently as a respiratory reflex triggered to expel foreign bodies that mechanically irritate the nasal mucosa [13,14]. Characterized by explosive exhaling, sneezing is said to

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cause strong concentric contraction of the rectus abdominis (RA) muscles and often sudden forward inclination of the trunk when in an upright posture. This forward inclination increases the lever arm from the center of rotation of the lower back to the center of mass in the upper body, thereby increasing the LBM. Moreover, since the forward trunk inclination angle (TA) is suddenly increased while sneezing, it is assumed that the acceleration applied to the center of gravity (COG) of the trunk also increases. This increase in acceleration entails a strong increase in the force that bends the trunk, so the erector spinae (ES) muscles must contract to maintain posture. Forward trunk inclination and ES contraction are reported to increase the CF [15], and therefore sneezing can be regarded as an action that increases low back load. However, no studies to date have reported objective measurement and biomechanical analysis of the low back load when sneezing.

Various types of media targeting people with LBP often recommend maintaining an upright posture or leaning with both hands on a table when sneezing to counter such pain [16]. These recommendations are made despite the lack of evidence for their efficacy. In this study, we conducted biomechanical tests to verify the hypothesis that maintaining an upright position or leaning with both hands on a table when sneezing reduces the low back load.

2. Methods

2.1. Subjects

Participants were 12 healthy young men (mean age, 23.25 SD 1.54 years; mean height, 170.30 SD 4.00 cm; mean weight, 60.90 SD 7.39 kg) with no history of LBP or spinal column pain. All provided written consent to participate after the study protocol was approved by institutional ethics committees.

2.2. Experimental conditions

Measurements were conducted under the following three conditions (Fig. 1): NORMAL condition for sneezing, characterized by forward trunk inclination; STAND condition, deliberately maintaining an upright posture of the trunk when sneezing; and TABLE condition, bending the trunk and leaning with both hands on a table when sneezing. Subjects stood on force plates and freely chose the distance between their feet and the position of their hands on the table. Subjects induced sneezing by irritating the nasal mucosa with a long, thin strip of tissue paper [17]. Measurements were taken 3 times under each experimental condition. In total, 9 trials with 1-min recovery intervals were conducted.

2.3. Experimental setup

Fig. 1 shows the measurement system used. Movement was recorded with a three-dimensional (3D) motion capture system (Vicon 612, Vicon, Oxford, UK) consisting of four force plates (AMTI, Watertown, MA) and 12 infrared cameras with a sampling rate of 120 Hz. Thirty-two infrared (IR)-reflective markers (diameter, 14 mm) were attached to each subject: top of the head, C7 spinous process, T10 spinous process, L5 spinous process, manubrium sterni, xiphoid process and bilaterally on the acromion process, lateral epicondyle, ulnar styloid process, anterior and posterior superior iliac spine, iliac crest, acetabulofemoral joint, medial knee joint, lateral knee joint, medial and lateral malleoli, and the first and fifth metacarpophalangeal joints. The obtained physical coordinates and ground reaction force (GRF) data were processed with a 6 Hz and 18 Hz second-order low-pass Butterworth filter (dual-pass for zero lag), respectively [18].

To measure muscle activity during movement, electromyograms were obtained (Biometrics, Newport, UK) at a sampling rate of 1000 Hz for the right RA (1 cm to the side of the umbilical region and 2 cm to the side of the medial line) [19] and the right ES (2 cm to the side between the L4 and 5 vertebrae) [20]. Electrodes were attached to only the right side because the left and right sides were expected to behave in a similar manner. Electromyography signals were prefiltered, producing a bandwidth of 20–460 Hz, and amplified with a differential amplifier (common-mode rejection ratio > 96 dB at 60 Hz, input impedance > 10 TΩ). Subjects wore a wristband connected to the grounding electrodes on the right hand. Subjects performed in the supine position against gravity with maximum resistance applied by the experimenter to obtain the maximum voluntary contraction of the RA (sit-up with straight leg while imposing resistance to the breast region) and in the prone position to obtain the maximum voluntary contraction of the ES (back extension with their hand resting on their head while imposing resistance to the scapular region) [21]. The subjects were required to produce maximal isometric extension efforts while resistance was provided by a single examiner with a physical therapy license.

Pressure sensors (DKH, Tokyo, Japan) were connected to the electromyographs and force plates to synchronize the

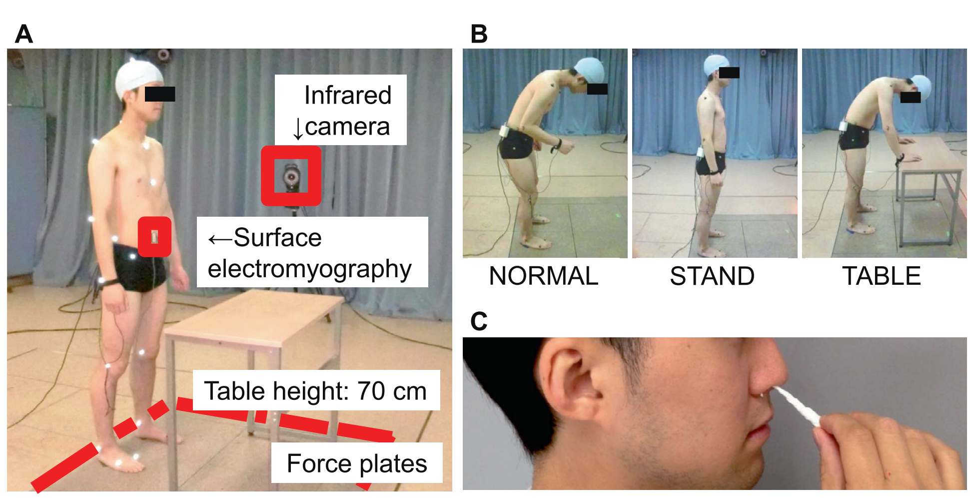

Fig. 1. (A) Experimental setup. (B) The three experimental sneezing conditions examined. In the NORMAL condition, subjects sneezed with no instructions. In the STAND condition, subjects were instructed to maintain an upright position as long as possible. In the TABLE condition, subjects were instructed to immediately place both hands on the table when they felt they would sneeze. (C) To promote sneezing, each volunteer irritated his nasal area using a roll made by twisting a sheet of tissue paper.