ČESTNÉ PROHLÁŠENÍ

Prohlašuji, že tento výzkumný článek "Dependance of the shot put performance on the selected kinematic parameters of the technique" obsahuje výsledky práce vzniklé v průběhu realizace projektu „Zaměstnáním nejlepších mladých vědců k rozvoji mezinárodní spolupráce“ (POSTDOC II.), reg. číslo CZ.1.07/2.3.00/30.0037.

Brno, 30.5.2014

Mgr. Martin Vaváček, Ph.D.
**DEPENDANCE OF THE SHOT PUT PERFORMANCE ON THE SELECTED KINEMATIC PARAMETERS OF THE TECHNIQUE**

**Martin Vaváček and Marek Hardoň**
*Faculty of sport studies, Masaryk University, Brno, Czech Republic*

**Abstract**

The paper aims to define, by means of correlation analysis, the dependency between the achieved performance and selected kinematic parameters of the technique of top shot putters at the level of 17 - 23 meters, and also after dividing them with discriminant analysis to weaker (17 - 20 m) and better (20 - 23 m) performances. On the basis of biomechanical analyses of the performances in shot put, and with the help of correlation analysis, we determined the dependence of selected parameters on performance, which essentially determine the length of the shot put. Hypothesis No. 1 has been confirmed as the relationship between the power and velocity of the shot at the moment of release in the whole group of putters was at 1% level of statistical significance ($r = 0.68$). Correlation between the performance and take-off angle was not statistically significant. The dependence of the performance on speed components of the shot in the moment of release in our study was statistically significant at 5% level only in the horizontal component ($r = 0.55$). The dependence of release height in the whole group went to 1% level of significance ($r = 0.64$), thus confirming this parameter to be one of the limiting factors of shot put technique. In the group of 20 - 23 m, the dependence of the angle of take-off was insignificant, with a correlation coefficient $r = -0.07$, confirming the hypothesis No 2 that assumed the group with better performances will have larger dependence on the release velocity than on the parameter of the angle of take-off. Further research is needed because this work deals only with selected performance parameters and these results do not provide sufficient basis for complex recommendations for comprehensive training.

**Key words:** shot put, dependence, kinematic parameters, correlation analysis

**Introduction**

The quest for maximum performance, one of the most important attributes of sport, is evident especially where it is possible to measure the performance objectively. Without a doubt we can consider shot put to be one of those, as there exists a prediction equation (Leško, 2000) and it is directly determined by measured results.

\[
l = \frac{v_0^2 \cos \alpha}{g} \left( \sin \alpha + \frac{2h}{v_0^2} \right)
\]

$l$ - shot put length  
$v_0$ - release velocity  
$\alpha$ - release angle  
$g$ - gravitational acceleration  
$h$ - release height

Shot put is one of the technically most demanding athletic disciplines. A number of factors determine the performance and from the biomechanical point of view, we are dealing with a complex of forces different to all the other athletic disciplines.

To achieve high performance is a priority in every sport, while it is important to focus on the individual factors limiting the performance. It is important to know and pay attention to the conditions helping to reach maximum sports performance. In general, these conditions are well known. Above all, they include the dispositions of a particular athlete for a given sports activity and mastery of an optimum technique. Top performance requires solution of the problem of optimization of the technique, especially in disciplines where the biomechanical parameters of the movement pattern determine achieving top performances. This biomechanical approach is based on application of the mechanical principles while taking into account the biological characteristics of an athlete’s body and his or her individual predispositions.

In an attempt to improve the training process and the technique of an athlete, means using modern technical equipment and procedures are used increasingly. The experienced eye of a coach is often no longer adequate to define the deficiencies in an athlete’s technique, and in many cases, kinogram analysis is the only means to capture and analyze the movement pattern.
What creates the basis of this study is the examination, comparison and especially finding the relationships and dependencies between individual measured values of selected kinematic parameters of the technique of top shot putters from available literature and bibliographical sources.

**Objective, hypotheses and tasks**

**Objective**

The aim is to find and define, by means of correlation analysis, the dependency between the achieved performance and selected kinematic parameters of the technique of top performances in the shot put at the level of 17 - 23 meters.

A partial objective is to find and compare the relationships of individual parameters at different performance levels.

**Hypotheses**

H1: We assume that the dependence of selected kinematic parameters will be different depending on the performance level.

H2: We assume that in the better performance group the dependency of performance on the overall shot release velocity will be greater compared to the parameter of the shot release angle.

**Aims**

1. To make a research on selected kinematic parameters of the technique of top shot putters from the available top competitions.

2. To determine the relationship between the performance and selected kinematic parameters of the technique of top competitors.

3. To display graphically the dependences of the performance on selected kinematic parameters of the technique globally, as well as according to the various performance levels.

