BIOMECHANICAL ANALYSIS OF PULLING PHASES IN WEIGHT LIFTING – A CASE STUDY

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The purpose of this study was to analyze specific aspects of weight lifting techniques. In analyses of snatch lift, identification of the pulling phase, in order to determine the critical points is the primary task. The kinematics and kinetics parameters are closely interrelated with pulling phases. Because of the differences in definitions of phase structures, the data from previous studies couldn't be compared with each other directly. Therefore, this study investigated the phase structures in snatch lift and established the relationship between several variables of kinematics, such as the knee angle, the barbell vertical velocity and position, etc. It is clear that in the course of analyses, identifying the phases by means of the barbell vertical velocity, is the most convenient and logical method for obtaining fast feedback. Based on the above definitions of the phases, the mechanical data of two snatch lifts by an elite have been measured and analyzed

KEY WORDS: snatch lift, phase definition, weight lifting

INTRODUCTION: In analyses of snatch lift, the primary task is to identify the pulling phases and to determine the critical points of the performances. In video analyses of the technique, they are key frames. The kinematics and kinetics parameters are closely interrelated with pulling phases. Numerous studies on snatch lift have been done in the past. However, due to the differences of the methods of the studies, the definitions of pulling phases were not alike and so could not be compared. Based on knee angle research by Lee et al. (1995), the phase structures of the snatch lifts were divided into First Pulling (FP) and Second Pulling (SP). These phases were different to the barbell liftoff period, weight loss period, falling period, supporting period and stand up period according to the force curves that were measured from force-platform by Wang and Lu (1990). Shan (1998) also described the phases as pre-activation phase, barbell lifting, exerting, squat-support and stand up phase. Because of the differences in divisions of phase structures, data from these studies couldn't be compared directly with each other. In this study, phase structures in snatch lifts are digitized and analyzed. The phases are divided on the basis of the barbell vertical velocity.

METHODS: Two snatch lifts that were performed by an elite athlete during competition was recorded with video camera. The rate of which was 50Hz. One lift was 170kg weight of barbell and the another was 172.5kg weight The subject's body weight and height were 83kg and1.69m respectively. The digitized data were smoothed by a second-order Butterworth digital filter with a cutoff frequency of 6Hz. The MATUI model (Japan) has been adopted to digitize the performances.

RESULTS AND DISCUSSION: Figure 1 illustrates the barbell vertical displacement and velocity for the subject's snatch lift with 170kg weight of barbell. The phase structures were examined based on the variables of knee angle, barbell vertical velocity and position in the whole process of snatch lift. Each critical time (or key frame) was marked with letters in-order. The mark "A" (0.12s) corresponds from the time of the barbell lift-off from ground. The mark "B" (0.58s) represents the time the knee angle reaches an extreme and at the same time begins to decrease, or the hip begins to move forward. "C" (0.64s) marks the time the barbell vertical velocity reaches its first maximum. After that, the barbell vertical velocity decreases with the flexion of the knees. The mark "D" (0.72s) is the time that the knee angle reaches minimum, the moment of which is defined as the beginning of the "exerting" phase by some studies. Lee (1995) defined this time as the end of "FP" and the beginning of "SP". The mark "E" (0.74s) is the time when the velocity decreases to a minimum while the knees flex. The mark "F" (0.86s) corresponds to the time when the knee angle reaches another maximum. This time is defined as the end of “exerting” phase by Shan(1998) or the end of “SP” by Lee (1995). The mark “G” (0.90s) indicates the moment when the barbell vertical velocity reaches the maximum value in the whole snatch lift process. The mark “H” (0.94s) indicates the beginning of takeoff of the body and then the barbell moves upward by the inertia of itself. But by test and calculation below, even if the body is in liftoff phase, the upward force that the arms add to the barbell is not equal to zero. At this time the human body has an acceleration which is more than gravity (g), and the barbell has an acceleration which is less than g. The mark “I” (1.14s) corresponds to the time when the barbell reaches the highest point, the velocity is zero, and the body squats quickly. The mark “J”(1.50s) is a sign that the height of the barbell reduces to the lowest position and the barbell is supported.

