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MEDICO-BIOLOGICAL SUPPORT OF YOUNG PERSPECTIVE CROSS-COUNTRY SKIERS

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Abstract

Sport selection and sport talent support are important biological and social issues of nowadays society. These aspects are extremely actual in the period of biological growth spurt. The proposed research was focused on investigation of the functional and fallout parameters of four young perspective cross-country skiers. Four young skiers who succeeded in national competitions in season 2017/2018 (mean age 14.75 ± 0.96 years; height – 176.13 ± 10.36 cm, body mass – 59.5 ± 8.3 kg) – one male and three female athletes – were recruited for the study. We performed sports laboratory examinations to evaluate comprehensive functional state of athletes. The following procedures were undertaken: anthropometric measurements, hemodynamic monitoring during active orthostatic test, maximal RAMP-protocol cycling test with gas-exchange measurements, arm-cycling Wingate test, high intensive interval training test (Tabata protocol) on Thorax Trainer with gas-exchange evaluation and performance analysis for vertical jumps with the use of force platform. We found that: (i) each studied skier possessed at least one higher than average parameter of physical preparedness; (ii) athletes had different functional profiles providing outstanding results in cross country competition; (iii) medico-biological support helped to determine adequate methods for training design. Careful and in-depth research of young perspective cross-country skiers revealed their individual features and weaknesses in the functional profiles. Medico-biological support is in sharp necessity for sport talents in adolescence as it helps to determine adequate methods for training design.

Keywords: Individualized approach, medico-biological support, perspective cross-country skiers.

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1. Introduction

Successful professional sport career depends upon a large number of biological, sociological, psychological and even cultural and financial factors. To find natural sport talent is only the first step in coaching. Early in life the good sport result may be achieved thanks to (1) quick development of certain physical ability, (2) biological acceleration, (3) early sport specialization, (4) real natural talent, etc. However, other abilities may be underdeveloped but have no effect on the sports results and success in youth. These weaknesses may become apparent later and limit adult athlete’s progress. Since physical abilities have sensitive periods for their enhancement or demand long-term development, missing the right time in adolescence, may result in failing to catch-up in adulthood. Thus, to provide a prospective sport career of the young sport talent it is important to control inner state and look after its adequate enhancement without gaps. Only periodic sports laboratory control with sufficient number of indicators may be a reliable source of information accompanying the coach and athlete in a long way to elite sport.

2. Problem Statement

Having at the disposal good selected through competition mesh young cross country skiers aged 14-16 the coach reflects how to train these skiing stars. For adequate training in youth it is necessary to realize what are the strengths and, possibly, weaknesses of the young athlete (state X), what the target configurations of adult elite athlete are (target state T) and how to get from X to T.

3. Research Questions

For the research following questions were stated:

- What is there in the basis of sport success of the young athlete? Is it a temporary advantage or it will be fundamental for future sport success
- Are the essential features in sport and functional profile for the certain athlete within age norms?
- Are there any weaknesses in an athlete? Is it important to be improved for sport success in elite sport or may be left without special attention and echo-effect

4. Purpose of the Study

Based on mentioned above we suggested the following aim of our research: to investigate the functional and fallout parameters of young perspective cross-country skiers (age 14-16) that succeeded in national competitions in season 2017/2018.

5. Research Methods

Four young (mean age 14.75±0.96 years) perspective cross-country skiers (height – 176.13±0.36 cm, body mass – 59.5±8.3 kg) – 1 male and 3 female athletes – participated in the proposed research. Athlete #1 (male) was the winner of regional competition for 3 years. Athlete #2 was the bronze medal holder in Russian Spartakiada of schoolchildren (March, 2017), winner of Ural regional competition in

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individual races and relay and was in Top 10 in Russian youth competition in December 2017. Athletes #3 and #4 are twins. They were holding 3rd, 5th and 11th places in Russian national youth championship-2018 taking part in such momentous competition for the first time. They were also the winners of traditional Russian competition among schoolchildren in March, 2018 as well as in 2017.

All studied athletes had more than 5 years of sport experience in cross-country skiing. Tested subjects were free of cardiovascular or any other chronic or acute disease. The proposed study conforms to the principles of the Declaration of Helsinki of the World Medical Association. All athletes signed informed consent to participate in the study. The study was approved by the Ural Federal University Ethics Committee.

