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THE VARIABILITY PARAMETERS OF ANAEROBIC ENDURANCE IN SPECIAL PREPARATION AND COMPETITION PERIODS IN 17–18 YEAR OLD ICE-HOCKEY PLAYERS

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SUMMARY

The objective of the present study was to assess the changes of anaerobic capacity level in hockey players, members of Polish National Team (18-year old or younger) during 7-month preparation period for World Championship. The study group included 26 hockey players (17–18-year old), members of Polish National Team in ice hockey and at the same time students of Sport Ice Hockey School of Polish Federation of Ice Hockey in Sosnowiec. On the basis of analysis of changes observed in parameters values of 30-s test performed on cycle ergometer, a considerable increment of energetic cost of performed work before the direct preparation period for World Championship was noted. The obtained increment of power and total work performed was not adequate to the energetic cost. The employment of a single 30-s exercise test performed on cycle ergometer for the purpose of anaerobic endurance assessment is limited. This test however may be used in diagnostics of effectiveness of anaerobic processes.

Key words: anaerobic endurance, ice-hockey, training periods

INTRODUCTION

Assessment of anaerobic capacity in sportsmen has been the objective of studies for the last years (Klasnja et al., 2010; Mikulic et al., 2010; Szmatlan-Gabrys et al., 2008; Szmatlan-Gabrys et al., 2004; Zupan, 2009). The 30-s cycloergometric test is one of the most common procedure used in many sport events (Gabrys et al., 2000, Heller, 1995, 1999; Heller, Bunc, Peric, 1998; Schickhofer & Hamar, 1999; Szmatlan-Gabryś, 2000; Watson & Sargaent, 1986), though this ergometric exercise test was subjected to many modifications. The parameters which are evaluated in this test such as: load index, work time, the method of recording of power and work performed, time at which the load was included into the test, were subjected to number of changes, according to requirements of a given sport event and the type of investigation. In the ice hockey game, these

modifications are related to the time of work and the load selection index. Smith et al. (1982) proposed the 40-s version of the cycloergometric test. This 10-s time elongation (Smith et al., 1982) aimed at the approximation of the work time to the player's single work period in the ice rink. In diagnostics of Czech hockey players, the 30-s time period was not changed, whereas the load index was increased from 7.5% of the body weight to 10% (Heller, 1999). This modification allowed for maintenance of optimal frequency of revolutions, which is required in this type of test, (110–120 revolutions per 1 minute, Gabrys, 2000). Lower value of load (7.5% index value) resulted in such a frequency, which the subject was unable to increase due to the lack of movement co-ordination. The inclusion of load as soon as the optimal frequency of revolutions is reached, is not commonly used among hockey players performing the cycle ergometric test (such a frequency is reached after the lapse of about 5 seconds of work without the load). This principle undoubtedly results in lower values of recorded maximal power and time of maximal power holding. Thus the diagnostics of anaerobic capacity does not include the very essential data related to ice hockey, namely the player's capacity of maximal power development. This parameter really is very important, since during the hockey game periods of maximal intensity do not last longer than 4–9 seconds. The covering of the entire ice rink takes about 6–7 seconds (Gabrys & Rutkowski, 2002; Starsi et al., 1999). In athletic practice, the kinetics of blood lactate concentration is determined and broadly applied to evaluate the proportion of anaerobic metabolism (Heck, 1990; Weltman, 1995; Madsen, Lohberg, 1987. Kinderman, Keul (1977) prove that determination of blood lactate concentration during muscle work is indispensable for being able to evaluate energy production under oxygen deficiency. In the Saltin et al. study (1971), exercising on a cycloergometer was accompanied by an increase in blood lactate concentration after 10 seconds of supra-maximal effort at 110% VO_2max. Mercier et al. (1991) found that after 6 seconds of maximum intensity exercise on the cycloergometer subjects' blood lactate concentration was significantly raised. From the above studies it follows that high-intensity physical work performed for not longer than 10 seconds intensifies the anaerobic glycolysis process. Therefore, considering the duration and intensity of hockey players' work, it is fully justified to use blood lactate concentration as an indicator of their effort. The level of anaerobic endurance, so the ability for undertaking of multiple work incidents of maximal and submaximal intensity is just another essential element of player's preparation (Green, 1978). This sphere of player's preparation is considerably conditioned by the level of anaerobic glycolytic capacity (Green et al., 1978). The ability for multiple undertaking of work is limited by the volume of muscle glycogen reserves and by the rate at which it is resynthesised during breaks between consecutive periods of work in the ice rink. The second essential element affecting this particular ability is effectiveness of utilisation of this source of energy during work. A multiple performance of work at maximal intensity is possible only when the main energy source (typical for a given type of work) is rationally used (Green & Huston, 1975; Nespereira 1999). The assessment of anaerobic endurance in single work period is limited, but the assessment of effectiveness of anaerobic processes is possible. The decline of lactate concentration in blood in consecutive periods of training with maintenance of identical power and total work would indicate the increment of effectiveness of performed work. The opposite characteristic proves the unfavourable changes in this sphere (Gabrys, 2000).