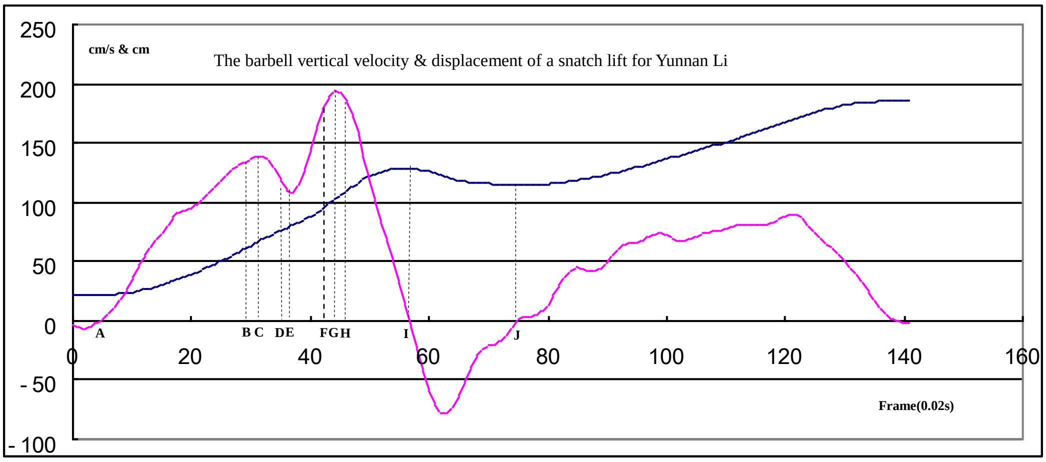

Figure 1 - The barbell (170kg) vertical velocity & displacement of snatch.

As Figure1 shows, after the phases with different variables, such as knee angle or barbell velocity, were identified, the different kinematics parameters in each phase would be obtained. For example, when the knees begin to flex at mark “B”, the velocity still increases a bit, there is still an acceleration upward and the lift force from arms is still greater than the gravity of the barbell. Until the time of the mark “C”, the barbell vertical velocity reaches to the maximum. So if the “lifting” phase were identified by knee angle, it would be from time A to time B; and if it were identified by barbell velocity, it would be from time A to time C. For the same reason, the “exerting” phase would be from time D to time F judged by knee angle or from time E to time G judged by barbell velocity. In this case, it is reasonable to consider that the maximum point “C” of the velocity is identified as the end of “lifting” phase but not mark “B”. There are still lifting forces, which are larger than the gravity of the barbell between time B and time C. Similarly, the velocity is still reduced when the knee angle is at the minimum “D”. The velocity reduces to its minimum until to “E”. When the knee angle reaches its maximum “F”, the velocity is still increased, and the lift force is still greater than the gravity of barbell, until reaching the point “G” the velocity reaches its maximum. So identifying the mark “E” as the beginning, and the mark “G” as the end of “exerting” phase is more logical than it is from time D to time F judged by knee angle. In the former case, there is always upward acceleration in the “exerting” phase.

It is obvious that the peak level of the barbell velocity lagged a little behind the peak level of knee angle. There are differences between the phases identified by knee angle and those by barbell velocity. There are four reasons to identify the phases by barbell vertical velocity: 1. The phase judged by barbell vertical velocity corresponds to the structure of the snatch lift. 2. Defined by this method, the orientation of resultant force on barbell is identical in the same phase. Therefore, the force obtained by barbell is easier to judge in each phase. 3. The curve of velocity in each phase is similar to a straight line. This way the average acceleration can be estimated by calculating the slope of the straight line, and then the average force obtained by barbell can be estimated by the average acceleration. 4.The phase identified by barbell vertical velocity can be easily computerized so that fast feedback of kinematics analyses can be achieved.

In this study, according to the above statement, the phase structures are defined as six phases: lifting, flexion, exerting, squatting, falling and stand up. As Figure 1 shows, the mark “A” to mark “C” is defined as the lifting phase, in which the velocity is from zero to the first maximum. The mark “C” to mark “E” is defined as the flexion phase. In this phase the velocity value decreases to a minimum with the knee flexed. The mark “E” to mark “G” is defined as the exerting phase, in which the velocity value reaches the maximum again. The mark “G” to mark “I” is defined as the squatting phase. In this phase the barbell is cast upward, the velocity of the barbell reduces to zero and the height of barbell rises to a maximum. The mark “I” to mark “J” is defined as the falling phase. In this phase the velocity from zero drops to negative and then goes back to zero. The barbell falls to a minimum height and is supported by arms. After the mark “J” is defined as the stand up phase.

Based on the above definitions, the kinematic paremeters of two snatches was measured and calculated (see Table1 and Table 2). Table 1 shows the displacements and velocities of barbell in different phases. The Py represents the vertical positions of the barbell and the Vy1 represents the vertical velocities of it. The critical time or frames are marked with letters from A to J explained above. In Table 2, the DT represents periods for each phase. The DP is displacements of barbell in each phase. The DV is the differences in velocities between two ends of each phase. The MA is the barbell vertical average accelerations calculated by the differences of velocity values between two ends of the linear part in the middle of each phase. The F is the estimation of the lift force got by barbell in the middle of each phase by the formula F=m(g+MA).

