



Kinematic analysis of classical skiing technique in sprint for young and adult athletes

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Abstract

Objective of the study was to determine the features of the kinematics of the alternating two-step course of young athletes at a sprint distance and to compare the angular characteristics of the main phases of the course with the indicators of the **strongest athletes in the world**.

Methods and structure of the study. A biomechanical analysis of the classic skiing technique for men and women in the prologesprint at the stage of the World Cup and boys and girls aged 14-16 at the distance of the Russian Championship was performed. The angular characteristics of the key moments of the ski course are determined and the main differences in the technique of young and adult athletes of various qualifications are revealed.

Results and conclusions. The analysis of the kinematic characteristics shows that the technique of sprinting uphill skiers and skiers of different ages and levels of fitness has significant differences. Men and boys more often use the modern running version of the alternating two-step move, women, although they run uphill without a rolling phase, as a rule, demonstrate the traditional version without active bending of the fly leg. Young men use various variants of uphill sprinting, including the modern way of movement "Klaebostyle", but the average values of the angular characteristics in the lunge, ski stop and sit-down positions indicate the existing reserves for improving the technique.

Keywords: *cross-country skiing, young cross-country skiers, highly skilled cross-country skiers, sprint, video analysis, alternating two-step classical course, angular characteristics.*

Introduction. In the ski sprint, athletes compete at distances from 1 km to 1.8 km, and there is a break of several hours between qualification and final races. Only 30 strongest athletes go to the next round of the competition, which leads to high competition, the density of prologue results and the importance of maximum speed at each section of the distance. These factors, as well as the evolution of technology, the improvement of equipment and ski slopes, led to the emergence of a cross-country way to overcome climbs in the classic sprint, the so-called "Klaebostyle" [4]. The differences between the running variant of the alternating two-step run and the traditional ski gliding run are a pronounced flight phase, a strong flexion of the fly leg at the knee

joint up to 50-60°, placing the ski on the heel part, an acute angle of the stick 70°-73°, less extension of the knee joint at the end of the repulsion and its rapid flexion during the swing movement [2].

It has also been shown that the running version allows minimizing the friction force, reaching the peak of the support reaction force earlier and increasing the frequency of movements [3].

The strongest cross-country skiers use the cross-country version of the alternating two-step course on steep climbs in sprints and during tactical accelerations in distance races. Young cross-country skiers must have a wide range of motor skills for variable use in the changing conditions of cross-country skiing, including mastering the mod-



ern cross-country mode of movement. Despite a significant amount of research on the technique of highly skilled male skiers, the features of sprinting of women and young athletes have been studied to a lesser extent.

Objective of the study was to determine the features of the kinematics of the alternating two-step course of young athletes at a sprint distance and to compare the angular characteristics of the main phases of the course with the indicators of the strongest athletes in the world.

Methods and structure of the study. Video filming of the skiing technique was carried out on the slopes of the sprint qualification distances at the Russian Championship on February 17, 2022 in Syktyvkar and at the World Cup stage in Kuusamo (Finland) on November 26, 2021. The Sony HDR-CX 730 EV video camera was installed motionlessly perpendicular to the track so that at least 3 cycles of movements fell into the frame. Boys and girls aged 14-16 competed at a distance of 1390 m, participants of the World Cup - at a distance of 1400 m. The steepness of the ascent in both cases was 8-9°, the weather was stable, the track was hard, the snow temperature was -1° in Syktyvkar and -8° in Kuusamo. The resulting videos were processed in the DartfishPro program, and the kinematic indicators of the best young and adult athletes at each distance were determined. Statistical data processing was performed in the RStudio program. The hypothesis about the significance of intergroup differences was tested by the nonparametric Mann-Whitney test.

Results of the study and their discussion. In the course of the study, videos of sprinting of 140 young and adult athletes were processed. Running without a sliding phase was used by 74% of girls, 70% of boys, 100% of women and 68% of men. However, only men and some young men (less than 10%) used the modern running version of the alternating two-step move, which is characterized by active flexion of the fly leg, similar to athletics running.

The frequency of movements of girls and women did not have significant differences, but adult highly skilled skiers performed repulsion faster (Table 1). The frequency of movements of men was higher than that of boys, and the time of squatting and repulsion was significantly less.

An analysis of the angular indicators in the main phases of the ski run shows that at the moment of the end of the repulsion, the girls perform a wider lunge with the fly leg - the angle of the lower leg is closer to the vertical, and the knee is less bent than in women (Table 2). At the moment the ski stops, the angle of inclination of the shin of the girls is 85°, which leads to a significant lag in the projection of the pelvis from the foot of the fly leg and is compensated by the inclination of the torso. At the moment of squatting, the values of the angle of inclination of the lower leg in women and girls do not have significant differences, but young athletes bend the push leg more strongly in the knee joint. In general, adult skiers throughout the course cycle occupy a higher position, in which the projection of the center of mass is close to the support, and the girls perform a wide lunge and deep squat, which, apparently, is the reason for the long repulsion. In general, the angular characteristics of the alternating two-step move of girls aged 14-16 in sprint and long distances practically do not differ [1], while highly skilled skiers demonstrate smaller angles of the fly leg at the end of the repulsion and the supporting leg at the moment the ski stops. The sprint run of the World Cup participants does not have a complete resemblance to the Klaebostyle variant, however, the sharp angle of inclination of the shin of the fly leg at the moment of lunge (individual values reach 65°) may indicate that the technique of the strongest skiers approaches the structure of movements of male sprinters.

