ON THE WAY FROM STRADDLED TO STRETCHED TKATCHEV ON HIGH BAR

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Reversing the direction of rotation is the main issue for the flight element Tkatchev on high bar. The principles are well described. There is a lack of knowledge to apply this to motor learning. Aim of the study is to analyse an individual gymnast’s performance and support the change from straddled to stretched Tkatchev. An instrumented high bar (force measurement) was used to give the gymnast immediately feedback about the performance. The gymnast was informed about the magnitude of the force maxima during the preparatory giant swing. After 5 training sessions with 42 trails the gymnast transferred more energy (higher forces) to the bar. But this results not in a higher angular momentum during the Tkatchev flight. Possible causes for this result where discussed. The complex demands on energy transfer and precise performance are important.

KEY WORDS: men’s artistic gymnastics, motor learning, feedback, force measurement.

INTRODUCTION: Flight elements on High bar are not only a requirement concerning the competition rules (Fédération Internationale de Gymnastique [FIG], 2009). Because of these elements high bar competitions are one of the spectacular events in gymnastics. For young gymnasts the Tkatchev (Figure 1 left) is one of the first flight elements to learn. The straddled Tkatchev, also the piked exercise are specified on difficulty level C (0.3 points). One level higher (D, 0.4 points) is the stretched version of the flight element.

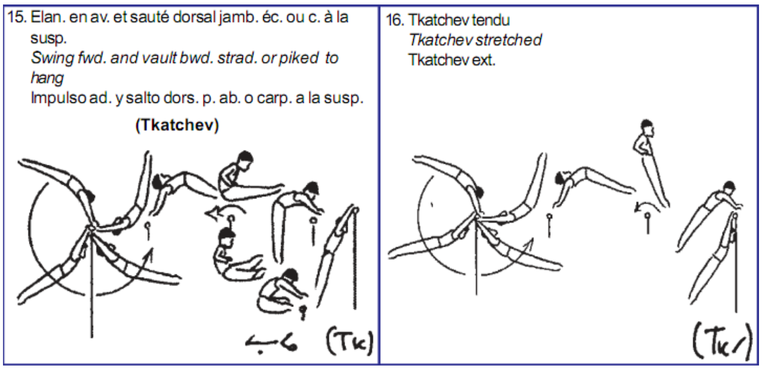

Figure 1: The flight element Tkatchev in the Code of Points (FIG, 2009, p. 123).

The Tkatchev is also an interesting skill for biomechanical research. It requires the gymnast to reverse the direction of rotation between the preparatory giant swing (backward rotation) and the flight phase from release until regrasp (forward rotation). The mechanical energetic processes during the giant swing before the Tkatchev were well explained by Arampatzis and Brüggemann (2001) by using an instrumented high bar with synchronised kinematic and dynamometric measurements of Knoll, Drenk & Krug (1996). Krug and colleagues used the measured reaction forces to describe the principles of using the elastic properties of the high bar (Knoll et al., 1996) and analysed dismounts and flight elements (Kovacs) (Knoll, 2001). Both groups showed the relationship between force or energy of the bar and the angular momentum of the gymnasts.

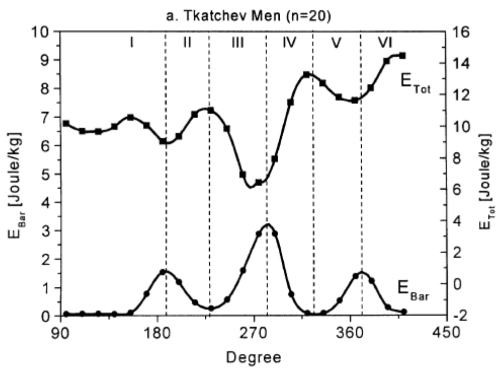

Figure 2: Mean strain energy of the bar and total energy of the gymnast (n=20) during the giant swing before the Tkatchev (Arampatzis & Brüggemann, 2001, p. 510).

Arampatzis and Brüggemann (2001) calculated the total body energy of the gymnast and the strain energy of the bar and showed the energy exchange between. The exchange of energy for the Tkatchev preparation is divided into six phases. During the first, third and fifth phase the energy of the gymnast is transferred to the high bar. The energy from the bar is transferred back to the gymnast during phases two, four and six. The

