KINEMATIC COMPARISONS OF KETTLEBELL TWO-ARM SWINGS BETWEEN EXPERTS AND BEGINNERS

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The purpose of this study was to investigate kinematic comparisons of kettlebell two-arm swings between experts and beginners in order to find out biomechanical key points for preventing sports injuries and enhancing kettlebell performance. Four experts and three beginners performed kettlebell two-arm swings fifteen times with a 16 kg kettlebell. Experts demonstrated larger ranges of motions (ROM) of pelvic segment and hip joint than beginners, while beginners revealed larger ROM of shoulder joint than experts. Magnitudes and sequential orders of peak angular velocities of major joints were significantly different between two groups. Conclusively, the mobility of pelvic segment and hip joint are required, while the stability of the other joint are needed to produce appropriate kettlebell two-arm swings. The activation and strength of gluteus muscles would be key contributors.

KEY WORDS: kettlebell two-arm swing, kinematics, multi-joint coordination, pelvis, gluteus

INTRODUCTION: Kettlebell exercise is a new typed functional training to promote strengths of core muscles. Historically this exercise was originated from Russian athletes and has unique characteristics in performing repeated motions. A kettlebell has a concentrated heavy mass with a rounded grip. People can hold a grip part with one hand or two hands during swings. Normally people swing a kettlebell in the mid-sagittal plane with flexing and extending hip, knee, and shoulder joints rhythmically (McGill & Marshall, 2012). Since the centrifugal force created by a kettlebell motion, people need more stabilizing forces than other lifting activity. Especially the glutes and hamstring muscles are much stimulated by kettlebell swings than other training methods.

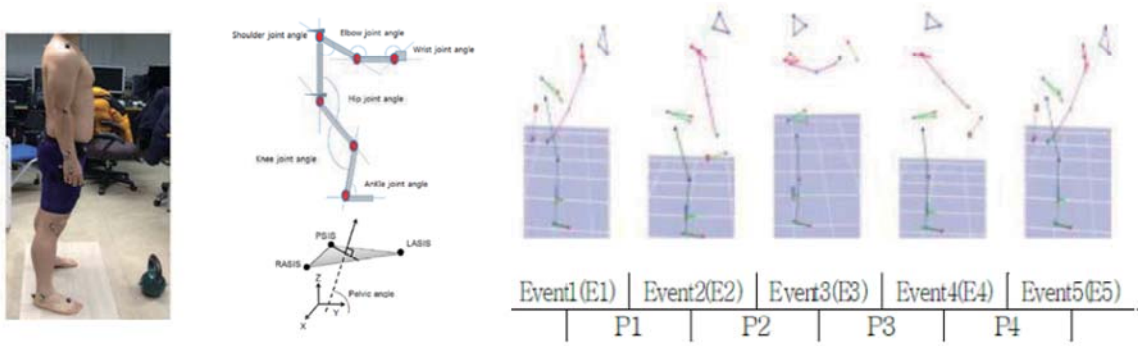
Sports injuries associated with kettlebell swings were frequently reported. People exercising kettlebell swings are struggling with the pains of back, knees, and shoulders. This might be partially attributed to inappropriate postures in rhythmically lifting and lowering a weight and the improper coordination of multiple joint motions.

The purposes of this study were to compare kinematic results of kettlebell two-arm swings between experts and beginners and to find out the biomechanical key points discriminating experts from beginners in an attempt to minimize sports injury from kettlebell swing.

METHODS: Four kettlebell experts (height, 169.7±1.5 cm; mass, 70.5±1.8 kg; age, 32.0±1.0 yrs) having a licence of teaching kettlebell exercise and three beginners (height, 173.7±4.1 cm; mass, 78.3±3.8 kg; age, 30.0±1.4 yrs) having no experience of kettleball exercise participated voluntarily in this study. They had no physical disease within last six months at the time of data collection. Subjects admitted their acceptance on a consent form prior to experiment.

Motion capturing system consisting of five high-speed cameras (Osprey®, Motion Analysis, Santa Rosa, CA, US) and a data-collecting software (Cortex 4.0®, Motion Analysis Santa Rosa, USA) were used to collect motion data. Nineteen reflective markers were attached on major anatomical (Figure 1A). Since left and right limbs moved simultaneously, the analysis of the motion was considered as a two-dimensional motion. The markers were placed on only right side except pelvis and shoulder markers. The mass of a kettlebell was 16 kg which is used for male beginners.

