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Effects of Straps and Movements on the Pressure Distribution Induced by a Backpack

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Abstract

Backpacks have been widely used to increase load carriage capacity, but the pressure at the body surface may cause discomfort or pains. Previous studies revealed that chest straps and hip belts of backpack helped to relieve the discomfort feeling, but how the pressure changes are still unclear. In this study, the influence of strap tying and the posture change on the pressure distribution were investigated. A daily backpack with 5kg load was used in the experiment. Five young females carried the backpack to stand, walk and jog. The pressures were measured at the shoulder, waist and hip, which are the primary load bearing regions. The trunk forward lean angle (TFL) was captured by using the Vicon motion capture system. Results showed that tying both the chest strap and hip belt reduced the shoulder pressure and increased the pressure at the hip and waist. From standing, walking to running, TFL increased gradually and the pressure transferred from shoulder to back and hip. These findings help us to better understand and quantify the load carrying performance of a backpack.

Keywords: Backpack; Pressure Distribution; Straps; Lean Angle

1 Introduction

Backpacks are used to carry some belongs in outdoor sports, for children going to school, military marching, and labor handling, etc.. While carrying a backpack, the pressure at the body surface induced by the backpack may cause discomfort or pains. Knapik et al. showed comfort associated with the load position and pressure on specific body parts [1]. Shoulder have been found to bear the most of the loads when carrying a backpack and be the area with the highest ratings of pain and discomfort. Shoulder discomfort increase was rated as the most limiting factor for failing to complete a load carriage task [2-4].

Many efforts have been made to alleviate the negative effect when carrying a backpack, particularly by improving the pressure distribution over the body. The static pressures caused by the shoulder straps may cause local fatigue of the superior trapezius, but the hip region was more tolerant to static pressures [5-8]. Many packs have added components such as the hip belt, chest strap, load lifters to help even the pressure distribution. Physiological studies showed that using

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the chest strap and hip belt may relieve the discomfort feeling by analysis the energy expenditure of locomotion [9], but how the pressure changes are still unclear.

When carrying a backpack during standing, walking and running, the wearer's posture has been shown to effect the pressure. One parameter under study is trunk forward lean (TFL), defined as the angle formed between a line joining the right acromion and right greater trochanter and a vertical reference line [10]. It is described as a compensatory strategy used during ambulation to maintain balance as the body changes its center of gravity [11, 12] Goodgold et al. found from standing, walking to running, the trunk forward lean increased [13]. Pelot et al. found with the increase of the TFL, the static pressure on the shoulder transfer from front to back [14]. But there is few research on the effect of the postural changes on the dynamic pressure on the wearer. In this study, the influence of strap and belt tying and the posture change on the pressure distribution were investigated.

2 Methods

2.1 Participants and Exercises

Five healthy female college students (22.3±2.9 years; 160±5 cm; 55±5.3 kg) volunteered to participate in the experiment. A daily backpack with a chest-strap and a hip-belt was used for the study. To ensure a stable center of gravity, five sand bags weighed 1 kg each were evenly placed in the backpack. Subjects were asked to stand still, walk at 4.5 km/h and jog at 6.5 km/h, ton a treadmill respectively, to simulate daily activities.

2.2 Measurements

The pressures on the torso were recorded every 0.1 s by using the Pressure Measurement System (AMI3037S-5, AMI, Ltd., Japan) with air-bags as pressure sensors. The pressures were measured at six main load bearing areas shown in Fig. 1 [15, 16]. The static pressures during standing were measured with four different strap tying conditions, which were shown in Fig. 2, noted as NB (no belts), CB (only chest-strap), HB (only hip-belt) and TB (both chest-strap and hip-belt). The dynamic pressures during walking and jogging were measured with the condition of CB and TB. Trunk forward lean angle (TFL) [10], was obtained from the angle formed by a line linking the right acromion and right greater trochanter and the ground plane, and the movements of the two points were captured by using a 8-camera Vicon motion analysis system (Oxford Metrics Limited, Oxford, UK).

3 Results and Discussion

3.1 The Effect of Strap Tying Ways

Fig. 3 shows the static mean pressures of five subjects in four strap tying conditions. The highest pressure is at the point A3 and the lowest pressure is at the point W. From NB to CB, the pressure at the points from A2 to A4 decreased by 0.15 ka, 0.3 kpa, 0.32 kpa and A1 and H increased by