The objective of the present study was to assess the changes of anaerobic capacity level in hockey players, members of Polish National Team (18-year old or younger) during 7-month preparation period for World Championship.

MATERIAL AND METHODS

The study group included 26 hockey players (17–18-year old, body height 179.88 ± 4.87 cm, body weight 73.24 ± 5.90 kg, BMI 22.61 ± 1.19 kg/m^2), members of Polish National Team in ice hockey and at the same time students of Sport Ice Hockey School of Polish Federation of Ice Hockey in Sosnowiec. The assessment of anaerobic capacity with the use of the 30-s cycle ergometric test was carried after the completion of preparation training period and before the league play-offs (I measurement), after the completion of the 1st part of league play-offs II measurement), before the 3-week period preparation immediately before the World Championship (III measurement). The control group consisted of 24 hockey players, members of Polish Olympic Team (I RP), who were subjected to similar testing procedure, after the completion of the 1st part of league play-offs. Ergometric test was performed on Cyclus 2 (RBM electronik-automation GmbH Germany). The ergometric test was carried out according to the following protocol: the load was selected individually and it constituted 10% of the body weight, the test was preceded by a 5-min warm-up with the 30% load of that used during the test and with a revolution frequency of 60 rev./minute. After the warm-up and 3-min break each subject began the test with full load from the frequency of 100 ± 16 rev./min (differently than in the Wingate protocol). The subjects started to exercise with maximal intensity. When 30 rpm was achieved, the load was activated automatically to continue for 30 seconds. In that period, the subjects were to maintain maximum rotational frequency. The following parameters were recorded during the test: maximal power (P_{max}), average power (P_{av}), total work performed (W_{TOT}), time-to-reach P_{max} (T_{uz}), P_{max} holding time (T_{ut}), power decline index (ID). The lactate concentration in the blood (LA) was established before the test, than in 4th and 8th minute after the completion of the test. The LA increment after the completion of test (ΔLA) was established on the basis of recorded values. The LA value was calculated with the use of lactate analyzer (Biosen S-Line, EKF, Germany). The blood samples in amount of 20 µl were collected from the pulp of a finger. The obtained results were subjected to statistical analysis. Mean value (x), standard deviation (SD), the range of results (min-max) and level of statistical relevancy were calculated with the t-Student test. After being informed about the study and test procedures, and any possible risks and discomfort that might ensue, their written informed consent to participate was obtained in accordance with WMADH (2000).

RESULTS

The mean values of ergometric parameters and LA concentration recorded during 30-s test performed on cycle ergometer in the group of hockey players (U-18) after the completion of successive periods of training are presented in table 1.

