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Lower Extremities' Kinematic Sequence and Kinetics during first Pull in Classic Snatch

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Abstract

The primary purpose of this study was to identify and compare the lower extremities' kinematic joints initiation sequence during the first pull phase of the classic snatch among male and female elite weightlifting athletes. As the secondary purpose, the maximal angle extension of joints, sub-phase duration, joint angular displacement and velocity, barbell velocity and the ground reaction force produced during the classic snatch sub-phases were determined and compared between genders. Six men (age: 19.9±2.29 years, height: 1.67±0.04 m, and body mass: 87.96±2.68 kg) and six women (age: 19.72±1.35 years, height: 1.55±0.42 m, and body mass: 70.25±10.78 kg) were tested for 85% of their 1 repetition classical snatch movement. Kinematics were captured at 100 Hz using a Qualisys motion capture system with eight cameras, and markers were placed bilaterally on the hips, knees and ankle joints. Kinetics were captured using the Kistler fixed force plate. The results revealed that a significant difference between males and females in term of hip joint initiation sequence, ground reaction force and barbell velocity. The hip angle among the female athletes initiates the start movement earlier than among male athletes. The ground reaction force and barbell velocity are higher in males compared to females. These findings suggest that the female weightlifters are not in a position to produce higher degrees of extension, thus reducing their efficiency in lifting and ability to take more substantial resistance. Having a limited angle extension results in the involved muscles not being fully contracted.

Keywords: *weightlifting, initiation sequence, joint kinematics, joint kinetics, biomechanics, snatch*

Introduction

Weightlifting can be considered a competitive strength-based sport that demonstrates power and techniques, by which athletes shift the barbell location from the floor to the above-head position in attempting a maximum weight single lift. The entire lower kinematic and kinetic chain works to complete its motion. Weightlifting performance is strongly dependent on technique, explosive strength, and flexibility (Schilling et al., 2002). Weightlifting is a full-body exercise that involves even minor muscles. The lower extremities play a vital role in weightlifting, not only by starting the initial movement but directing the motion of the barbell and force produced for the movement. To succeed in the snatch movement, a high level of skill is required in using physical output excellently to the barbell and holding the barbell above the head. Importantly, the snatch in which the barbell is held above the head lasts not more than two seconds. Not only force is involved, but a great amount of explosive power output is required in this motion (O'Shea, 2000).

The classic snatch, one of two Olympic weightlifting events, is the focus of this paper. The snatch involves the most technically sophisticated component of a weightlifting competition (Gourgoulis, Aggeloussis, Mavromatis, & Garas, 2000). The classic snatch exercise is commonly used to improve explosiveness and develop overall athleticism (Daws, 2007). The snatch is merely moving a barbell from the floor to above head in one quick movement (Gourgoulis et al., 2000). However, this primary explanation barely begins to describe the in-

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tricacy of the lift. The movement requires a combination of strength, coordination, explosiveness, mobility, and stability.

A 3-D analysis of snatch movement under competitive conditions was carried out by Bauman, Gross, Quade, Galbierz, and Schwirz (1988). In that study, the entire movement was divided into six phases: (1) the first pull (Figure 1), (2) the transition from the first to the second pull, (3) the second pull, (4) the turnover under the barbell, (5) the catch phase, and (6) the rising from the squat position (Bauman et al., 1988).

From the biomechanical point of view, a few studies have described the movements of the bar and the lifter; these include those such as those carried out by Lukashev, Medvedev, and Melkonian (1979), Bartonietz (1996), Bauman et al. (1988), Isaka, Okada, and Funato (1996), Stone, O'bryant, Williams, Johnson, and Pierce (1998), Gourgoulis et al. (2000), and Schilling et al. (2002). These papers provide in-depth information on the action of the parameters that cause the lifters' maximum performance. Although most lifters use similar technical styles (Garhammer, 1981), several differences in barbell trajectories and kinematic or kinetic characteristics exist among lifters with diverse experience or skill levels (Bauman et al., 1988; Burdett, 1982; Enoka, 1979; Garhammer, 1981; Garhammer, 1985). However, papers focusing on differences between lower extremities kinematic of male and female lifters during the first pull phase are rare.

