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ORIGINAL ARTICLE

Kinematic analysis of "*Russian*" circles in gymnastics

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ABSTRACT

The kinematic analysis of the Russian wendeswing technique performance in different types of supporting surfaces was undertaken using the 3D Qualisys motion capture system. A high-level qualified gymnast performed 5 routines of three Russian circles on the floor and same on pommel horse. The average performance time of Russian circle on the floor was about 0.3 s less than the same skill performance time on pommel horse. The phase structure of each circle contained 4 hand steps of 0.3-0.4 s duration each. Russian circles control actions are performed through the arms. On floor there was a change of the shoulder joint angle in the range of 4° to 35°, whereas on pommel horse, the performance showed the shoulder joint angle range of 9° to 40°. In our research, the main difference between Russian circles performed on different apparatus was found in the positions and shifting of hip joints and the sacrum attached markers. On floor, the Russian circle performance showed a shift in the vertical sacrum marker in the range of 19 cm compared with 11 cm on pommel horse. The results indicated that floor circles demand higher rotation speed from the athlete and presumes bigger vertical hips shifting. On pommel horse, Russian circles performance registered a lower range of angular velocity and vertical hip shifting but had greater shoulder joint angle.

Keywords: Performance analisys of sport, Physical conditioning, Russian wendeswing, Circle, Pommel horse, Floor exercise, Gymnastics.

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INTRODUCTION

Russian circles otherwise known as Russian "*wendeswing*" (turning swing) is a gymnastic skill that is executed mainly on the pommel horse but also during floor exercises (Figure 1).

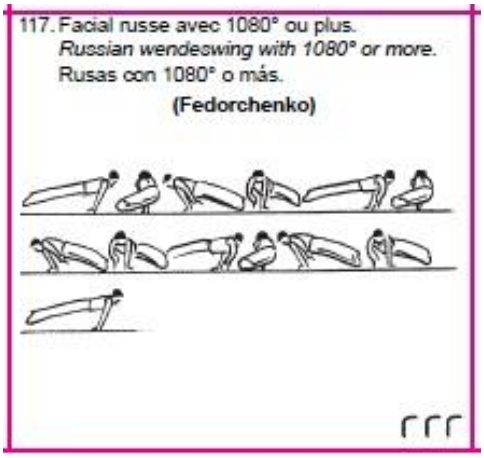

Figure 1. "*Russian*" circle or Russian wendeswing.

High quality execution of this "*circle*" rewards gymnasts with higher scores and, as such, affects the final outcome of the gymnasts' competitions. Kinematic analysis was employed to identify and log the biomechanical features of the Russian circle on two distinct gymnastics' surfaces, namely the pommel horse and floor.

Many studies have been undertaken to explore pommel horse circles techniques and biomechanics of these skills (Baudry, et al., 2006; 2009 Fujihara, 2006; Grassi et al., 2005; Qian, et al., 2012). However, the main interest of researchers has focused on the most common double leg circles in front and cross support on the pommel horse or gymnastic mushroom, a training aid for pommels so called due to its mushroom-like shape (Fujihara, T., 2006). As Fujihara and Gervais (2010) noted "*the different sets of physical constraints of the apparatus require a gymnast to adapt circles technique*".

Russian circles are more difficult skills compared to normal double leg circles. As such, we hypothesise that the performance of Russian circles in different support conditions should cause a significant adjustment in the way the technique is executed which, accordingly, should be reflected in kinematics parameters. Thus, the purpose of our study was to establish the key differences in the Russian circles performance techniques in different conditions of hand support and to determine the kinematics parameters corresponding to them.

MATERIAL AND METHODS

This case study used one highly qualified adult male gymnast to perform 5 sets of three Russian circles on the floor. Each move in gymnastics is scored for difficulty by the Fédération Internationale de Gymnastique (FIG) with values noted in it Judging Code of Points. On floor, three Russian circles are denoted as a "*C*" difficulty, while on pommel horse they are valued as a "*D*".

Fifteen Russian circles were performed on the floor, with the same number being performed on pommel horse with pommels. Additionally, another 15 were performed on pommel horse BUT without pommels.

Data was captured using Qualisys 3-D motion capture system (Qualisys AB, Kvarnbergsgatan 2, 411 05 Göteborg, Sweden), with subsequent analysis being conducted using compatible software, namely *Qualisys Track Manager*. Eight high-speed video cameras were placed around the apparatus to capture the skill movements. Seven reflective markers were fixed on the left and right sides of the gymnast's body to show limb and joint positioning. A further two markers were placed on the sacrum and back of the neck (7 cervical vertebra) (Figure 2), to make a total of 16 markers. The data collected were joint angle dynamics, angular velocity, angular acceleration, duration of the movement and vertical axis shifting of the sacrum.