Table1. The mean values of parameters recorded in the hockey players in U-18 group

Group	Statistical index	Parameters						
		P_{max} [W/kg]	W_{TOT} [J/kg]	ID [W/kg/s]	T_{uz} [s]	T_{ut} [s]	LA_{max} [mmol/l]	ΔLA [mmol/l]
Goalkeepers	**Measurement I**							
	Mean	12.66	304	0.26	4.53	3.11	14.5	12.81
	SD	0.71	14.17	0.02	0.84	0.85	0.81	0.72
	Min	11.52	285	0.242	3.81	2.41	12.9	10.87
	Max	13.38	317	0.28	5.45	4.06	15.3	13.71
	Measurement II							
	Mean	13.73	322	0.289	4.07	2.8	15.41	12.81
	SD	0.22	5.43	0.01	0.24	0.97	0.98	0.38
	Min	13.49	315	0.281	3.9	2.11	13.9	12.63
	Max	13.94	325	0.296	4.24	3.49	16.12	13.71
	Measurement III							
	Mean	13.88	317	0.279	3.55	2.53	20.25	18.66
	SD	0.98	8.6	0.09	0.39	0.66	2.76	1.8
	Min	12.87	311	0.218	3.27	2.06	18.3	16.16
	Max	14.26	323	0.34	3.83	2.99	22.2	20.34
Defender	**Measurement I**							
	Mean	11.77	300	0.18	4.62	3.88	13.92	11.22
	SD	0.89	12.64	0.03	0.89	1.39	3.17	3.32
	Min	10.79	298	10.91	3.66	2.421	9.24	7.95
	Max	12.94	334	12.83	6.23	6.82	17.84	14.12
	Measurement II							
	Mean	13.41	321	0.254	4.52	3.02	14.85	12.22
	SD	0.89	10.81	0.06	0.91	0.72	3.42	3.57
	Min	12.28	299	0.152	3.4	2.11	11.57	9.11
	Max	14.72	344	0.324	5.85	3.55	18.12	16.06
	Measurement III							
	Mean	13.59	329	0.251	3.9	2.48	15.55	13.71
	SD	0.81	12.85	0.04	0.79	0.94	2.33	2.47
	Min	12.22	306	0.166	2.76	1.88	11.41	9.22
	Max	14.88	351	0.312	5.23	3.51	20.1	18.16

Group	Statistical index	Parameters						
		P_{max} [W/kg]	W_{TOT} [J/kg]	ID [W/kg/s]	T_{uz} [s]	T_{ut} [s]	LA_{max} [mmol/l]	ΔLA [mmol/l]
Forward	**Measurement I**							
	Mean	12.12	297	0.236	4.6	2.76	14.22	11.97
	SD	0.87	12.11	0.04	0.84	0.89	2.82	2.66
	Min	10.72	277	0.181	3.45	1.76	9.42	6.88
	Max	13.84	334	0.305	6.58	3.95	18.1	15.87
	Measurement II							
	Mean	13.53	317	0.272	4.08	2.37	14.21	11.33
	SD	1.49	13.8	0.06	0.95	0.89	1.77	1.81
	Min	11.6	293	0.177	2.58	1.56	9.92	7.31
	Max	17.56	336	0.438	5.88	3.39	15.4	14.11
	Measurement III							
	Mean	13.24	315	0.278	4.25	2.62	16.91	14.51
	SD	0.91	12.22	0.05	0.72	0.82	2.56	2.89
	Min	11.21	281	0.207	2.78	1.89	13.6	11.22
	Max	14.15	357	0.355	5.52	3.51	18.71	15.11