energy transfer alternates from the gymnast to the bar and reverse (Figure 2). An effective technique is characterised by an increase of the gymnasts' body energy. The three bar energy maxima are identical with three force maxima. There is a low angular momentum of the gymnast's body during the first force maximum, the highest angular momentum (backward rotation) is at the same time as the second force maximum and the third maximum is near the point of switching from backward rotation to forward rotation. Taking this principles into account the measurements unit with the dynamometers in connection with synchronised video recordings are suitable for the training of the gymnastics technique including feedback information (Knoll, Drenk & Krug, 1996).
Learning a stretched Tkatchev is based on a successful straddled Tkatchev. To reach the higher level element type there are different possibilities. The gymnast needs more vertical release velocity to get a higher flight, a higher angular momentum to counterbalance the bigger moment of inertia or a combination of the two possibilities. Kerwin and Irwin (2006) analysed ten straight Tkatchev and compared the results to the reported data for 20 straddled Tkatchev from Arampatzis and Brüggemann (2001). Surprisingly only the vertical velocity was 10% higher but the angular momentum was 13% lower for the straight Tkatchev. But the reported studies did not use the same gymnasts and analysed two different competitions. The compared angular momentum was absolute and only Kerwin and Irwin (2006) used normalised angular momentum.
These results cannot be used for learning the stretched type of Tkatchev. Individual analyses are necessary to select the right possibility to learn the stretched Tkatchev. Aim of this study is analysing an individual gymnasts performance, the selection of the right possibility to change from straddled to stretched Tkatchev and to use an instrumented high bar described above to give the gymnast immediately feedback about the performance.

METHODS: One junior elite gymnast (18 y, 1.65 m, 59.4 kg) was assessed. A successful straddled Tkatchev and an attempt of a stretched Tkatchev (passing the high bar in stretched body position without regrasping the bar) were analysed with dynamometric and kinematic methods.
The Tkatchev was performed at an instrumented (dynamometric) high bar following the high bar of Knoll, Drenk and Krug (1996). But 15 years later the video technique was changed to digital video and transferring video data direct to the computer (IEEE 1394 interface). The synchronisation of force and video data were realised by a common signal (audio signal in the video and a third measuring channel added to the voltage measurement for vertical and horizontal forces at the bar).
A two-dimensional video analysis (perpendicular to the plane of motion, fixed DV-Camera Panasonic NV-GS 300, 50 Hz, 2D-DLT) was utilised for kinematic analysis and calculation of different biomechanical variables. We digitised seven anatomical body landmarks (ankle, knee, hip, shoulder, head, elbow and wrist) and calculated the center of mass (CM) (Saziorski, Aruin & Selujanow, 1984) and the angular momentum (L) (Hay, Wilson, Dapena & Woodworth, 1977). The angular momentum was normalised to a standard gymnast of 1.60 m and 55 kg.
To identify differences between the actual performance of the junior gymnast and a model performance, the best stretched Tkatchev was selected from ten successful performed Tkatchev at the European Championships 2011. The selection was based on the execution of a full giant swing before the Tkatchev, judges selection and the highest mean and minimum relative moment of inertia (J, normalised to the standard gymnast) during the flight phase to secure the best stretched posture. Ten Tkatchev were measured by the dynamometric and kinematic methods.
Intervention: During the learning phase the junior gymnast perform 42 trials of Tkatchev (20 of them without release) within 5 training sessions. Based on the results of the analysed Tkatchev the instruction for the gymnast was to execute the giant swing before the Tkatchev with more flexed hip and shoulder joint (vertical over the bar). After every trial the gymnast was informed about the magnitude of the first two force maximum (F_{max1}, F_{max2}) as an indicator of the transferred energy to the bar. At the end of the learning phase a detailed kinematic analysis was applied to the last trial of the Tkatchev.

RESULTS: The results of the two Tkatchev (straddled and stretched) performed by the junior gymnast and the model performance are shown in Table 1. Concerning the three discussed possibilities the results call attention to the difference of the angular momentum and the first force maximum. Raise the first maximum by transferring more energy to the bar could affect higher angular momentum. To achieve this, the gymnast should use a higher range of motion at the hip and shoulder joint. Passing the vertical over the bar during the giant swing before the Tkatchev with more flexed hip and shoulder joint can offer this higher range of motion.

Table 1: Dynamometric and kinematic variables of the different Tkatchev (Jun=Junior, M=Model).

Tkatchev	max rel. L (giant swing) (kg m^2.s^{-1})	rel. L (flight) (kg m^2.s^{-1})	CM max height over the bar (m)	mean J (flight) (kg m^2)	F_{max1} (body-weight)	F_{max2} (body-weight)	F_{max3} (body-weight)
Jun straddled	107	20,6	1,15	5,3	5,68	6,00	4,38
Jun stretched	108	25,2	1,14	8,0	5,92	6,55	4,80
M stretched	117	33,4	1,15	8,2	6,22	6,56	4,96
rel. diff. stretched	-7,7 %	-24,5 %	-0,8 %	-2,4 %	-4,8 %	-0,2 %	-3,2 %

Figure 3 shows the trail by trail results for the magnitude of the three Force maxima. The third maximum is affected by the execution type (with or without release). Concerning the hypotheses of achieving a higher level of force a rank order correlation between the trail number and the first two force maxima show a significant result for the first maximum (F_{max1}: r=0.52; p<0.05), but not for the second force maximum (F_{max2}: r=0.24; p=0.12). The instruction to execute the giant swing before the Tkatchev with more flexed hip and shoulder joint and the feedback of the force maximum values result into a higher first force maximum. Proving the relationship between the body posture for the giant swing before (minimum of the sum from hip and shoulder angle) and the first force maximum verified this explanation (Pearson correlation: r=-0.75, p<0.05).