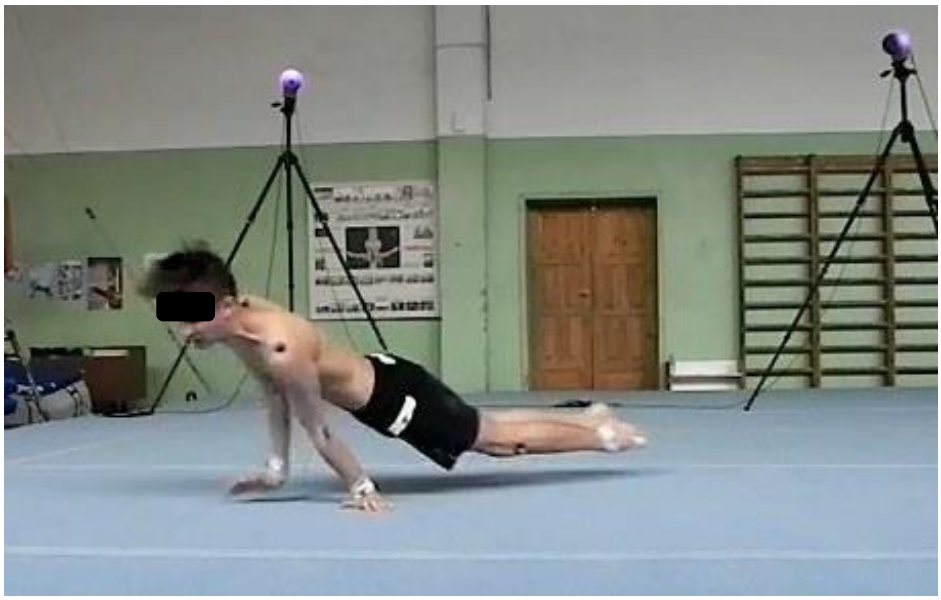

Figure 2. "*Russian*" circle kinematics registration procedure.

RESULTS

Following data collection and subsequent kinematic analysis, differences in time and space parameters were identified between Russian circles performed on the floor compared with those performed on pommel horse (Table 1). The average time to execute a single Russian circle on the floor was 0.98 ± 0.09 s, whereas the same skill performed on pommel horse, with or without pommels, was approximately 0.3 s slower (pommel horse without pommels, 1.29 ± 0.07 s; competitive – with pommels - pommel horse was 1.29 ± 0.14 s).

Table 1. The average duration of single Russian circle.

Type of circle	Duration (Mean), s	SD
Russian circle on the floor	0.98	0.09
Russian circle on the horse without pommels	1.29	0.07
Russian circle on the pommel horse	1.29	0.14

The phase structure of each circle contained 4 hand steps of between 0.2-0.4 s duration for each hand step (Table 2). It is noticeable that circles on the floor were faster and smoother than those on pommel horse. Performance of this skill on the floor took almost the same time in each phase of movement which corresponded with a single hand step. Timing parameters of the Russian circle performance on the pommel horse as well as without pommels showed that the 1st and 4th phases distinctly slower than 2nd and 3rd phases duration.

Table 2. The phase structure of Russian circles.

	Russian circle on the floor, M ± SD	Russian circle on the horse without pommels, M ± SD	Russian circle on the pommel horse, M ± SD
Phase 1	0.26 ± 0.04	0.36 ± 0.11	0.38 ± 0.06
Phase 2	0.22 ± 0.03	0.28 ± 0.06	0.28 ± 0.04
Phase 3	0.26 ± 0.04	0.32 ± 0.04	0.33 ± 0.08
Phase 4	0.24 ± 0.02	0.33 ± 0.03	0.29 ± 0.15

The explanation for this fact is the nature of the gymnast's body posture on the apparatus, when at the beginning and the end of the movement legs are lowered below the support level, thereby reducing the speed of their movement (Figure 3).

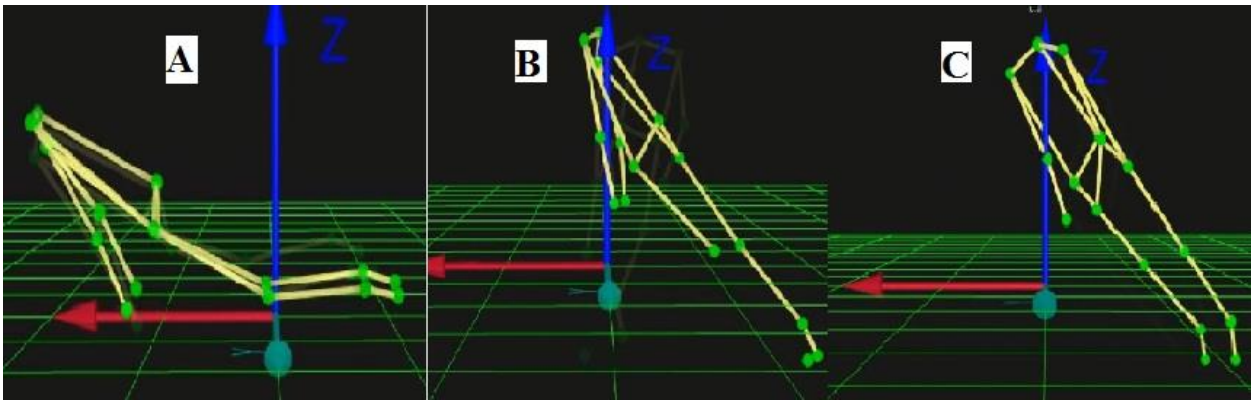

Figure 3. Phase 4-1 transition in different types of Russian circle performance (A – Floor, B – Horse without pommels, C – Pommel horse).