Since the group of goalkeepers consisted only of 3 players, the statistical analysis here was considerably limited. The comparative analysis of borderline parameters values recorded during the test was conducted. Between the 1st measurement and the 2nd test measurement P_{max} range increase was noted (from the value of 11.52–13.38 up to 12.27–14.03 W/kg), W_{TOT} (from the value of 280–315 up to 314–321 J/kg). The observed increment of the values of ergometric parameters was related to effectiveness of performed work, which was verified by similar level of anaerobic glycolysis activation (ΔLA): 10.87–13.70 mmol/l in the 1st and 12.63–13.71 mmol/l in the 2nd test. After the period preceding the 3rd measurement, stabilisation of the values of ergometric parameters is noted, P_{max} at the level of 12.72–14.11 W/kg and W_{TOT} at 312–327 J/kg. At the same time the increment of work effectiveness and anaerobic alactic capacity continues (ATP-PCr), which may be seen in further drop in glycolysis activation during the work to the level of ΔLA of 13.81–17.29 mmol/l.

In the group of defenders after the completion of the time period between the 1st and 2nd measurement the statistically significant progression of all ergometric parameters was observed ($p \geq 0.01 - p \geq 0.05$), except the time of P_{max} holding. The P_{max} value increased from the level of 11.54 ± 0.58 to 13.41 ± 0.89 W/kg, W_{TOT} from the level of 300 ± 12.64 to 321 ± 10.81 J/kg. The considerable increment of power and work was not accompanied by statistically significant increment of ΔLA value (from 11.22 ± 3.32 to 12.22 ± 3.57). The successive measurement carried out after the 3-month period of break indicated further P_{max} increment from the value of 13.41 ± 0.89 to 13.59 ± 0.81 and W_{TOT} from 321 ± 10.81 up to 321 ± 12.85 J/kg, which however was not statistically significant. The observed change of the level of ergometric parameters was accompanied by increase of

anaerobic glycolysis activation (ΔLA increment from 12.22 ± 3.45 to 13.71 ± 2.47 mmol/l, $p \geq 0.05$). The energetic cost of this statistically insignificant progression of ergometric parameters was considerably higher than the cost of statistically significant increment, which was observed between the 1st and the 2nd measurement.

Between the 1st and 2nd measurement in the group of forward here was a significant increment of P_{max} value from the level of 12.22 ± 0.77 to 13.53 ± 1.52 W/kg ($p \geq 0.01$) and W_{TOT} from 297 ± 12.11 to 317 ± 11.5 J/kg, $p \geq 0.01$). The time-to-reach P_{max} and P_{max} holding values decreased. Intensification of glycolysis (evaluated with the use of ΔLA parameter) decreased, though that decrease was not statistically significant (from the value of 11.97 to 11.33 mmol/l). After the completion of consecutive period of training preparation, which was characterised by intensification of competition loads (league and National Team games), the drop in the level of ergometric parameters such as P_{max} (to 13.24 ± 0.91 W/kg) and W_{TOT} (to 315 ± 12.12 J/kg) was noted. Though both of the above changes were not statistically significant. However, statistical relevancy ($p \geq 0.005$) was found in increment of glycolysis intensification (ΔLA) in analysed period from the values of 11.33 ± 1.87 to 14.51 ± 2.89 mmol/l. The observed characteristic of changes indicated the increment of energetic cost of performed work and accompanying power and volume drop.

Table 2. The mean values of parameters recorded in the hockey players in RP-I group.

Statistical index	Parameters						
	P_{max} [W/kg]	W_{TOT} [J/kg]	ID [W/kg/s]	T_{uz} [s]	T_{ut} [s]	LA_{max} [mmol/l]	ΔLA [mmol/l]
Goalkeepers							
Mean	13.05	288	0.32	3.44	2.27	16.25	12.8
SD	1.23	34.26	0.002	0.79	0.21	4.17	6.07
Min	12.18	264	0.313	2.88	2.12	13.3	8.5
Max	13.92	313	0.317	4	2.42	19.2	17.09
Back players							
Mean	13.65	310	0.32	3.52	3.22	18.32	15.11
SD	1.62	22.37	0.06	0.62	0.79	3.48	2.67
Min	11.44	277	0.23	2.63	2.11	13.7	11.78
Max	15.95	344	0.38	4.39	4.12	22.3	19.13
Forward							
Mean	13.62	318	0.3	3.61	3.41	17.82	15.16
SD	1.06	19.84	0.05	0.54	1.12	2.28	2.16
Min	12.19	281	0.24	2.3	2.14	15.2	11.55
Max	15.31	346	0.4	4.62	5.31	23.6	19.57