5.1. Anthropometric measurements

To estimate body composition we used MC-980MA Plus Multi Frequency Segmental Body Composition Monitor (TANITA, Japan) based on the advanced FDA cleared Bioelectric Impedance Analysis (BIA) technology. This analyzer provided with data on the following parameters: body mass (kg), body mass index (BMI), muscle mass (kg; %), fat mass (kg; %), fat free mass (kg), bone mass (kg), intracellular and extracellular water (%), metabolic rate (kcal), segmental analysis of each arm, leg and the trunk area and muscle mass balance.

5.2. Laboratory tests

Laboratory tests were conducted in the research laboratory “Sports and health technologies” of the Institute of Physical education, sports and youth policy, UrFU (Yekaterinburg, Russia) and included hemodynamic monitoring, maximal ramp cycling test and HIIT-test on Thorax Trainer with gas-exchange evaluation, Wingate test and performance analysis for vertical jumps.

5.2.1. Hemodynamic monitoring

The active orthostatic test was carried out with the use of hemodynamic monitor MARG 10-01 "MicroLux" (Chelyabinsk, Russia). Central hemodynamics indicators were automatically registered with beat-to-beat record (Shishkina et al., 2014; Zakharova, Mekhdieva, & Smirnov, 2016): heart rate (HR, bpm) in 2 positions (supine and standing), stroke volume (SV, ml), end-diastolic volume (EDV, ml), stroke index (SI, ml/m2) and end-diastolic index (EDI, ml/m2) which are the ratio of stroke volume and end-diastolic volume to the body surface area in square meters.

5.2.2. Maximal ramp cycling test

Aerobic performance of skiers was evaluated with the use of a cycle ergometer ERG 911S (Schiller AG, Switzerland) and a desktop metabolic monitor Fitmate PRO (COSMED, Italy). We applied maximal ramp protocol in accordance with ACC/AHA 2002 guideline update for exercise testing (Gibbons et al., 2002). We proposed to start the test from the load of 0 W during warm-up stage (1 min) with further load increase (40 W per minute). Studied skiers were recommended to keep the cadence about 80 rpm.

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The following parameters were recorded continuously during exercise testing: oxygen consumption (VO_2, ml/kg/min), heart rate (HR, bpm), stated exercise load (P, W), volume of ventilation (Ve, l/min) and respiration rate (Rf, 1/min).

Additionally, we were interested in estimation of efficiency of respiration at a maximal level of effort (Ve_{max}, l/min – maximal volume of ventilation per minute) and strength of athletes (P VO_{2max} – the power reached at VO_{2max}). These indicators are considered as maximal individual for this particular type of test.

5.2.3. Cycling Wingate test

Cycling Wingate test was conducted with the use of the ergometer TOP EXCITE 700 MD (TechnoGym, Italy). Anaerobic power measures were obtained using arm cycling Wingate anaerobic test, and included peak power (PP, W), relative PP (W/kg), average power (AP30) and its relative value (AP30, W/kg) and time of PP attained (s).

5.2.4. High intensive interval training test (Thorax trainer test) with gas-exchange measurements

A high-intensity interval training test (HIIT-test) (Tarbeeva, 2011; Zakharova, Berdnikova, Tarbeeva, & Matvienko, 2015; Zakharova & Berdnikova, 2016; Zakharova, Mekhdieva, & Berdnikova, 2017) for the assessment of skier specific upper body power and strength abilities was performed on the patented training machine Thorax Trainer™ PRO CARDIO (Denmark) and a desktop metabolic monitor Fitmate PRO (COSMED, Italy).

The simulator Thorax Trainer is equipped with ball bearing super-glide rails for ski poles movement that facilitates the modeling of skiing technique. Thorax Trainer has a 10-level resistance system. During the testing, the load on the training machine was set in accordance with the weight of the subject: the resistance units were equated with the decimal ($1/10^{th}$) weight values (weight = 54 kg, load = 5 units). Using the finger-touch computer measuring system during HIIT-test the following parameters were automatically recorded with every stroke: Time (s), Power (W), Frequency of strokes as well as maximal and average speed and covered distance during each interval.

Athletes performed HIIT-test (Tabata Protocol) of 8 sets of 20-second interval with an “all-out” effort (Tabata et al., 1996). During each set and 10 seconds of rest interval the heart rate (HR, bpm), oxygen consumption (VO_2, ml/kg/min), volume of ventilation (Ve, l/min) and respiration rate (Rf, 1/min) were measured using the Garmin chest belt and metabolic monitor Fitmate PRO (COSMED, Italy).