**Methods**

This is an ex post facto research design. The group of subjects consisted of 43 top performances in the shot put using rotational technique in male category. The performances were subjected to 2D or 3D biomechanical analysis. On the basis of these analyses, we collected selected kinematic parameters of the technique, then we organized the acquired empirical data into tables and we used mathematical and statistical methods to evaluate the data, with the help of a computer program EXCEL. Some of the analyzed performances do not contain all the parameters. The selected parameters and their distribution are displayed in Tab. 1.

The dependency between variables were determined by means of pair correlation analysis with calculation of pair correlation coefficient \( r \) according to Pearson (Wallace, Snedecor, 1931), while the dependency was observed globally - i.e. in the whole group and separately, in the group of weaker performances with 17 - 20 m and in the group of better performances with 20 - 23 m. These groups were created on the basis of discriminant analysis.

The statistical significance was assessed on the level of 1% (**) and 5% (*). The results of the research were subjected to logical analysis and synthesis with the use of deductive and inductive reasoning.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>the overall number</th>
<th>the number of 17 - 20 m</th>
<th>the number of 20 - 23 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>performance</td>
<td>43</td>
<td>18</td>
<td>25</td>
</tr>
<tr>
<td>release height</td>
<td>28</td>
<td>12</td>
<td>16</td>
</tr>
<tr>
<td>release angle</td>
<td>43</td>
<td>16</td>
<td>25</td>
</tr>
<tr>
<td>overall velocity</td>
<td>28</td>
<td>12</td>
<td>16</td>
</tr>
<tr>
<td>horizontal velocity</td>
<td>14</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>vertical velocity</td>
<td>14</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Phase 6</td>
<td>13</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>1st step</td>
<td>16</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>2nd step</td>
<td>16</td>
<td>10</td>
<td>6</td>
</tr>
</tbody>
</table>
Results and discussion

From the physical point of view, shot put is an angled throw and it is given by its length, which is conditioned by the following factors: release velocity, optimum release angle and release height.

The initial velocity of the shot, which substantially determines the length of the put, depends on the trajectory on which the shot putter acts on the shot from the moment of taking the release position. Even though the dependence between performance and release velocity was confirmed at 1% level of statistical significance in all the puts (Fig. 1), the statistical significance of the same factor was only at 5% level in the group of 20 - 23 m. (Fig. 2). In the group of performances between 17 and 20 meters, the dependence of the performance on the overall initial velocity of the shot was not confirmed as significant (Fig. 3).

The release angle is one of the key parameters of the performance. The angle is formed by the intersection of two straight lines. The first one forms a tangent to the trajectory of the shot in the moment of release and the other straight line is parallel with the ground, or the area of the circle and it crosses the centre of gravity of the shot in the last position, when the shot is still in contact with the shot putter’s hand.

According to Tutević (1969), the optimum release angle in a performance of 20 m is about 42.5°. The foreign study of Bartonietz and Borgston (1995) also brought an interesting finding. By means of 2D analysis, they examined the finalists of the World Cup in athletics in Gotenborg. In this competition, J. Godina, M. Halvari and R. Barnes were between those shot putters who used rotational technique. The authors stated, according to calculations, an optimum angle of 40 - 42° for them. However, not even one reached such values. J. Godina, in his best performance 21,47 m, achieved a release angle of 31°, M. Halvari, in a shot put 20,93 m long, had a 35° angle and R. Barnes, in an attempt of shot put 20,41 m long, had a release angle of only 30°. The authors further stated that if the release angle was closer to the optimum values, the shot put could be lengthened by up to one metre.
According to other sources (Putnam, 1993 and Linthorne, 2001), in elite shot putters at the level of 20 m, the optimum release angle ranges between 30° - 40°.

In fact, this was also our case, as no statistically significant dependence between the performance and release angle was confirmed based on calculations, not even in one of the three groups of performances. In the entire set of 43 performances, the correlation of the performance and release angle was at the level of -0.11, in the group of 17 - 20 m (n = 18), the correlation coefficient value was r = 0.02, and in the group of 20 - 23 m (n = 25) r = -0.07. The explanation can be found in the relative stability of this parameter, which is not changing significantly with the changing performance, and thus there is no concurrence, which can be identified by correlation coefficient.

Winter (1990) says that the larger the angle, the more effort must the shot putter make to overcome the weight of the shot, which is, however, at the expense of the horizontal component of the force and the subsequent acceleration of the shot. As he states further, the structure of the body is more designed to overcome resistance rather in horizontal than in vertical plane, what we can see in an example of a comparison of force of only the upper body part, where most of the athletes overcome greater weight in bench press than in standing military press or clean and jerk.