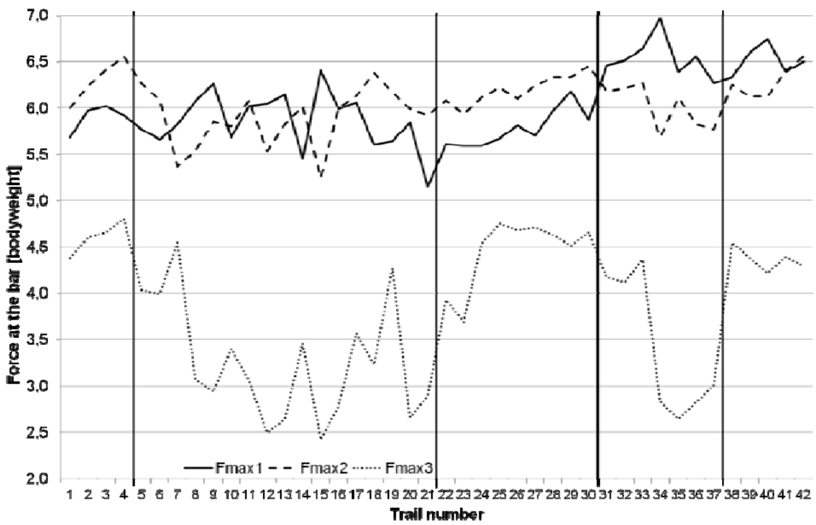

Figure 3: Development of the three force maxima during the 42 trials of Tkatchev (vertical lines separate the training sessions).

After 42 trials the detailed kinematic analysis showed a higher angular momentum during the giant swing (117 kg m^2 s^{-1}, same as the model performance) but no development for the angular momentum during the flight (25.2 kg m^2 s^{-1}). A successful trail of the stretched Tkatchev was not possible.

DISCUSSION: The gymnast generate more energy to the bar (higher first force maximum), this leads to a higher maximum angular momentum for the giant swing, but not to a higher opposite angular momentum during the flight phase. The third force maximum (the point of switching from backward to forward rotation) was 0.67 bodyweight lower than in the first trails. The gymnast was not able to block the more angular momentum and turn it into backwards rotation. One reason shows Figure 4. The vector direction of the two force maxima indicate a shift into the direction of the release point (rank order correlation to the trail number: F_{max1}: r=0.35, p<0.05; F_{max2}: r=0.29, p=0.06). The higher range of motion in the hip and shoulder joint induce not only higher first force maxima but also later force maxima. The model performance shows the force maxima about ten degree earlier.

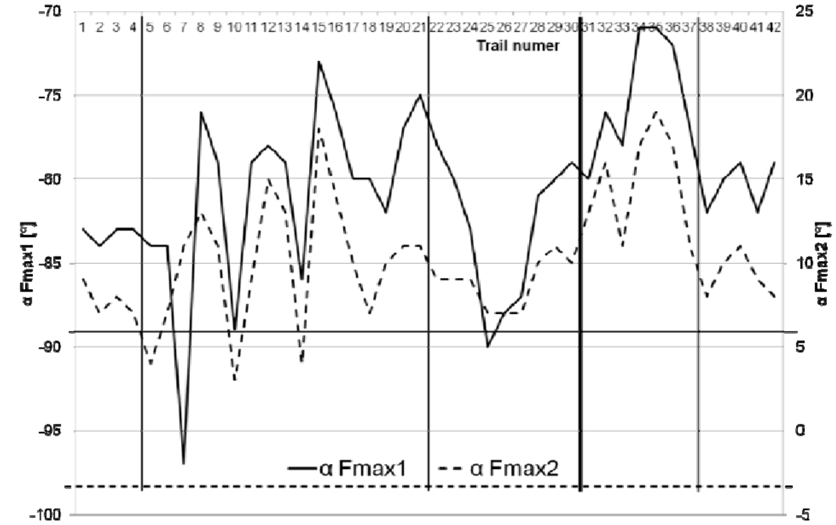

Figure 4: Angle of the force vector for the first and second force maximum during the 42 trials.

CONCLUSION: The changes of some details (more flexed hip and shoulder joint) in the movement result in higher energy transfer to the bar (higher force values at the bar). Now the gymnast must use the more energy and focus on precise exercise performance. Using the instrumented high bar as a feedback system give the gymnast objective information about the transferred energy and the timing of the movement.

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