This study aims to analyse and compare the angular kinematics of lower extremities (i.e., the hips, knees, and ankle joints) among male and female elite weightlifters during the first pull phase of the classic snatch, by evaluating the techniques of those elite weightlifters according to sub-phases, as described in this study, and stated as the relative position of the lower extremities joints in relation to the weightlifting bar when it is at start, shank, knee, and mid-thigh. The rationale is that by understanding the biomechanical variables such as the kinematic angle of hips, knee, and ankle joint on bilateral limbs during the snatch technique, we could obtain information that could further facilitate the technical and physical training of weightlifters, ultimately enhancing overall performance.

Methods

The analysis would excerpt and analyse an observable set of biomechanical patterns that would be linked to improvement in techniques which are important for weightlifting performance. To identify the similarity between biomechanical design and techniques improvement, we measured the kinematic and kinetic data of the hip, knee, and ankle joints. The participants need to lift 85% of their respective one repetition maximum (1RM). Joint kinematic and joint kinetic data were recorded to provide the most detailed information about movement performance (Bauman et al., 1988). Ethical approval for this study was granted by the human research ethics review committee of the Sultan Idris Education University. Each participant voluntarily provided written informed consent before participating.

Participants

Twelve subjects consisted of six men (age: 19.9±2.29 years, height: 1.67±0.04 m, and body mass: 87.96±2.68 kg) and six women (age: 19.72±1.35 years, height: 1.55±0.42 m, and body mass: 70.25±10.78 kg) were recruited for this study. All the subjects vigorously engaged in a resistance training plan that includes weightlifting routine and were presumed to be technically capable. They were all coached by elite national weightlifting coaches. All the participant were tested during the in-season training phase.

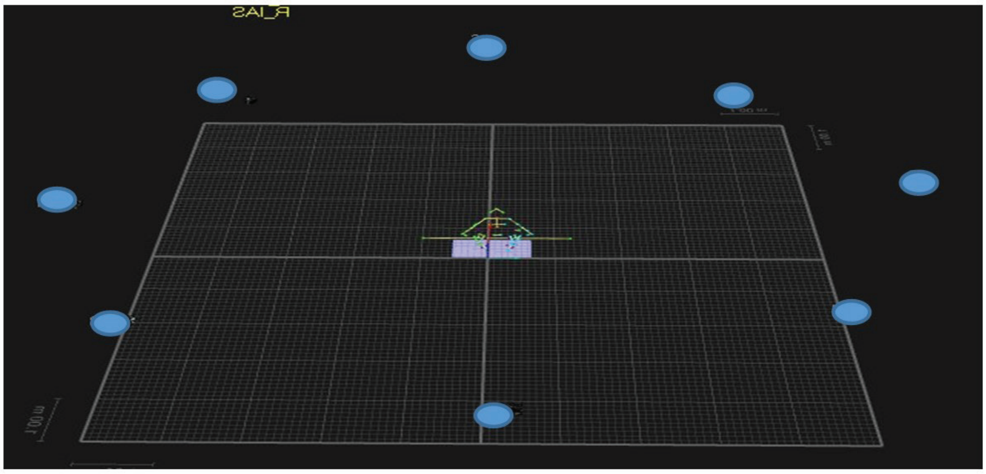

FIGURE 1. Camera Position

Experimental Equipment

An eight-camera Qualisys 3D motion analysis system was utilized to record the lower limb movements at a sampling rate of 100 Hz. Three cameras were placed in front of the participant and three behind them. Another two cameras were positioned to the left and right of the subject (Figure 1). One force plate (Kistler model 9281A, Kistler Instrument Corp., Amherst, NY, USA) that was built into a weightlifting platform used to collect kinetic data at 1,250 Hz (Kipp et al., 2011). Qualisys Track Manager Version 2.17 (Qualisys Motion Capture Systems, Qualisys AB, Sweden) software was used to analyse the classical snatch movement and extract the data collected.

