Journal of Human Sport and Exercise
E-ISSN: 1988-5202
jhse@ua.es
Universidad de Alicante
España

PAPADOPOULOS, CHRISTOS; NOUSSIOS, GEORGE; MANOLOPOULOS, EVAGGELOS; KIRITSI, OLGA; NTONES, GEORGE; GANTIRAGA, EVANGELIA; GISSIS, IOANNIS
Standing long jump and handheld halters; is jumping performance improved?
Journal of Human Sport and Exercise, vol. 6, núm. 2, 2011, pp. 436-443
Universidad de Alicante
Alicante, España

Original Article

Standing long jump and handheld halters; is jumping performance improved?

CHRISTOS PAPADOPOULOS, GEORGE NOUSSIOS ✉, EVAGGELOS MANOLOPOULOS, OLGA KIRITSI, GEORGE NTONES, EVANGELIA GANTIRAGA, IOANNIS GISSIS

Laboratory of Sport Biomechanics, Department of Physical Education and Sports Science at Serres, Aristotle University of Thessaloniki, Greece

ABSTRACT

Papadopoulos C, Noussios G, Manolopoulos E, Kiritsi O, Ntones G, Gantiraga E, Gissis I. Standing long jump and handheld halters; is jumping performance improved? *J. Hum. Sport Exerc.* Vol. 6, No. 2, pp. 436-443, 2011. The purpose of this experimental study was to document the kinematic and dynamic characteristics of the standing long jump without extra loading and with handheld weights (halters) of different mass and to investigate any association between the former and jumpers' performance. Fifteen subjects (13 males and 2 females) between the ages of 19 and 21 years old participated in this horizontal prospective study. Each participant performed standing long jumps. Regarding the jumping technique, free arm swinging without or with handheld halters of different weights (1.5 kg and 3 kg in each hand) was used. The subjects repeated the jumping set (consisted of free arm swinging jump, jumping with 3 kg and then with 6 kg handheld halters) three times and the three different technique jumps were performed in a random order. The jumping distance was significantly increased 7 cm (2.7%) with 3 kg handheld halters compared to free arm jumps (p=0.006). In addition the subjects jumped 5 cm further with 6 kg handheld weights (2.67±0.27 m) than without (2.62±0.21 m) (statistically significant difference, p=0.005). The horizontal displacement of the center of mass was significantly increased with 3 kg and 6 kg handheld compared to free arm jumps (p=0.007, p=0.005 respectively). Take off angle of center of mass difference was statistically significant between 0 kg (36±5º) and 6 kg (29±5º) handheld weights (12.13% decrease, p=0.001). A gradual significant increase in the horizontal take off velocity of the center of mass was depicted between free arm and 3 kg halters jump (3.5% increase) and 3 kg weights and 6 kg ones (3.69% increase). In conclusion greater distance is achievable during a loaded standing long jump due to 1) horizontal translation of the center of mass, 2) the greater ground reaction force that is generated, 3) decrease in take off angle of center of mass and 4) increase in the horizontal take off velocity of the center of mass. **Key words**: STANDING LONG JUMP, HALTERS, JUMPING DISTANCE.

✉ **Corresponding author.** Vassileos Georgiou 34GR 54640, Thessaloniki, Greece.
E-mail: geornous@hotmail.com
Submitted for publication April 2011.
Accepted for publication June 2011.
JOURNAL OF HUMAN SPORT & EXERCISE ISSN 1988-5202

doi:10.4100/jhse.2011.62.24

INTRODUCTION

Long jump was featured in the ancient Olympics after it was introduced in 708 BC as part of the pentathlon. However, there was an intriguing difference between the way ancient athletes performed their jumps and the way modern ones do: Ancient jumpers took off holding halteres, or handheld weights, which were, made of stone or lead in order to improve their performance (Gardiner, 1904; Tasch, 1952; Minetti & Ardigó, 2002).

In the literature there are few studies that have compared the role of handheld weights in jumping distance (Ashby, 2005; Minetti & Ardigó, 2002). In particular, Minetti and Ardigó (2002) analyzed the effect of extraloading in jumping performance. Assuming an unchanged take off speed, the authors estimated that carrying a 3-kg weight in each hand would allow an athlete to enjoy a 6% increase in jump distance. They explored, both with human subjects and computer simulations, how halteres affect take off speed. Minetti and Ardigó (2002) asked their study subjects to jump vertically, with and without halteres. The experiment determined that take off speed actually increased by 5-7% when jumpers were loaded with halteres weighing from 2 to 9 kg each. According to Minetti and Ardigó (2002), halteres can lead to an increased take off velocity because moderately loaded muscles exert greater force than unloaded muscles, while still contracting at reasonable rates. Thus, loaded muscles can generate increased power.

