©Journal of Sports Science and Medicine (2012) **11**, 162-169
http://www.jssm.org

Research article

A gender-based kinematic and kinetic analysis of the snatch lift in elite weightlifters in 69-kg category

Erbil Harbili
Selçuk University, School of Physical Education and Sport, Alaeddin Keykubat Campus, Konya, Turkey

Abstract
The objective of this study was to compare the kinematic and kinetic differences in snatch performances of elite 69-kg men and women weightlifters, the only category common to both genders. The heaviest lifts performed by 9 men and 9 women weightlifters competing in 69-kg weight class in Group A in the 2010 World Weightlifting Championship were analyzed. The snatch lifts were recorded using 2 cameras (PAL). Points on the barbell and body were manually digitized by using Ariel Performance Analysis System. The results showed that maximal extension angle of the ankle and knee during the first pull, the knee angle at the end of the transition phase, and maximal extension angle of the knee in the second pull were significantly greater in men ($p < 0.05$). The angular velocity of the hip was significantly greater in men during the first pull ($p < 0.05$). During the second pull, women showed significantly greater maximal angular velocity at the hip and ankle joints ($p < 0.05$). Moreover, the maximal vertical linear velocity of the barbell was significantly greater in women ($p < 0.05$). The absolute mechanical work and power output in the first pull and power output in the second pull were significantly greater in men ($p < 0.05$). However, the relative mechanical work was significantly greater in women during the second pull ($p < 0.05$). The results revealed that in 69-kg weight class, women were less efficient than men in the first pull, which is strength oriented, whereas they were as efficient as men in the second pull, which is more power oriented.

Key words: Biomechanics, weightlifting, body weight category, sex.

Introduction

Weightlifting, an event restricted only to men in the past, has gained popularity among women since the first Women's World Weightlifting Championships in 1987, yet the performance development in this event has not been studied as much in women weightlifters as in men (Garhammer, 1991; 1998; 2002; Gourgoulis et al., 2002; Hoover et al., 2006).

It was demonstrated that the women weightlifters of different categories who competed in the first Women's World Weightlifting Championships in 1987 could generate higher short-term power outputs than previously documented, but not as much as men in absolute values and relative to body mass (Garhammer, 1991). It was also reported that in the 1998 World Weightlifting Championship, the duration of the pull in women weightlifters for each type of lift increased by 12% when compared to the 1987 results, and for the snatch lift, the second pull power values increased by 33% while the duration of the second pull decreased by 30% (Garhammer et al., 2002). The larger horizontal displacement of the barbell observed in women weightlifters in a national competition in 1999 was attributed to the weightlifters' inconsistency, and less than half of the snatch attempts demonstrated by the women weightlifters in that study displayed the optimal toward-away-toward horizontal bar trajectory (Hoover et al, 2006). It was demonstrated in another study that the mechanical work done for the vertical displacement of the barbell in men was greater in the first pull than in the second pull, while it was found to be similar in both phases in women (Gourgoulis et al, 2002). It was found in the same study that women flexed their knees less and more slowly in the transition phase than men and that the drop-under time during the turnover and catch phases was also longer in women (Gourgoulis et al., 2002). A recent study showed that the magnitudes of the barbell's linear kinematics, the angular kinematics of the lower limb, and other energy characteristics did not exactly reflect those reported in the literature and that the snatch lift patterns of the elite women weightlifters were similar to those of male weightlifters (Akkus, 2011). The differences observed between women's and men's snatch performances were mainly associated with the recent participation of women in weightlifting (Garhammer, 1991; Gourgoulis et al., 2002; Hoover et al., 2006) and it was stated that women needed time to recruit and develop their performance in the snatch lift (Garhammer, 1991; Gourgoulis et al., 2002).

Significant variations were reported in the kinematics of the snatch technique between weightlifters of different weight categories (Garhammer, 1985). It was also reported that the barbell trajectories varied greatly in the snatch lifts of elite male junior lifters of different weight and that lifters belonging to heavier categories were more efficient, as they managed to have longer barbell propulsion trajectories (Campos et al., 2006). Currently, there are eight bodyweight categories for men (56, 62, 69, 77, 85, 94, 105, +105 kg) and seven for women (48, 53, 58, 63, 69, 75, +75 kg) in Olympic weightlifting. Of all the weight classes, the 69-kg is the only category common to both genders. It was maintained in a study that the 69-kg category was indeed representative of national caliber performance in the snatch, and recent history has confirmed the caliber of the athletes competing in this weight class and the larger field (Hoover et al., 2006); however, no studies were found in the present literature that compared the snatch performances of men and women in this weight class. In the only previous study that analyzed the 69-kg weight class in women, this category

Received: 28 December 2011 / Accepted: 13 February 2012 / Published (online): 01 March 2012

was identified as the weight class with the greatest depth of participants from top to bottom as well as one of the classes with the best potential for setting a national record during competition (Hoover et al., 2006). Therefore, the kinematic analysis of snatch performance in men and women weightlifters in the 69-kg weight class would provide an opportunity to compare genders independently of body weight variable.