Procedures

For kinematic analysis, 38 reflective markers were placed on the iliac crest, the greater trochanter, the medial and lateral femoral condyles, the sacrum, the anterior superior iliac spine, the medial and lateral malleolus, the heel and the head of the first and fifth metatarsals. Four markers consisting of rigid bodies were attached to the shank and thigh. Kinematic information was analysed to assess the angular movement of the knee, ankle, and hip joints. To observe the trajectory of the barbell, two markers were fixed on both ends of it. Finally, the first pull phase was divided into three phases (static-shank, shank-knee and knee-mid thigh) based on movement in the knee angle and the position of the barbell.

The lifters were first briefed about the procedure and what they had to do. Their weight and height were then recorded using the Tanita WB-3000 Digital Health Care Scale (Tanita, Japan). They were then instructed to do their warm-up in a similar way as they would prior to their competitions. The lifters then performed 2–3 repetitions at 55, 65, and 75% of their self-reported 1RM for the classical snatch exercise for familiarization. They then proceeded to do the three repetitions of the classic snatch at 85% of their 1 RM while their kinematic and kinetic data were recorded by the 3D cameras around them. Three minutes of rest were given between each repetition. The subjects were let to sit or stand for their rest session as they preferred, but fatigue was never an issue. For analysis in this study, 85% of 1RM weight were used because the weightlifting technique stabilizes at loads >80% of 1RM; the 85% load was used as a reference for competitive weightlifting performance (Lukashev et al., 1979). Another reason is for this was that technique correction needs to be done at a weight that is neither light nor too heavy. A heavier weight will result in an autonomous movement that is difficult to be corrected by the lifters.

Data Analysis

All marker data were low-pass filtered using a Butterworth filter with a cut-off frequency of 6 Hz. Qualisys provided valid and reliable data on its own (Figueiredo et al., 2013; Senior, 2004). A fourth-order Butterworth filter was also used to filter kinetic data at 25 Hz (Winter, 2005). The contrasts in the kinematic and kinetic variables between male and female lifters were analysed by using a t-test for independent samples. The period of the phases was compared using a two-way (gender × phase) analysis of variance (ANOVA) for independent samples. The angular kinematics were analysed using two-way (gender × joint) ANOVA for independent samples. Bonferroni tests were performed post hoc to pinpoint the effect(s). All statistical analyses were made using the Statistical Package for Social Science version 25.0 (SPSS, Chicago, IL, USA). The level of significance was set at $p<0.05$.

Results

The results show that there was no significant interaction between gender and angle sequence initiation time of ankle and knee joints for males and females ($p>0.05$). However, there was a significant main effect of the hip joint sequence initiation between males and females ($p<0.05$; Table 1). The hip angle among the female athletes initiates the start movement earlier than among the male athletes.

Table 1. Angle Initiation Sequence and Maximum Angle Extension

	AIS (sec)		MAE (deg°)	
Joint	**Male**	**Female**	**Male**	**Female**
Ankle	0.17	0.18	19.93	14.82
Knee	0.1	0.08	62.14	47.47
Hips	0.3	0.19*	55.12	44.69

Legend: *-p<0.05; AIS - Angle initiation sequence; MAE - Maximum angle extension

For maximum angle extension of the joints between genders, the results show that there is no significant interaction between gender and maximum angle extension of the ankle, knee, and hip joint, ($p=0.139$; $p=0.066$ and $p=0.184$; Table 1). The maximum angle extension in male is greater in the ankle, knee, and hip joints when compared to those of women, but there was no significant difference between them.

As for the first pull sub-phase duration, no significant interaction was observed between gender and joint in the duration of the sub-phases ($F=3.199$, $p>0.05$, power=0.480; Table 2). In contrast, there was a significant main effect between sub-phases in duration ($F=16.223$, $p<0.05$, power=0.995). The static-shank phase was of the longest duration, while the knee-midthigh phase was the shortest duration.