5.2.5. Performance analysis for vertical jumps

Vertical jumps were performed on a force plate TJ4002 (Marafon-Electro, Russia). Original custom-designed software for ongoing analysis was used for acquisition and processing of the vertical component of the ground reaction force. Based on the collected data, we measured and analyzed: flying time (t, s); jump height (Jh, cm); maximum force for take-off (F/kg, N).

Initially, studied skiers were familiarized with the technique of each jump. They were given the task to make triple jumps with short rest time between jumps:

- countermovement jumps (CMJs) with hands on hips,

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- squat jumps (SJs) with hands on hips,
- single leg jumps on the right and left legs bending hands on hips,
- CMJs with arms swing.

One minute of rest was allowed between the consecutive trials of jumps.

Each athlete was instructed to perform the jumps with the maximum effort. Only the best attempt of each type of jump was further taken into account for the ongoing analysis.

5.3. Statistical analysis

As only four athletes were under consideration limited number of statistical methods were used. Statistical analysis was performed with the use of software package Excel 2010 (Microsoft). Individual athletes' profiles were analyzed through radar charts.

6. Findings

The obtained results of anthropometric measurements (Table 1) in young skiers allowed us to analyze detailed body composition. Distributed data show that major anthropometric parameters were in lines with norms in regards to athletes' age and gender. High values of lean mass point at sufficient training process of skiers. Meanwhile differences in percentage of fat compound may serve as a consequence of different metabolic rate in studied individuals.

Table 01. Anthropometric and body composition analysis of young skiers

Parameters	#1	#2	#3	#4
Height, cm	172	161	180	179
Weight, kg	66.5	47.5	63	61
MM, kg	51.6	38.8	45.6	45.2
MM, %	77.6	81.7	72.4	74
Fat, kg	11.3	5.7	13.8	12.8
Fat, %	17.3	12.3	22.3	21.2
BMI, kg/m^2	22.4	18.3	19.4	19

Hemodynamic parameters in adolescents fall off the ones in adults but they must be within age norms. As a rule there are two main issues in heart-and-vessels system of teenagers inspected through hemodynamics monitoring: (1) insufficient heart volume or (2) overmuch delta of HR in orthotest related with intense growth.

HR at supine 1 (Table 2) is low enough for adolescences in cyclical kinds of sports. Considering heart rate dynamics in young cross country skiers during orthotest we may conclude that 3 of them insufficiently adapted to their current state: athletes # 1, # 2 and # 4 have their $\Delta HR_{standing} - HR_{supine}$ are higher than norm. As we observed high values of ΔSI and ΔEDI in observed athletes at supine and standing positions, high $\Delta HR_{standing} - HR_{supine}$ may be the consequence of hormonal adjustment in athletes # 1 and # 2, i.e. their pubertal period and active muscle mass gain. While athletes #3 and # 4 are in active

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growth phase. Herewith in athlete #3 this phase was 5-6 months ago, athlete #4 was tested during active growth phase

Table 02. Hemodynamic parameters of young skiers

Hemodynamic parameters and indices	#1	#2	#3	#4	Adult athletes' norm
$HR_{at\ supine}$, beats/min	60	49	58	51	55
$HR_{standing}$, beats/min	88	81	78	84	65
$\Delta HR_{standing}-HR_{at\ supine}$, beats/min	28	32	20	33	<18
$SI_{at\ supine\ 1}$, ml/m^2	68	71	61	62	>70
$SI_{standing}$, ml/m^2	43	43	43	41	–
$EDI_{at\ supine\ position}$, ml/cm^2	110	113	99	99	>100
$EDI_{standing}$, ml/cm^2	78	82	83	77	–

Note: SI – stroke index; EDI – end-diastolic index.

Results of maximal cycling test (Table 3) showed that the most part of measured parameters corresponded to athletes' norm. Meanwhile, individual data of young skiers varied within a certain range. In particular, although athlete #1 demonstrated excellent level of aerobic abilities (high VO_{2max}, volume of ventilation, V_{max} as well as satisfactory recovery rate), attained maximum relative power was lower than expected. Athlete #2 showed high values of measured parameters, the only weak aspect was respiratory response to exercise load (low maximal volume of ventilation and V_{max}). Athlete #3 demonstrated balanced aerobic fitness (high values of VO_{2max}, P-VO_{2max}/kg, Ve_{max} and recovery rate). These data serve as a proof of good development of oxygen transport and utilization system.

