THE EFFECT OF HAND-HELD WEIGHTS ON STANDING LONG JUMP PERFORMANCE

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The standing long jump was one of the events in ancient Olympiad Games. Extra weights were held in the hands of athletes during the jump. It has long been debated whether the extra weights were used to make the challenge more difficult or to enhance the jumping performances. The purpose of this study was to investigate the effect of extra weights on standing long jump performance. A Redlake high-speed camera was synchronized with a Kistler force platform to collect the data of eight male jumping performances. The results indicate that the total horizontal propelling time, time to maximal horizontal force, horizontal impulse and horizontal velocity of body CG at takeoff all increased with loaded jumps. In addition, the vertical velocity of body CG and angles at takeoff decrease with loaded weights. It was suggested optimal extra weights for extending standing jump distance is 8% of body mass.

KEY WORDS: biomechanics, standing long jump, extra weight

INTRODUCTION: The standing long jump was one of the events in the ancient Olympic Games. It is clear that extra weights (halteres) were held in the hands of performers during this event; however, it is not clear whether these extra weights were used to increase the difficulty of the event or to enhance the jumping performance. Halteres were swung back and forth by the jumper before take-off, thrust forwards during the first part of the flight, and finally swung backwards just before landing. Minetti and Ardigo (2002) use computer simulation to determine the optimal extra weights that would be needed to maximally increase a jumping distance. They suggested that the extra mass 2-9 kg would increase a 3-meter jump by at least 17 cm. However, empirical data collected to test their simulation models were gathered while subjects were doing vertical jumps- not long jumps. The purpose of this study was to investigate the effect of extra weights on standing long jump performance.

METHODS: Eight male sprint runners (age 23.6 $\pm$ 2.5 yr, height 179.0 $\pm$ 3.9 cm, body mass 70.6 $\pm$ 3.9 kg) served as subjects for this study. All subjects were informed of the experimental procedures and gave their consent before participating. Before performing any jumps, the subjects were instructed to warm up for a few minutes by doing some light running, jumping, deep-knee bends, and stretching. For each trial, the subjects were instructed to initially stand on a force platform and jump as far as possible once given a verbal signal. Each subject performed maximal standing long jump and swung his upper limbs forward and upwards while loaded with one pair of dumbbell randomly donated out of 7 (0,2,4,6,8,10,12) that ranged from zero (unloaded) to 12 kg of total extra mass. Each subject performed six jumps: two jumps with unloaded and two jumps with two different loaded weights. Three best jumps (one unloaded and two loaded trials) for each subject were selected for analysis. The subjects were asked to drop the handbell backward in the mid-air. A Redlake high-speed camera (125 Hz) was synchronized with a Kistler force platform (9287B, 1250 Hz) to collect the kinematical and kinetic data of jumping performance. Nine body landmarks (ear, shoulder, elbow, wrist, hip, knee, ankle, toe and heel) were digitized by Peak Motus system. Dempster's study (1955) was used to calculate body segment parameters. A Butterworth digital recursive filter with 6 Hz cutoff frequency was used to filter the random noise during the digitizing process. The ground reaction forces and impulses of standing long jump were analyzed by Kistler Bioware software. The jumping distance was defined as the horizontal displacement of toe at takeoff and heel at landing. Total time (T total) was defined as total time of horizontal propelling force (positive horizontal force).

RESULTS AND DISCUSSION: The standing long jump distance for eight unload trials ranged from 2.50 m to 2.85 m, and for the loaded 16 trials ranged from 2.55 m to 3.29 m. The mean values for the unloaded and loaded trials are 2.67 $\pm$ 0.13 m and 2.79 $\pm$ 0.19 m respectively. Compared with unload trials, fifteen out of sixteen loaded trials improved the distance. The average gain is 0.12 m. One subject improved distance by 15.4% (from 2.85 m to 3.29 m) with 2 kg extra mass. Figure 1 shows the effects of different extra weights on jumping distance. Average values of the best jumps for each loads (barbell weight / BW) are shown as a percentage of the value for an unload jump. Curve is best-fit by using second-degree polynomial regression. Minetti and Ardigo indicated that 5-6 kg of extra weight is optimal for extending jumping distance for their simulation study. By solving the equation, Figure 1 shows the optimal extra weight for extending jumping distance is around 8% of BW. For the subject mean body weight of 70.6 kg in this study, the optimal extra weight is 5.6 kg which is in agreement with the result of Minetti and Ardigo study.

