# Physical fitness and skiing technique in elite biathletes with different efficiency of performance

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**Abstract**

**Objective of the study.** To identify the values of a morphology, physical fitness and skiing technique in high-class biathletes with a different efficiency of performance (PE).

**Methods and structure of the study.** The PE criterion was the average points in one race during the competitive period among 46 leading Russian biathletes, "purified" from the influence of the shooting accuracy and the differences in physical fitness.

**Results and conclusions.** Athletes with high PE had shorter gliding phase, lower push-off activity with higher vertical oscillations of the BCM, but lower losses of horizontal speed in the cycle. Such athletes had higher body and muscle mass, as well as better aerobic power, especially of upper body.

***Keywords:*** *biathlon, skiing technique, biathlete's physical fitness.*

**Introduction.** The greatest difficulty in studying skiing technique is the lack of a clear criterion for "good technique". This is due to the high variability of external conditions of competitive activity, technical difficulties in recording running parameters on snow, a large number of ski moves and their variations associated with variable terrain, the influence of sliding conditions, equipment, lubricants, etc. There is also a second problem. The main running parameters are not only influenced by the above factors and are associated with the speed of movement, but are also interconnected with the level and profile of physical fitness of athletes [2]. As a result, it is often difficult to determine which features of the biomechanical running parameters are determined by the level of "technicality" of the athlete, and which are simply determined by the features of the structure of his body, the properties of the neuromuscular apparatus, the power of the supporting systems, etc.

One of the ways to solve the problem of the "technicality criterion", including when studying the relationship between the biomechanical parameters of running and the physical fitness of athletes, may be to use the coefficient of "implementation efficiency of competitive activity" (RE) of an athlete [1]. Indeed, if of the two most significant factors of a sports result – physical fitness and technique – we exclude the influence of one of them (for example, physical fitness), then the remaining inter-individual dispersion of the sports result will be associated mainly with the second factor – in this case with technique, and the RE itself will serve as the desired assessment of the technical fitness of the athlete. The RE can be calculated by calculating the regression residuals of the dependence "sports result" – "physical fitness".

**Objective of the study** is to identify indicators of morphological status, physical fitness and skiing technique in high-class biathletes with different levels of competitive activity (CAT) implementation efficiency.

**Methods and structure of the study.** Based on video recordings of 43 high-class biathletes during races at the World Cup, IBU Cup and major Russian competitions in the 2018/19–2024/25 seasons, 20 kinematic parameters of the simultaneous one-step skating stroke (SOSKS) were calculated. A total of 644 video recordings were processed. For each athlete, the technique parameters were averaged over all laps of the distances of all races and reduced to the same speed (5.89 m/s) to eliminate its influence on the parameter values. The physical fitness and morphological status of the same athletes (hereinafter referred to as “physics”) were determined based on 24 indicators obtained during the stage-by-stage comprehensive examinations (SCCE) conducted in August-October for the same athletes in the corresponding seasons. For more details on the methodology, see [2].

The athletes’ RE was calculated as follows. First, the influence of shooting accuracy on the sports result was eliminated using the regression residual method for the dependence of “average performance in a race for the season” – “average shooting accuracy for the season” (according to the Russian Biathlon Union website). The resulting regression residual served as an estimate of the average distance speed of an athlete in a given season (hereinafter referred to as “speed”) in the logic presented above in the “Introduction”. Then, the regression residual of the dependence “speed” – “integral index of physical fitness” was calculated in a similar way, which, in turn, was calculated in a standard way based on the athletes’ IVF data [2].

This regression residual was used as the PE coefficient. All athletes were divided into two groups according to the PE criterion: a group of “effective” biathletes and a group of “ineffective” biathletes. The reliability of differences between the groups in the average indicators of “technique” and “physics” was determined using the Mann-Whitney criterion in MSExcel.