Table 03. Maximal RAMP protocol cycling test parameters of young skiers

Parameters		#1	#2	#3	#4	Adult athletes' norm
VO_{2max}, ml/kg/min		61.3	52.9	53.7	49.7	55
HR_{max}, bpm		203	188	174	163	180-195
P-VO_{2max}, W		315	228	332	289	-
P-VO_{2max}/kg, W/kg		4.74	4.8	5.3	4.74	>5
Ve_{max}, l/min		152	94	112	102	>150 (m); >120 (f)
$HR_{recovery}$ velocity, bpm/min	1st min	30	27	36	41	30
	two min	58	65	60	68	65

P-VO_{2max} - power reached at VO_{2max}; Ve_{max} – maximal volume of ventilation; $HR_{recovery}$ velocity – heart rate recovery speed – the decrease of heart rate during one and two minutes after the test (bpm/ 1 min, bpm/ 2 min).

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Furthermore, we revealed a number of flaws in athlete's # 4 aerobic performance: low maximal HR, insufficient strength (P-VO_{2max}/kg = 4.74 W/kg) and lower than expected VO_{2max} value. We can assume that all these drawbacks in skier #4 were caused by lowered power abilities that is inherent in active growth phase revealed in athlete # 4 during hemodynamic monitoring.

Table 4 shows the results of arm cycling Wingate test of studied skiers. Previous findings based on the results of our earlier studies of upper extremities power of elite athletes (Russian national team in cross-country skiing) allowed to determine the adult athletes' norm of Wingate test results (Table 4).

Table 04. Wingate-test parameters of skiers

Parameters	#1	#2	#3	#4	Adult athletes' norm
PP, W	567	284	316	228	
PP/kg, W/kg	8.53	5.98	5.01	3.74	≥ 8
AP_{30}, W	402	236	257	190	
AP_{30}/kg, W/kg	6.05	4.96	4.08	3.25	≥ 6.5
Fatigue, %	54	44	51	45	< 30
t_{pp}, s	7	8	11	5	5-6

Note: PP – peak power; AP_{30} – average power; t_{pp}, - time of PP attainment.

Undertaken analysis of the existing scientific data showed that power requirements for the preparedness of skiers are sometimes higher than in sports demanding high anaerobic capacity of the upper extremities. Thus, the reference values of the PP are: in handball athletes and rowers on canoe kayak – 7.84 ± 0.67 W/kg (Kounalakis, Koskolou, & Geladas, 2009), kick-boxers 5.89 ± 0.69 W/kg (Ouergui et al., 2013) and national level swimmers and water polo players – 6.71 ± 0.88 W/kg (Colantonio, Barros, & Peduti Dal Molin Kiss, 2003). Nevertheless, the results of Koutedakis & Sharp study (1986) on anaerobic work of the upper body in elite junior oarsmen and club level rowers showed that upper limb PP values in Wingate test were 11.77 ± 0.45 W/kg and 9.51 ± 0.78 W/kg respectively. Probably, the difference in the obtained data is due to the difference in the method used to determine the load during the test and the testing equipment.

In our study high values (close to the desirable adult athletes' values) of PP were observed in athlete #1. Skiers # 2 and # 3, taking into account their young age, also demonstrated high level of power and speed abilities. Athletes #1, #2 and #3 showed a slow achievement of peak power values at high values of PP. Targeted work on explosive power would increase the level of speed-power preparedness of skiers/ High level of power endurance is characterized by a slight decrease in the arm pedaling power at 15^{th} and 30^{th} seconds of the test. Close to the optimal level of power endurance were observed in sportsmen #2 and #3. Assessment of the level of preparedness of the athlete #4 in this component is considered impossible in connection to the initially low level of power preparedness.

Performance analysis for vertical jumps on force plate (Table 5) provided with estimation of level of young skiers' lower limbs power abilities.

We found that high values of jump height (> 30 cm) in CMJ in athletes #1 and #2 characterize optimal level of power performance of thigh extensor muscles as well as high level of intramuscular

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coordination – sequential concurrent work of agonists and antagonists muscles (Gissis et al., 2006; Pupo, Detanico, & Santos, 2012). Obtained values of jump height in CMJ in studied group are comparable with results of elite male cross-country Swedish skiers (32.2 ± 3.0 cm) in Carlsson et al. (2012) research.