Therefore, the aim of this study was to compare the kinematic and kinetic differences in snatch performances of elite 69-kg men and women weightlifters that competed in the 2010 World Weightlifting Championship. We hypothesized that, because of the elimination of the potential effects of different bodyweights on the kinematics of the barbell, this comparative analysis of the snatch performances in the 69-kg weight class would demonstrate subtle differences between genders, thus providing valuable information for athletes and their coaches to integrate into training and competition.

Methods

Subjects

The data were collected during the 2010 78th Men's and 21st Women's World Championships in Antalya, Turkey. The heaviest lifts performed by 9 elite men and 9 elite women weightlifters competing in 69-kg weight class in Group A were analyzed (Table 1). Necessary official permissions for video recordings were provided by the Turkish Weightlifting Federation and the World Weightlifting Federation. This study was conducted in accordance with the guidelines set forth by the Institutional Review Board of Selçuk University.

Table 1. The characteristics of men and women weightlifters in 69-kg category.

Subject	Age (y)		Body mass (kg)		Barbell mass (kg)	
	Men	Women	Men	Women	Men	Women
1	25	27	68.75	68.23	160	116
2	23	19	68.85	68.26	160	113
3	25	22	68.88	67.32	157	112
4	28	26	68.64	68.72	148	106
5	21	20	68.33	68.42	145	105
6	19	24	68.98	64.85	145	103
7	18	26	68.40	67.94	143	100
8	23	24	68.47	68.25	140	100
9	27	23	68.47	68.64	140	97
Mean (±SD)	23.2 (3.4)	23.4 (2.7)	68.64 (.23)	67.85 (1.20)	148.7 (8.2)	105.8 (6.6)

Experimental design

This study is a comparative analysis, performed to determine kinematic differences between genders in snatch lift performance independently of the weight class variable. A three-dimensional (3-D) motion analysis was carried out to study the kinematics of the snatch lifts of men and women weightlifters competing in the 69-kg category in the 2010 World Weightlifting Championship. The differences between men and women lifters were assessed using the linear kinematics of the barbell and the angular kinematics of the lower limb.

Procedures

Snatch lifts were recorded using two digital cameras (Sony DCR-TRV18E, Tokyo, Japan), which captured images at 50 fields per second. Two digital cameras were positioned on the diagonal level of the platform at a distance of 9 m from the weightlifters, forming an approximate 45° angle with the sagittal plane of the weightlifters (Figure 1). The lift-off of the barbell was used to synchronize the 2 cameras.

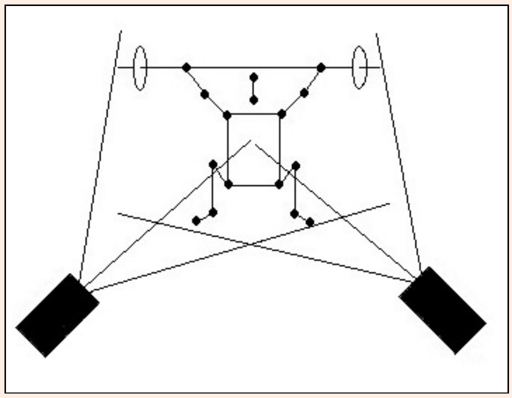

Figure 1. Experimental setup.

To determine 3-D linear kinematics of the barbell and the angular kinematics of the hip, knee, and ankle joints during the snatch lifts, one point on the barbell and five points on the body were manually digitized using the Ariel Performance Analysis System (APAS, San Diego, USA). The digitized points included the 5th metatarsal joint, lateral malleolus, the lateral epicondyle, the greater trochanter of the femur, and the greater tuberosity of the humerus. All the points were placed on the right side of the body. In addition to these points, the digitized point on the barbell was located on the medial side of the right hand.

A rectangular cube (length: 250 cm, depth: 100 cm, height: 180 cm) was used to calibrate the movement space. The 3-D spatial coordinates of the selected points were calculated using the direct linear transformation procedure of the analysis system with 12 control points. The calibration cube was placed on the platform prior to the competition, recorded, and then removed. The mean reconstruction errors described in RMS values were 2.9, 1.9, and 2.7 mm for the X, Y, and Z directions, respectively. A fourth-order Butterworth low-pass digital filter with a cut-off frequency of 4 Hz was used to smooth the raw position-time data (Gourgoulis et al., 2000; Gourgoulis et al., 2002). A residual analysis of the difference between filtered and unfiltered data over a wide range of cut-off frequencies was used in order to select a cut-off frequency (Winter, 2005).

The snatch lift was divided into 6 phases: the first pull, the transition, the second pull, the turnover under the barbell, the catch phase, and the rising from the squat position. The phases were determined according to the change in direction of the knee angle and the height of the barbell (Baumann et al., 1988; Gourgoulis et al., 2000; Hakkinen et al., 1984). The first 5 phases of the lift, from the lift-off of the barbell to the catch phase, were studied in this study.