The purpose of this experimental study was to document the kinematic and dynamic characteristics of the standing long jump of non professional or amateur jumpers, without extra loading and with handheld weights (halters) of different mass and to investigate the association between the former and jumpers' performance.

MATERIAL AND METHODS

Fifteen subjects (13 males and 2 females) between the ages of 19 and 21 years old participated in this horizontal prospective study (Table 1). Participants were selected randomly using a computed generated list and they were all of them students in Aristotle University of Thessaloniki. Written informed consent approved by the Human Ethics Committee of the Aristotle University of Thessaloniki was obtained prior to participation. Participants had no history of musculoskeletal trauma especially in the lower extremities the last three to six months and they were kept away of any strenuous exercises 24 hours prior to participation.

Table 1. *Summary statistics of subjects' characteristics.*

N=15 (13 males, 2 females)	Mean (SD)	Minimum	Maximum
Age (years)	19.8 (0.83)	19	21
Body height (cm)	178 (7)	171	186
Body mass (kg)	67.69 (8.22)	60	76

Each participant performed standing long jumps. The point of take off was located onto a force platform (Kistler, type 9281CA, Winterhur, Switzerland) and the subjects were landed onto a mattress of 5 cm thickness. The take off and landing areas were in the same horizontal plane. A metric tape was used to measure the jumping distance of each participant. Regarding the jumping technique, free arm swinging without or with handheld halters of different weights (1.5 kg and 3 kg in each hand) was used. Handheld halters were swung back and forth by the jumper before take off, then forwards during the first phase of flight and finally swung backwards just before landing. The subjects repeated the jumping set (consisted of free arm swinging jump, jumping with 3 kg and then with 6 kg handheld halters) three times and the three different technique jumps were performed in a random order. All jumps were performed with maximum physical effort. Between each set participants were invited to rest for five minutes and in addition a 45 seconds interval was given between different jumps to minimize the effects of fatigue on jump performance. The experimental session was preceded by preparatory exercise of 10 minutes using Monark Ergomedic (814 E, class A, din 32932) as well as by three test jump efforts for each participant.

The locomotor tasks described above were assessed by analysis of kinematic and dynamic variables. Kinematic data were obtained using 2D Ariel Performance Analysis System (APAS) (Ariel, 1990), consisting of one video camera (Panasonic PV-900, 60Hz) located to the right of a calibrated area of 180 cm X 180 cm. The position of the subject's main body segments was determined by means of retro reflective markers of 12 mm attached on the following bony landmarks on the right side: 5th metatarsal bone, lateral malleolus, lateral femoral condyle, greater trochanter, greater humeral tubercle, elbow joint, wrist joint. Anthropometric parameters of each subject were computed from the markers' positions and used for estimation of internal joint centers. These in turn enabled calculation of body parts kinematics.

Ground reaction forces were measured by means of a force platform (Kistler, type 9281CA, Winterthur, Switzerland). The resulting signals were used for the calculation of force-time curve characteristics concerning: a) power and work b) center mass (CM).

Specific sets of parameters for the characterization of each jump were used (Table 2). Jumping distance was defined as the horizontal displacement of the toes between the initial and landing positions.

For each subject variables (were averaged) we have chosen the best over the three trials of each jumping set. One-way Anova test was used to analyze the kinematic and dynamic differences among the three different jumping techniques and Pearson correlation factor determined any significant correlation among kinematic and dynamic variables of each jump and jumping distance. Level of significance was set to 0.05 ($p \leq 0.05$).

Table 2. *Jump parameters.*

Kinematic variables	**Symbol**	**Unit**
Jumping distance	L	M
Positive vertical displacement of center of mass	ΔSCM-y	cm
Horizontal displacement of center of mass	ΔSCM-x	cm
Vertical take off speed of center of mass	VCM-to-y	m/s
Horizontal take off speed of center of mass	VCM-to-y	m/s
Take off angle of center of mass	φCM-to	^{o}
Dynamic variables		
Index of relative maximum vertical force	$F_{max-y/BW}$	Index
Index of relative maximum horinzotal force	$F_{max-x/BW}$	Index
Duration of support [eccentric phase]	t_{ecc}	ms
Duration of support [concentric phase]	t_{con}	ms
Total duration of support	t_{tot}	ms
Mean positive power in vertical axis	Pm-th-y	Watt
Mean power in horizontal axis	Pm-x	Watt
Total mechanical work in vertical axis	Wtot-y	Joule
Total mechanical work in horizontal axis	Wtot-x	Joule

RESULTS

The summarized kinematic and dynamic data are outlined in Table 3. The jumping distance was significantly increased 7 cm (2.7%) with 3 kg handheld halters compared to free arm jumps (p=0.006). In addition the subjects jumped 5 cm further with 6 kg handheld weights (2.67±0.27 m) than without (2.62±0.21 m) (statistically significant difference, p=0.005). The 2 cm difference in jumping performance with halters of different weights was proven insignificant.

