SHOCK ATTENUATION MECHANISM AT THE BACKPACK WEIGHT CHANGE IN DROP LANDINGS

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The purpose of this study was to investigate the shock attenuation mechanisms while varying the loads in a backpack during drop landing. Ten subjects (age: 22.8±3.6, height: 173.5±4.3, weight: 70.4±5.2) performed drop landing under five varying loads (0, 5kg, 10kg, 20kg, 30kg). By employing two cameras (Sony VX2100) the following kinematic variables (phase time, joint rotational angle and velocity of ankle, knee and hip) were calculated by applying 2D motion analysis. Additional data, i.e. max vertical ground force (VGRF) and acceleration, was acquired by using two AMTI Force plates and a Noraxon Inline Accelerometer Sensor. Through analysing the power spectrum density (PSD), drop landing patterns were classified into four groups and each group was discovered to have a different shock attenuation mechanism. The first pattern that appeared at landing was that the right leg absorbed most of the shock attenuation. The second pattern to appear was that subject quickly transferred the load from the right leg to the left leg as quickly as possible. Thus, this illustrated that two shock attenuation mechanisms occurred during drop landing under varying load conditions.

KEY WORDS: shock attenuation mechanism, backpack, drop landing.

INTRODUCTION: There are a number of sports i.e. basketball, volleyball, etc. that involve jumping and landing, hence, it's important to reduce and examine the impact caused by landing. It is important because if the impact is too high, then injury will occur. According to research (Valiant & Cavanagh, 1985) the vertical ground reaction force ranges between 3.5 to 7 times the subjects weight, and the speed at landing is proportional to the drop height. The higher the drop height, the higher the impact and probability of injury (Dufek & Bates, 1990). Other published research discusses, how the subject deals with the landing is divided into two parts; the first is when the subject flexes their joints and lands on the whole sole of the foot (Dufek & Bates, 1990; Devita & Skelly, 1992; Zhang et al, 1996), the second is when the subject lands on the front part of their foot (Gross & Nelson, 1988; Valiant & Cavanagh, 1985).

Moreover, during hiking especially for periods of longer than one day, additional loads like food, etc. are carried usually in a backpack. For civilians loads of 13 to 25kgs are carried but for military personnel loads up to and over 30kgs are not atypical. While mountaineering drop landing occurs repeatedly and as the subject is carrying heavy loads the impact is clearly higher.

In this study, the kinetic and kinematic variables of the lower limbs are analyzed during drop landing while wearing a backpack in order to examine the shock absorption at impact, landing.

METHOD:

Data Collection:

Subjects: Ten healthy male subjects participated in this study. All of the subjects had no lower limb injuries within the last 2 years.

Experimental Equipment: The kinematic variables were recorded (sampling rate of 60Hz, shutter speed 1/250) using two cameras one on the left side and one on the right side. The kinetic variables were recorded by two force plate platforms (AMTI, sampling rate of 1000Hz). The manual trigger (TTL), to activate the LED and force plate platform was used to ensure the synchronization between of the video data with the force plate platform's data.

The backpack's load was varied by the addition and subtraction of weights; two 7.5kg weights, one 5kg weight and two 2.5kg weights. To maintain consistency, all the subjects wore the same hiking shoe(size 270mm). Noraxon's inline accelerometer sensor (range 2~10G, bandwidth 5 Hz~6 kHz) was used to calculate the acceleration of the shank.

Experimental procedure: To reproduce the drop landing conditions a box 40 cm high was place 80 cm away from the force plate platform. Then the 2D control box was set in place and the reference points for digitizing were recorded. 16 reflective markers were fixed on to the subject, 6 were fixed onto the hiking boots and 4 were fixed onto the backpack so that auto digitizing could be performed.
In order to calculate the acceleration, the accelerometer was firmly attached to the tibial tuberosity and the shanks direction was set as the x axis. The five loading conditions 0, 5, 10, 20, 30 kg were randomly rotated during the data acquisition of the drop landing. Before the data acquisition began, the subject's weight was measured by the force plate platform and for the drop landing the subjects were instructed to land on the same leg and as naturally as possible. When loading the backpack a quilt was first inserted so that the weights didn't move and that the weights were placed in the top section of the backpack. Also the backpack was securely fixed to the subject by the waist strap.

