Optimalisation of the Snatch Technique in Weightlifting Based on Kinematic Measurements

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Abstract: - The aim of this work was to determine and compare the kinematic features of the snatch with a lower weight performed by athletes with a different level of technical maturity. It was a case study in which we focused on the analysis of the snatch of a Czech national bicross representative who uses this element in her strength training. The control group comprised of two lifters who are also Czech national representatives. To record and evaluate the data we used two synchronized hi-frequency cameras and Simi Motion software system, which was created to analyse the human locomotion. By digitalization of the locomotion we determined time, space and velocity features of chosen body parts and the barbell. With the mutual comparison of the individual data we discovered technical insufficiencies which were related mainly to the duration period of different phases and the extension locomotion in joints of lower extremities. Subsequently we formed recommendation for practical training.

Key-Words: - Biomechanics, kinematic analysis, technique, performance, weightlifting

1 Introduction
The snatch is an event in which the lifter lifts the barbell from the platform to locked arms with one smooth continuous movement without stopping, one hand lagging behind or extra pushing above the head. The lifter usually uses wide grip which enables lifting the barbell faster and higher. One try to lift the barbell from the pull off the platform to the squat does not take more than two seconds, depending on how exact the movement is and the level of muscle work. The lifter usually lifts less weight at the snatch then at the clean and jerk [1]. This movement structure can be divided into several parts. Different authors use different number of phases [1-3], we incline to the following: 1. initial position, 2. first pull, 3. transition from the first pull to the second pull, 4. second pull, 5. the turnover under the barbell, 6. the catch phase (fig. 1).

From the kinematic point of view, the basic variables to influence the success or failure of a single try are the timing features of individual phases of this movement structure [3-5]. Then there are the space features, mainly the trajectory of the barbell locomotion, changes of its position by both vertical and horizontal axis, the difference in the maximum reached height and the final height of the barbell [6-9]. The most monitored angular features are the changes of angles in ankle, knee and hip joints [10-14]. The quality of the performed snatch is closely related to velocity features, both barbell linear velocity and angular velocity of different joints.

These authors [15, 16] monitored the performance of the snatch at different body-weight
and age category lifters, men and women at top level. Their performances served to create patterns of optimal execution of the snatch. According to some of the authors [17] there are no significant differences in the performance of different categories. Thanks to the fact that the authors worked with quite large research files the results are statistically important and it is possible to generalise them. This strength Olympic sport is not only relevant for the lifters. Other top athletes use weight lifting to build their strength. In this case, we must regard the weightlifting technique from a different point of view. These athletes do not usually lift the maximum weight. However, they use weights which are heavy enough to develop explosive strength of relevant body parts. Regarding the fact that this is only a complement to their training process, they do not put emphasis on the correct technique but the training unit volume. Bad technique can, however, also have negative impacts. Wrong muscles can be involved and therefore the muscles which should be built are not developed as required. During a long term incorrectly exercised weight lifting which significantly influences the body locomotive organs, mainly the joints and spine, there might evolve long term health problems or even irreversible changes in the organism. This is why it is absolutely necessary to optimise the technique, not only with lifters but also with other athletes. Recently, in the area of top sports, we cannot be without a detailed biomechanical analysis of a chosen locomotion with the newest technology, which is able to find the mistakes in the performance of the locomotion and their cause. These analyses must be carried out individually with each athlete and cannot be generalised. However, they are irreplaceable for each athlete.

This contribution brings closer the case study which deals with the optimization of the snatch of Czech national bicross representative who uses the snatch as a part of her strength training. Her aim is not to lift the maximum weight. During her training, she uses a barbell with approximately the half of the weight she could lift. We can compare the features of her performance with the values stated by the authors above. However, their results correspond with the conditions when the lifter lifts the maximum weight. That is why we considered it useful to make the kinematic analysis of the snatch with two Czech representatives when lifting the weight equal to one half of their maximum performance. Therefore we will be able to compare the results of the monitored person – Czech bicross representative with the tries of top lifter in similar conditions.

2 Methods

The aim of the work is to carry out 3D kinematic analysis of the snatch of athletes with a different level of technical maturity and use the results to make recommendations to optimize the technique.

This work is composed as a case study with the research file comprising of these three persons:

MP 1: male, 17 yrs old/183 cm/85 kg, the best snatch performance to date - 110 kg, barbell at the judging - 55 kg. TO 1 contest lifter for 8 yrs. Achievements: 3x Czech record in the Youth 1 category, 3x Czech champion in the Youth 2 category, Junior Czech champion in the category up to 17 yrs of age, 2nd place in the junior category up to 20 yrs of age.