Results of SJ are achieved mainly due to the force of central nervous system impulse towards working muscles at concentric work. All tested skiers demonstrated high level of power abilities. Notably, these results not only correspond to high standards of elite adult skiers (SJh = 26.6 ± 3.1cm; Carlsson et al., 2012), but also are within the same range without a wide spread.

We were also interested in investigation of balance of lower limbs muscles power (Lawson, Stephens, DeVoe, & Reiser, 2006; Impellizzeri, Rampinini, Maffiuletti, & Marcora, 2007; McElveen, Riemann, & Davies, 2010). We found evidence of asymmetry of lower limbs in two athletes among studied (#2 and #3).

To qualitatively assess the level of athlete specific preparedness, it is preferably to use tests that most accurately simulate the conditions of competitive activity. The use of the training machine Thorax Trainer™ made it possible to reproduce the biomechanics of the upper body movement of a skier with simultaneous repulsion, i.e. double poling technique. Double poling is actual and effective style in cross country skiing nowadays due to effective storage and recovery of elastic energy, a greater proportion of the forces being directed along the line of travel, and a lower air resistance due to greater trunk and hip flexion (Hoffman & Clifford, 1992).

HIITest results (Table 6) allowed to estimate different sides of skiers' preparedness. One can judge about speed-and-strength abilities by maximal relative power and distance in the first and as a rule the best result among 8 intervals.

Table 05. Performance analysis for vertical jumps of skiers

Parameters	#1	#2	#3	#4
CMJ h, cm	35	30	29	27
CMJ t, s	0.53	0.49	0.49	0.47
CMJ F/kg, N/kg	16.3	20.7	18.7	18.5
SJ h, cm	27	25	27	26
SJ t, s	0.47	0.46	0.47	0.46
SJ F/kg, N/kg	20.8	18.9	19.6	19.5
RLJ h, cm	22	20	16	15
LLJ h, cm	22	17	11	15
ASJ h, cm	43	36	37	33
ASJ t, s	59	0.54	0.55	0.52
ASJ F/kg, N/kg	19.9	21.1	22	20.2

CMJ – countermovement jump, h – jump height, t – flying time, F– maximum force for take-off, SJ – squat jump, RLJ – single leg jump on the right leg, LLJ – single leg jump on the left leg, ASJ – countermovement jump with arms swing.

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An acceptable for adolescents results (distance in the1st interval) were demonstrated only by skiers #1 and #3. Their results are considerably lower than the length of elite skiers distance in the 1st interval (120 m and more), but higher than those of age mates.

Table 06. Parameters of HIITest (Thorax Trainer) with gas-exchange measurements of young skiers

Parameters	#1	#2	#3	#4
Distance in the 1st interval, m	85.8	63.2	81	72.7
Distance in all 8 intervals, m	617.5	449.9	608.3	555.5
Average power during the test, W/kg	1.61	1.36	1.56	1.14
HR_{max}, bpm	203	191	170	153
Ve_{max}, l/min	166.1	107.5	99.5	86.2
VO_{2max}, ml/kg/min	61.8	55.9	47.2	43.6

The level of specific endurance was assessed by summarized distances in 8 intervals. Skiers #1 and #3 were the leaders at finish. Notably, the overall results of these skiers are close to adults' distances in HIIT-test (700 m and more), but values of relative average power during the test are much lower than in elite cross country skiers (2.4 W/kg).

Skier #1 (Figure 1) demonstrated good relative power in the 1st interval, but poor strength endurance in next 3 intervals. The graph of skier #2 has the required configuration for this test although it might be located higher.

Analyzing the athlete conditioning in double poling in HIIT-test we came to the conclusion that studied skiers had poor strength readiness of the upper body.

Comparing the results of gas-exchange measurements and HR values between maximal ramp cycling test (Table 3) and HIIT-test with the use of Thorax Trainer (Table 6) provided with valuable information on specifics of cardio-respiratory changes in response to various exercise. In particular, we found that athletes #3 and #4 showed significantly higher VO_{2max} and HR_{max} in maximal cycling test, while athlete #2 had slightly higher results in HIIT-test. Notably, athlete #1 had no differences in VO_{2max} as well as HR_{max} and maximum ventilation between tests.