Regarding the extent of dependence of horizontal and vertical component of the shot release velocity, only the dependence of the performance on the horizontal component of shot release velocity in the set of 14 performances was significant at 5% level of statistical significance. In other cases, the dependence of the performance on these parameters, also after dividing them into 2 groups, was statistically insignificant.

Since the entire set consists of performances of shot putters using only rotational technique, it has been confirmed that these shot putters use more of the horizontal component of the velocity compared to the shot putters using back technique. This is due to the more efficient use of the spring mechanisms, even if the shot stops at a certain phase, there is an enormous initial tension resulting from the contradictory twisting of the pelvic axis towards the axis of the shoulders. Apart from accumulated elastic energy of the strain system of the muscle-tendon apparatus, proprioceptive stimulation of the reflex response after a quick stretch is also used (myotatic reflexes facilitate). This makes it possible, with proper timing, to biomechanically use myofascial chains more effectively, especially in the horizontal direction, which results in better sports performance. In the back technique, the shot putters have to put more force on the shot in the vertical plane, because they use rotational strain system less effectively.

The height of the centre of gravity of the shot in the moment of release ($h$) is the length of the vector perpendicular to the base between the centre of gravity of the shot in the last position, when it touches the hand and the base.

The dependence of the performance on the release height (Fig. 4) was statistically significant (1%) in the entire group, which confirms this parameter to be one of the limiting factors of technique. In the performance level of 20 - 23 m, this parameter is significant at 5% level of statistical significance; in performances of up to 20 m this parameter appears to be statistically insignificant. Therefore, in the weaker and smaller shot putters there must be different compensatory mechanisms improving the final performance.

The release height and some external factors (side wind) influence the size of the take-off angle, but in shot put it is to a much smaller extent than in discuss or javelin throw.

The relationship between the performance and the time of the 2nd double-support phase of the release (Fig. 5) is significantly limiting for the performance in shot put, statistically significant at 1% level of significance. This seems to
be the key factor for proper technical performance of the shot put. Based on the results we can conclude that the longer the time of the impact on the shot in the second double-support phase, the better the chance to impact on the shot at a longer distance, which probably results in higher values of operating forces and thus also into a better sports performance. From the practical point of view, this is a common phenomena when coaches often point out late landing of the left foot (in right-handed athletes), or early rotation of the axis of the shoulders towards the direction of the shot put. For a broader interpretation of the effect of this parameter it would be more than appropriate to analyze also the relationships of factors such as peripheral speed, action angle of vault and release, as these complete the overall picture of the distance and time acting on the shot.

The parameters of the length of the 1st and 2nd step in relation to the performances were statistically insignificant globally, as well as in individual groups based on discriminant analysis.

Conclusions

Hypothesis 1 has been confirmed as the dependence and statistical significance of selected kinematic parameters was different depending on the level of performance in these parameters:

a) The initial velocity of the shot, which substantially determines the length of the put, has been confirmed to be statistically significant at 1% level between the performance and initial velocity of the shot in the entire set of puts (r = 0.68), however in the group of 20 - 23 meters, this factor achieved only 5% level of statistical significance (r = 0.59) and in the performance group of 17 - 20 meters, the dependence of the performance on overall initial velocity of the shot has not been confirmed as significant (r = -0.28).

b) In the entire set of 43 performances, the correlation of the performance and release angle was at the level of -0.11, in the group of 17 - 20 m (n = 18), the correlation coefficient value was r = 0.02, and in the group of 20 - 23 m (n = 25) r = -0.07. Neither of these cases represents statistical significance.

c) The extent of horizontal and vertical component of the velocity of shot release in our group was statistically significant, namely at 5% level, only between the performance and horizontal component of release velocity in the group of 14 performances (r = 0.55). In other cases, the dependence of the performance on these parameters, also after dividing them into 2 groups, was statistically insignificant.

d) The dependence of the performance on the release height in the entire group was significant at 1% level (r = 0.64), which confirms this parameter to be one of the limiting factors of the technique. In this parameter, at the performance level of 20 - 23 m, there was a dependence with the values of sports performance at 5% level of statistical significance (r = 0.54), in performances of up to 20 m this parameter appears to be statistically insignificant (r = 0.14).

In the set of performances between 20 and 23 meters, the dependence of the performance on the overall release velocity at 5% level of statistical significance has been found with r = 0.59. In the same group of 20 - 23 m, the dependence of the performance on the take-off angle was insignificant, with correlation coefficient r = -0.07, which confirmed the 2nd hypothesis. The angle appears to be a relatively fixed parameter of the technique of these shot putters, the difference between the performances is determined especially by the parameter of the overall release velocity. The paper deals only with selected performances and parameters, therefore it is not possible to give relevant and complex recommendations for training and sports practice. Therefore, we suggest continuing with the research.

References