Biomechanical Assessments of the Snatch Lift: A Case Study

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Abstract

The main aim of this study was to assess the Snatch lift technique - performed by elite weight lifter - by (a) comparing the angular kinematics of upper and lower body joints in both side, and (b) determining the mechanical work, the power output, and the linear kinematics of the barbell during the first and second pulls in the snatch lift. For performing data collection and evaluation, the following software have been utilized: Vicon motion-capture system (Nexus 1.8.4) synchronized with two force plates – in addition to using Polygon 3.5.2 and Siliconcoach software. The result of this study shows that the maximum barbell height is about (1.44 m; that is, 93% of his height 1.55 m) and drop displacement is about (29.7 cm; which is, 20% of his maximum barbell height 1.44m). While during the first pull, the lifter has shown 34 degree of knees flexion; in the second pull, athlete planter flexed his ankle for about 17 degree, which is considered an important part to be included in the explosive phase as it contributes to 10% of the total power produced for the pull. During the second pull phase, the relative power outcome has increased by 100 % in comparison of first phase. The velocity in the second pull was significant (2.5 $m.s^{-1}$), which might be secondary to the relatively lightweight that was lifted (40 Kg). Thus, it will be interesting to see the impact of increasing the weight lifted on the performance of the athlete as well as its influence on the biomechanical variables measured when evaluating the Snatch lift.

الخلاصة : الهدف الرئيسي من هذه الدراسة هو تقييم تقنية رفع الخطف أوالتي يؤديها رافع نخبة الوزن – عن طريق (أ) مقارنة حركيات الزوي من مفاصل الجسم العلوية والسفلية في كل جانب، و (ب) تحديد آلية عملها، وانتاج الطاقة وعلم حركة الحديد الخطية خلال السحب الأولى والثانوي في رفع الخطف.

تم استخدام برنامج (VICON) –نظام حركة الالتقاط (نيكزس ١,٨,٤) متزامن مع اثنين من لوحات القوة –بالإضافة إلى استخدام مضلع البرمجيات ٣,٥,٢ و Silicon coach. كأداء لجمع وتقييم البيانات

ونتيجة لهذه الدراسة ظهر أن الحد الأقصى لارتفاع الحديد (١,٤٤ م، وهذا هو، ٩٣٪ من طول قامته ١,٥٥ م) وقطر التشريد حوالي (٢٩,٧ سم؛ وهو، ٢٠٪ من الحد الأقصى لارتفاع الحديد ١,٤٤M) . بينما خلال السحب الأول قد أظهر رفع ٣٤ درجة انثناء في الركبتين.

في السحب الثاني، استعرضوا الكاحل الرياضي الزارع لنحو ١٧ درجة، والتي تعتبر جزءا مهما ليتم تضمينها في المرحلة المتفجرة كما أنها تساهم في ١٠٪ من إجمالي الطاقة المنتجة للسحب خلال مرحلة الانسحاب الثانية،

ازدادت نتيجة القوة النسبية بنسبة ١٠٠٪ بالمقارنة مع المرحلة الأولى.

كانت السرعة في سحب الثاني كبيرة (٢,٥ العربي ص ١)، والتي قد تكون ثانوية بالنسبة للوزن الخفيف نسبيا (٤٠ كغم).

وبالتالي، سيكون من المثير للاهتمام أن نرى تأثير زيادة الوزن ترفع على الأداء الرياضي، وكذلك تأثيرها على متغيرات قياس النشاط الحيوي عند تقييم رفع الخطف.

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Introduction

The weight lifting technique of snatch is the most technical component; that is implemented for lifting a weight/bar from the initial phase to straight arm over head position in one attempt[1]. The core evaluation of the skill mainly originated to describe the complexity of the weight lifting; since, the uniqueness of snatch is the combination of various motor physical components like strength, explosive strength, coordination, stability and mobility that are not seen in any other sports techniques[2] .

