Kinematic Analysis of the Snatch Technique used by Japanese and International Female Weightlifters at the 2006 Junior World Championship

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[Received March 3, 2008; Accepted October 31, 2008; Published online March 30, 2009]

The purpose of the present study was to compare the snatch techniques of Japanese and international female weightlifters using kinematic analysis. Motion analysis of the snatch techniques conducted using videos recorded at the 2006 Women's Junior World Weightlifting Championship. The results indicated no significant differences between the snatch techniques of Japanese and international weightlifters in terms of the kinematic parameters expressed by the barbell trajectory and joint angles. However, the interval of time between the peak velocity of the hip joint and peak vertical velocity of the barbell was longer for Japanese weightlifters, while the power applied to the barbell was 35% greater for international weightlifters. These findings indicate that differences in strength and power production affected the performances of Japanese and international weightlifters.

Keywords: weightlifting, snatch, female, kinematic analysis, elite

1. Introduction

In weightlifting competitions, weightlifters compete on combined (total) lifted weight for the clean and jerk and the snatch. To succeed in a lift of the clean and jerk or the snatch, an essential skill is to transmit physical output effectively to the barbell and support the barbell over the head. Especially in the snatch, in which the barbell is lifted over the head in less than 2 seconds, not only force but also explosive power output is required (Garhammer, 1980; O’Shea, 2000). Thus, weightlifting is considered to require high levels of physical ability and skill together.

Many studies on analysis of snatch techniques have been conducted at laboratories and competitions. For example, laboratory research examined movements simulated by assuming competitive conditions of 3 attempts, etc. (Gourgoulis et al., 2002). However, such simulation experiments are disadvantageous in that they differ from actual competitions in which important factors as weight selection and mental concentration on the attempt. On the other hand, many research studies on competitions have conducted kinematic analysis using VTRs.

Regarding weightlifting techniques, analysis of barbell movements is informationally important as it involves weightlifters’ physical movements. Many previous studies have evaluated variable parameters obtained from the barbell displacement (Burdett, 1982; Garhammer, 1985; Baumann et al., 1988; Garhammer, 1991; Isaka et al., 1996; Gourgoulis et al., 2000, 2002, 2004; Campos et al., 2006; Hoover et al., 2006).

Women’s weightlifting, for which the first World Championships was held in 1987, has a shorter history than men’s. Recently, kinematic studies of female weightlifters during the snatch have been reported for the U.S. National Weightlifting Championships (Hoover et al., 2006) and the Greek national
weightlifting squad (Gourgoulis et al., 2004). Hoover et al. made a 2-dimensional kinematic analysis on weightlifters in the U.S. National Weightlifting Championships and then suggested that the drop distance during the catch phase was long in comparison with existing reports on male weightlifters (Figure 1). Further, a study on international level weightlifters reported that male weightlifters had slower maximum velocities of the barbell being lifted than female weightlifters had (Garhammer, 1991). Thus, the previous studies on female weightlifters have shown several differences from male weightlifters. To be more competitive, it may be important to accumulate information about not only such gender differences but also various factors, e.g., Japanese domestic competitors vs. international competitors, competitive level, and age.

The purpose of the present study was to clarify the technical characteristics of international and Japanese weightlifters, by analyzing kinematic movements during the snatch of female weightlifters who appeared in the Junior World Weightlifting Championships. Junior weightlifters refer to competitors 20 years old and younger, but some of them have established world or national records, outperforming senior weightlifters. By evaluating the techniques of those elite weightlifters, the present study was also intended to describe the snatch techniques of current female weightlifters and obtain information that contributes to competition improvement for Japanese competitors participating in international competitions.