The horizontal displacement of the center of mass was significantly increased with 3 kg and 6 kg handheld compared to free arm jumps (p=0.007, p=0.005 respectively). Regarding vertical displacement of center of mass a significant decrease was recorded between both free arm and 3 kg halters jumps and 3 kg and 6 kg weights.

Table 3. *Kinematic and dynamic data of the different standing long jumps (the shaded cells were proven statistically significant).*

Kinematic variables	**Symbol**	**Unit**	**0 kg**	**3 kg**	**6 kg**
Jumping distance	L	M	2.62±0.21	2.69±0.22	2.67±0.27
Positive vertical displacement of center of mass	ΔSCM-y	cm	29±8	23±6	21±6
Horizontal displacement of center of mass	ΔSCM-x	cm	73±9	79±6	81±6
Vertical take off speed of center of mass	VCM-to-y	m/s	2.28±0.33	2.11±0.27	1.83±0.28
Horizontal take off speed of center of mass	VCM-to-x	m/s	3.14±0.32	3.25±0.32	3.37±0.38
Take off angle of center of mass	φCM-to	o	36±5	33±4	29±5
Dynamic variables					
Index of relative maximum vertical force	$F_{max-y/BW}$	Index	2.3±0.59	2.49±0.51	2.46±0.61
Index of relative maximum horinzotal force	$F_{max-x/BW}$	Index	1.11±0.13	1.11±0.12	1.11±0.12
Duration of support (eccentric phase)	t_{ecc}	ms	569±245	650±212	783±163
Duration of support (concentric phase)	t_{con}	ms	205±55	236±84	204±78
Total duration of support	t_{tot}	ms	774±205	886±170	987±136
Mean positive power in vertical axis	Pm-th-y	Watt	1168±493	1247±493	1252±468
Mean power in horizontal axis	Pm-x	Watt	1638±620	1487±448	1989±913
Total mechanical work in vertical axis	Wtot-y	Joule	586±120	693±166	838±330
Total mechanical work in horizontal axis	Wtot-x	Joule	2108±639	236±671	2649±831

Vertical take off velocity of the center of mass was decreased significantly between free arm (2.28±0.33 m/s) and 3 kg halters (2.11±0.27 m/s) (7.46% decrease, p=0.049) as well as between 3 kg weights and 6 kg ones (1.83±0.21 m/s) (13.28% decrease, p=0.000). According to our data, a gradual significant increase in the horizontal take off velocity of the center of mass was depicted between free arm and 3 kg halters jump (3.5% increase) and 3 kg weights and 6 kg ones (3.69% increase). Take off angle of center of mass was insignificantly decreased with the 3 kg weights compared to the free arm jump (33±4° versus 36±5°, 8.43% decrease) while the same difference was statistically significant between 0 kg (36±5°) and 6 kg (29±5°) handheld weights (12.13% decrease, p=0.001).

Regarding total support time, significant differences were observed between free arm and 3 kg halters jumps (14.47% increase, p=0.022) as well as between 3 kg and 6 kg weights (11.39% increase, p=0.003).

Total mechanical work in vertical axis was increased significantly during 3 kg jumps (693±166 J) compared to free arm jumps (586±129 J) (18.26% increase, p=0.048).

Finally strong positive correlation was observed 1) between jumping distance and vertical take off velocity of center of mass and jumping distance and peak horizontal force during both free arm jump (r=0.764, p=0.027 and r=0.852, p=0.007 respectively) and 3 kg handheld halters jump (r=0.747, p=0.033 and r=0.751, p=0.032 respectively), 2) between jumping distance and vertical take off velocity of center of mass and jumping distance and horizontal displacement of center of mass during 6 kg handheld halters jump (r=0.764, p=0.027 and r=0.829, p=0.021 respectively).