Table 2. Sub-phase execution time and angular displacement during sub-phase between genders

	Sub-phase (sec)		AD (deg°)	
Sub-phase	**Male**	**Female**	**Male**	**Female**
Static-Shank*	0.36	0.2	Ankle: 9.16 Knee: 25.20 Hips: 5.59	Ankle: 5.61 Knee: 14.91 Hips: 3.22
Shank-Knee	0.21	0.2	Ankle: 9.64 Knee: 28.18 Hips: 19.56	Ankle: 8.81 Knee: 27.94 Hips: 19.68
Knee-Mid Tight*	0.17	0.12	Ankle: -4.35 Knee: 4.80 Hips: 34.82	Ankle: -4.74 Knee: 2.45 Hips: 26.95

Legend: *-p<0.05; Sub-phase - Sub-phase execution time; AD - Angular displacement

As for angular displacement (angle) between subphase, there was no significant interaction between genders and joints in the angular displacement of the lower extremities joint that is the ankle joint angle, ($F=0.710$, $p>0.05$, power=0.143), knee joint angle, (F=0.869, p>0.05, power=0.165) and hip joint angle, (F=1.111, p>0.05, power=0.201; Table 2). Angle extensions of the ankle, knees, and hip joints at the end of the static to shank phase have greater value in men, but not significantly. Furthermore, during the shank-knee phase, the knee angle flexed approximately 28° in men and 27° in women, thus showing a small difference between them. Men showed greater knee extension at the end of the knee-midthigh phase compared to women but not significantly. The difference is just a small degree in comparison.

As for angular velocity, the ankle joints' velocity showed no significant interaction between gender and joint in the angular velocity of lower extremities (F=0.113, p>0.05, power=0.064; Table 3). However, there was a significant main effect of the sub-phase in velocity (F=42.209, p<0.05, power=1.000). The shank-knee phase demonstrated the highest pace (velocity), and the static-shank phase was lowest in pace. The knee joint velocity, in contrast, also shows no significant interaction between gender and phase in the duration of phases (F=0.030, p>0.05, power=0.054). However, there was a significant main effect between phase in joint velocity (F=20.270, p<0.05, power=0.999). The shank-knee phase was of higher velocity, while the knee-mid thigh phase was the slowest. The hip joint velocity also shows no significant interaction between gender and phase (F=0.025, p>0.05, power=0.053). However, there was a significant main effect between sub-phases in hip joint velocity (F=30.124, p<0.05, power=1.000). The knee-mid thigh phase was of the higher velocity while the static-shank phase was the slowest.

Table 3. Angular velocity, ground reaction force and barbell velocity value over sub-phase between gender

	AV (deg/s)		GRF (N)		BV (mm/s)	
Sub-phase	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
Static-Shank	Ankle: 25.92 Knee: 71.02 Hips: 15.18	Ankle: 28.73 Knee: 74.59 Hips: 15.56	1403.44*	959.17	573.23*	517.95
Shank-Knee	Ankle: 45.72 Knee: 134.25 Hips: 93.71	Ankle: 45.73 Knee: 144.54 Hips: 103.61	1356.97*	732.73	989.74*	878.68
Knee-Mid Tight	Ankle: -31.55 Knee: 21.07 Hips: 226.19	Ankle: -37.25 Knee: 22.68 Hips: 224.69	1786.98*	1020.10	1402.5*	1168.86

Legend: * - p<0.05; AV - Angular velocity; GRF - Ground reaction force; BV - Barbell velocity

There was a significant main effect between the genders in the ground reaction force produced during a classic snatch (F=65.650, p <0.05, power=1.000). There is also a significant effect among gender between difference subphase of the first pull in the snatch (F=1.528, p<0.05, power=0.263; Table 3).