MP 2: male, 20 yrs/175 cm/75 kg, the best snatch performance to date - 95 kg, barbell at the judging – 47.5 kg. TO 2 contest lifter for 9 yrs. Achievements: 2nd place at the Czech Youth 1 category championship, Czech champion in Youth 2 and Junior category up to 17 yrs of age, 2nd place in the Junior category up to 20 yrs of age, 3rd place in Men category in the Czech championship.

MP 3: female, 22 yrs/168 cm/65 kg, the best snatch performance to date - 50 kg, barbell at the judging - 25 kg. TO 3 lifts weights as a part of her bicross training for three years, she is the representative of the Czech Republic in bicross.

System Simi Motion, which was made by a German company SIMI Reality Motion Systems GmbH residing in Unterschleissheim, was used for the three dimensional analysis. This company works at the development of analytic software. There were 15 retro-reflex markers attached to the monitored persons to these anatomic parts: right and left tiptoe, right and left ankle, right and left knee, right and left hip, right and left shoulder, right and left elbow, right and left wrist, and head. Two retro-reflex markers were attached to the barbell – left and right end.

Based on the set aim of the work, we focused on the evaluation of basic time, space, and velocity variables which we can subsequently work with: changes in ankle, knee and hip joints, changes of the barbell position in vertical axis, the speed of the barbell.

3 Results

3.1 Angular features of the locomotion

Table 1 clearly shows the average values of three attempts, maximal reached ankle angle of individual monitored persons and time of reaching this angle.
Next is stated the angle in the second ankle angle at the same moment and the difference between the two angles.

Table 1 Maximal angle of the ankle joint and relevant time

<table>
<thead>
<tr>
<th>Monitored person</th>
<th>Maximal ankle angle (°)</th>
<th>SD (s)</th>
<th>Angle of the second ankle (°)</th>
<th>SD (s)</th>
<th>Difference (°)</th>
<th>SD (s)</th>
<th>Time - maximal ankle angle (s)</th>
<th>SD (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MP 1</td>
<td>137.6°</td>
<td>5.3</td>
<td>135.0°</td>
<td>5.3</td>
<td>2.6°</td>
<td>0.43</td>
<td>0.731 s</td>
<td>0.068</td>
</tr>
<tr>
<td>MP 2</td>
<td>125.5°</td>
<td>4.9</td>
<td>121.7°</td>
<td>6.4</td>
<td>3.8°</td>
<td>0.57</td>
<td>0.760 s</td>
<td>0.052</td>
</tr>
<tr>
<td>MP 3</td>
<td>135.5°</td>
<td>5.6</td>
<td>121.1°</td>
<td>7.1</td>
<td>14.4°</td>
<td>0.86</td>
<td>0.425 s</td>
<td>0.076</td>
</tr>
</tbody>
</table>

Ankle angles changes of individual MPs can also be seen in graph (fig. 2) which depicts the change in angle between the foot and the shank. The vertical line shows the moment when the ankle angle reaches the maximum value (always at the ankle with a higher measured value).

The biggest average maximum ankle angle was reached by MP 1 - 137.6°. A little less was measured at MP 2, exactly 135.5° and the least at MP 2, where the maximum value of the ankle angle equalled 125.5°. A very important data is the difference in angles of right and left ankle, mainly with MP 3, where the 14.4° cannot be ignored. As to the time features, with MP 1 and MP 2 we recorded the maximum angle in nearly the same microphase of the locomotion (0.731 s and 0.760 s), however, with MP 3 the moment came in nearly half of the time, in average at 0.425 s.

We further evaluated the changes of knee and hip angles during the locomotion. As there were not significant differences between the right and left side of the body, we only quote the values measured at the left knee and hip angles. The measured values are stated in table 2.

Table 2 Time and angular changes in left knee and hip joints of MPs at the end of individual phases