*Table 1. Values and standard deviations (SD) of kinematic indicators in athletes with high (Eff, n=21) and low (NEff, n=22) implementation efficiency of competitive activity*

| Indicator | Eff | SD | NEff | SD |
|---|---|---|---|---|
| Sales Performance Index | 31,2 | 13,3 | 10,5# | 4,7 |
| Length of steps, m | 5,54 | 0,18 | 5,60 | 0,14 |
| Ratio of rolling length to step length | 0,47 | 0,02 | 0,50# | 0,02 |
| Ratio of arm push-off duration to leg push-off duration | 1,73 | 0,21 | 1,80 | 0,18 |
| The ratio of the duration of free sliding (rolling) to the duration of pushing off with hands | 2,48 | 0,31 | 2,89# | 0,39 |
| The ratio of the duration of free sliding (rolling) to the duration of the push-off with the foot | 1,45 | 0,07 | 1,60# | 0,13 |
| Distance traveled during pushing off with hands, m | 1,79 | 0,09 | 1,75* | 0,08 |
| Distance traveled during foot push-off, m | 1,17 | 0,11 | 1,08# | 0,10 |
| Distance during the active push-off phase (arms and legs), m | 2,96 | 0,10 | 2,82# | 0,14 |
| Distance during free sliding, m | 2,58 | 0,14 | 2,77# | 0,16 |
| Angle of the pole at the end of the push-off, degrees | 26,4 | 1,21 | 26,5 | 1,05 |
| Time between the start of pushing off with the arms and the start of knee extension, s | 0,22 | 0,03 | 0,23 | 0,03 |
| Hip joint angle at the moment of placing the poles (HJ1) | 129 | 3,27 | 129 | 3,76 |
| Hip joint angle at the lowest point of flexion (HJ2) | 100 | 4,93 | 102 | 5,04 |
| Change in the angle in the hip joint (difference HB1-HB2) | 29,1 | 4,02 | 27,2 | 4,62 |
| Angle at the knee joint when placing the poles (KS1) | 148 | 3,27 | 145* | 3,21 |
| Angle of the knee joint at the moment of the lowest point of flexion (KS2) | 126 | 3,17 | 126 | 3,28 |
| Change in angle in KS (difference KS1-KS2) | 21,9 | 3,38 | 19,1* | 3,64 |
| Angle at the shoulder joint at the moment of placing the poles (PS1) | 59,4 | 8,30 | 63,3 | 9,15 |
| Angle in PS at the moment of breaking away of poles from support (PS2) | 13,3 | 4,57 | 13,1 | 4,70 |
| Angle of change of angle in PS (sum of PS1+PS2) | 72,6 | 7,04 | 76,7 | 10,2 |

*Note: * – differences are significant at α=0.05; # – differences are significant at α=0.01.*

**Results and conclusions.** Table 1 presents the data on the kinematic indicators of running OOKH in athletes with different implementation efficiency. More "effective" athletes with α=0.06 had a shorter step length. With α=0.05 and lower, they had a shorter free roll length, but greater values of the roll length during the push-off with arms and legs. Accordingly, "effective" biathletes had lower ratios of the roll length to the step length and the roll time to the push-off with arms and legs. They had a larger angle in the knee joint at the moment of placing the poles on the support and a greater amplitude of movement in the knee joint during the push-off with the leg.

Table 2 presents data on the physical fitness indicators of athletes with different implementation efficiency. More "effective" athletes had a larger body mass due to a larger mass and volume of muscles with a tendency (p=0.06) of a lower proportion of fat mass in the body. Of the physical fitness indicators, they only had a higher anaerobic threshold power (AnT) when working with arms on a ski ergometer and a higher heart rate at the AnT level when running. However, it should be noted that with a fairly high probability (p<0.1) they had a higher index of "oxidative muscle fiber power" of the shoulder girdle muscles, but a lower index of stroke volume of the heart when running on a treadmill.

**Discussion.** This is the first study to identify the physical fitness and skiing technique indicators of elite athletes with different ER, which in this context could

*Table 2. Indicators of physical fitness and anthropometric indices in athletes with high (EFF, n=21) and low (NEFF, n=22) implementation efficiency of competitive activity*