Barbell velocity also shows a significant difference between gender with (F=14.635, p<0.05, power=0.939) whereas no significant different on barbell velocity among gender between the sub-phase in the first pull of the classic snatch.

Discussion

This study aimed to provide information on the weightlifting biomechanics that differ between male and female elite athletes and, in turn, could contribute to differences in the performance of both genders.

For female lifters, the first pull was almost synchronized with hip and knee joint moving simultaneously. From a technical point of view, the women tended to shift the load to lower back early instead of breaking the first pull with the quads group of muscles, which is a disadvantage, especially when the intensity of lifting is greater.

The reason that it shows no significant different probably lies in the fact that the athletes that were tested are elite, which means that they are the best among the best, and they were being coached every day in the same way regardless of their gender, this could lead to the relatively same pattern and sequence of initiation between the angle joint of males and females.

For the maximal angle extension of joints between genders, the results show that there were no significant differences between males and females for the maximum angle of triple extension in the ankle, knee, and hip angles. However, men had a relatively higher range of motion compared to women. From a technical point of view, this is a disadvantage for women as they do not contract their muscles to a greater range of motion, which causes them to fail when undertaking higher intensities.

Females tend to execute smaller maximum angle compared to men, which could ultimately affect their performance. For example, an inadequate ankle joint execution means that the muscle involved is not fully contracted, which in turn reduced the sum of force generated from the ankle joint during the process of pulling the bar in the classic snatch movement (triple extension).

Men seem to have a slightly longer duration in execution time compared to women. Technically, this difference could be caused by the differences in body height and the time required for the displacement of the bar. There is a trend of continuous acceleration on the bar. Among female athletes, we can see the bar velocity is almost the same during the static-shank and shank-knee phase. The reason that the static-shank phase in male is slower could lie within the aspect of body segment length difference between male and female, which is because the body segment length in male is relatively longer compared to female. This could be the underlying reason for the results shown. Another possible reason could be the fact that the anatomical structure of females reduces the displacement distance of the female arm length relatively shorter distance compared to the male arm displacement. That is why the time travel of the barbell between static to shank is faster in females than in males.

The subjects of this study are elite weightlifters who are very familiar with the classic snatch techniques and have been training together for a long time. This could be the reason there is no significant difference in term of angular displacement (angle) between male and female along the sub-phases of the first pull in the classic snatch.

The women had higher knee and hip joint angular velocity in the shank-knee phase. This phase is quite critical for lifting the weight in a streamline that is vertically upward. Higher knee and hip joint angular velocity in this phase lead to the bar being pulled backwards, resulting in the displacement of the body from its original stance position (a sort of backward jump).

The probability of women having higher knee and hip joint velocity during the first pull was the result of drawing the bar away from the body resulting in a backward jump among the female athletes. To generate the backward jump, the athletes need to displace the central gravity beyond the base of support.

In weightlifting, the ankle, knee, and hip joints extensor muscles contribute to the movement of antagonistic muscles in a sequence starting from the hip to the ankle. This movement is related to the sequence of the three phases of the pull during this lifting task (Isaka et al., 1996). In the present study, referring to the joint velocities, the velocity of the hip joint showed a significant increase during the end of the first pull. In adult weightlifters, the hip joint is the lead joint to reach its maximal extension velocity during the second pull. Followed then by the knee and ankle joints, each reaches its maximum extension velocities (Gourgoulis et al., 2000).

This study highlight the critical component in the first pull phase of the classic snatch, which could be essential in the success or failure of the lift. In term of techniques in the first pull, the women took less time in initiating the moment due to the short nature of their body segments. The hip joint and knee joint extension velocity in women in a controlled manner are crucial in the classic snatch during the 1st pull. The women tend to have higher knee and hip joint velocities, which resulted in backward jumps during the receiving of the bar in the squat position, which would lead to failure of lift and probable injury when executed with higher intensity. The result also highlighted that the women are not in a position to produce higher degrees of extension, thus reducing their efficiency in lifting and ability to take more substantial resistance. This should be examined closely in order to prevent any injury. Having a limited angle extension results in the muscles involved is not fully contracted. Muscles that are not fully contracted are prone to injury.