The success of snatch depends on mastery of skill, techniques and punctilious of the training program as per the guidance of coaches or sports. In the snatch, as the case in other sports techniques, the sports scientist have a great interest of accruing accurate and complete information about the performance characteristics of the elite players/weight lifters. Following the initial/ preparation position, is the phases of the Snatch lift, which is considered as the key factor of the snatch performance[3] can be divided into five phases; that are, the 1st pull, transition, 2nd pull, turnover, and catch phase. The first-pull phase is when the weightlifter lifts the barbell - with external weight - from the floor to clear knee height. For better performance during the first phase, flexion of hip, knee, and ankles is essential, while outward pointing of toe. The main action the lifter should perform during the Transition phase, that is between first and second pull phase, is to adjust the body in relation to the barbell. The second pull of the snatch starts from the bar when clears the knee height and ends when reaching full extension of lower limbs. During the second Pull, the weightlifter fully extends the knee and hips while the bar should be as close as possible to the body. When the bar reaches chest level, the aim is to drop beneath the bar and catch in a squat position. The lift of the bar is finishes with the bar at the static (hold) standing position. In other words, the main principle of snatch is to lift the barbell-weight, from the floor, to a stable standing position at overhead with the locked arm. While the mechanical inertia of an object is defined as its resistance to change, mechanical work during snatch is described as the total magnitude of the force that is applied in a specific distance. For a successful weight lifting in a snatch techniques, the bar height has to be high enough to allow the weightlifter to get into the catch placement under the bar, as well as to overcome the gravitational force that is working in the opposite direction of the pull. To overcome the gravitational force and to obtain positive benefit from inertia, for gaining maximal vertical displacement above the point at which force can significantly be applied, the player must produce momentum[4].

During the phase of first pull, changes are noticed in the bar kinetic and potential energies; as the potential energy goes higher and the athlete had to maintain a significant amount of work for a long period to overcome the effect of inertia[1]. In the second pull phase, the athlete had to work too quickly as compare to first pull phase because of duration variance. Duration of first pull is greater as compared second pull. Therefore, and while the first pull is relatively slow, which can be considered strength oriented phase, the second pull, which should be quick, can be considered as power generation phase or power oriented[5].Stone (1998) revealed that the phase of second pull has the most critical role in snatch lifts, during which the maximum power most be generated[6]. Additionally, Reiser et al. (1996)[7] describe the bar kinematics as the indicative of errors in the technique of lifting. Successes snatch lift attempts have been described by Isaka et al. (2010)[8] as those that maximized pull after second pull and minimized the loss in height of the bar during the squat. In the context of weightlifting, the majority of previous biomechanical studies addressing Snatch lift, have focused on the kinematics of the body segment and barbell during international events,[9,10] with a common aim; that is, to find out the kinematical differences for measuring the technical factors of snatch. Overall, there are relatively limited studies available for the examination of kinematic and kinetics parameters while performing the Snatch lift. Therefore, the main aim of this study is to evaluate the Snatch lifting technique of an athlete, by assessing the biomechanical advantages, and evaluating some kinematic and kinetics variables that are taking place during the Snatch.

Methodology

Participants

One male elite weightlifter, who is a current member of Saudi National Weightlifting team, has been selected as the participants of the study. Regarding the anthropometric data, the participant has an age of 34 years old, standing height 1.55 m, and body weight of 65 kg. The weightlifter had not any neurological or musculoskeletal disability that would strike snatching performance or any cognitive impairment that would inhibit motor learning. The weightlifter provided consent before data collection session.

Instrumentation

Data recording was conducted in the biomechanics laboratory, in the Department of Physical Therapy, at University of Dammam, KSA. Three-dimensional movements of the full-body segments were tracked by using 10 Bonita digital infrared cameras with 8.5 mm lenses, collecting at 100 Hz. Full calibration of all cameras were conducted - obtaining refinement 1000 frames samples at 100Hz while waving an active wand using frying pan technique. Our experimental sets up a standard meet, if not exceed, the standards used in the previous researches.Two AMTI force platform (Watertown, MA), with six-channel on each, was synchronized with the Vicon-motion capture system, to be used for collecting ground reaction force data at 2000 Hz. The two force platform was connected directly to the Vicon MX hardware, and data was processed using the Vicon Nexus (Centennial, CO) motion analysis software version# 1.8.4 and was smoothed using a Woltringquintic spline, low-pass filter with a cutoff frequency of 6 Hz. Data was analyzed with Vicon Polygon (Centennial, CO) software version# 3.5.1 and was presented by using Microsoft Excel 2011 program.

