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Effects of natural posture imbalance on posture deviation caused by load carriage

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ABSTRACT

Purpose: The purpose of this study was to explore posture deviation variability caused by load carriages depending on natural posture imbalance to provide information about a carrying habit exaggerating an individual's posture imbalance. All people exhibit some imbalance from the standard anatomical pose which assumes alignment with the frontal and median planes. In this study natural posture imbalance is the starting point for determining posture deviation which is posture imbalance resulting from an activity, carrying an item.

Methods: Seventeen female participants, 19–37 years old, were recruited from university staff, faculty members, and students. Participants were each scanned wearing their own underwear (bra and panties) in: (a) the anatomical pose (P1) face forward and feet placed at shoulder width without carrying an item, (b) carrying a backpack (P2), (c) carrying a shoulder bag on the right shoulder (P3R) and the left shoulder (P3L), (d) carrying a bag cross-body with a strap placed on the left shoulder to place the weight at the hip level on the right side (P4R) and the strap and handbag placed in the opposite direction (P4L), and (e) carrying a bag with the right hand (P5R) and the left hand (P5L). The bag weight was approximately 10% of a participant's body weight. Five body angles were obtained in each scanning position (eight positions total) for all participants and statistical analyses were conducted for posture assessment. Three statistical test methods were used: (a) Paired *t*-test to determine posture changes in each loaded position compared to natural posture in P1. (b) Paired *t*-test to identify differences of the degree of posture changes between right-side load (R) and left-side load (L) positions to determine a posture deviation tendency with asymmetrical load carriages. (c) Bivariate (Pearson) correlation test to examine how natural posture imbalance and posture deviation co-vary.

Results: (a) Asymmetrical load positions exhibited greater changes on shoulder and spine posture than a symmetrical load position, exhibiting obvious changes in P3 and P4 rather than P5. (b) The degrees and directions of posture deviation resulting from an asymmetrical load carriage varied depending on those of an individual's natural posture imbalance. When a participant exhibited great posture imbalance in P1, significant differences of posture deviation on the shoulder and spine between R and L positions were observed in P3 and P4. (c) Significant correlations between natural posture imbalance and posture deviation resulting from load carriages were found for most body angles.

Conclusions: People need to be aware of their natural posture imbalance and try to avoid carrying heavy handbags or any type of carriages making their posture imbalance worse to prevent possible further distortion.

Relevance to Industry: Although this study used handbags and a backpack as the load carrying devices, the way a person carries a load of any type is relevant in many industries and in the military.

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1. Introduction

1.1. Effects of load carriage on posture

Poor posture indicates the result of musculoskeletal distortion

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in the neck, and upper and lower back exhibiting an excessive anterior curve of the cervical and thoracic spine and an exaggerated curve of the lower back (Jelínková, 2015). Since poor posture can cause possible psychological discomfort and physical abnormalities such as scoliosis, kyphosis, or lordosis, prevention of poor posture is important in living a healthy life (Birbaumer et al., 1994). Previous studies indicated that carrying heavy bags (symmetrical or asymmetrical loads), often daily, can result in negative health effects such as poor posture, pain in various parts of the spine, and increase in blood pressure and oxygen consumption (Holewijn, 1990; Kilbom et al., 1990; Lai and Jones, 2001; Negrini, and Carabalona, 2002; Puckree et al., 2004; Singh and Koh, 2009). To avoid significant negative effects of heavy load carriages on health, some researchers examined the correlations between backpack loads and posture changes which are the differences of posture between a loaded position and unloaded position (Hong and Cheung, 2003). The results indicated that heavier backpacks cause an increase in more forward inclination of the trunk and head. Some studies focused on the effects of asymmetrical load carriages on posture changes. Bettany-Saltikov et al. (2008) demonstrated that asymmetrical loads on one shoulder negatively affect posture changes more than a load distributed on both shoulders. A few studies examined the effects of school bags on students' trunk muscle electrical activity and the results consistently exhibited a far greater increase in trunk muscle activity when carrying a shoulder bag rather than a backpack (Motmans et al., 2006). O Shea et al. (2006) found significantly less impact on spine posture from carrying a bag cross-body as compared to carrying a shoulder bag for healthy women. Although some researchers examined the negative effects of carrying asymmetrical loads on posture, little is known about posture deviation which is posture imbalance caused by a load carriage, right-side and left-side loading respectively, based on an individual's natural posture imbalance. Natural posture imbalance is defined as the postural imbalance in the anatomical pose; standing in a comfortable position face forward and feet placed at shoulder width. This study explored posture deviation variability from natural posture imbalance, when carrying four types of bags, to provide information about a carrying habit possibly making an individual's posture imbalance worse.