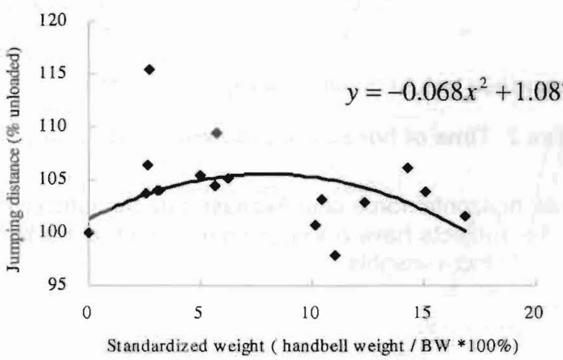

Figure 1 Standing long jump distance.

Table 1 Variables of Standing long jump on Unloaded and Loaded trials.

	Unloaded (n=8) Mean ± SD	Loaded (n=16) Mean ± SD
Vertical velocity CG takeoff (m/s)	2.53 ± 0.33	2.28 ± 0.25
Horizontal velocity CG takeoff (m/s)	3.17 ± 0.24	3.34 ± 0. 27
CG takeoff (deg)	38.4 ± 5.1	34.2 ± 4.1
Horizontal positive impulse (N*s)	212.9 ± 17.8	244.8 ± 22.3

Table 1 shows the biomechanical variables between loaded and unloaded jumps for eight subjects. The vertical velocity of body CG at takeoff and the body CG angle at takeoff were decreased with loaded jumps. The horizontal velocity of body CG at takeoff and horizontal positive impulse were increased with loaded jumps. The greater impulse was due to the extra weights cause the arm and the shoulder muscles to generate greater force to accelerate the hands in forward and upward arm swing. The total horizontal propelling time, time to maximal horizontal force (Figure 3), horizontal impulse and horizontal velocity of CG at takeoff all increased when jumping with extra weights.

Figure 2 shows the linear trend as the subject jumping with extra weights increased, the time of horizontal propelling force also increased. The longer horizontal propelling force contributed a larger horizontal impulse when jumping with extra weights.

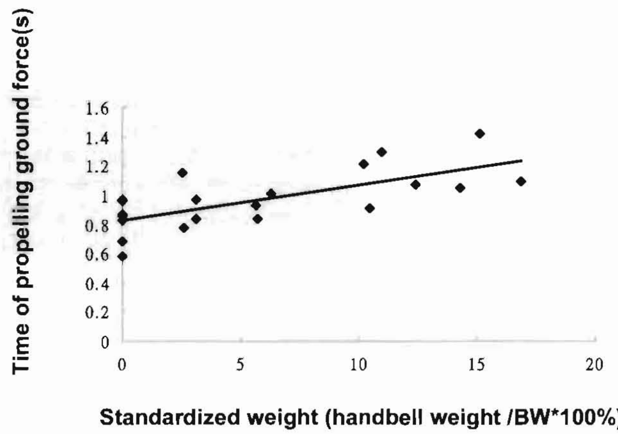

Figure 2 Time of horizontal propelling force.

Figure 3 indicates time to peak horizontal force also increased as the jumper loaded with a larger weight. This suggests the subjects have a longer time to generate a large horizontal propelling force when jumping with extra weights.