Data Collection

A group of biomechanics conducted data collection at biomechanics laboratory, in the Department of Physical Therapy, at University of Dammam, KSA. The athlete was asked to wear the comfortable non-reflective weight-lifting outfit and their preferred weight lifting shoe during the data recording session. Before obtaining informed consent letter from the participant, the athlete filled out a brief history of injury to ensure he was healthy and fit for the snatch performance at the time of trials.Also, to two markers that were affixed to both ends of the barbell, to quantify/visualize the trajectory of the bar while performing the Snatch, 39 reflective markers were attached on the participate, to form a full-body skeletal model that can be captured in 3-dimensions. Markers were affixed on the following body parts: Left/Right front head, Left/Right back head, Seventh cervical vertebrae, Tenth thoracic vertebrae, Clavicle, Sternum, Right back, Left/Right shoulder, Left/Right upper arm, Left/Right elbow, Left/Right Forearm, Left/Right wrist - thumb side, Left/Right wrist pinkie side, Left/Right second finger – dorsal side, Left/Right anterior superior iliac spine, Left/Right posterior superior iliac spine, Left/Right lateral thigh, Left/Right knee, Left/Right lateral shin, Left/Right ankle, Left/Right heel, Left/Right head of second toe. To overcome the occlusion that might occur to the two anterior superior iliac crest, of the right and lift side, two additional markers along the iliac crest, just superior enough to the corresponding right and lift side, were included in the skeletal-template as two of the anterior markers that would be visible for constructing the pelvic segment during the deep squat (catch) phase of the Snatch.

Subject Preparation

After a good worm-up session of lifting the bar (free of weight), the subject was asked to stand on a static T-pose position on the two force plates for static calibration. After processing the static/calibration trial, and before capturing the dynamic (Snatch lifting) trials, the full-body anatomical coordinate system was constructed for each segment based on the static trial, through using of the Vicon Plug-In Gait standard full body marker set. During the dynamic trials, the subject was asked to perform his preferred Snatch technique with 40 kg of weight (barbell with external weight) in a specified area (over two force plates). Total of Ten successful snatch trials were recorded in the biomechanics lab. For the purpose of the study, six successful snatch trials were selected and processed, to be used for the analysis.

Data Reduction

After initial data processing by the Vicon Nexus 1.8.4, and through the utilization of two Bonita (720c) digital video cameras – capturing the trials from two views (anterior and lateral view), six different phases of the snatch tails were identified as following: preparatory, first pull, transition, and second pull turnover and catch phase.Digital video clip taken from Two DV Bonita (720c) cameras were played in Silicon Coach, in the biomechanics lab, to identify and measure some variables (grip distance, the trajectory of the barbell) needed for qualitative analysis.

The average of joint angles in different phases, bar velocity, absolute work, relative work, absolute power and relative power were measured and analysis from normalized individual trial data. The work done for lifting the bar was measured, as suggested in Blazevich's book "Sport Biomechanics The Basics: Optimizing Human Performance" (2010)[11], through multiplying the sum of ground reaction force (measured by the two force plate) by the distance the bar traveled during the lift (measured by tracking the trajectory of the bar). The relative power and work values were calculated by dividing the absolute work and power values by the lifter's body mass (65 Kg). The calculated power outputs only included the vertical work done by lifting the barbell, as suggested by Garhammer (1993)[12].

Data Analysis

To find out differences between the right and left side of the body, segments angle were examined using a *t*-test; additionally, R-L trend lines were created. As for the research design, Correlation and Regression analyzes were utilized to examine the relationship between different parameter. All statistical analyzes were conducted using the (SPSS) v.18 statistical package for the social science. A significance level of $P< 0.05$ was used.

Results and discussion

Angle	Right	Left	*t*-value
	(M (SD	(M (SD	
Wrist	53.50 (2.88)	56.46 (1.72)	2.83
Elbow	162.42 (1.51)	161.19 (2.33)	1.08
Shoulder	48.21 (1.44)	50.30 (1.16)	2.75
Hip	48.90 (1.25)	50.25 (3.10)	0.98
Knee	80.66 (1.38)	94.35 (1.15)	*18.59
Ankle	76.90 (1.00)	94.35 (1.15)	2.82

Note: *M*=mean, *SD*=standard deviation. * Significance at 0.05 levels.

