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Original article

The effect of active sitting on trunk motion

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Abstract

Background: Prolonged sitting is a risk factor for low-back pain. The primary purpose of this study is to determine if prolonged active sitting will result in increased trunk motion.
Methods: Fifteen healthy female participants volunteered to sit for 30 min on each of three surfaces including an air-cushion, a stability ball, and a hard surface. Trunk motion was monitored using a Vicon motion capture system, and foot center of pressure was collected with two AMTI force plates.
Results: Our findings indicated that the average speed of the trunk center of mass significantly increased with seating surface compliance. There were significant differences in right and left foot centers of pressure in the antero-posterior direction between the ball and air-cushion conditions and the ball and chair conditions.
Conclusion: Active sitting results in increased trunk motion and could have a positive effect on low-back health.
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Keywords: Active sitting; Air-cushion; Center of pressure; Low-back pain; Stability ball; Trunk motion

1. Introduction

Presently, there is a high incidence of low-back pain, which is a major health care concern. In the United States alone, the total costs for low-back pain surpass US$100 billion per year.[1] Indirect costs due to lost wages and decreased job-related productivity account for two-thirds of these costs.[2] Prolonged sitting is a well-known risk factor for low-back pain.[1] A possible reason is that it could result in extended static loading of spinal tissues.[3,4] Continuous static compression on the intervertebral disks was surmised to alter water and proteoglycan contents as well as bring alterations in the structure of the motion segments and the annulus fibrosus architecture.[5] The negative effects from prolonged sitting include compromised disc nutrition, lack of spinal movement, and increased pressure on the discs.[6] Thus, dynamic sitting (e.g., active sitting) is suggested for individuals sitting for extended periods of time.[3]

Active sitting is classified as the use of an unstable seating surface which requires the user to engage in more trunk movement to maintain an upright sitting posture. This type of sitting can be performed on an extremely compliant surface, such as a stability ball, or a moderately compliant air-cushion placed on the seat of a chair. In general, the following benefits garnered from active sitting have been suggested: increased burning of fat tissue, reduced pressure on the vertebrae, encouraged contraction of core muscles, increased control and awareness of body position, and better spinal positioning during sitting.[3,4,7–11] Some of the mentioned benefits have been biomechanically examined. For example, a recent study showed that sitting on unstable surfaces (stability ball or air-cushion) leads to a greater caloric expenditure.[11] It was also reported that sitting on an unstable surface results in greater

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spinal motion.[6] Interestingly, activation levels of the superficial core muscles (lumbar multifidus, internal oblique, iliocostalis lumborum pars thoracis, external oblique, rectus abdominus, and erector spinae) were found to be similar between sittings on stable and unstable surfaces.[6,11] It was speculated that profound core muscles may be more active during active sitting.[6] To date, biomechanical analyses of active sitting were constrained to data obtained from 5 to 10 min sitting tests.[6,11] As prolonged sitting was thought to inflict low-back conditions,[2] it is important to examine the trunk biomechanics during active sitting over a longer time period (e.g., 30 min or more).

Furthermore, the effect of active sitting on the pattern of foot center of pressure has been overlooked in the past. Although it was reported that sitting on an unstable surface results in increased spinal motion,[6] it is not clear whether core muscles are exclusively used to modulate the trunk position. In a recent study, some leg muscles such as hip adductors, soleus, and tibialis anterior were found to increase their activity levels as the level of sitting compliance increases.[11] Thus, it may be possible that lower-extremities may partially contribute to the adjustment of the trunk posture during active sitting. However, it has yet to be determined whether lower extremities play a role in maintaining trunk posture during active sitting. In particular, the patterns of the foot center of pressure need to be examined.

The primary purpose of this study was to determine if increased seating surface compliance would result in increased trunk motion during prolonged sitting. As the seating surface becomes unstable, there could be an increase of the trunk motion. We hypothesized that the stability ball and air-cushion conditions would significantly increase trunk motion signified by increased trunk range of motion (T_ANG), trunk angular speed (T_AVEL), and trunk center of mass speed (T_COM), compared to the stable chair condition. The secondary purpose of this study was to examine whether lower-extremities are involved in active sitting. As seating surface compliance increases, it may be possible to have some contribution from the lower-legs to the adjustment of the trunk posture. Thus, we hypothesized that the unstable seating surfaces may lead to increases of foot center of pressure speed during sitting.

2. Methods

2.1. Subjects

Fifteen healthy females (age = 25.8 ± 10.3 years; height = 164.1 ± 7.1 cm; mass = 64.5 ± 12.8 kg) who sit for an average of 8 h per day volunteered for this study. Participants had a body mass index below 30 kg/m^2 (23.8 ± 3.7 kg/m^2), no known neuromuscular conditions, no history of low-back pain, and were able to sit for three 30-min sessions while maintaining upright posture. Each participant completed an informed consent document approved by the Ball State University Institutional Review Board.

2.2. Experimental protocol

Participants completed three different sitting tasks in a randomized order. The sitting tasks included sitting on an Automatic Abs air-cushion (Licensing Services International Inc., Philadelphia, PA, USA), a stability ball (Cando®; Fabrication Enterprises Inc., White Plains, NY, USA), or an immobile surface (chair) for a duration of 30 min each while kinematic and ground reaction force data were collected. A 5-min break was offered between each sitting condition. The immobile surface condition required participants to sit on a wooden box 40 cm in height without a backrest. In the air-cushion condition, the participants sat on the same wooden box with an Automatic Abs air-cushion placed on top. The Automatic Abs air-cushion was an air-filled cushion 30.5 cm in diameter and 5 cm thick. During the stability ball condition, the participant sat on a stability ball 177 cm in circumference.

The sitting posture was standardized for all participants. For each condition, participants were instructed to place each foot on a separate force plate. Participants remained seated with an upright trunk, their hands resting on their thighs, and their knees flexed at 90° during data collection. For the duration of each trial, the participants viewed a 52-inch flat screen television 20 feet away which displayed a television show at approximately eye level. All participants wore compression shirts and shorts and were barefoot during testing.

2.3. Data collection

Anthropometric measurements were taken of each participant, including height, weight, leg length, anterior superior iliac spine and posterior superior iliac spine distances, ankle, knee and wrist width, shoulder offset, and hand thickness. Thirty-two retro-reflective markers (diameter = 14 mm) were placed on the participant using a modified Plug-in-Gait model with additional makers placed over the fifth metatarsal head, the sacrum, and the superior rim of the side of the iliac crest. Past research had examined and verified the validity of the Plug-in-Gait protocol in a gait laboratory setting.[12,13] To ensure reliability of the experiment, an experienced researcher (KW) was designated to perform subject measurements and marker placements for all the participants. Posture was monitored by 12 Vicon MX-40 infrared cameras sampling at 60 Hz (Vicon; Oxford Metrics, Oxford, UK). The Vicon system tracked the position of the reflective markers in space for the duration of each trial. Ground reaction forces at the feet were collected using two AMTI OR6-7 force plates (Advanced Mechanical Technology Inc., Watertown, MA, USA) sampling at 600 Hz by placing one foot on each force plate. Data were processed using Vicon Nexus v.1.7 and the biomechanical variables were calculated using Visual 3D v.4.9 (C-motion Inc., Germantown, MD, USA).

Trunk angle, trunk center of mass, and center of pressure were measured for each sitting trial. Trunk angle was defined as the angle between the pelvis and the trunk around the medio-lateral (ML), antero-posterior (AP) axis, and the

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