Men and boys perform a swing with a bent leg, and at the end of the repulsion, the angle of the swing leg in the knee joint is 115° in both groups (Table 3). At the same time, in adult skiers, the inclina-

Table 1. Time characteristics of an alternating two-step move at a sprint distance.

Kinematic indicators	Movement frequency	Kick-off time, s	Time of squatting, s
Girls, n=50	76,85±5,83	0,14±0,02	0,16±0,03
Women, n=18	79,95±5,15	0,12±0,01	0,15±0,02
Statistical significance of differences	p>0,05	p<0,01	p>0,05
Boys, n=47	81,44±6,29	0,13±0,02	0,13±0,03
Men, n=25	86,52±5,96	0,12±0,01	0,11±0,02
Statistical significance of differences	p<0,01	p<0,05	p<0,01



Table 2. The values of the articular angles in the alternating two-step course of women and girls at the sprint distance

Ski cycle moment	Corner characteristics	Girls, n=50	Women, n=18	Statistical significance of differences
Lunge at the end of the repulsion	Lower leg tilt	82,90±8,49	75,97±6,22	p<0,01
	Knee joint	125,92±10,80	121,74±6,45	p<0,05
	Hip joint	94,56±8,78	98,28±4,59	p>0,05
Support leg at the time of ski stop	Lower leg tilt	84,85±5,54	79,60±5,19	p<0,01
	Knee joint	131,09±6,16	130,67±7,13	p>0,05
	Hip joint	96,10±6,86	101,83±5,13	p<0,01
Supporting leg at the moment of squatting	Lower leg tilt	46,71±6,45	48,03±4,30	p>0,05
	Knee joint	112,54±7,28	118,62±4,93	p<0,01
	Hip joint	117,12±7,08	118,74±8,19	p>0,05
Pushing leg at the end of the repulsion	Lower leg tilt	41,15±4,33	39,10±4,00	p>0,05
	Knee joint	153,09±6,98	150,53±8,38	p>0,05
	Hip joint	161,17±12,91	160,62±6,70	p>0,05

Table 3. The values of the articular angles in the alternating two-step course at the sprint distance for men and boys

Ski cycle moment	Corner characteristics	Boys, n=47	Men, n=25	Statistical significance of differences
Lunge at the end of the repulsion	Lower leg tilt	74,79±10,76	66,17±7,51	p<0,01
	Knee joint	114,93±11,96	115,00±10,45	p>0,05
	Hip joint	90,29±7,22	99,49±5,86	p<0,01
Support leg at the time of ski stop	Lower leg tilt	83,04±5,62	76,20±4,68	p<0,01
	Knee joint	128,26±6,64	130,08±4,42	p>0,05
	Hip joint	93,17±5,68	102,09±3,85	p<0,01
Supporting leg at the moment of squatting	Lower leg tilt	46,35±6,53	45,94±4,30	p>0,05
	Knee joint	110,66±6,45	119,16±6,76	p<0,01
	Hip joint	113,47±6,44	120,60±6,24	p<0,01
Pushing leg at the end of the repulsion	Lower leg tilt	35,58±3,69	35,25±3,92	p>0,05
	Knee joint	151,31±15,58	154,48±7,68	p>0,05
	Hip joint	165,19±6,27	166,93±6,29	p>0,05

tion of the lower leg to the surface of the track is on average 66°, which is statistically significantly less than in young men.

At the moment the ski stops, the angle in the knee joint in young and adult riders does not have significant differences, but highly skilled athletes, due to a more pronounced inclination of the lower leg and a vertical position of the body, occupy an advantageous attacking position, which allows them to perform a quick squatting and repulsion. During squatting with the same inclination of the lower leg, large angles in the knee and hip joints in the strongest skiers indicate a shift in the center of gravity forward, which contributes to an increase in the horizontal component of the repulsive force.

Conclusions. The analysis of the kinematic characteristics shows that the technique of sprinting uphill skiers and skiers of different ages and lev-

els of fitness has significant differences. Men and boys more often use the modern running version of the alternating two-step move, women, although they run uphill without a rolling phase, as a rule, demonstrate the traditional version without active bending of the fly leg. Young men use various variants of uphill sprinting, including the modern way of movement "Klaebostyle", but the average values of the angular characteristics in the lunge, ski stop and sit-down positions indicate the existing reserves for improving the technique.

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