With regard to the analysis of data of joint angles during preparation phase of the snatch, and where a significance difference of the knee angle (KA) exists between the right and left side during the preparation phase (with *t*-value=18.59), insignificant differences were noticed in the rest of the angles measured - as obtained '*t*' ratio is less than the required *t*-value of 2.23.

Even though lifter's height might have an effect on the thigh and shin angle, the trunk angle should be constant, that is, around 30 degrees horizontally, during the preparation phase[13]. The findings of the study show that the athlete's trunk angle was approximately 42 degrees, which might influence his Snatch technique. The higher trunk position might be due to the significant difference between right and left knee flexion, poor trunk stability, or lack in the hip and thoracic mobility, that would probably default to flexion at the lumbar spine. Additionally, there is a noticeable difference in terms of grip distance — measured from the inner border of the barbell to the outer border of each hand—, as the grip distance measured from the right side = 0.2 meter while (Left) side grip distance = 0.14 meter, with difference of about 6 centimeters that may affect the leverage of the bar. From the same context, and as recommended by Zachary (2004), the athlete can determine his optimal grip width by measuring the distance from the deltoid of one arm to the fist of the opposite arm - that is abducted to 90 degrees.

Table:2 Kinematics differences and the Relative angle between right and left side at first pull.

Angle	Right	Left	*t*-value
	(M (SD	(M (SD	
Wrist	(2.31) 51.70	(1.30) 60.95	*8.53
Elbow	160.47 (1.55)	162.77 (1.72)	*2.43
Shoulder	(1.91) 49.40	(1.60) 51.49	2.05
Hip	(1.97) 81.86	(1.97) 85.01	*2.76
Knee	139.11 (1.72)	139.30 (3.91)	0.10
Ankle	100.08 (1.54)	101.70 (3.05)	1.15

Note: *M*=mean, *SD*=standard deviation. * Significance at 0.05 levels.

The analysis of data represented in (Table 2) shows that there is an insignificant difference in kinematics between right and left side of bodily joints during first pull phase of the snatch; that is in, shoulder angle (SA), knee angle (KA) and ankle angle (AA), as obtained '*t*' ratio is less than the required '*t*' value of 2.30. Whereas significance differences of wrist angle (WA), elbow angle (EA) and hip angle (HA) exist between of right and left side in the first-pull phase (with *t*-value = 8.53, 2.43, and 2.76, respectively).

Since maintaining trunk angle is very important to conserving kinetic chain and transfer the force in next phase[1,14], which considered to be the key factor of the performance during the first phase[15,16], it is essential that the torso of the athlete to be constant in the same position relative to the floor during the first pull (about 30 degrees above horizontal). As stated by Hoffman et.al, (2004)[16], the initial/first pull from the ground should be done by extending the knees, while maintaining torso angle above the horizontal line, and the higher than the hip. The finding of our study shows that the athlete arose his hips early. Consequently, the bar deviated slightly in front of the lifter's body due to the variation in grip distance and the significant differences in wrist, elbow and shoulder angle between right and left side.

Overall, the basic concept of snatch is that once the barbell lifted from the ground, the body of the athlete and the barbell should act as one unit, for better performance. The functions of this unit work optimally when the barbell is moving close to the vertical line of gravity. In other words, if the barbell goes too far from lifter's body during any parts of the execution, more energy will be required to control the loaded barbell[1,17]. Therefore, it is recommended for the athlete to get into the proper alignment and correct position of all bodily segments, starting from the initial position for the Snatch from the floor, all the way through the phases that follow.

Table 3: *Kinematics differences and Relative Angle between right and left side at transition phase.*

Angle	Right	Left	*t*-value
	(M (SD	(M (SD	
Wrist	51.13 (2.11)	53.38 (2.97)	1.51
Elbow	155.33 (3.79)	158.35 (5.75)	1.07
Shoulder	35.65 (1.61)	39.71 (2.58)	*3.26
Hip	116.50 (4.61)	120.23 (1.91)	1.82
Knee	144.05 (4.03)	143.50 (1.69)	1.01
Ankle	91.83 (2.48)	94.38 (1.69)	1.10

Note: *M*=mean, *SD*=standard deviation. * Significance at 0.05 levels.