The angular displacements and velocities of the ankle, knee, and hip joints were analyzed to investigate the angular kinematics of the lower body. In addition, linear displacement and velocity of the barbell was calculated. A vertical line drawn through the starting position of the barbell was used as a reference to determine the horizontal displacement of the barbell (Garhammer, 1985). Movement of the barbell toward the lifter was regarded as a positive horizontal displacement, and movement of the barbell away from the lifter represented a negative horizontal displacement.

The vertical work performed on the barbell during the first and second pull was calculated from changes in the barbell's potential and kinetic energies. Power applied to the barbell was calculated by dividing work done during each phase by its duration (Garhammer, 1993). The relative work and power values were calculated by dividing the absolute work and power values by the barbell's mass. The calculated power outputs only included the vertical work done by lifting the barbell.

Statistical analysis

All data were presented as means ± SD. Kolmogorov-Smirnov and Levene tests were used to test the normality of distrubitions and the homogeneity of variance, respectively. Differences in the kinematic and kinetic variables between men and women weightlifters were analyzed by the *t*-test for independent samples. Duration of the phases was compared using a two-way (gender × phase) analysis of variance (ANOVA) for independent samples. The angular kinematics were analyzed using two-way (gender × joint) ANOVA for independent samples. When significant main effects or interactions were found, Bonferroni tests were performed post-hoc to localize the effect(s). Effect size (η^2) and statistical power analysis values were used to interpret the magnitude of main and interaction effects. As an effect size, Cohen's *d* was of 0.2 as small, 0.5 as medium, and 0.8 as large (Cohen, 1988). All statistical analyses were performed using the Statistical Package for Social Science version 16.0 (SPSS, Chicago, IL, USA). The level of significance was set at $p \leq 0.05$.

Results

The average mass of the barbell was significantly greater in men weightlifters ($t_{16} = 12.243$, $p < 0.05$).

Table 2. Duration of the phases in the snatch lift. Data are means (±SD).

	Men (n=9)	Women (n=9)
First pull (s)	.546 (.064)	.511 (.042)
Transition (s)	.115 (.019)	.108 (.031)
Second pull (s)	.133 (.024)	.153 (.020)
Turnover under the barbell (s)	.235 (.016)	.235 (.019)
Catch (s)	.324 (.044)	.355 (.050)

No significant interaction was observed between gender and phase factors in duration of phases ($F_{4,80}$ = 2.199, p > 0.05, η^2= 0.099, power = 0.623). On the other hand, there was a significant main effect of the phase factor in duration ($F_{4,80}$ = 376.991, p < 0.05 η^2 = 0.962, power = 1.000). The first pull phase was of the longest duration, and the transition phase was the shortest (Table 2).

Table 3. Angular (degree) displacement of the ankle, knee, and hip joints in the first and the second pulls. Data are means (±SD).

	Men (n=9)	Women (n=9)
KA at the start of the lift	70.9 (16.0)	68.6 (8.4)
First pull		
Ankle	128.5 (6.6)	119.6 (4.3)*
Knee	146.8 (14.1)	134.7 (3.6)*
Hip	103.4 (6.7)	96.6 (7.7)
KA at the end of the transition phase	134.7 (7.9)	127.3 (6.4)*
Second pull		
Ankle	144.3 (4.3)	142.6 (8.4)
Knee	169.7 (3.5)	165.3 (5.1)*
Hip	191.8 (5.9)	193.0 (9.7)

KA: knee angle, *p < 0.05

There was a significant interaction between gender and joint factors in the angular displacement of the lower joints both in the first pull ($F_{5,48}$ = 51.934, p < 0.05 η^2 = 0.844, power = 1.000), and in the second pull ($F_{5,48}$ = 101.420, p < 0.05 η^2 = 0.914, power = 1.000) (Table 3). Maximal extension angles of the ankle and knee joints at the end of the first pull were significantly greater in men. Furthermore, during the transition phase, the knee angle flexed approximately 12° in men and 7° in women, and men showed significantly greater knee extension at the end of the transition phase. On the other hand, maximal knee extension during the second pull was greater in men. Besides, there were significant differences between maximal extension angles of the lower limb joints both in men ($F_{(2,24)}$ = 44.543, p < 0.05, η^2 = 0.504, power = 0.870) and in women ($F_{(2,24)}$ = 110.208, p < 0.05, η^2 = 0.794, power = 0.910) in the first pull. Maximal extension angle of the knee during the first pull was significantly greater in both genders than those of the ankle and hip (p < 0.05). Moreover, maximal extension angle of the ankle during the first pull was also significantly greater than that of the hip (p <0.05). Significant differences were found between maximal extension angles of the lower joints both in men ($F_{(2,24)}$ = 229.550, p< 0.05, η^2 = 0.944, power = 1.000) and women ($F_{(2,24)}$ = 90.595, p < 0.05, η^2 = 0.614, power = 0.841) in the second pull. During this phase, the maximal extension angle of the hip was significantly greater both in men and women than that of the knee and ankle. In addition, the maximal extension angle of the knee during the second pull was also significantly greater than that of the ankle (p < 0.05).