<table>
<thead>
<tr>
<th>MP 1</th>
<th>Time (s)</th>
<th>SD (s)</th>
<th>Knee angle (°)</th>
<th>SD (s)</th>
<th>Hip angle (°)</th>
<th>SD (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P 1</td>
<td>0</td>
<td>0</td>
<td>46.627</td>
<td>3.125</td>
<td>38.779</td>
<td>3.016</td>
</tr>
<tr>
<td>P 2</td>
<td>0.474</td>
<td>0.029</td>
<td>137.997</td>
<td>3.375</td>
<td>91.567</td>
<td>3.916</td>
</tr>
<tr>
<td>P 3</td>
<td>0.602</td>
<td>0.036</td>
<td>127.911</td>
<td>4.025</td>
<td>118.633</td>
<td>4.275</td>
</tr>
<tr>
<td>P 4</td>
<td>0.780</td>
<td>0.041</td>
<td>156.347</td>
<td>4.275</td>
<td>155.378</td>
<td>4.326</td>
</tr>
<tr>
<td>P 5</td>
<td>1.057</td>
<td>0.044</td>
<td>85.930</td>
<td>3.916</td>
<td>100.651</td>
<td>4.075</td>
</tr>
<tr>
<td>P 6</td>
<td>1.630</td>
<td>0.052</td>
<td>60.352</td>
<td>3.627</td>
<td>68.755</td>
<td>3.125</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MP 2</th>
<th>Time (s)</th>
<th>SD (s)</th>
<th>Knee angle (°)</th>
<th>SD (s)</th>
<th>Hip angle (°)</th>
<th>SD (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P 1</td>
<td>0</td>
<td>0</td>
<td>52.891</td>
<td>2.976</td>
<td>30.986</td>
<td>2.968</td>
</tr>
<tr>
<td>P 2</td>
<td>0.593</td>
<td>0.036</td>
<td>136.922</td>
<td>3.016</td>
<td>94.774</td>
<td>3.125</td>
</tr>
<tr>
<td>P 3</td>
<td>0.652</td>
<td>0.044</td>
<td>132.652</td>
<td>3.627</td>
<td>108.360</td>
<td>3.627</td>
</tr>
<tr>
<td>P 4</td>
<td>0.830</td>
<td>0.052</td>
<td>154.864</td>
<td>3.925</td>
<td>154.998</td>
<td>4.125</td>
</tr>
<tr>
<td>P 5</td>
<td>1.076</td>
<td>0.058</td>
<td>89.845</td>
<td>3.716</td>
<td>101.124</td>
<td>3.816</td>
</tr>
<tr>
<td>P 6</td>
<td>1.343</td>
<td>0.063</td>
<td>66.096</td>
<td>3.575</td>
<td>74.736</td>
<td>3.426</td>
</tr>
</tbody>
</table>
Maximum values of angles, which mean maximum extension of angles, during the monitored locomotion, were noted in phase 4 with all the MPs. The angles of MP 1 and MP 2 were nearly the same in size (156.3° a 154.9°), so were the time data (0.78 s a 0.83 s). MP 3 was close to the values with the degree of extension of knee angles – average value 146.1°. Extension of hip joints was distinctly smaller (131.1°). The time data relevant to this moment (0.44 s) was also different from the first two MPs. The body posture at the moment of maximum extension is shown in the pictures (fig. 3). The coordination of knee and hip joints locomotion is shown in graphs (fig. 4). Vertical lines in these graphs represent different phases of the attempts.

3.2 Barbell trajectory

From the barbell trajectory features we evaluated the height of top dead centre (H1), bottom dead centre (H2) and the difference between these two positions during three attempts of each MP (tab. 3). Top dead centre comes up at the moment when the barbell loses contact with the platform – between phases 4 and 5 and bottom dead centre comes up at the catch phase (phase 6).

Table 3 The height of top and bottom barbell dead centre of individual MPs

<table>
<thead>
<tr>
<th>Monitored person</th>
<th>H1 (m)</th>
<th>SD (s)</th>
<th>H2 (m)</th>
<th>SD (s)</th>
<th>H1 – H2 (m)</th>
<th>SD (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MP 1</td>
<td>1.596</td>
<td>0.058</td>
<td>1.287</td>
<td>0.056</td>
<td>0.309</td>
<td>0.022</td>
</tr>
<tr>
<td>TP 2</td>
<td>1.455</td>
<td>0.060</td>
<td>1.259</td>
<td>0.043</td>
<td>0.196</td>
<td>0.018</td>
</tr>
<tr>
<td>MP 3</td>
<td>1.560</td>
<td>0.063</td>
<td>1.244</td>
<td>0.068</td>
<td>0.316</td>
<td>0.026</td>
</tr>
</tbody>
</table>

The lowest average values of monitored parameter – difference between the top and bottom dead centre was reached by MP 2 – 20 cm. The other two MPs had higher measured values – MP 1 – 31 cm and MP 2 – 32 cm.

3.3 Barbell velocity

In table n. 4, we quote the highest measured average values of absolute velocity of each monitored person.