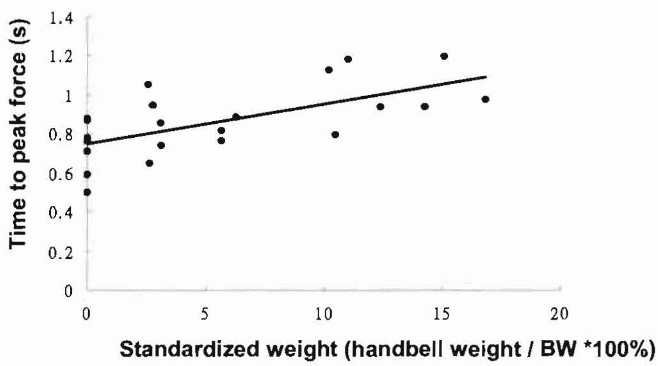

Figure 3 Time to peak horizontal force.

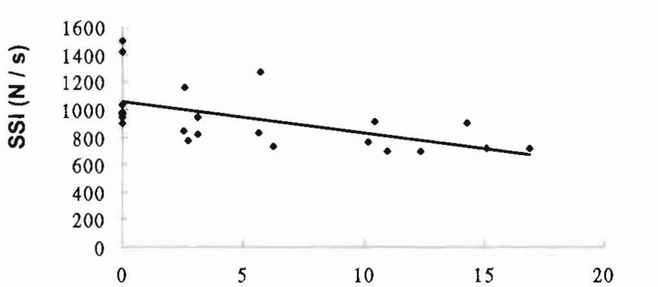

Figure 4 Speed Strength Index (SSI).

The Speed Strength Index (SSI) is the rate of increase in horizontal force, calculated by the dividing peak horizontal force by the time to the peak horizontal force. Figure 4 shows SSI decreased when subjects jumping with extra weights. The SSI is one of important variables for determining explosive strength. The standing long jump is classified by a power event. However, when jumping with extra weight, the SSI is decreased due to the increase time to the peak horizontal force. Minetti and Ardigo (2002) indicated that muscles are not linear actuators and capable of producing greater force and power at lower contraction speeds.
Figure 5 shows the horizontal GRF of subject A with unloaded, and loaded trials (8 kg, 2 kg extra weights) one second before standing long jump takeoff. The peak horizontal GRF was near 1 BW and no obvious difference was observed among three trials. However the positive horizontal impulse of loaded trials (0.319 BW*s and 0.304 BW*s) were greater than the unloaded trial (0.274 BW*s). This indicates that greater positive horizontal impulse with loaded trials before takeoff contribute the greater jumping performance.

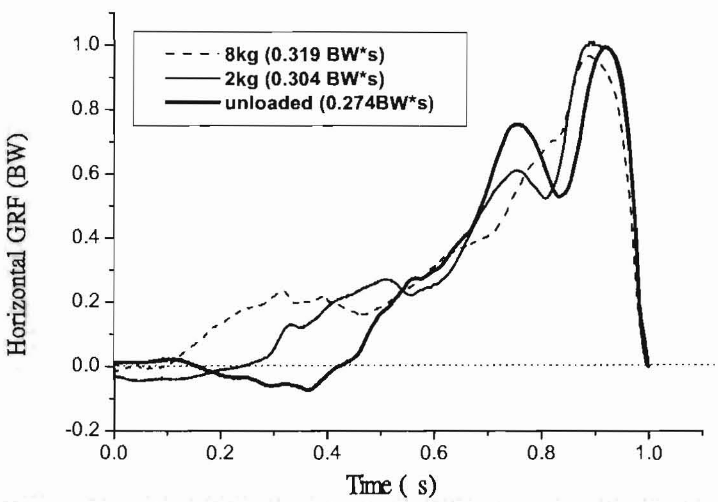

Figure 5 Horizontal GRF of typical subject one second before takeoff.

CONCLUSION: The study demonstrated that the use of extra weights improved standing long jump performance. The longer horizontal propelling time and a greater horizontal impulse before takeoff contribute jumping distance when loaded with extra weights. It was indicated optimal extra weights for extending standing jump distance is 8% of body mass. It is suggested that athletes use optimal hand-held weights during the training session to enhance the jumping performance.

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