There was a significant interaction between gender and joint factors in the angular velocity of the lower joints both in the first pull ($F_{5,48}$ = 46.041, p < 0.05 η^2 = 0.827, power = 1.000) and in the second pull ($F_{5,48}$ = 10.912, p < 0.05 η^2 = 0.532, power = 1.000) (Table 4). Maximal extension velocity of the hip was significantly greater in men during the first pull, whereas during the second pull, women showed significantly greater maximal extension velocity at the hip and ankle joints. Besides, during the transition phase, there were no significant differences between genders in knee flexion velocity. On the other hand, significant differences were detected between the maximal extension velocities of joints in both men ($F_{(2,24)}$ = 98.795, p < 0.05, η^2 = 0.774, power = 0.901) and women ($F_{(2,24)}$ = 35.495, p < 0.05, η^2 = 0.644, power = 0.921) in the first pull. During the first pull, maximal extension velocity of the knee was greater than in the ankle and hip in both men and women (p < 0.05). During the second pull, there were significant differences between the maximal extension velocities of joints both in men ($F_{(2,24)}$ = 11.001, p < 0.05, η^2 = 0.435, power = 0.883) and in women ($F_{(2,16)}$ = 8.938, p < 0.05, η^2 = 0.394, power = 0.697). In this phase, maximal extension velocities of the knee and hip were significantly greater than that of the ankle in men. In women, maximal extension velocity of the hip was greater than those of both the ankle and knee joints (p < 0.05). In addition, the maximal extension velocity of the knee was also greater than that of the ankle in women (p < 0.05).

Table 4. Angular velocity of the ankle, knee, and hip joints in the first and the second pulls. Data are means (±SD).

	Men (n=9)	Women (n=9)
First pull		
Ankle (deg·s^{-1})	71.1 (7.6)	80.1 (18.9)
Knee (deg·s^{-1})	232.7 (33.6)	214.4 (53.0)
Hip (deg·s^{-1})	160.7 (24.5)	125.0 (19.7)*
KFV in the transition phase (deg·s^{-1})	150.3 (79.4)	95.5 (64.9)
Second pull		
Ankle (deg·s^{-1})	244.6 (35.8)	315.1 (67.2)*
Knee (deg·s^{-1})	342.1 (63.9)	348.8(60.0)
Hip (deg·s^{-1})	330.3 (39.8)	444.9(74.8)*

KFV: Knee flexion velocity. * p <0.05

The linear vertical velocity of the barbell was significantly greater in women during the second pull (Table 5). No significant differences were observed between men and women either in the linear vertical kinematics or horizontal kinematics of the barbell (Figure 2).

A significant phase and gender interaction effect ($F_{(1,16)}$ = 11.893, p<0.05, η^2 = 0.426, power = 0.899) was found for the mechanical work. The absolute mechanical work was significantly greater in men during the first pull. In addition, the relative mechanical work was significantly greater in women during the second pull (Table 6). Moreover, in men, the absolute mechanical work ($F_{(1,8)}$ = 20.00, p < 0.05, η^2 = 0.714, power = 0.973) and the relative mechanical work ($F_{(1,8)}$ = 20.80, p < 0.05, η^2 = 0.722, power = 0.978) were significantly greater in the first pull than in the second pull. However, in women, no significant differences were observed between the first and the second pulls, either in absolute or relative mechanical work. On the other hand, there was a significant interaction between gender and phase in power output ($F_{(1,16)}$ = 5.874, p < 0.05, η^2 = 0.269, power = 0.624). Absolute power output was significantly greater in men both in the first and second pulls (Table 6). Also, the absolute power output was significantly greater in the second pull than in the first pull both in men ($F_{(1,8)}$ = 285.39, p < 0.05, η^2 = 0.973, power = 1.00) and women ($F_{(1,8)}$ = 237.88, p < 0.05, η^2 = 0.967, power = 1.00). Moreover, the relative power output was also significantly greater in the second pull than in the first pull both in men ($F_{(1,8)}$ = 302.86, p < 0.05, η^2 = 0.974, power = 1.00) and women ($F_{(1,8)}$ = 306.88, p < 0.05, η^2 = 0.975, power = 1.00).

Table 6. Mechanical work and power output in the first and the second pulls. Data are means (±SD).