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Conflict of Interest
The authors declare that there are no conflicts of interest.

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References

Bartonietz, K. E. (1996). Biomechanics of the snatch: Toward a higher training efficiency. *Strength Conditining*, *18*, 24–31.
Bauman, W., Gross, V., Quade, K., Galbierz, P., & Schwirz, A. (1988). The snatch technique of world class weightlifters at the 1985 World Championships. *International Journal of Sport Biomechanic*, *4*, 68–89.
Bernstein, N. A. (1967). *The Coordination and Regulation of Movement*. Baltimore: Pergamon Press.
Burdett, R. G. (1982). Biomechanics of the snatch technique of highly skilled and skilled weightlifters. *Res Q Exerc* Sport 53: 193–197.
Daws, J. (2007). Muscle Snatch. *Strength and Conditioning Journal*, *29*(6), 55-57.
Enoka, R. M. (1979). The pull in Olympic weightlifting. *Med. Sci. Sports, 11*, 131–137.
Enoka, R. M. (1988). Load and skill-related changes in segmental contributions to a weightlifting movement. *Med Sci Sports Exerc, 20*, 178–187.
Figueiredo, P. R., Silva, P. L., Avelar, B. S., Chagas, P. S., Oliveira, L. C., & Mancini, M. C. (2013). Assessment of gait in toddlers with normal motor development and in hemiplegic children with mild motor impairment: a validity study. *Brazilian journal of physical therapy*, *17*(4), 359–366.
Garhammer, J. (1981). Biomechanical characterisitics of the 1978 world weightlifting champions. *Int Series Biomech, 3*, 300–304.
Garhammer, J. (1985). Biomechanical profiles of Olympic weightlifters. *Int J Sport Biomech, 1*, 122-130.
Gourgoulis, V., Aggeloussis, N., Mavromatis, G., & Garas, A. (2000) Three-dimensional kinematic analysis of the snatch of elite Greek weightlifters. *Journal of Sports Sciences, 18*, 643-652.
Isaka, T., Okada, J., & Funato, K. (1996). Kinematic analysis of the barbell during the snatch movement of elite Asian weightlifters. *J. Appl. Biomech*., *12*, 508–516.
Kauhanen, H., Ha ¨Kkinen, K., & Komi, P.V. (1984). A biomechanical analysis of the snatch and clean & jerk techniques of Finnish elite and district level weightlifters. *Scand. Sports. Sci*., *6*, 47-56.
Kipp, K., Harris, C., Sabick, M. B. (2011). Lower extremity biomechanics during weightlifting exercise vary across joint and load. *J Strength Cond Res, 25*, 1229–1234.
Lukashev, A. A., Medvedev, A. S., & Melkonian, A. A. (1979). Snatch technique of weightlifters executing repetitions with 70 percent of maximum. *Teoriya i Praktika Fizicheskoi Kultury, 12*, 13–15.
O'Shea, P. (2000). *Theory of athletics power production.* In: Quantum Strength Fitness II. Corvallis. OR: Patrick's Books.
Schilling, B., Stone, M., O'bryant, H., Fry, A.C., Coglianese, R., & Pierces, K. (2002). Snatch Technique of collegiate national level weightlifters. *J. Strength Cond. Res*., *16*, 551–555.
Senior, D. (2004). *Qualisys Medial AB: Qualisys Track Manager User Manual*. Gothenburg: NRC Publications Archive (NPArC).
Stone, M. H., O'Bryant, H. S., Williams, F. E., Johnson, R. L., & Pierce, K.C. (1998). Analysis of bar paths during the snatch in elite male weightlifters. *Strength Cond., 20*(4), 30–38.
Winter, D. A. (2005). *Biomechanics and Motor Control of Human Movement*. Hoboken, NJ: John Wiley & Sons.