With regard to the analysis of data of joint angles during transition phase of the snatch, and where a significance difference of the shoulder angle (SA) exists between the right and left side during the preparation phase (with *t*-value=3.26), insignificant differences were noticed in the rest of the angles measured - as obtained '*t*' ratio is less than the required *t*-value of 2.3.

The main aim of Transition phase, that is between first and second pull phase, is to adjust the body in relation to the barbell. In this phase, the lifter has shown knee flexion of about 34 degree, which is more than what has been found by Bartonietz (1996)[14]; that is, about 20 degree of knee flexion during the transition phase. This flexion of the knee joint, during the transition phase, permits the athlete to use stretch reflexes of the knee extensors and provoke potential energy to generate the explosive muscular power needed for the second pull[16]. Furthermore, this also assists to adjust the center of gravity to utilize the power generated by hip in the second pull.

Table 4: Kinematics differences and Relative Angle between right and left side at second pull phase.

Angle	Right	Left	*t*-value
	(M (SD	(M (SD	
Wrist	44.23 (1.16)	45.58 (3.31)	0.94
Elbow	146.03 (2.49)	146.95 (3.49)	0.32
Shoulder	40.15 (2.03)	43.85 (1.09)	*3.90
Hip	141.55 (2.10)	147.03 (1.84)	*4.80
Knee	175.88 (2.89)	175.82 (2.04)	0.04
Ankle	114.13 (3.60)	121.55 (2.02)	*4.39

Note: *M*=mean, *SD*=standard deviation. * Significance at 0.05 levels.

The analysis of data in (Table 4) shows that there is an insignificant difference shown between right and left side of body kinematics during second pull phase of the snatch; that is in, wrist angle (RA), elbow angle (EA) and knee angle (KA) as obtain '*t*' ratio is less than the required '*t*' value of 2.30. Whereas significance differences of shoulder angle (SA), hip angle (HA) and ankle angle (AA) exist between of right and left side in the phase of the second pull.

The second pull, as the most explosive and powerful phase of the snatch, begins when the knees reach maximum flexion during the transition phase. During the phase of second-pull, the hips, knees and ankles are required to be violently extended; therefore, the final stage of second-pull phase is known as "triple extension" position as the athlete's ankles, knees and hips at their maximum extension range of motion [2]. During the second pull, the shoulders are rapidly flexed to position the body to support the barbell overhead; and with the violent raise of the shoulder -and pulling of arms- the resultant position support for continued elevation of the barbell while the athlete jumps under the barbell[14]. The findings of our study show that there is a significant difference with regard to hip, ankle and shoulder angles in both sides. These differences may be due to shifting the weight toward strong leg to generate maximum explosive strength (lauder and lake, 2008).

During the phase of the second pull, and as stated by Bartonietz (1996)[14], the plantar flexion of the ankles joint results in the heels rising off the ground, which add to the power needed for arising the bar. In this phase, athlete planter flexed of the ankle joint about 17 degree, which is considered an important part to be included in the explosive/second-pull phase as it contributes to 10% of the total power produced for the pull, as stated in literature[10] .

Table 5: *Kinematics differences and Relative Angle between right and left side at Turnover phase.*

Angle	Right	Left	*t*-value
	(M (SD	(M (SD	
Wrist	(1.15) 67.01	(1.36) 70.20	*4.37
Elbow	138.05 (3.67)	143.88 (2.56)	*3.02
Shoulder	116.65 (3.24)	117.42 (1.69)	*3.85
Hip	(3.23) 91.55	(2.53) 96.05	*2.69
Knee	(1.95), 99.80	100.58 (3.19)	0.51
Ankle	(1.79) 74.66	(1.54) 76.21	1.60

Note: *M*=mean, *SD*=standard deviation. * Significance at 0.05 levels.

The analysis of data in (Table 5) shows that there is an insignificant differences show between right and left side body kinematics during turnover phase of the snatch; that is in, knee angle (KA) and ankle angle (AA) as obtain '*t*' ratio is less than the required '*t*' value of 2.30. Whereas significance differences of wrist angle (RA), elbow angle (EA), shoulder angle (SA) and hip angle (HA) exist between of right and left side in the turnover phase.

The turnover phase begins at max knee extension and ends when the barbell reaches the max height, as the feet re-establish full contact with the ground before the start of the catch phase[14]. During the turnover phase, and while feet leave the ground and jump outward to a receiving or squatting stance, about shoulder width, the lifter begins moving the body downward to be positioned underneath the barbell.