DISCUSSION AND CONCLUSIONS

Contrary to initial expectation, jump distance is increased with moderate additional weights. This was familiar to ancient Greek athletes where halters were a part of the original Olympic pentathlon. Ancient pictorial and written sources report that athletes jumped more than 15 m with handheld weights, during pentathlon which enabled them to jump further than without these weights. Elbert (1963) recorded a 15-20 cm improvement in jumping performance with a pair of halters of 2.5 kg each. In 2002, Minetti and Ardigo used a software model of a jumper to simulate vertical jumps loaded with different weights in the range 0-18 kg. The authors observed that take off speed was 2% greater for a pair of halters with a total mass of 6 kg, compared to unloaded arm jumps. In addition they concluded that jumping performance began to decline when halters weighed more than 10-12 kg. Their results indicated that greater distance (at least 0.17 m in a 3-m jump) is achievable during a loaded standing long jump due to both horizontal translation of the center of mass and the greater ground reaction force that is generated. In 2004, Lenoir et al. reported that four trained athletes jumped significantly further during a five-fold with handheld halters (14.64±0.76 m) than without weights (13.88±0.70 m). The authors concluded that the extra distance jumped when using halters was probably due to changes in the position of the jumper's center of mass both at take off and landing and an increase in take off velocity. During standing long jumps, Butcher et al. (2004) observed greater distance (0.25 m) for an adult male, who was loaded with 7.2 kg and 0.16 m increase when a female subject used 4.6 kg weights. Ashby et al. (2005), reported 0.39 m increase in jumping distance during standing long jumps with halters. In our experimental study, jumping performance was improved with handheld weights of a total mass of 3 kg and 6 kg (0.07 m in 3-kg jump, greatest jumping distance; 0.05 m in a 6-kg jump). According to our data the horizontal displacement of the center of mass before take off was significantly increased with 3 kg and 6 kg handheld compared to free arm jumps and total mechanical work in vertical axis was increased significantly during 3 kg jumps because of greater peak vertical ground reaction force. Regarding jumping distance our calculated values are smaller than the ones encountered in the literature, probably because peak jumping performance is achieved with personalized optimum loading (Thaller et al., 2003) and influenced by individuals' muscle strength.

The major functional aim in long jumping is to reach maximal distance. Long jump is a projectile event and the distance achieved is strongly influenced by take off conditions. In 1993, Hay proposed that optimum take off angle is a primary goal in improving jumping performance. It is generally accepted that high take off velocity improves jumping performance. When jumping at low take off angles a subject has increased horizontal speed at landing and he can land with his feet far ahead of his body (Linthorne et al., 2002). According to Wakai and Linthorne (2005), the total jump distance in the standing long jump is the sum of three component distances (take off, flight and landing). The flight distance was strongly affected by a decrease in jumper's take off velocity with increasing take off angle and the take off and landing distance steadily decreased with increasing take off angle due to changes in jumper's body configuration. Wakai and Linthorne (2005) concluded that the optimum take off angle in the standing long jump is considerable less than 45^{o}, among 20^{o} and 30^{o}. For the five participants in their study the calculated optimum take off angles were 19-27^{o}. However, according to their data, the loss in jump distance through using a sub optimum take off angle was relatively small. Aguado et al. (1997) and Horita et al. (1991) reported horizontal take off velocities of 3.19±0.49 m/s and 3.27±0.19 m/s respectively. According to our data, a gradual significant increase in the horizontal take off velocity of the center of mass was depicted between free arm and 3 kg halters jump (3.5% increase) and 3 kg weights and 6 kg ones (3.69% increase). Take off angle of center of mass was insignificantly decreased with the 3 kg weights compared to the free arm jump (33±4^{o} versus 36±5^{o}, 8.43% decrease) while the same difference was statistically significant between 0 kg (36±5^{o}) and 6 kg (29±5^{o}) handheld weights (12.13% decrease, p=0.001).

Standing long jump has more difficulty producing the horizontal velocity which is necessary to project the center of mass forward to the air. Handheld halters were swung back and forth by the jumper before take off, then forwards during the first phase of flight and finally swung backwards just before landing. As a result of the position of the upper limbs, the body's center of mass was more anterior at take off and more posterior with respect to foot contact on landing. This horizontal displacement resulted in an increase in jumping distance (Ebert, 1963; Ward-Smith, 1995; Minetti & Ardigo, 2002). Ashby and Heegaard (2002) investigated also the role of arm motion on the performance of the standing long jump. According to their results, the participants jumped 21.2% (8 cm) further on an average with arm movement (2.02±0.03 m) than without (1.72±0.03 m). Seventy-one percent of the increase in performance was attributable to a 12.7% increase in take off velocity of the center of mass. Increases in the horizontal displacement of the CM before take off accounted for the remaining 29% of improvement in jumping distance. In addition swinging the arms backwards during the flight phase produced excessive forward rotation about the center of mass. In our study the horizontal displacement of the center of mass before takeoff was significantly increased with 3 kg and 6 kg handheld compared to free arm jumps and this yielded in greater jumping distance.