The values of the parameters recorded in the 1st Polish National Team (I-RP) in ice hockey after the completion of the 1st competition period (table 2) were used as a

reference point in analysis of dynamics of parameters recorded in 30-s test performed on cycle ergometer. The characteristic of mutual correlation expressed in percentage values is presented in fig. 1–3 (values recorded in 1st Polish National Team constituted 100% value).

In the group of goalkeepers, initially clear differences between both groups are seen as far as the level of P_{max} holding time, time-to-reach P_{max}, P_{max} value and W_{TOT} are concerned. The results of P_{max} holding and power decline index recorded in junior players seem to be better when compared to senior players, though they differ unfavourably as far as time-to-reach P_{max}, P_{max} and W_{TOT} are concerned. After the 1st competition period, observed differences concern only the level of P_{max} holding (in favour of U-18 group) and time-to-reach P_{max} (unfavourable for U-18 group). After the completion of the 2nd part of league play-offs, the type of differences between groups U-18 and I-RP did not change. Ergometric parameters reached similar level in both groups, whereas considerable difference in the LA_{max} and ΔLA level was noted, which was not observed in earlier stages of training cycle. On the basis of analysis of characteristic of parameters changes it may be stated that similar values of ergometric parameters obtained by goalkeepers from groups U-18 and I-RP required a considerable activation of energy reserves (glycogen). The work performed by young goalkeepers, though similar to that noted in the players of the 1st Polish National Team, was characterised by low level of effectiveness and high energetic cost.

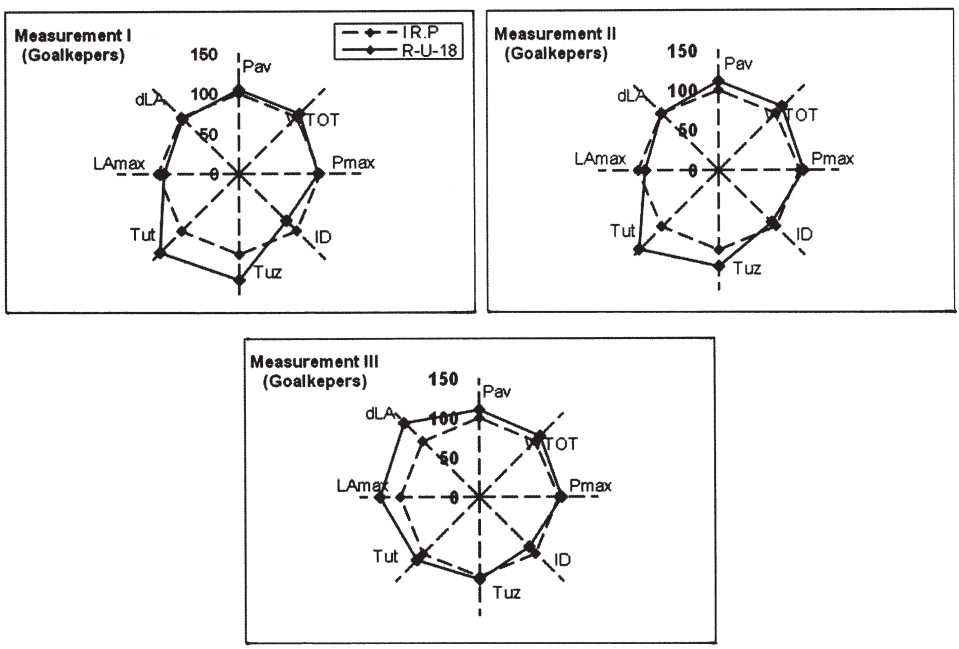

Figure 1. The characteristic of mutual correlation expressed in percentage values U-18 vs. I RP (goalkepers).