	Men (n=9)	Women (n=9)
First pull		
Absolute work (J)	556.1 (78.7)	361.3 (35.2)*
Relative work (J·kg^{-1})	3.75 (.55)	3.41 (.30)
Absolute power (W)	1025.2 (184.8)	712.7 (94.7)*
Relative power (W·kg^{-1})	6.89 (1.16)	6.73 (.81)
Second pull		
Absolute work (J)	375.6 (75.2)	334.0 (49.6)
Relative work (J·kg^{-1})	2.52 (.43)	3.15 (.40)*
Absolute power (W)	2851.2 (225.8)	2188.8 (291.5)*
Relative power (W·kg^{-1})	19.18 (1.24)	20.65 (2.14)

* p < 0.05

Discussion

Angular kinematics

It was reported in literature that the angular kinematics of the ankle joint in the first pull, the knee joint in the transition, and the hip joint in the second pull were important (Garhammer, 1980; Isaka et al., 1996; Gourgoulis et al., 2000). According to Isaka et al. (1996), the extensor muscles about the ankle, knee, and hip joints contribute to the control of antagonistic muscles in a sequence progressing from the hip to the ankle during the pull. This sequence is related to the sequence of the three phases of the full pull during lifting task (Isaka et al., 1996). During the second pull phase, women showed significantly greater extension values than men in the ankle and the hip joints, likely because of greater flexibility in women than in men (Gourgoulis et al., 2002). Contrary to literature, women weightlifters in the present study showed relatively lower values of extension in the knee and ankle joints, especially during the first pull. This inconsistency with

Table 5. Linear kinematics of the barbell in snatch lifts. Data are means (±SD).

Vertical kinematics	**Men (n=9)**	**Women (n=9)**
Barbell height at the end of the first pull (m)	.50 (.04)	.49 (.02)
Barbell height at the end of the second pull (m)	.89 (.04)	.89 (.04)
Maximal height of the barbell (m)	1.16 (.05)	1.17±0.05)
Drop displacement of the barbell (m)	0.14 (.03)	.15 (.02)
Maximal vertical linear velocity of the barbell in the first pull (m·s^{-1})	1.14 (.15)	1.03 (.12)
Maximal vertical linear velocity of the barbell in the second pull (m·s^{-1})	1.69 (.07)	1.80 (.12)*
Horizontal kinematics		
Horizontal displacement toward weightlifter in the first pull (cm)	3.56 (1.40)	4.26 (1.25)
Horizontal displacement away from weightlifter in the second pull (cm)	2.27 (2.94)	1.55 (4.74)
Horizontal displacement toward weightlifter after beginning of descent from maximum height (cm)	3.52 (1.89)	5.41 (4.20)