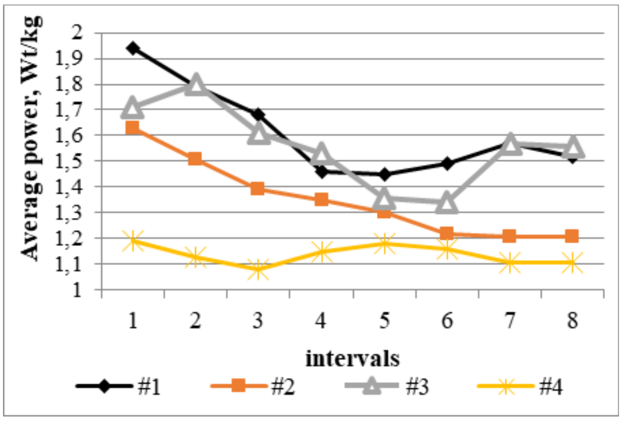

Figure 01. Young skiers (n=4) individual results of HIITest (double polling at Thorax Trainer).

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In cross country skiing for success in high performance sport it is necessary to obtain the highest level of general and specific endurance, strength and strength endurance of muscles providing locomotion in competition. That is why a number of priority parameters were selected to combine the cross country skier's functional profile graded by 3 levels (Figure 2). In athletes' profile we assume 2 as good level of sport development for the age and level while 3 – excellent.

Elite cross country skiers must have balanced development of priority physical capabilities in individual functional profile. Young perspective athletes especially during puberty are developing heterochronically: some systems of organism may have prior development and thus provide the development of required physical abilities, while other body systems are retarded.

Laboratory testing of young cross country skiers revealed that similar level of sport performance in youth was achieved through different functional features and fitness level. Individual profiles of specific preparedness (Figure 2) vary greatly and have imbalances that must be eliminated for future sport performance progress and success in adult elite sport.

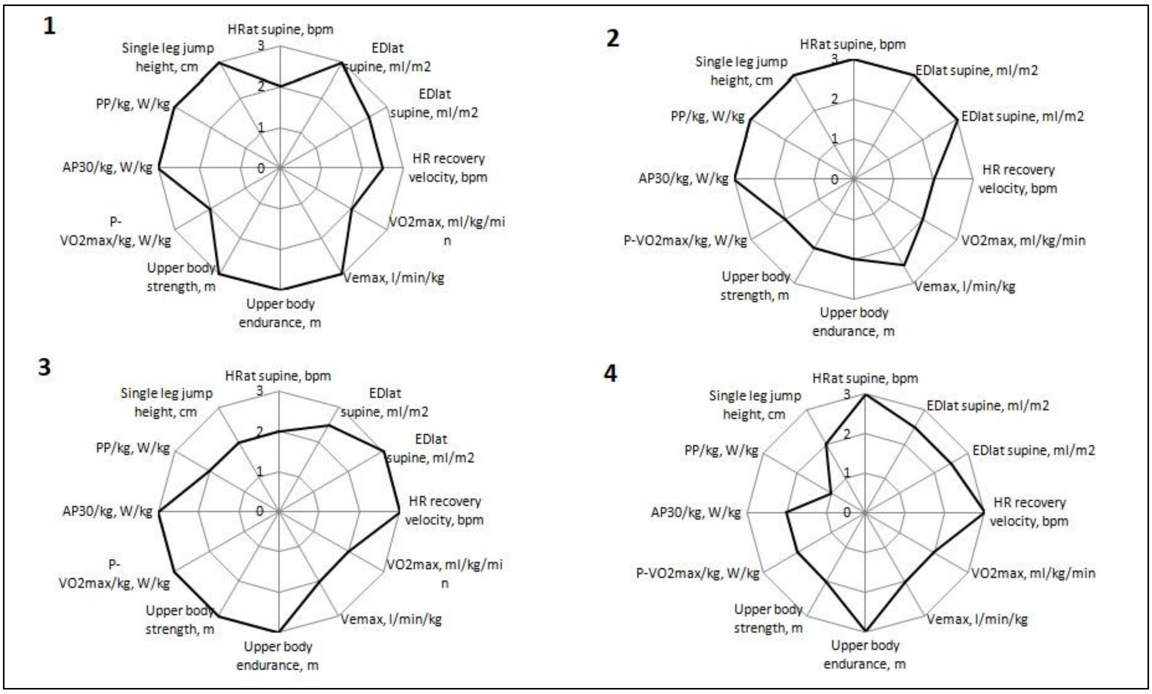

Figure 02. Young skiers' functional profiles.

7. Conclusion

Careful and in-depth research of young perspective cross-country skiers revealed their individual features and weaknesses in the functional profiles. Medico-biological support is in sharp necessity for sport talents in adolescence as it helps to determine adequate methods for training design.

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