2. Methods

2.1. Material and subjects

In the 12th Women's Junior World Weightlifting Championships, held in Hangzhou, China from May 28 to June 3, 2006, the attempts of Japanese representative weightlifters and higher-ranking winners in each class were recorded by a video camera. The recordings were done as part of a research project of the Japan Weightlifting Association Sports Medicine Committee. Of the recorded attempts, the best performed attempts of the World champion (WC) and Japanese representative (JP) weightlifters were analyzed. Table 1 shows the final result and body weight of the analyzed weightlifters based on the official records. It should be noted that no JP weightlifter appeared in the women's 75 kg class and 2 JP weightlifters appeared in the women's 63 kg class. Of the WC weightlifters in the snatch, the 58 kg, 63 kg, 69 kg, and 75 kg class champions also won at the combined lifted weight (Total). In addition, the JP-4 (63 kg class) and WC-6 (75 kg class) weightlifters established a new national record and a new world record for the total, respectively. This suggests that the analyzed weightlifters potentially had a competitive level comparable to senior weightlifters despite being only junior weightlifters in terms of age.

2.2. Video recording and analytical procedures

For video recording in the present study, a digital video camera (DCR-PC-300 K, Sony, Japan) was used. To allow for kinematic analysis in the sagittal plane from a right lateral view of the attempting weightlifter, the video camera was placed at a distance of 15 m from the right end of the barbell and the lens height was set 1.5 m above the floor such that the lens was positioned in about the middle of the movement range of the barbell. Also, a calibration scaling required for the analysis (2 m x 2 m) was done between attempts.
The frames recorded on the videotapes were acquired on a personal computer to be converted to AVI-format files and then were analyzed on a 2-dimensional basis by using kinematic analysis software (Frame-DIAS, DKH, Tokyo, Japan). The sampling frequency of the video frames was 30 frames/s. The analysis zone was from when the barbell was taken off the floor (lift off) to when it was supported over the head. The following movement points were digitized on a frame basis: (1) right barbell end, (2) vertex, (3) neck, (4) shoulder, (5) elbow, (6) hand, (7) trochanterion, (8) knee, (9) heel, (10) toe, (11) lumbale, and (12) metatarsale laterale (ML). This digitization was done by the same examiner, and in frames where a joint was hidden by a disc, the hidden joint was carefully estimated in reference to previous and subsequent frames where the joint appeared. After the procedures, the resultant displacement-time data of the 2-dimensional coordinate (x, y) were smoothed at a cutoff frequency of 4 Hz by the quadratic Butterworth filter (Garhammer, 1989). Based on these data, variable parameters associated with the barbell and the respective joints were determined. Regarding the kinematics of the joints, after a shoulder-trochanterion-knee stick was defined as the hip joint, a trochanterion-knee-ML stick was defined as the knee joint, and a knee-ML-toe stick was defined as the ankle joint, the joint angles and the angular velocities were calculated.

2.3. Definition of barbell displacements and variable parameters

The trajectory of the barbell is usually an S-shaped pattern: the barbell is lifted up with a backward (i.e. toward the body) movement from the start position as soon as it is taken off the floor, then it is lifted up with a forward movement,” before being moved backward again until it reaches the highest point, finally it is moved down to the catch position (Figure 1). Thus, the backward and forward displacements (X1 and X2, respectively), maximum height, catch height, and maximum velocity (Vmax) were determined as variable parameters obtained from the barbell trajectory. These height indices and the height at which Vmax appears were expressed as a height ratio by using the estimated value obtained from the digitized model. In addition, the maximum power applied to the bar, obtained by multiplying the lifted weight by Vmax, was expressed as power per unit body weight (W/kg) (Hori et al., 2006). According to the definitions by Campos et al. (2006), the phase from the barbell take-off to the first knee extension is the first pull phase, the phase from the first knee extension to the maximum knee flexion is the transition phase, the phase from the maximum knee flexion to the second knee extension is the second pull phase, and the phase from the maximum height to the barbell catch is the catch phase. In the present study, the barbell velocity reached during the first pull phase was determined based on the above definition.

2.4. Statistical processing

The parameters were expressed as mean±standard deviation in each of the JP and WC groups. An unpaired t-test was used for testing the difference in mean value; the significance level was p<0.05.