*p < 0.05

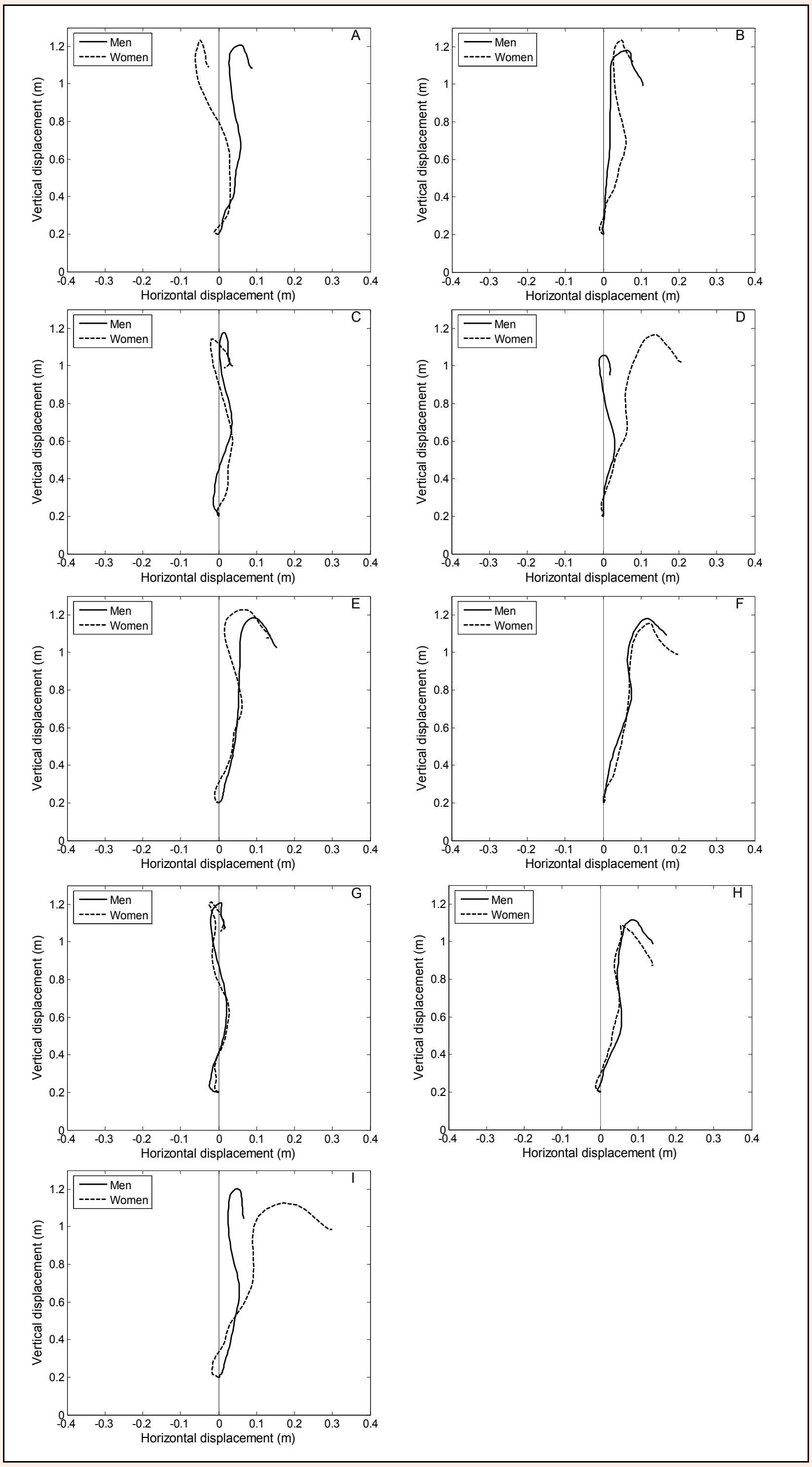

Figure 2. The barbell trajectories during the snatch lifts in 9 men and 9 women weightlifters competing in 69-kg weight category (group A), each figure depicting the comparision of 1 man and 1 woman weightlifters of the same rank in the list of the championship.

literature was not indicative of weaker flexibility in women; rather, it suggested weakness in the angular kinematics of the lower limb. As a result, women should strengthen the ankle plantar flexor and knee extensor muscles to perform lifts as effectively as men.

On the other hand, the transition phase is very critical and should be executed quickly with a small knee flexion to be effective (Enoka, 1979; Gourgoulis et al., 2000; 2009). The countermovement in the vertical jump and second bending (flexion) of the knees during a snatch lift as the barbell rises above knee level may be performed rapidly enough to store recoverable elastic energy and to elicit a stretch reflex facilitation of the immediately following concentric contraction of knee and hip joint extensor muscles (Garhammer and Gregor, 1992). A previous study indicated that women flexed their knees less and more slowly in the transition phase than men (Gourgoulis et al., 2002). Likewise, women weightlifters in the present study showed less knee flexion than men.

It was reported in a previous study that during the second pull, the maximal extension velocity of the hip was greater than the maximal extension velocity of the knees, increasing the acceleration of the barbell and contributing to the execution of an explosive second pull (Gourgoulis et al., 2009). It was determined in the present study that the angular velocity of the knee joint was greater in men during the first pull, whereas the angular velocity of the hip and ankle joints was greater in women during the second pull. In addition, the greatest angular velocity was observed in the knee joint in both men and women in the first pull, and in the second pull, it was in the hip joint in women and in the knee and hip joints in men. The greater angular velocity observed especially in the hip joint in women showed that women performed explosive strength more effectively during the second pull.

Linear kinematics of the barbell

Three key position values have been identified for assessment of horizontal barbell displacement during the snatch (Garhammer, 1985). The first is toward the lifter in the first pull, the second is away from the lifter during the second pull, and the third is toward the lifter once the barbell began to ascend from peak height (Garhammer, 1985). It was reported in literature that the toward-away-toward pattern of the barbell did not alter according to gender (Gourgoulis et al., 2002). In another study, an optimal toward-away-toward pattern was observed in 6 of 14 lifts performed by women weightlifters competing in 69-kg category (Hoover et al., 2006). In the present study, no significant differences in the horizontal displacement pattern were observed between men and women weightlifters. The horizontal movement of the barbell during the pull phase should be considered an effective application of muscle power, and a small horizontal movement is necessary for good lifting technique (Isaka et al., 1996). The greater variation in the horizontal displacement of the barbell during the lift, the more energy a lifter must extend to control the loaded barbell (Burdett, 1982; Hoover et al., 2006). In the present study, no significant differences in the horizontal displacement pattern were observed between men and women weightlifters. This result revealed that women used their energy as effectively as men.