Table 3. The joints angle kinematics of Russian circles performance.

Russian circle on the floor, M ± SD				
	Left shoulder	Right shoulder	Left hip	Right hip
Phase 1	10.8° ± 3.2	22.7° ± 0.7	165.3° ± 1.7	158.6° ± 3.4
Phase 2	19.7° ± 5.2	18.7° ± 4.3	161.2° ± 5.2	160.7° ± 3.3
Phase 3	19.2° ± 4.2	17.3° ± 3.7	164.5° ± 8.2	161.0° ± 4.9
Phase 4	18.1° ± 7.4	21.1° ± 1.6	166.9° ± 3.3	166.9° ± 3.3
Russian circle on the horse without pommels, M ± SD				
	Left shoulder	Right shoulder	Left hip	Right hip
Phase 1	15.4° ± 1.1	22.5° ± 2.0	153.3° ± 2.8	158.6° ± 0.7
Phase 2	13.9° ± 1.1	19.9° ± 1.5	150.5° ± 4.6	172.3° ± 5.4
Phase 3	14.7° ± 0.5	18.1° ± 0.7	171.3° ± 2.4	165.5° ± 0.6
Phase 4	15.0° ± 3.3	21.2° ± 4.9	147.6° ± 0.7	164.3° ± 2.5
Russian circle on the pommel horse, M ± SD				
	Left shoulder	Right shoulder	Left hip	Right hip
Phase 1	17.8° ± 4.3	21.7° ± 2.8	151.2° ± 2.8	154.4° ± 2.7
Phase 2	16.7° ± 0.8	19.1° ± 1.5	153.9° ± 3.2	174.0° ± 2.8
Phase 3	13.2° ± 1.7	17.2° ± 2.5	169.7° ± 2.9	167.6° ± 4.4
Phase 4	21.7° ± 3.5	20.0° ± 5.8	145.7° ± 1.6	161.6° ± 4.8

Control of Russian circles is substantively performed through dynamic arm and shoulder movements with shoulder joint angle changes being in the range of 4° to 35° on floor execution. The gymnast's body posture is mainly dependent of the hip joints angle. Thus, Table 3 represents the shoulder and hip joints kinematics of circles performance in this research.

Shoulder joint angles ranged from 9° to 40° and from 10.8° to 22.7° on average during the Russian circle performance on pommel horse. Irrespective of apparatus on which the circles were conducted, body positions were quite similar with hip angles ranging from 140°-179°.

The main differences between the Russian circles performed on the three different types of surfaces were the level of vertical axis shifting of hip joints and the sacrum attached marker. Large differences were noted between floor performances in which the vertical sacrum marker shifted on average, and the performances on pommel horse in which there was only an 11 cm shift. Additionally, angular velocity and angular acceleration showed substantial differences between floor and pommel horse performances (respectively 1.4 m/s floor versus 0.68 m/s pommels; 40.4 m/s^2 on floor versus 27.2 m/s^2 on pommel horse).

DISCUSSION

A comparison of the three presented varieties of Russian circles shows the presence of some differences in the technique of its execution. So Russian circles on the floor are performed more quickly and smoothly compared to the pommel horse technique performance. At the same time, due to the more intense nature of pushing with the hands, the gymnast's body jumps slightly, as evidenced by the vertical movement of the sacrum attached marker, and with it the pelvis of the gymnast, which is more significant compared to the circles on the pommel horse.

When Russian circles were performed on a pommel horse, in terms of movement, the gymnast can lower his legs below the level of the hands support, which is accompanied by a slight decrease in the speed of the legs swing movement and a change in the hip angle. But further on gymnast needs to accelerate the movement and make great efforts with his hands to lift his legs above the apparatus. This is also reflected in the kinematics of the gymnast's body. This feature is especially well traced in Russian circles performance on a horse with pommels as the gymnast needs to keep his body high enough above the horse and increase the range of his shoulder angles to produce proper body position compared to performing Russian circles on the floor.

CONCLUSIONS

The results indicate kinematic differences between Russian circles performed on floor compared with those executed on pommel horse. On floor, Russian circles require higher rotation speed and greater vertical hips shift to maintain body position clear of the floor and ensure no or fewer points deductions. By contrast, Russian circles executed on pommel horse showed lower ranges of angular velocity and vertical hip shifting, as the body can drop below the horizontal plane without contacting the horse, but concomitantly, the shoulder joint angle found was bigger.

AUTHOR CONTRIBUTIONS

Vyacheslav Shlyakhtov directed the project, Denis Semenov and Aleksandr Rumyantsev organized the research and data processing. All authors discussed the results and contributed to the final manuscript.

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

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