3. Results

Table 2 shows the variable parameters based on the displacements of the barbell and Table 3 shows the joint angles and angular velocities in JP and WC groups. No significant differences were observed in vertical (Y-displacement) parameters, the maximum
barbell velocity (Vmax), maximum height, catch height, and drop distance (maximum height minus catch height), between the WC and JP groups. Also, no significant differences were observed in height ratio values for the Vmax appearance height, maximum height, and catch height between them (Table 4). The determined horizontal (X-displacement) parameters were the displacement toward the body immediately after take-off (X1) and the subsequent forward displacement (X2) (Table 2). These parameters did not differ between both groups similarly to the Y-displacements. For the maximum values of the joint angles and angular velocities in the hip, knee, and ankle joints during the lift, no significant differences were observed between the WC and JP groups (Table 3).

Table 4 shows the maximum power applied to the bar. The WC group (31.3±3.5 W/kg) exhibited a 35% higher power value per unit of body weight than the JP group (23.1±3.0 W/kg) (p<0.001).

**Figure 5** exemplifies the angular velocity of the hip joint and the velocity curve of the barbell for weightlifters WC-6 (who established a world record for the total there) and JP-6 (who weighed close to WC-6); it should be noted that no Japanese weightlifters appeared in the same class as WC-6. The vertical velocity of the barbell during the first pull phase did not differ significantly between the JP (1.06±0.06 m/s) and WC (1.09±0.15 m/s) groups, while it was 57.1%±4.0% and 56.0%±6.9% of Vmax for the JP and WC groups, respectively. Further, to evaluate the time for body movement to apply its force to the barbell, the difference in the appearance time between the peak angular velocity of the hip joint extension and Vmax was determined. This time difference of the peak appearance was significantly low (p<0.05) in the WC group (0.10±0.03 s) compared to the JP group (0.14±0.02 s).
The purposes of the present study were to clarify the technical characteristics of international elite and Japanese female weightlifters, by analyzing kinematic movements during the snatch of those weightlifters who appeared in the Junior World Weightlifting Championships, and to compare Japanese and international weightlifters. As a result, no significant difference was observed in the trajectory of the barbell between the WC and JP groups. However, the WC group exhibited 35% higher power output than the JP group.

### Table 3  Kinematic analysis of the joint angle.

<table>
<thead>
<tr>
<th>Lifter</th>
<th>Maximum joint angle</th>
<th>Peak angular velocity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hip deg</td>
<td>Knee deg</td>
</tr>
<tr>
<td>JP-1</td>
<td>189</td>
<td>159</td>
</tr>
<tr>
<td>JP-2</td>
<td>183</td>
<td>147</td>
</tr>
<tr>
<td>JP-3</td>
<td>179</td>
<td>144</td>
</tr>
<tr>
<td>JP-4</td>
<td>192</td>
<td>156</td>
</tr>
<tr>
<td>JP-5</td>
<td>189</td>
<td>155</td>
</tr>
<tr>
<td>JP-6</td>
<td>193</td>
<td>154</td>
</tr>
<tr>
<td>JP-7</td>
<td>185</td>
<td>155</td>
</tr>
<tr>
<td>Mean</td>
<td>187</td>
<td>153</td>
</tr>
<tr>
<td>SD</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

### Table 4  Y-displacement of the bar/stature ratio.

<table>
<thead>
<tr>
<th>Lifter</th>
<th>Height at Vmax</th>
<th>Maximum height</th>
<th>Catch height</th>
</tr>
</thead>
<tbody>
<tr>
<td>JP-1</td>
<td>0.44</td>
<td>0.63</td>
<td>0.49</td>
</tr>
<tr>
<td>JP-2</td>
<td>0.41</td>
<td>0.59</td>
<td>0.44</td>
</tr>
<tr>
<td>JP-3</td>
<td>0.44</td>
<td>0.60</td>
<td>0.49</td>
</tr>
<tr>
<td>JP-4</td>
<td>0.45</td>
<td>0.65</td>
<td>0.55</td>
</tr>
<tr>
<td>JP-5</td>
<td>0.43</td>
<td>0.62</td>
<td>0.52</td>
</tr>
<tr>
<td>JP-6</td>
<td>0.48</td>
<td>0.66</td>
<td>0.55</td>
</tr>
<tr>
<td>JP-7</td>
<td>0.45</td>
<td>0.64</td>
<td>0.55</td>
</tr>
<tr>
<td>Mean</td>
<td>0.44</td>
<td>0.63</td>
<td>0.51</td>
</tr>
<tr>
<td>SD</td>
<td>0.02</td>
<td>0.02</td>
<td>0.04</td>
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<table>
<thead>
<tr>
<th>Lifter</th>
<th>Height at Vmax</th>
<th>Maximum height</th>
<th>Catch height</th>
</tr>
</thead>
<tbody>
<tr>
<td>WC-1</td>
<td>0.41</td>
<td>0.60</td>
<td>0.54</td>
</tr>
<tr>
<td>WC-2</td>
<td>0.41</td>
<td>0.57</td>
<td>0.46</td>
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<tr>
<td>WC-3</td>
<td>0.39</td>
<td>0.58</td>
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</tr>
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<td>WC-4</td>
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<td>WC-5</td>
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<td>SD</td>
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</tr>
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</table>