The present study did not exhibit any differences in the linear vertical and horizontal kinematics of the barbell between men and women except for the maximum vertical linear velocity of the barbell during the second pull. The linear vertical velocity of the barbell was significantly greater in women during the second pull. Barbell velocities and its drop velocities from maximum height show great inter- and intralifter variations (Stone et al., 1998). There are two typical velocity curves: One has two velocity peaks, and the other shows a steady increase in velocity to a single maximum value (Baumann et al. 1988). The latter is characteristic of better weightlifters. Isaka et al. (1996) explained that skillful lifters could pull the barbell more smoothly during the transition phase without a marked deceleration of the barbell. During the transition phase, elite weightlifters occasionally show a decrease in barbell velocity, possibly because of too fast a starting movement or fatigue (Bartonietz, 1996; Gourgoulis et al., 2000). In addition, women weightlifters in this study showed a steady increase in velocity to a single maximum value during the full pull, characteristic of elite men weightlifters in literature, and the time-velocity relationship in all but 2 men weightlifters was found to be similar to that of women. On the other hand, the velocity of the barbell and its trajectories are affected by changes in the external load (Kipp et al., 2011). As the load of the barbell increased, decreases were found in the maximum vertical displacement of the barbell, the drop-under displacement, and the maximum vertical velocity of the barbell (Hoover et al., 2006). According to Gourgoulis et al. (2002), the finding that maximum linear velocity of the barbell was greater in women than men might not be considered as an indicator of the better technique of women and should be attributed to the lesser load of barbell that women had to overcome. The barbell load and its maximum vertical velocity of the elite 69-kg women weightlifters in the present study were observed to be greater than the results found for national level women weightlifters of the same body weight category reported in literature (Hoover et al., 2006). This inconsistency might be attributed to the higher skill level of the elite women weightlifters included in the present study.

The mechanical work and power output

Gourgoulis et al. (2000) reported that the mechanical work was greater in the first pull than the mechanical work in the second pull, and on the contrary, the power output was greater in the second pull than in the first pull. The first phase of the total pull is relatively slow and can be considered strength oriented, while the second pull is faster and can be considered more power oriented (Garhammer, 1991). In the present study, men showed a greater absolute mechanical work and power output in the first pull. Since the barbell height, its linear vertical velocity, and the duration of the phase in the first pull were similar in both sexes, it would appear that the greater barbell energetics recorded from the men was a consequence of them lifting loads that were 40% greater than the loads lifted by women weightlifters. During the second pull, the absolute power output was significantly greater in men than in women. On the other hand, when the mechanical work and power output were divided by the barbell's mass, power output values between men and women were similar, whereas the relative mechanical work was significantly greater in women than in men. This difference might have resulted from the fact that the duration of the second pull in women was greater than men by 15%. Although absolute power output values were determined in the present study to be greater in men in the second pull, the finding that relative power output values were similar in both sexes in the first and second pulls when the power output was divided by the barbell's mass indicated that women could be as skillful as men in power execution. In a study with a similar calculation of the relative power output values to that of our study, in which the relative power output values were calculated by dividing the absolute power output by the barbell's mass, Gourgoulis et al. (2004) reported that relative power output values during the first and second pulls were greater in adults than in adolescents, which means adolescents have lower ability in executing the movement powerfully.

It was reported in the current literature that the large improvements observed in women weightlifters from 1987 to 1998 are connected to changes in technique during the second pull (Garhammer et al., 2002). Garhammer (1991) demonstrated that the relative power output values in the second pull increased by 80% with regard to relative power output in the total pull and that this change was only about 53% in men. Women's power ratio of faster movements to slower movements, as in when the second pull is compared to the complete pull, was consistently higher than men (Garhammer, 1998). It was also reported in the present literature that women showed less ability in activities where a slow force development was needed relative to activities that required fast force development (Gourgoulis et al., 2002). Women might begin at a lower level of strength and muscle mass than men, partly because of the hormonal differences between the 2 sexes, but their potential for proportional improvement in strength is probably quite similar (Gourgoulis et al., 2002).

Conclusion

In the present study, relatively decreased extension values in the ankle and knee joints observed in women during the first pull indicated that women could not extend their joints as well as men weightlifters. Although women weightlifters were reported to be more flexible than men, the decreased extension values of the lower limb observed in women during the first pull suggested that their maximal strength was lower than men. Except for the greater relative mechanical work values in women during the second pull, the relative work and power output values were found to be similar in men and women during the first and second pulls. The results revealed that in 69-kg weight class, women were less efficient than men in the first pull, which is strength oriented, whereas they were as efficient as men in the second pull, which is more power oriented.

References

Akkus, H. (2011) Kinematic analysis of the snatch lift with elite female weightlifters during the 2010 World Weightlifting Championship. *Journal of Strength and Conditioning Research*, (In press).

Bartonietz, K.E. (1996) Biomechanics of the snatch: Toward a higher training efficiency. *National Strength & Conditioning Association Journal* **18**, 24-31.

Baumann, W., Gross, V., Quade, K., Galbierz, P. and Schwirtz, A. (1988) The snatch technique of World Class Weightlifters at the 1985 World Championships. *International Journal of Sport Biomechanics* **4**, 68-89.

Burdett, R.G. (1982) Biomechanics of the snatch technique of highly skilled and skilled weightlifters. *Research Quarterly for Exercise and Sport* **53**, 193-197.

Campos, J., Poletaev, P., Cuesta, A., Pablos, C. and Carratala, V. (2006) Kinematical analysis of the snatch in elite weightlifters of different weight categories. *Journal of Strength and Conditioning Research* **20**, 843-850.

Cohen, J. (1988) *Statistical power analysis for the behavioral sciences*. 2nd edition. Mahwah, NJ: Lawrence Erlbaum Associates.