Table 4 Maximum value of absolute velocity of all monitored persons

<table>
<thead>
<tr>
<th>Monitored person</th>
<th>The highest measured velocity in (abs max)</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>MP 1</td>
<td>2.66 m/s</td>
<td>0.36</td>
</tr>
<tr>
<td>MP 2</td>
<td>2.39 m/s</td>
<td>0.22</td>
</tr>
<tr>
<td>MP 3</td>
<td>3.42 m/s</td>
<td>0.32</td>
</tr>
</tbody>
</table>
The results of the tests showed that the highest speed of the barbell was reached in the snatch by MP 3 (3.42 m/s) and MP 2 (2.39 m/s). Graphs (fig. 5) show the progress of vertical velocity $v(Z)$, horizontal velocity $v(Y)$ and absolute velocity $v(abs)$ of the barbell in time. With MP 1 and MP 2 we can see that the velocity has one important peak, while MP 3 performs locomotion with nearly constant maximum velocity for the time of approximately 0.15 s. Pictures (fig. 5) show in which point the maximum velocity was reached.

### 4 Discussion

The result of the study shows that the technical maturity of the lifter appears in the values of the snatch kinematic features. According to the authors [3], we can watch two maximums in the ankle angle during the monitored locomotion, the size of the first one is approximately 116.45° and of the second 130.10°. We did not see a significant first peak at our monitored persons; however, there appeared a small change in the curve increase between 110° and 120°. The size of maximum extension at our MPs (137.6°, 125.5° and 135.5°) was close to the stated value of the second maximum [3]. Possible bigger extension in the ankle joint should not be a problem if we consider the authors’ contention [1] that in the final part of lifting the barbell the lifter should stand on the tiptoe to prolong the trajectory of the barbell in the vertical direction. We cannot miss seeing the data of MP 3 which show a big difference in the size of angles of the right and left angles. That is a mark of a bad locomotive coordination and low technical maturity. This asymmetry of ankle joints locomotion transfers through knee and hip joints and leads to more technical imperfections. However, it can also be a sign of a physiological problem which prevents the right ankle from reaching a bigger angle. Beside the changes in ankle joint angles, the moment of reaching their maximum value is also substantial. Authors [1] state that not only ankle joints but also knee and hip joints should reach the maximum extension nearly at the same time, at the end of the fourth phase, when finishing the second pull. This requirement of the simultaneous extension of ankle joints and knee and hip joints was satisfactory. MP 1 performed the maximum extension of the ankle angle 0.049 s before the maximum extension of knee and hip joints, with MP 2 the time difference was only 0.07 s and with MP 3 just insignificant 0.01 s. The question remains if the extension were carried out at the correct time in the frame of the whole locomotion.

Authors [3, 6, 11-14] all agree how the progress of the locomotion should look like. During the first pull, knee joint makes extension and subsequently comes into flex during the transition into the second phase. Finally there is a second extension during the second pull. This characteristic of the locomotion in knee bends is apparent at MP 1 and MP 2; we can watch the first maximum, then a slight decline in the curve and subsequent reaching oh the second maximum. MP 3 completely lacks tucking the knees under the axis of the barbell in the transition from the first phase to the second pull. According to the authors [3] the size of the first extension should be...
around 145.17°, at the end of the transition phase about 128.0° at the end of the second pull this value reaches 162.5°.

Campos et al. [2] reached the conclusion at their work that the optimal value of the second extension is 170°, Lenjannejadjan and Rostami [11] state even 180°. The values we measured were lower, however, with MP 1 and MP 2 they were close to the model. In the case of MP 3, with the value of knee extension equal to 146.1°, we found quite a big difference not only from the recommended values but also from the values measured with MP 1 and MP 2. Concerning the maximum hip joints extension, the authors [3, 11] recommend nearly the same size – 182.7° and 180°. As the measuring showed (155.4°, 155° a 131.1°) all monitored persons have insufficient hip joint extension. The biggest insufficiency is visible from MP 3, where the difference between recommended and performed size of extension is approximately 50°. In graph (fig. 4) you can also see that the time coordination of the knee and hip joint locomotion is not optimal. The peak of both curves should come up at the same time and then they should descent in the phase of turnover under the barbell, as we can see in graphs (fig. 4) of MP 1 and MP 2. The time features of finishing different phases are nearly the same at MP 1 and MP 2, as you can see in table 2, at MP 3 the time for which the phases last is significantly different, mainly for the first four phases. The end of phase four was at the time of 0.78 (MP 1), 0.83 (MP 2), and 0.44 (MP 3) from the locomotion initiation. These data give evidence that MP 3 performed the first four phases too fast. From the previous data we can see that this was at the expense of correct technique. Single parts of the locomotion were not carried out in proper extent.