### 4. Discussion

The purposes of the present study were to clarify the technical characteristics of international elite and Japanese female weightlifters, by analyzing kinematic movements during the snatch of those weightlifters who appeared in the Junior World Weightlifting Championships, and to compare Japanese and international weightlifters. As a result, no significant difference was observed in the trajectory of the barbell between the WC and JP groups. However, the WC group exhibited 35% higher power output than the JP group.
group \((p<0.001)\). In addition, for the interval of the appearance time between the peak angular velocity of hip joint extension and Vmax during the lift, the WC group tended to have a shorter interval than the JP group.

After the comparison of the JP and WC groups for the evaluation indices based on the barbell trajectory and the angles of lower limb joints, no statistically significant differences were observed. This finding demonstrates that Japanese female weightlifters were comparable to the international female weightlifters regarding technical levels evaluated based on the
barbell trajectory and that the Japanese female weightlifters, middle-ranked in the Junior World Weightlifting Championships, and the champions in these championships did not differ in the averaged values for the snatch techniques.

However, the competition results differed widely between the JP and WC groups. The JP weightlifters had 10%-25% lower lifted weights than the WC weightlifters in the same class (Table 1). Thus, after maximum power applied to the bar was estimated by using a simple method where the barbell weight was multiplied by $V_{max}$ (Hori et al., 2006), the WC group was found to output 35% higher maximum power per unit body weight ($31.3\pm3.5$ W/kg) than the JP group ($23.1\pm3.0$ W/kg) ($p<0.05$). Since the lifted weights in weightlifting correlated highly with the lean body mass (Okada & Funato, 1993), those findings may be attributed mainly to differences in capability to exert force and power such as muscle volume, its distribution, and muscle strength per muscular cross-sectional area.

During the snatch, it may be suggested that the moment of the hip joint corresponds to 2-4 times that of the knee joint and load on the hip joint is increased with increasing barbell weight (Baumann, 1988). Therefore, the extension movement of the hip joint is positioned as the most contributing joint movement during the snatch. In the present study, the time for body movement to apply its force to the barbell was focused on and the angular velocity curve of the hip joint and the velocity curve of the barbell were examined. As a result, the appearance of the peak values of the angular velocity of hip joint extension and the velocity of the bar were observed during the second pull phase, and the peak of the angular velocity of the hip joint appeared prior to that of the barbell $V_{max}$. Comparison of the WC and JP groups for that time difference showed that the time to transmit physical output to the barbell tended to be earlier in the WC compared to JP group.

It has been 20 years since female classes were added to the World Weightlifting Championships, and female weightlifters have been improving their competitive performance remarkably. For the clean and jerk in women, the world record of the 48 kg class is 120 kg (2.5 times body weight) and that of the +75 kg class is 186 kg (as of November 2008). The present study analyzed weightlifters in a junior (under 20 years old) competition, in which the WC-6 and JP-4 weightlifters established senior world and national records, respectively; this would mean that junior weightlifters should not be considered to have poor or immature technical levels compared to senior weightlifters. However, analysis on the techniques has reported gender differences and it has been opined that female weightlifters still have immature technical levels compared to male weightlifters (Gourgoulis, 2002; Hoover, 2006).

For indices of barbell height, the maximum height, catch height, and difference between them (drop distance) are usually used. Reported ratios of maximum height to body height are 0.62 for the 1975 World Men

![Figure 5](http://www.soc.nii.ac.jp/jspe3/index.htm) Velocity of the barbell and angular velocity of hip joint.