Enoka, R.M. (1979) The pull in Olympic weightlifting. *Medicine Science in Sports* **11**, 131-137.

Garhammer, J. (1980) Power production by Olympic weightlifters. *Medicine & Science in Sports and Exercise* **12**, 54-60.

Garhammer, J. (1985) Biomechanical profile of Olympic weightlifters. *International Journal of Sport Biomechanics* **1**, 122-130.

Garhammer, J. (1989) Weightlifting and training. In: *Biomechanics of sport*. Eds: Vaughn, C.L. Boca Raton, FL: CRC press. 169-211.

Garhammer, J. (1991) A comparison of maximal power outputs between elite male and female weightlifters in competition. *International Journal of Sport Biomechanics* **7**, 3-11.

Garhammer, J. and Gregor, R. (1992) Propulsion forces as a function of intensity for weightlifting and vertical jumping. *Journal of Applied Sport Science Research* **6**, 129-134.

Garhammer, J. and Takano, B. (1992) Training for weightlifting. In: *Strength and Power in Sport*. Ed: Komi, PV, Blackwell Scientific Publications. 357-362.

Garhammer, J. (1993) A review of power output studies of olympic and powerlifting: Methodology, performance prediction, and evaluation tests. *Journal of Strength and Conditioning Research* **7**, 76-89.

Garhammer, J. (1998) Weightlifting performance and techniques of men and women. In: *International Conference on Weightlifting and Strength Training*. Ed: Komi, P.V. Lahti, Finland: Gummerus Printing. 89-94.

Garhammer, J., Kauhanen, H. and Hakkinen, K.A. (2002) Comparison of performances by woman at the 1987 and 1998 world weightlifting championships. In: *Science for Success Congress, Jyvaskyla, Finland, October 2-4*. Available form URL: http://www.csulb.edu/~atlastwl/98vs87womenWLcompare(poster).pdf)

Gourgoulis, V., Aggelousis, N., Mavromatis, G. and Garas, A. (2000) Three-dimensional kinematic analysis of the snatch of elite Greek weightlifters. *Journal of Sport Science* **18**, 643-652.

Gourgoulis, V., Aggeloussis, N., Antoniou, P., Chritoforidis, C., Mavromatis, G. and Garas, A. (2002) Comparative 3-Dimensional kinematic analysis of the snatch technique in elite male and female Greek weightlifters. *Journal of Strength and Conditioning Research* **16**, 359-366.

Gourgoulis, V., Aggeloussis, N., Kalivas, V., Antoniou, P. and Mavromatis, G. (2004) Snatch lift kinematics and bar energetics in male adolescent and adult weightlifters. *Journal of Sports Medicine and Physical Fitness* **44**, 126-31.

Gourgoulis, V., Aggelousis, N., Garas, A. and Mavromatis, G. (2009) Unsuccessful vs. successful performance in snatch lifts: a kinematic approach. *Journal of Strength and Conditioning Research* **23**, 486-494.

Hakkinen, K., Kauhanen, H. and Komi V.P. (1984) Biomechanical changes in the Olympic weightlifting technique of the snatch and clean and jerk from submaximal to maximal loads. *Scandinavian Journal of Sports Sciences* **6**, 57-66.

Hoover, D.L., Carlson, K.M., Christensen, B.K. and Zebas, C.J. (2006) Biomechanical analysis of women weightlifters during the snatch. *Journal of Strength and Conditioning Research* **20**, 627-633.

Isaka, T., Okada, T. and Fuanto, K. (1996) Kinematic analysis of the barbell during the snatch movement in elite Asian weightlifters. *Journal of Applied Biomechanics* **12**, 508-516.

Kipp, K., Harris, C. and Sabick, M.B. (2011) Lower extremity biomechanics during weightlifting exercise vary across joint and load. *Journal of Strength and Conditioning Research* **25**, 1229-1234.

Stone M.H., O'Braynt, H.S., Williams, F.E. and Johnson, R.L. (1998) Analysis of bar paths during the snatch in elite male weightlifters. *National Strength & Conditioning Association* **20**, 30-38.

Winter, D.A. (2005) *Biomechanics and motor control of human movement*. 3th edition. John Wiley and Sons, Inc. New Jersey.

Key points

- Women weightlifters should do assistant exercises to strengthen their ankle flexor and knee extensor muscles in order to increase their maximal strength in the first pull.
- Women weightlifters should be able to execute a deeper and faster knee flexion in the transition phase in order to obtain a greater explosive strength during the second pull.

AUTHORS BIOGRAPHY

Erbil HARBİLİ
Employment
Assist. Prof. School of Physical Education and Sport, University of Selçuk, Konya, Turkey
Degree
PhD
Research interests
Sport biomechanics, training sciences
E-mail: eharbili@selcuk.edu.tr

✉ **Erbil Harbili**
Selçuk University, School of Physical Education and Sport, University of Selçuk, Alaeddin Keykubat Campus, 42003, Konya, Turkey