Data Analysis:
By entering the raw data in the following programs Kwon 3D V.3.1, Kwon GRF V.2.0, MS Office Excel 2003 and Noraxon MR XP V.1.06 program, the kinematic and kinetic variables were calculated.
1) Kinematic Variables: periodic time, ankle angle, knee angle, hip angle, Center of Gravity COG height.
2) Kinetic Variables: In other research (Mizrahi et al., 2000), the acceleration was set at a sampling rate of 1500 Hz to calculate shock absorption. When the accelerometer's value rose above 0.1g for 0.01s the right leg's acceleration was recorded.
Using the absolute max acceleration, period's median frequency (MDF), Fast Fourier Transformation (FFT) and Power Spectral Density (PSD) the impact peak and active peak frequency were calculated. When running the MDF for the lower leg ranges from 11-13Hz, at the sacrum ranges from 7 to 9 Hz and for the head 3 to 4 Hz. This shows that the high frequencies are removed as the shock is absorbed by the body.
The impact peak is when the foot contacts with the ground and a high frequency is produced, whereas the active peak is when the foot is pushing off the ground and a low frequency occurs. Using the force plate platform, the vertical GFR was calculated for both the absolute and relative (normalized Max. Fz) values to compare the values. By the vertical GRF, time and gradient the Max loading rate was calculated (N/s).

Statistical Analysis:
To verify the statistical difference between the kinematic and kinetic variables, one-way repeated ANOVA analysis was executed, with a p value of 0.05. All the statistical analysis was executed in the SPSS 12.0 package.

RESULTS:

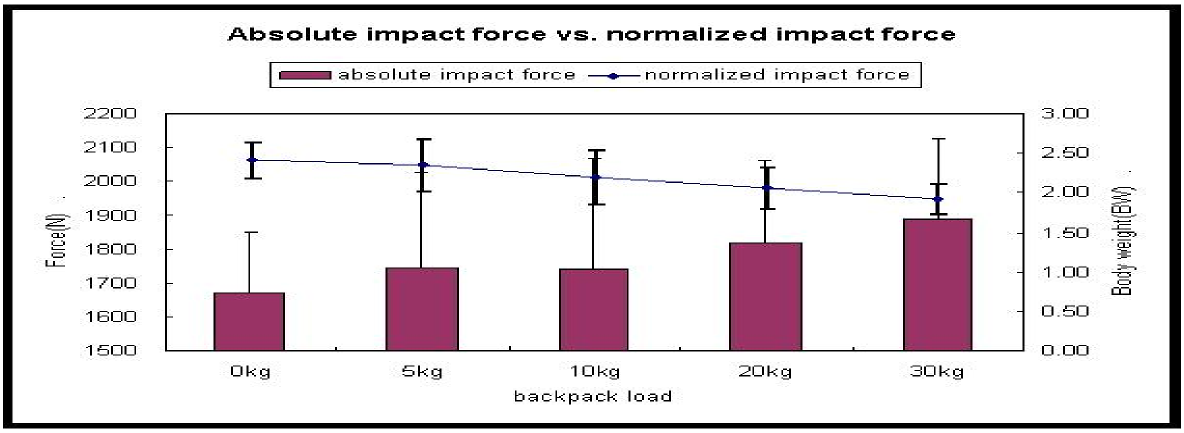

Figure 1: Max impact force

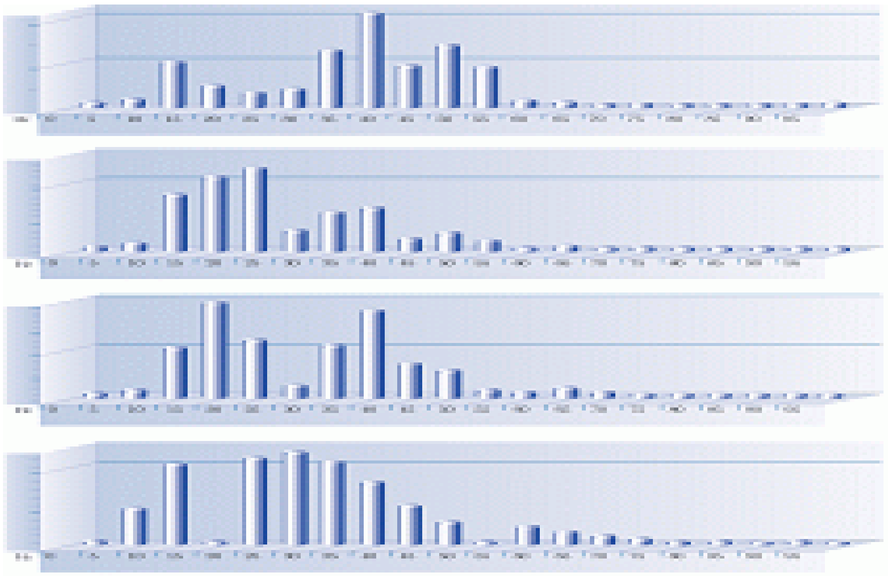

Figure 2: PSD Pattern

Table 1: Drop Landings Max Acceleration(g)

Load	Acceleration
0	3.78
5	5.49
10	4.78
20	4.91
30	5.12

DISCUSSION: The right leg's vertical GRF was calculated and shown in graph 1 and the trend is as predicted the absolute value increases. An interesting point is revealed in the graph and it is about the difference between the load of 5 and 10 Kg. As seen in figure 1 the GRF reduces and then rises again also the acceleration with a 5 kg load is 5.49g and a 10 kg load is 4.78g. I think that this is due to the proprioceptive nature of humans as we realize that the 10 kg is heavy and that we need to prevent injury. After observing the normalized GRF one see that the force reduces and this is due to the shock absorption of the subject.
In order find the reason how the subject's dealt with the shock absorption, kinematic and kinetic analysis was performed. But the subject variability was so high that another method PSD had to be employed to reveal the 4 types of shock absorption at landing (figure 2).
The first pattern to emerge was that the impact peak was large than the active peak and so the shock was larger. The second pattern was the opposite and this meant that the subject did something to overcome the impact shock. The third and fourth pattern to emerge but it verified the video analysis that the experimental controls had been flawed and so these patterns could be ignored.
After examining the video evidence, the subject's upper body leaned forward more as the right foot contacted with the force plate in the pattern 2 than pattern 1. To verify the video evidence, the subject's center of mass (cm) and center of pressure (cop) was determined with the force plate. For the type 1 the subject's cm was behind the cop but for the pattern 2 the subject's cm was either closer to the cop or in front of it. This confirmed that the subject's leaned their bodies forward to deal with the impact. As the subjects with pattern 1 did not lean their bodies forward that meant that the impact force was higher.
In other words, the subjects with pattern 1 did not properly prepare for the drop landing and their bodies were in a straightened position and their lower extremities were extended. On the contrary, the subjects with pattern 2 flexed their knees and leaned their body forward in preparation to land efficiently and to propel their bodies onto the next step by pushing off the ground.

CONCLUSION: In this study, we demonstrated that there are two patterns that deal with drop landing with or without extra loads i.e. backpack. For the pattern 1 the impact forces were higher due to the pre-extension of their lower extremities at landing. After landing the subject flexed their right leg, absorbed all the shock and swung the body weight on to their left leg to continue walking. Conversely, for the pattern 2 the impact forces were lower due to the preparation of flexing their right leg before the landing. Then after landing they quickly pushed off their right leg and so they recovered efficiently.

In conclusion, there are two mechanisms for drop landing, first is to absorb all of the shock with the landing leg, and the second is to quickly transfer the shock from the landing leg to the other leg.

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