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Load distribution and postural changes in young adults when wearing a traditional backpack versus the BackTpack

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ABSTRACT

Backpacks lead to poor posture due to the posterior placement of the load, which overtime may contribute to low back pain and musculoskeletal complications. This study examined postural and load distribution differences between a traditional backpack (BP) and a nontraditional backpack (BTP) in a young adult population. Using a 3D motion analysis system, 24 healthy young adults (22.5 ± 2.5 years, 12 male) completed both static stance and walking trials on a treadmill with No Load and with 15% and 25% of their body weight using the two different backpacks. There was a significant difference in trunk angle, head angle, and lower extremity joint mechanics between the backpack and load conditions during walking ($p < .05$). Notably, relative to the No Load condition, trunk angle decreased approximately 14° while head angle increased approximately 13° for the BP 25% state on average. In contrast, average trunk and head angle differences for the BTP 25% state were approximately 7.5° and 7°, respectively. There was also a significant difference in head angle from pre- to post-walk ($p < .05$) across backpacks, loads, and time. Taken together, the results indicate that the BTP more closely resembled the participants' natural stance and gait patterns as determined by the No Load condition. The more upright posture supported by the BTP may help reduce characteristics of poor posture and, ideally, help to reduce low back pain while carrying loads.

1. Introduction

Load carriage can be the most convenient way to transport items (e.g. military, students, athletes). Previous reports indicated over 40 million students in the United States used backpacks on a regular basis [1]. Improper backpack use (unilateral or excessive posterior loading) has led to alignment issues such as forward head posture (FHP), rounded shoulders, kyphosis, low back pain, and an asymmetrical axial skeleton [2–5].

Posture is the amalgamation of the position of multiple joints, bones, and muscles along the longitudinal axis of the body [6]. A neutral posture aligns these components in equilibrium. However, continuous poor postural compensations can lead to musculoskeletal imbalances and pain. Forward head posture occurs when the head is held anterior to its neutral, balanced position and stresses the cervical vertebrae and posterior neck muscles [7,8]. Low back pain may be caused by forward flexion of the trunk, which stresses the ligaments and intervertebral discs of the lumbar region [9,10].

Researchers have investigated the weight of backpacks, duration of wear, and postural and gait changes during load carriage. Postural compensations have been reported in conjunction with loads above approximately 20% body weight [11,12]. These compensations were reported in static trials where increased weight was correlated with an increase in FHP, trunk flexion, spinal asymmetry, and tensile forces in the intervertebral discs [4,5,13]. Similarly, postural changes with backpack use are seen during gait, including FHP, rounded shoulders, and forward trunk lean [14–16]. Backpack loads can also impact gait by increasing horizontal braking forces [14], ankle dorsiflexion, and hip and knee flexion [16].

By maintaining a neutral posture through load displacement around the body's vertical axis, nontraditional backpacks seek to reduce, and perhaps avoid, postural compensations seen in traditional backpacks. Alterations in load distribution have been assessed using a double-pack design, which distributed the load both in front and behind the participant and demonstrated decreased trunk lean and smaller center of mass displacement compared to traditional backpacks [17]. Alternatively, front-packs,

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which place the load anterior to the wearer, produce less FHP and hip flexion than traditional backpacks resulting in greater upright posture [18]. However, front-packs have also created an increase in thoracic kyphosis [19].

The principal purpose of this study was to assess postural changes at the spine between a traditional backpack and a nontraditional backpack (load placed bilaterally on the wearer). Additionally, the effects of load distribution on hip and knee joint mechanics during static stance and heel strike during walking were evaluated. It was hypothesized that the nontraditional backpack would result in more upright posture showing less forward trunk inclination and FHP. It was also hypothesized that the nontraditional backpack would result in smaller joint moments in the sagittal plane than the traditional backpack.

2. Methods

2.1. Participants and sampling procedures

Twenty-four healthy young adults (22.5 ± 2.5 years, 12 males) participated in this study. Participants were free from lower extremity and back injury and any other musculoskeletal or neurological condition inhibiting their ability to carry a backpack at 15% and 25% of their body weight. Participants carried a traditional backpack on a regular basis (3+ days/week) and completed a university-approved consent form and health questionnaire prior to participation.

2.2. Measurements

Posture and gait mechanics were captured using a 14-camera Vicon infrared motion capture system (VICON Inc., Denver, CO, USA) and an AMTI force instrumented treadmill (AMTI Inc., Watertown, MA, USA) collecting at 120 and 2400 Hz, respectively. A traditional backpack (U.S. Polo Assn Sport Backpack, Colfax, LA, USA) and a BackTpack (BackTpack LLC, Salem, OR, USA) were used to manipulate load carriage (Fig. 1). Load was added to the backpacks in increments of 1, 5, and 10 pounds to equal 15% and 25% of the wearer's body weight, representing loads below and above those recommended in the literature [11,15,20,21]. This load was evenly distributed in the backpacks, placing the heaviest weight closest to the spine for the traditional backpack (BP) and balancing the weights between the two pockets for the BackTpack (BTP). The shoulder straps were adjusted for each participant's height to place the BP above the hips at the low back and the BTP level with the hips. Neither a sternum strap nor hip-loading belt was utilized for the BP as not all traditional backpacks have these features. Per design requirements, a sternum strap and non-load-carrying lap strap were utilized and individually fitted for the BTP.

2.3. Procedures

Anthropometric measurements, height, and weight were recorded, and a Vicon (Vicon Motion Systems Ltd., Denver, CO, USA) Plug-In Gait marker set (legs, trunk, head) was used with standard retro-reflective markers and modified four-marker thigh and shank clusters on each leg. Lateral thigh clusters were placed anteriorly to compensate for the BTP's lateral bags. Body weight measurements were used to determine backpack loads of 15% and 25% body weight.

Participants completed 15 collection conditions which included: static upright posture recordings pre and post walking with no backpack/load ('No Load') and while wearing each of the BTP and BP loaded with 15% and 25% body weight (total 10 static posture conditions); and walking recordings were collected under the same No Load, and 15% and 25% conditions (total 5 walking conditions). Participants were instructed to "walk naturally with your head facing forward." Following the No Load state, backpack and load conditions were randomized. Participants walked at a constant speed of 1.4 m/s for 6 min to help desensitize them to the backpack during which, but not earlier than 1 min, data was extracted over a 7-s period corresponding to optimal conditions

Fig. 1. Traditional backpack (left) and nontraditional BackTpack (right).