Table 1 The Critical Frame, Time, Vertical Position and Vertical Velocity of Barbell Between Phases

			170 kg				172.5 kg			
Phase	Critical	Mark	Frame	Time	Py	Vy	Frame	Time	Py	Vy
Lifting	liftoff	A	6	0.12	22	6.7	6	0.12	22.8	6.9
	Knee max	B	29	0.58	60.1	133.9	29	0.58	62.5	133.5
Flexion	Vmax	C	32	0.64	68.3	137.7	31	0.62	139.7	139.7
	Knee Min	D	36	0.72	78.1	110.4	35	0.70	78.1	116.0
Exerting	Vmin	E	37	0.74	80.3	108.2	36	0.72	80.4	117.4
	Knee Max	F	43	0.86	98.7	189.2	43	0.86	102.6	193.9
Squatting	Vmax	G	45	0.90	106.4	192.1	44	0.88	106.4	92.3
	Takeoff	H	47	0.94	113.6	172.8	46	0.92	113.6	174.7
Falling	Pmax	I	57	1.14	128.7	-5.6	56	1.12	130.8	-0.38
Stand up	Pmin	J	75	1.50	114.6	0.8	74	1.48	117.0	2.7
	Up fully		141	2.82	185.1	-1.4	145	2.90	185.1	-1.2

Table 2 The Period of Phases, Increment of Barbell Heights, Increment of Vertical Velocities, Average Accelerations and Forces for Linear Part in Each Phase

	170 kg					172.5 kg				
Phase	DT (s)	DP (cm)	DV (cm/s)	MA (cm/s^2)	F (N)	DT (s)	DP (cm)	DV (cm/s)	MA (cm/s^2)	F (N)
Lifting	0.52	46.3	131.0	267.4	2121	0.50	45.3	132.9	301.3	2210
Flexion	0.10	12.0	-29.5	-331.3	1103	0.10	12.3	-22.3	-225.0	1302
Exerting	0.16	26.1	83.9	808.8	3041	0.16	26.0	74.9	740.0	2967
Squatting	0.24	22.3	-197.7	-892.0	150	0.24	24.4	-192.7	-892.5	151
Falling	0.36	-14.1	6.4	0.36	-13.8	0.36	-13.8	3.1		
Stand up	1.32	70.5	-2.2	1.42	68.1	1.42	68.1	-3.9		

It has been determined that it is difficult to obtain accurate instantaneous accelerations from

displacement data by mathematical calculations. It was because differentiation would generate errors. Therefore, in this study, the average acceleration is applied to analyses of kinematics. The average accelerations can be calculated by the differences of the velocities between two ends of a linear part in velocity curves, and then the average forces in the period was estimated. To calculate the average accelerations, the velocity curve should be linear in that period. If the velocity were not linear, even if the two velocities values at both ends of the period were equal, it could not be concluded that the average accelerations were zero in the period.
The test value in "exerting" phase is discussed below, the other phase is similar to that shown in Table1 and Table2. In exerting phase mark "E" to mark "G", it takes 0.16s, The barbells have been raised by 26.1cm, 26.0cm for 170kg and 172.5kg weight of barbell snatch lift respectively. The velocities have increased by 83.9cm/s, 74.9cm/s. In the middle of the phase, the average acceleration are 740.0 cm/s^2, 808.8 cm/s^2 calculated by the differences of the barbell velocity values between two ends of the linear part in the middle of the "exerting" phase (see Figure1). The two ends of the linear part are on the inside of the phase, but they are not the ends of the phase. The lift forces (F1, F2) given the barbell by the arms are 2967N(302.8kg) and 3041N(310.3kg) are calculated by the average acceleration above.

CONCLUSION: The definitions of the phases in snatch lift analyses are not exactly alike in different studies. In this study, the phases of snatch lift was defined by the barbell vertical velocity curve corresponds to the structure of the snatch lift. In this way the orientation of resultant force on barbell was identical in the phase. Therefore, the force obtained by barbell was easier to be identified in each phase. The curve of velocity in each phase was similar to a straight line. Thus the average acceleration can be estimated by calculating the slope of the straight line, and then the average force got by barbell could be estimated by the average acceleration. The phase identified by barbell vertical velocity could be easily computerized so that instantenous feedback of kinematics analyses could be achieved.
In this study the phases of snatch lift are identified by the barbell vertical velocity curve as six phases, "lifting", "flexion", "exerting", "squatting", "falling", "stand up". It is impossible to obtain the accurate instantaneous acceleration by the position coordinates. However, the average acceleration could be estimated by calculating the velocity slope of a linear part in middle of a phase, then the lift force in the middle of the phase could be estimated. The linear segments are usually in the middle of each phase.
The kinematic data obtained based on our definitions would have more comparability for the diagnoses of techniques in snatch lift. Results showed that there are always forces upward in the whole lift process, even in the "falling" phase there are about 147N(15kg) forces upward. The forces indicated that while the body takes off, the athlete still pushes the barbell upward to speed up the decline of the body. In the flexion phase, the decrease of the vertical velocity of the barbell is about 26cm/s for subject that is obviously greater than that of other athletes mentioned in some previous studies. Comparing the two snatch lifts performed by subject using the example of the utmost weight, 170kg weight of barbell lift, the athlete was faster and stronger in lifting and flexion phases. However, it would be not possible to sustain such exertion, for example in the 172.5 kg weight of barbell lift. This factor emphasizes the need for maintaining a steady pace, combined with balance of the body.

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