There were some limitations to our study. First the number of the participants was limited. Moreover the experimental session was preceded only by three test jump efforts for each participant.

In conclusion greater distance is achievable during a loaded standing long jump of non professional or amateur jumpers due to 1) horizontal translation of the center of mass, 2) the greater ground reaction force that is generated, 3) decrease in the take off angle of center of mass and 4) increase in the horizontal take off velocity of the center of mass. This experimental data can be used possibly by professional athletes in their everyday training program in order to improve their jumping technique and subsequently their performance.

REFERENCES

1. AGUADO X, IZQUIERDO M, MONTESINOS JL. Kinematic and kinetic factors related to the standing long jump performance. *J Hum Movement Stud.* 1997; 32:157-169. [Back to text]
2. ARIEL GB. *The Ariel Performance Analysis System.* 1990; *SPIE.* 1356:76-78. [Back to text]
3. ASHBY BM & DELP SL. Optimal control simulations reveal mechanisms by which arm movement improves standing long jump performance. *J Biomech.* 2006; 39(9):1726-1734. doi:10.1016/j.jbiomech.2005.04.017 [Back to text]
4. ASHBY BM & HEEGAARD JH. Role of arm motion in the standing long jump. *J Biomech.* 2002; 35: 1631-1637. doi:10.1016/S0021-9290(02)00239-7 [Back to text]
5. ASHBY BM. Optimal control simulations demonstrate how using halters (hand-held weights) can increase standing long jump performance. XXth Congress of the International Society of Biomechanics and 29th Meeting of the American Society of Biomechanics, July 32-August 5, 2005; Cleveland, OH, http://www.exponent.com. [Abstract] [Back to text]
6. BUTCHER MT & BERTRAM JEA. Jump distance increases while carrying handheld weights: Impulse, history, and jump performance in a simple lab exercise. *J Scie Education Technol.*2004; 33: 285-297. doi:10.1023/B:JOST.0000031267.98644.98 [Back to text]
7. EBERT J. Der Pentathlonsprung. Abh. Sochs. Akad. Wiss. Philo-Hisot. *Klasse*. 1963; 56:35-65. [Back to text]
8. GARDINER E. Fhayllus and his record jump. *JHS.* 1904; 70-80. [Back to text]

9. HAY JG. Citius, altius, longius (faster, higher, longer): The biomechanics of jumping for distance. *J Biomech*. 1993; 26 (1): 7-21. doi:10.1016/0021-9290(93)90076-Q [Back to text]
10. HORITA T, KITAMURA K, KOHMO N. Body configuration and joint moment analysis during standing long jump in 6-yr-old children and adult males. *Medi Scie Sports Exer.* 1991; 23: 1068-1077. [Abstract] [Back to text]
11. LENOIR M, DE CLERCQ D, LAPORTE W. The "how" and "why" of the ancient Greek long jump with weights. A five-fold symmetric jump in a row? *J Sports Scie*. 2005; 23: 1033-1043. doi:10.1080/02640410400022037 [Back to text]
12. LINTHORNE N, GUZMAN M, BRIDGETT L. Optimum take-off angle in the long jump. *J Sports Scie*. 2005; 23:703-712. doi:10.1080/02640410400022011 [Back to text]
13. MINETTI A & ARDIGO L. Halters used in ancient Olympic long Jump. *Nature.* 2002; 420 (69):141-142. [Back to text]
14. TASCH P. Conservation of momentum in antiquity: A note on the prehistory of the principle of jet propulsion. *Isis.*1952; 43:251-252. [Back to text]
15. THALLER S, SUST M, TILP M. Individual effects of additional weights used in ancient Greek Olympic pentathlon. (Abstract) 8th ECSS Congress, 2003; Salsburg, pp 387. [Abstract] [Back to text]
16. WAKAI M & LINTHORNE NP. Optimum take-off angle in the standing long jump. *Hum Movement Sci.* 2005; 24(1): 81-96. doi:10.1016/j.humov.2004.12.001 [Back to text]
17. WARD-SMITH AJ. The application of modern methods of biomechanics to the evaluation of jumping performance in ancient Greece. *J Sports Sci.* 1995; 13: 223-228. doi:10.1080/02640419508732231 [Back to text]