1.2. Posture assessment methods for load positions

To assess posture changes resulting from loads, three different methods have been used: (1) Three-dimensional motion analysis technique has been used for posture assessment for various purposes and reported to be valid (Sprigle et al., 2003) and reliable (Lissoni et al., 2001) in adults to provide user real-time biofeedback (Dunne et al., 2008). Woldstad and Sherman (1998) examined the effects of a back-belt on posture, strength, and spinal compressive force during static lift exertions using a 3D motion analysis system. Labaj et al. (2016) observed daycare workers to analyze low back forces in lifting children of different ages using 3D postural monitoring. However, these methods have some limitations associated with the social and physical discomfort which is a significant factor for wearable devices (Dunne et al., 2008). (2) As another 3D technology, 3D digitizers which are portable and low cost have been used to measure posture and back shape. Previous studies reported the reliability of this method (Warren et al., 2002) and it has been used to assess posture changes resulting from load carrying; O Shea et al. (2006) examined the effects of asymmetrical load carriages on posture in young adults using a digitizer. However, this method is limited for obtaining multiple body angles for the whole body surface. (3) Rasterstereography, a 3D technology, has been used for back shape and posture analysis (Drerup and Hierholzer, 1985, 1987). This method involves the multidirectional illumination of the back body surface during stereo video imaging to produce a high-resolution 3D computer reconstruction of the surface of body (Perry et al., 2008). Bettany-Saltikov and Cole (2012) examined the effects of front packs, shoulder bags and handheld bags on 3D back shape and posture in university students using the ISIS equipment. Although this method was found to be reliable (Goh et al., 1999), it is more costly in routine clinical use so that the results of this method typically have been compared to those of roentenography requiring radiographic images for clinical purposes (Asher et al., 2004). Asher et al. (2004) stated that although this method has an advantage which is not exhibiting radiation hazard, it has not been shown to be valid compared to roentenography. This method is also limited for calculating multiple body angles for the whole body surface.

To obtain multiple body angles from the whole body surface, another 3D technology used to assess posture was explored. 3D scanning technology proved reliable and valid as a static posture capturing system (Bye et al., 2008; Choi and Ashdown, 2011; Petrova and Ashdown, 2008). Since it captures the body dimensions in a fast and reproducible way and provides whole body surface information, many researchers have used this method for a variety of purposes (Yu et al., 2003). Although little is known about posture assessment using a 3D scanner for load situations, several studies have used a 3D scanner to extract various body angles as well as body measurements from the whole body surface and demonstrated that a variety of body angles and measurements including length, width, and circumference can be extracted from 3D scan data (Ashdown and Na, 2008; Chen et al., 2010; Cho et al., 2006). After reviewing several methods of assessing posture, 3D scanning technology was selected as the posture assessment method for this non-clinical purpose since 3D scanning technology has shown promise in assessing posture by providing numerical body segments on the 3D scanned body surface in a fast and duplicable way.

2. Methods

2.1. Subjects

Seventeen female participants, 19–37 years old (average age 24 ± 4.8 years), were recruited from university staff, faculty members, and students. Participants averaged 165.8 ± 7.4 cm in stature and 70.2 ± 11.9 kg in mass. Eight participants were Asian and nine participants were Caucasian. Fourteen participants were right handed and three participants were left handed.

2.2. Materials and apparatus

Participants were scanned using the 3D Human Solutions body scanner in the University of Minnesota Human Dimensioning© Lab. Before scanning, participants were guided to place their feet in a foot position device that projects slightly (0.6 cm) from the surface of the scanning platform. Participants were positioned similarly on the scanner platform with feet approximately 21.6 cm apart at the instep. Consistent foot positioning is important to reduce measurement errors caused by foot position variations. Load carrying devices were: (a) a backpack equipped with two identical straps for a symmetrical load position and (b) a handbag equipped with a long strap and two short handles for asymmetrical load positions. The strap lengths of each bag were identical for all participants. The load of the backpack and handbag was approximately 10% of a participant's body weight as suggested by Hong and Brueggemann (2000).