There is asymmetry in term of maximum elbow flexion in the pull phase; as there is a noticeable variance between the right and left max elbow flexion that were measured in the turnover phase (42 degree and 37 degree, respectively). Furthermore, the asymmetry that was found in wrist, elbow, shoulder and hip angles might be related to the grip distance variance that was noticed earlier, starting from the preparation phase. Overall, it is recommended that both elbows should be flexed to approximately 80 degree (100 relative angle) as the weight is raised, and then they are straightened completely for the remainder of the lift[2].

The analysis of data (Table 6) shows that there is an insignificant differences in kinematics of between right and left side of body segments during Catch phase of the snatch; that is in, wrist angle (WA), shoulder angle (SA), hip angle (HA) and knee angle (KA) as obtain ‘*t*’ ratio is less than the required ‘*t*’ value of 2.30. Whereas significance differences of elbow angle (AA), and knee angle (KA) exist between of right and left side in the catch phase.

Table 6: Kinematics differences and Relative Angle between right and left side at Catch phase

Angle	Right	Left	*t*-value
	(M (SD	(M (SD	
Wrist	(1.79) 74.66	(1.54) 76.21	0.55
Elbow	158.58 (4.32)	166.65 (5.38)	*2.82
Shoulder	114.28 (5.66)	122.35 (6.80)	2.23
Hip	(4.05) 60.66	(4.49) 63.50	1.14
Knee	(5.38) 63.45	(5.20) 72.22	*2.87
Ankle	(7.78) 71.82	(4.82) 73.85	0.54

Note: *M*=mean, *SD*=standard deviation. * Significance at 0.05 levels.

The catch phase is executed by locking the arms and stabilizing the barbell overhead position, while the lifter in a downward movement. Following the catch position, the athlete goes up from the squat to stand position for finishing the lift. During the catch and rise position, the mobility of shoulders is evaluated as the shoulders (> 180 degrees) flexed[2] , which is reported in our study.

The excessive flexion of the shoulders, in our findings, explains the increase in the horizontal displacement of the barbell - just after the beginning of descent from the maximum height; that is, HD3= 13.3 cm, with normal range of 3-9 cm as reported by Schilling et al. (2002)[18]. Lifter may need to monitor his excessive shoulders flexion, because the amount of energy exerted to control the loaded barbell increases as the horizontal displacement of the barincreases during the lift[17] .

In previous studies, and from a mechanical perspective, an ideal barbell trajectory has been considered as an indicator of a correct technique and an effective pull[8,19]. The horizontal displacement of the barbell during the snatch is one of the variables used to assess the technique of weightlifting[17], as well as to test the efficacy of muscle power, especially during the pulling phase[8].

As reported by Garhammer (1985)[19], the horizontal displacement of the barbell by men athletes has been reported to be between (3 and 9 cm) in the first pull, between (3 and 18 cm) in the second pull, and between (3 and 9 cm) just after the beginning of descent from the maximum height. The lifter in our study has moved the bar forward then inward (HD1= 0.44 cm) during the first pull, then the bar crosses the vertical line forward (HD2= 8.4 cm) during the second pull, before it is received behind the vertical line (HD3= 13.3 cm). During the first pull and second pull phase, the barbell has significant positive vertical velocity (1.29 and 2.5 $m.s^{-1}$, respectively). In the end of the first pull, the barbell reached approx. 51% of relative vertical velocity. This value lesser than the previous researches shows that by the end of first pull barbell should reach 70 % of its vertical velocity[20]. Overall, a continuous increase barbell velocity during the phases, with an absence of two peaks in the velocity curve[4], is an indication that the technique is approximately effective. However, since the trajectory of the bar travels forward at the start, this making the lifter lose leverage, which can be caused by the lifter swinging the bar, not having tight lats pulling the bar into the body, or the lifter starts with the bar too close to shins. Regardless of where the bar travels in relationship to this vertical line, it is imperative that the lifter keeps the barbell close to the body throughout the lift, to minimize the horizontal displacement of the bar and consequently diminishing the energy needed to control the bar trajectory[17].