More authors [1-3, 5, 6, 9] agree that top lifters can perform the attempt with a lower value of barbell trajectory culmination at the top dead centre stated by parameter H 1 and with a lower value of difference between the top and bottom dead centre (H1 – H2). Values that these authors measured in their research are, however, different. We found the lowest data at Campos et al. [2], who state that the lowering of the barbell during the catch phase was 7 and 6 cm at the first and second monitored groups. On the other hand the highest values of the difference between H 1 and H 2 were found out by Hoover et al. [5] - 20.78 cm. The results of other quoted authors reach the values from 10 to 15 cm, which we consider to be practicable at technically mature lifters. The values of our MPs show technical reserves. Their performance is not efficient and economical from the energy point of view. However, the reason for this might the weight cut down to 50% of the maximum.

Bartonietz [18] claims that the vertical velocity of the barbell should continuously grow up to the end of the second pull phase. He explains that if the velocity lowers during the locomotion, it is necessary to put in more mechanical energy to finish the second pull phase. The measuring of authors [3] show that the velocity grew up in the group of top lifters. The vertical speed at the end of the first pull phase reached in average 1.28 m·s⁻¹, at the end of the transition from the first pull phase to the second pull it was in average 1.36 m·s⁻¹ and at the end of second pull phase it was 1.72 m·s⁻¹. Similar maximum values of vertical velocity were found by Campos et al. [2], in their research. With research file one they measured 1.7 m·s⁻¹, with file two 1.78 m·s⁻¹, during the second pull. Leško et al. [1] state that the top lifter reach maximum values between 1.65 and 2.3 m·s⁻¹ with the maximum weight of the barbell. Our monitored persons exceeded these values (2.66 m·s⁻¹, 2.39 m·s⁻¹, 3.42 m·s⁻¹). This can be explained by lifting the weight of 50% of the maximum, so by different conditions than the authors above measured. However, quite unexpected is the barbell velocity of MP 3, which is higher than the maximum values measured at MP 1 and MP 2. We presume that the weight of the barbell of MP 3 did not have to refer to the half of her maximum. MP 3 probably never reached the real border of her potential during her training. The next fact is that lifters sometimes choose to use lower velocity than they could really reach. The reason is that during lifting the barbell with 50% of the weight maximum, excessive velocity can do more harm as the lifter would not be able to coordinate his locomotion correctly, which is apparent at MP 3. As we have already stated above, the excessive velocity, which means shortening of individual phases, lead to insufficient extent of the locomotion and wrong coordination of time and space.

5 Conclusion
Weightlifting is not only a matter of lifters but also of athletes of different sports events who use it as a part of their strength training. The aim of this study was to help optimize the technique of the snatch execution during the training. To be able to find out the substantial insufficiencies, which often correspond with only minimal deviations from different variables not visible to the naked eye, we used analysing system Simi Motions, which offers exact data. Thanks to this digital equipment we
digitalized the locomotion of chosen body segments a discovered which of them cause the most problems. As we focused on non-professional lifter, the aim was not to optimize the technique to reach the maximum performance, but to get a safe execution which does not endanger the human locomotive organs and risk injury. From this point of view we reached the following recommendations, mainly for MP 3.

We consider the first important step to lower the velocity of lifting the barbell so that all the phases are long enough to carry out the necessary corrections. If the weight is too heavy for MP 3 that it is not possible to slow the motion down, we recommend cutting down the weight. When implementing these conditions it is possible to focus on the insufficiencies and remove them step by step. It is necessary to synchronize the locomotion of ankle joints so the load on the body is not unilateral and cause muscle disbalance. It is then necessary to coordinate the work of knee and hip joints in time, because according to the results, they do not reach their angular maximum at the same time. There should not be an extension in knee joints without the hip joints extending too. This mistakes results in excessive bend forward accompanied by access load on the spine. This could lead to backache or, with using a bigger weight, to more serious problems and injuries like intervertebral disc displacement. From the technical aspect it might help to emphasize minimal horizontal deviation of the barbell. After the correction of these imperfections and mastering the correct locomotive stereotype, it is possible to increase the weight. In that case we believe it is suitable to make repeated judging of the technique with the analysing system.

This work was composed as a case study, so it is not possible to generalise its results. Nevertheless we believe that it can help the coaches and athletes who are engaged in weightlifting realize mistakes in technique, which might occur at the snatch. Kinematic analysis recently offers the necessary data to analyse the technique and is a good toll to the subsequent optimization, from both performance and health points of view.

References:


