

Effects of a low-center-of-gravity backpack on the trunk stability of mountaineers while ascending and descending

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Abstract. [Purpose] This study developed a backpack with a low center of gravity (LCG) and investigated the effects of the LCG backpack on the trunk stability of mountaineers while ascending and descending. [Subjects and Methods] Ten males aged 20–32 years were recruited. The subjects ascended and descended a road with an inclination of 30 degrees wearing the standard or LCG backpack, and trunk acceleration was measured using a tri-axial accelerometer. [Results] The anterior-posterior (AP) and medial-lateral (ML) trunk acceleration while ascending and descending with the LCG backpack were significantly lower than those with the standard backpack. [Conclusion] The results suggest that the LCG backpack could prevent falling injuries during mountaineering and mountain-related activities.

Key words: Backpack, Mountain climbers, Trunk Stability

(This article was submitted Jun. 11, 2015, and was accepted Jul. 23, 2015)

INTRODUCTION

Mountain climbing requires knee extensor moments in excess of the maximum isometric muscle strength available and places a high demand on the knee extensors while ascending that reaches the maximum isometric capacity and can exceed the maximum isometric capacity while descending¹⁾. Safe ascending and descending demand sufficient muscle strength (*i.e.*, concentric forces to propel the body upward and eccentric forces to control the body's descent) and considerable balance control^{1, 2)}. A backpack is positioned symmetrically when a load is carried, and the distribution of the load affects body posture and balance with posterior translation of the center of gravity^{3, 4)}. The military has conducted many physiological, biomechanical, and medical studies to investigate the effects of carrying backpacks^{3, 4)}. The comfort of a backpack depends on a combination of the biomechanical effects on the center of mass (CoM) of the body and the forward-leaning posture⁵⁾. Many studies have reported a correlation between the load of a backpack and pain⁶⁾. Therefore, we developed a backpack with a low center of gravity (LCG) and investigated the effects of the LCG backpack on the trunk stability of mountaineers while ascending and descending. The LCG backpack was gourd-shaped and had been remodeled from a standard climbing

backpack (company K, model B).

SUBJECTS AND METHODS

Ten male mountaineers, aged 30–35 years, with a mean height of 174.5 ± 6.2 cm and a mean weight of 67.1 ± 4.9 kg participated in this study. The subjects had no history of musculoskeletal disorders or pain associated with the lower extremities during the previous 6 months. The study purpose and methods were explained to the subjects before their participation, and they provided informed consent according to the principles of the Declaration of Helsinki.

Using a tri-axial accelerometer (Fit Dot Life, Suwon, Korea), this study measured trunk accelerations to evaluate trunk stability while ascending and descending. A sensor range of -8 to $+8$ g could be selected using the acquisition software (Fitmeter Manager 2, ver. 1.2.0.14, Korea). The raw data were measured using x, y, and z acceleration variables. The accelerometers were attached over the T5 spinous process using double-sided adhesive tape. Data were collected at a sampling rate of 128 Hz. The trunk acceleration was measured using the vector sum in the anterior-posterior (AP) and medial-lateral (ML) directions. The subjects adjusted the lengths of the shoulder straps so that the bottom of the pack was positioned at the L5 level. The subjects walked up and down a road with an inclination of 30 degrees wearing a standard climbing backpack (company K, model B) or the LCG climbing backpack. The subjects were asked to walk for 15 min on an inclined road at a speed of 1.5 m/s while carrying a backpack containing a 20-kg load.

The Statistical Package for the Social Sciences (SPSS, Chicago, IL, USA) was used for the statistical analyses. The paired t-test was used to analyze the differences in trunk

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acceleration while walking under two backpack conditions. The alpha level for statistical significance was set at 0.05.

RESULTS

The trunk accelerations in the AP (148.4 ± 32.9 g) and ML (95.2 ± 40.5 g) directions while ascending with the LCG backpack were significantly ($p < 0.05$) lower than those with the standard backpack (167.4 ± 51.1 and 119.2 ± 36.6 g, respectively), as were the trunk accelerations while descending (AP: 212.0 ± 59.8 vs. 285.9 ± 44.8 g; ML: 121.1 ± 46.2 vs. 145.2 ± 39.0 g, respectively).

DISCUSSION

Mountaineering and mountain-related activities are associated with significant risks of injury⁷. While ascending and descending during mountaineering, trunk movements are important for posture control because the trunk plays a key role in providing a stable support platform for the head and lower extremities by regulating the amplitude and structure of gait-related oscillations and affecting the visual and vestibular sensory input⁸. This study developed the LCG climbing backpack and investigated the effects of this backpack on the trunk stability in the AP and ML directions of mountaineers while ascending and descending. The results showed that the trunk accelerations while ascending or descending wearing the LCG backpack were significantly lower than those with a standard backpack.

Accelerometers are used widely in studies of gait analysis, balance evaluation, and energy expenditure^{8, 9}. The advantages of accelerometers include their small size, accuracy of measurement, and low cost compared with other motion-analysis equipment⁹. Overall trunk acceleration is used as an index of trunk oscillation during gait or move-

ment and is indicative of reduced balance⁸. The body is in a more optimal and stable position when the CoM is closer to the center of pressure⁹. The smoothness of trunk acceleration is also a useful indicator of whole-trunk movements and the risk of falls¹⁰.

In summary, our results suggest that the LCG climbing backpack can prevent falling injuries during mountaineering and mountain-related activities.

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