Despite the fact that the leverage has been lost, due to the forward movement of the trajectory during the first pull phase, which consequently affected the power output, barbell goes to maximum vertical velocity in the second pull phase was significant (2.5 $m.s^{-1}$), which might be secondary to the relatively lightweight that was lifted (40 Kg). Therefore, and as the load is considered to be an important factor that plays a significant role in the magnitudes of the horizontal and vertical kinematics as well as the velocity of the barbell, it will be interesting to see the impact of increasing the bar-weight on the performance of the lifter.

One of the feasible means to evaluate the technique of Snatch lift is to examine the maximum barbell height and the height of the bar during the catch phase. Lifting the barbell effectively requires minimizing (a) the peak height of the barbell at the end of the turnover and (b) the drop displacement while dropping under the barbell to the catch position. In other words, lower maximum bar-height and

***Table 7**: Linear kinematics of the barbell.*

		Value
Vertical kinematics	First pull-Barbell height (cm)	48.6
	Second pull-Barbell height (cm)	98.2
	Maximum barbell height (m)	1.448
	Drop displacement (cm)	29.7
	Maximum vertical velocity of the barbell in the 1st pull ($m.s^{-1}$)	1.286 (%51.44)
	Maximum vertical velocity of the barbell in the 2nd pull ($m.s^{-1}$)	2.5
Horizontal kinematics		
	First pull-Horizontal displacement (cm); (HD1)	0.44
	Second pull-Horizontal displacement (cm); (HD2)	8.4
	Horizontal displacement toward weightlifter after beginning of descent from maximum height (cm); (HD3)	13.3

the drop displacement are among the most important indicators of an effective technique for a maximal snatch lift in weightlifters[15]. In international weightlifters, and during the highest barbell height during maximum attempts is 70% of the weight lifter height[1], the drops distance from the maximum height to the catch position has been cited to be just about 9 to 11 percent of the bars maximum height (Campos et al., 2006). The lifter in this assessment has a max barbell height of about (1.44 m; that is, 93% of his height that is 1.55 m) and drop displacement of about (29.7 cm; which is, 20% of his maximum barbell height 1.44m). Additionally, it was found in the study of Gourgoulis et al. (2004)[5] that the barbell maximum vertical displacement of elite player was 1.25 m, although maximum vertical displacement value 1.15 m in other previous studies[10].The major reason for inconsistence in the displacement might be due to anthropometrical differences.

Table 8: Mechanical work and power output in the first and second pulls

	First pull	Second pull
Absolute work ((J	195.7	224
Relative work ((J/kg	3.0	3.44
Absolute power ((W	3.26	(Increase 83%) 16
Relative power ((W/kg	0.05	(Increase 100%) 0.24

The relative power and work values were calculated by dividing the absolute work and power values by the lifter's body mass (65 Kg). The calculated power outputs only included the vertical work done by lift-.ing the barbell

In weightlifting, total work done by the athlete has a significant influence on the levels of performance; since, it can be optimized by minimizing the amount of total work done by the athlete. Decreasing or increasing the total work, which is directly related to the ability and mastery of athlete, can be achieved by efficaciously utilizing the ability of power generation of muscles.

Consistent with Gourgoulis et al. (2002)[10] findings, the mechanical work performed by the lifter of our study during the first pull (195 J) was less than that performed during the second pull (224 J).During the phase of first-pull, changes appear in the bar kinetic and potential energies. The potential energy goes higher and the athlete had to maintain a significant amount of work for a long period to overcome the effect of inertia[1]. In the second pull phase, the athlete had to work too quickly as compare to first pull phase. Duration of first pull is greater as compared to second pull. While the first pull is comparatively slow and can be defined as strength oriented phase, the second pull is fast, and it can be considered as power generation phase[5].

Concerning the power output, and compared to the first pull phase, there is a considerable increase in the absolute and the relative power of the second pull phase by (83% and 100%, respectively). The significant changes in power outcome between 1stand 2nd pull phase, in the current study, is in good agreement with the findings reported by Akkus (2010)[15] which indicate that the power output during the 2nd pull phase is greater than that of the 1st pull phase. Additionally, the barbell vertical displacement that is greater in second pull, as noticed in the current study, is an indicator of an optimal explosive strength. This result of the study was uniform with the finding of Baumann et al., 1988[4] who proposed that quick movement execution during second pull phase added to the explosiveness of the second pull.

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