When preparation was finished, subjects performed repeated two-arm swings fifteen times according to the command of an operator. Two-arm swings were executed by gathered hands on the grip. The kettlebell was moved up and down by rhythmical flexion and extension of major joints such as knees, hips, and shoulders.



(A) (B) (C)

Figure 1: (A) Experimental set-up with reflective markers, (B) Definition of joint and segment angles, (C) Definition of events and phases during kettlebell two-arm swings

Collected motion data passed through a digital filter (Butterworth 2nd order low-pass filter with a cut-off frequency of 8Hz) prior to kinematic calculation. Six joint angles (shoulder, elbow, wrist, hip, knee, and ankle) and one segment angle (pelvic segment) were calculated at numerical analysis software (Matlab®, ver. 2009, MathWorks, USA) (Figure 1B). Five major events (E1 to E5) and four phases (P1 to P4) were defined to compare kinematic results between experts and beginners (Figure 1C). E1, E3, and E5 were the moments of the starting, the top of the kettlebell, and the ending position, respectively. E2 and E4 were the moments of the kettlebell's peak linear velocities of lifting and dropping.

The mean values from 15 repetitions were defined as the representative values for each subject. For statistical testing, the nonparametric Mann-Whitney U test was performed on these representative values with a significance of .05.

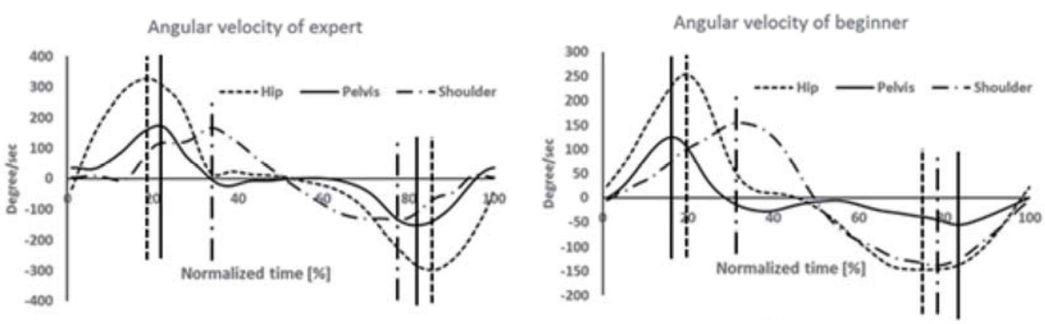
RESULTS: When the ROMs of major joints and pelvic segment were investigated, significant differences were detected in hip, knee, and shoulder joints (p<.05, Table 1). In hip joint angle, experts showed significantly larger joint angle at E3 than beginners (p<.05). In addition, experts revealed significantly larger knee joint angle at E4 than beginners (p<.05). Beginners, however, demonstrated significantly larger shoulder joint angles from E2 to E4. In pelvic segment angles, experts showed larger segment angles from E2 to E4 but statistically insignificant. Other joints produced similar levels of angles between two groups during kettlebell two-arm swings.

The multiple joint coordination was investigated by the sequence of peak angular velocity profiles such as hip joint, shoulder joint, and pelvic segment (Figure 2). There was distinct difference on the sequence of peak angular velocities between experts and beginners. Experts produced peak angular velocities of the hip joint first, pelvic segment secondly, and shoulder joint thirdly in lifting the kettlebell upward. When they lowered the kettlebell, they utilized peak angular velocities of shoulder first and pelvis and hip joint followed shoulder joint. However, beginners revealed the order of peak angular velocities from pelvis, hip, to shoulder in lifting the kettlebell and from hip, shoulder, to pelvis in lowering the kettlebell.

DISCUSSION: This study investigated kinematic differences between experts and beginners when they performed the kettlebell two-arm swings. It was purposed to find out the biomechanical key differences in order to enhance kettlebell swings with minimizing sports injuries.

Table 1. Comparisons of joint and segmenent angles at each event (unit: deg)

Joint or segment	Level	E1	E2	E3	E4	E5
Pelvis	Export	63.4±4.1	96.9±5.8	100.5±4.4	84.1±6.0	63.5±4.8
	Beginner	63.2±7.6	91.4±19.5	86.4±14.2	78.1±13.3	63.3±8.5
	p	.72	.48	.29	.48	.72
Hip	Export	80.1±3.5	159.1±11.9	179.4±5.1	143.3±9.7	80.0±3.6
	Beginner	89.9±10.3	151.1±8.9	168.4±6.6	127.6±9.9	89.5±3.6
	p	.16	.48	**.03***	.08	.16
Knee	Export	145.0±5.5	166.2±8.1	175.9±3.6	161.2±6.4	145.2±5.4
	Beginner	140.5±12.9	156.0±15.1	167.4±15.6	147.3±5.0	140.6±12.9
	p	.72	.29	.48	**.03***	1.0
Ankle	Export	96.9±4.4	91.8±4.1	90.1±5.2	91.5±3.9	96.7±4.4
	Beginner	97.8±6.1	93.8±14.5	93.1±14.6	94.0±5.6	97.7±6.2
	p	1.0	.72	1.0	.29	1.0
Shoulder	Export	20.6±4.1	38.8±2.3	77.0±5.4	35.1±2.8	24.9±4.2
	Beginner	27.9±1.2	52.7±2.8	100.3±2.6	63.2±3.5	27.6±1.3
	p	.29	**.03***	**.03***	**.03***	.29
Elbow	Export	85.7±0.3	85.8±0.3	86.5±0.4	85.9±0.4	85.7±0.3
	Beginner	85.6±0.9	85.7±0.5	86.6±0.6	86.1±0.5	85.6±0.9
	p	.47	.59	.72	.72	.48
Wrist	Export	89.0±0.2	89.1±0.1	89.2±0.1	89.1±0.1	89.0±0.1
	Beginner	89.3±0.3	89.3±0.2	89.4±0.2	89.4±0.2	89.3±0.3
	p	.201	.06	.36	.06	.21



(A) (B)

Figure 2: Comparisons of the order of peak angular velocities of multiple joints between experts and beginners.

According to the results, the distinctive differences of joint kinematics occurred in hip, knee, and shoulder joint. Pelvic segment revealed large differences between two groups but insignificance. Normally people were educated to pose erected spine posture during kettlebell swings and utilize hip extension dominantly in lifting the kettlebell (Tsatsouline, 2006). This was considered as an efficient way to sustain the large centrifugal force created by the angular motion of the kettlebell.

Results indicated experts allowed larger ROMs in hip joint and pelvic segment but they tried to limit the ROMs of the shoulder joint. Beginners, however, utilized them adversely. They allowed smaller ROMs of hip joint and pelvic segment but larger ROM of shoulder joint than experts.

The kettlebell is heavy (16 kg for this experiment) so that some joints should be stabilized (small ROMs) and others should be mobilized (large ROMs) to do the swing motion

successfully (Cook, 2012). According to results of this study, the shoulder should have smaller ROM and the hip and pelvis should have large ROMs. Because the heavy object (a kettlebell) moves upward with an arc trajectory, the small and weaker joint is vulnerable to the sports injury due to large centrifugal force. Therefore, the shoulder (relatively smaller and weaker joint than hip joint) would be better to have small ROM to minimize the centrifugal force.
The utilization of the ground reaction force is very important in kettlebell swing. The way that the pelvic segment – the bridge section between lower body and upper body – creates the angular momentum of swing motion is more efficient than small segments (e.g., arms) creates the momentum. Thus, experts tended to utilize hip joint and pelvic segment having strong and large muscles (e.g. glutes and hamstrings) than shoulder. Beginners, however, had insufficient experience of kettlebell exercise so that they might not be used to utilize glutes and hamstrings.
The insufficient strength of hip extensors might partially contributed to improper coordination of multiple joint motions (Michael, Scott & Brian, 2010). The transfer of angular momentum from proximal to distal order (hip, pelvic, and shoulder of experts) seemed to an efficient way to maximize the exercise effect of kettlebell swings. Therefore, beginners need to practice a lighter kettlebell first in order to build up the sequential order of muscle activation from proximal to distal segments.

CONCLUSION: Since the kettlebell is very heavy, people have to learn proper technique to lift the kettlebell. Hip joint and pelvic segment (large and strong muscles around them) should have large ROMs, while the shoulder joint (small and weak muscles around them) should have small ROM in order to minimize sports injuries associated with kettlebell swings. The practice of kettebell swing with a lighter weight is needed for beginners to get used to have the sequential order of angular momentum transfer (i.e., the proximal to distal segments) in kettlebell two-arm swings.

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