| Indicator | Eff | SD | NEff | SD |
|---|---|---|---|---|
| Body weight, kg | 77,6 | 7,00 | 73,1* | 4,70 |
| Body mass index (modified) | 41,0 | 1,50 | 43,2# | 2,1 |
| Muscle component, % | 52,0 | 1,62 | 50,6* | 1,33 |
| Muscle mass, kg | 40,3 | 3,9 | 37,0# | 2,7 |
| Fat component, % | 9,38 | 1,65 | 9,99 | 1,31 |
| Upper Body Lean Mass/Body Mass | 16,5 | 1,26 | 15,7* | 1,11 |
| Lean Lower Body Mass/Body Mass | 21,0 | 1,82 | 19,8* | 1,35 |
| Maximum leg muscle strength, N*m/kg | 2,67 | 0,23 | 2,73 | 0,35 |
| Speed-strength abilities of leg extensors, W/kg | 22,9 | 1,27 | 22,5 | 2,00 |
| Maximum strength of the muscles of the shoulder girdle and arms, W/kg | 3,91 | 0,60 | 3,66 | 0,49 |
| Maximum alactic power when working with hands, W/kg | 8,26 | 0,62 | 8,25 | 0,77 |
| Maximum alactic power during leg work, W/kg | 13,4 | 0,85 | 14,0 | 0,90 |
| Maximum impulse force when working with hands, W*s/kg | 9,36 | 1,03 | 9,46 | 1,16 |
| Power of slow fibers of the shoulder girdle muscles, c.u. | 44,2 | 6,4 | 41,7 | 5,8 |
| Index (assessment) of stroke volume of the heart, c.u. | 184 | 15 | 191 | 14 |
| Index (assessment) of maximum cardiac output, c.u. | 31,6 | 2,0 | 32,2 | 2,0 |
| $VO_2$ max when running with poles on a treadmill, ml/min/kg | 72,7 | 5,0 | 71,6 | 5,4 |
| Oxygen pulse on the AnP during hand work, ml/beat | 30,3 | 2,12 | 29,9 | 1,80 |
| Oxygen pulse on AnP during treadmill running, ml/beat | 33,8 | 2,7 | 34,5 | 1,9 |
| Oxygen consumption at the level of AnP during hand work, ml/kg/min | 51,9 | 2,9 | 50,5 | 3,4 |
| Power at the AnP level when working with hands, W/kg | 3,46 | 0,31 | 3,27* | 0,21 |
| Oxygen consumption at the level of AnP in treadmill running, ml/kg/min | 61,4 | 4,8 | 60,7 | 3,6 |
| Power at the level of AnP in running with poles on a treadmill, W/kg | 3,11 | 0,24 | 3,13 | 0,37 |
| Heart rate at anaerobic threshold during treadmill running, bpm | 181 | 7,0 | 176* | 6,1 |

*Note: * – differences are significant at α=0.05; # – differences are significant at α=0.01.*

serve as an integral assessment of sports and technical skill in the racing portion of the competitive exercise of biathletes.

The study revealed (Table 1) that athletes with higher ER had shorter stride lengths and, accordingly, higher step frequency solely due to shorter free sliding (rolling) lengths. At the same time, the rolling length in the active phases of the cycle, on the contrary, was longer. The ratio of shorter rolling but longer active phases resulted in lower rhythm coefficients, which, by analogy with the results of studies of runners, can be interpreted as lower "push-off activity" [2].

This allows us to make an unambiguous conclusion that "effective" athletes used a "non-active", "non-impulsive", but "economical" running style with less tension and concentration of muscle effort during push-off. In addition, a short roll reflects lower losses of horizontal velocity in the step cycle.

The third sign of "economization" of running can be considered a higher position of the body's center of mass during the roll, as follows from a larger angle in the knee joint and, accordingly, a smaller torque that the muscles counteract in the passive phase of the cycle. However, saving on losses of horizontal velocity, "effective" athletes did not save on vertical oscillations of the CMT, "squatting" more strongly when pushing off with the leg. It is possible that in this case the mechanism of recuperation of elastic deformation energy was used better.

When identifying the features of the morphological status and physical fitness characteristic of "effective" athletes (Table 2), a rather unexpected result was obtained. It was found that with a high probability ($p<0.01$), heavier biathletes with greater mass and muscle volume have an "economical" running style. At the same time, they are characterized by better aerobic indicators, especially when working with their arms. The explanation for such features of the "physics" of "effective" athletes can be as follows. To compensate for the greater body and muscle mass, especially when running uphill, when this is critical, one must be able to run "economically" to ensure one's competitiveness among the best biathletes in the world, especially considering the additional mass of the rifle. However, to compensate for the higher step frequency characteristic of "economical running" and the additional energy demand that arises with it, athletes must have better aerobic performance.

**Conclusions.** There are kinematic parameters of skiing that distinguish athletes with high and low ER. These are less rolling, low push-off activity with high vertical oscillations of the CMT, but low losses of horizontal speed in the step cycle. The development of an "economical running style" is facilitated by a relatively high body and muscle mass. "Economical style" assumes a high step frequency. This increases the energy demand, so "effective" athletes must have relatively high aerobic abilities.

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