Dashed line indicates the maximum velocity of the barbell. Arrows showed the time difference of the peak between Hip and Barbell.
Weightlifting Championships, 0.69 for the U.S. National College Weightlifting Championships (Burdett, 1982), 0.692 for lightweight classes of the European Junior Weightlifting Championships, 0.703 for heavyweight classes of these championships, and 0.773 and 0.755 for junior and adult weightlifters in the Greek national weightlifting squad, respectively (Gourgoulis et al., 2000). Thus, these ratios are assumed to be about 0.6-0.7 if weightlifters lift a weight close to their best record (maximum lifted weight) in competitions, while being assumed to be slightly higher in immaturely competitive weightlifters. In the present study, the ratios were 0.63 for JC and 0.64 for WC groups, which are within the above-described range and may be close to those of male elite weightlifters.

As the maximum height becomes higher, a larger turnover phase is allowed. To lift heavy weights higher, more intense power needs to be applied to the barbell, which may be an important factor affecting whether an attempt is successful. However, a deep squat style is mainly used in competitions, so the technique to enable catching of the barbell even at lower maximum heights leads to more likely success of a snatch attempt of higher weights. In previous studies, the drop distances of female weightlifters were reported to be 20±5 cm (Hoover, 2006) and 18.6±3.7 cm (Gourgoulis et al., 2004), which were consistent with 18 cm in the present study. On the other hand, the drop distances of male weightlifters were reported to be 11 cm, 12.7 cm (Gourgoulis et al., 2006), 13 cm (Gourgoulis et al., 2004), and 13.5 cm (Gourgoulis et al., 2002) on average, all of which were lower than female weightlifters. This assumes that the technique to succeed in an attempt by enabling catching of the barbell even at lower maximum heights may be better in male weightlifters.

The maximum vertical velocities of the bar in female weightlifters were reported to be 1.98±0.09 m/s in 6 female weightlifters of the Greek national weightlifting squad (Gourgoulis, 2002) and 1.648±0.191 m/s in the U.S. National Weightlifting Championships (Hoover, 2006); in the present study, the velocities were 1.86±0.09 m/s (ranging 1.70-1.96) for JP and 1.94±0.19 m/s (ranging 1.66-2.13) for WC groups, which were almost comparable to that of the weightlifters of the Greek national weightlifting squad.

In several previous studies, the velocity of the barbell during the first pull phase was determined for comparison with the maximum velocity. In this way, whether the first pull phase or the subsequent second pull phase more affected the barbell velocity may be presumed. For example, those determined velocity values for male weightlifters have been reported to be 1.13 m/s (Gourgoulis, 2002) to 1.17 m/s (Campos, 2006), which were 68% to 77% with respect to the maximum velocity; this means that the barbell velocity reached about 70% of the maximum velocity during the first pull phase. However, this percentage has been reported to be low in female weightlifters (56.7%) compared to male weightlifters (Gourgoulis, 2002). In the present study, a similar tendency was observed, which was on average 57% for the JP group and 56% for the WC group. These findings suggest that compared to male weightlifters female weightlifters may have low acceleration capability during the first pull phase or tend to withhold acceleration during the first pull phase and then accentuate the acceleration during the second pull phase; further research is required.

5. Summary

The present study aimed at clarifying the technical characteristics of female weightlifters who appeared in the Junior World Weightlifting Championships and at identifying the difference between the international champions and Japanese weightlifters. This was done by analyzing kinematic movements recorded on videotapes during the snatch in these championships.

As a result, no remarkable differences were observed in the techniques in terms of the barbell trajectory and joint angles between the champions and Japanese weightlifters. However, the champions tended to have an earlier timing to transmit physical movement to the barbell and applied 35% higher maximum power to the barbell than the Japanese weightlifters, presuming that the capability to exert muscle strength and power affected the competitive performance greatly.

Acknowledgments

The present study was part of a medical science project of the Japan Weightlifting Association, implemented with the aid of the Institute of Top Performance in the Project Research Institutes of Waseda University.

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