The group of defenders at the time of 1st measurement differed considerably from the I-RP group as far as the level of all parameters was concerned. P_{max} and W_{TOT} differences were within the range of 11–14%. The highest differences reaching the level of 45–35% were recorded between the values of power decline index, time-to-reach P_{max}, P_{max} holding and LAmax and ΔLA. This should be pointed out that defenders (U-18) reached P_{max} sooner and values of their power decline were lower during the entire 30-s test. Defenders (I-RP) were able to hold P_{max} for longer period of time, reached higher level of that parameter and performed more work during the entire test. The presented analysis revealed that defenders from U-18 group possessed lower level of speed-oriented preparation (P_{max} and P_{max} holding) than the defenders from I-RP group in the mid time of competition period. Lower value of the time-to-reach P_{max} resulted from lower values of power. This type of established structure of differences was to be expected in the analysed time period of preparation and when considering character of employed training means. After the 2nd measurement, structure of differences between parameters recorded in group U-18 and I-RP changed. The defenders (U-18 group) were able to hold P_{max} for longer period of time, but had higher time-to-reach values than defenders from group I-RP. The values of P_{max} and W_{TOT} at this stage of preparation did not differ statistically in both groups. In consecutive periods of preparation, especially when intensification of competition loads occurred (league play-offs, Polish Junior Championship and games of national team), ergometric parameters continued to become similar as far as their value was concerned and the difference between P_{max} level, W_{TOT} and time-to-reach P_{max} value continued to decrease. There was no difference between the remaining parameters.

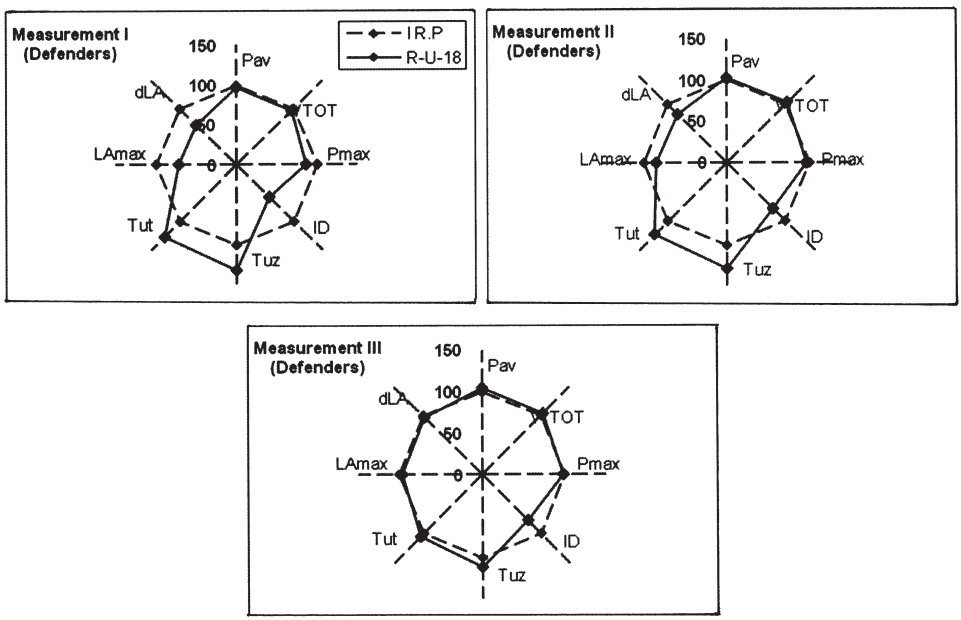

Figure 2. The characteristic of mutual correlation expressed in percentage values U-18 vs. I RP (defenders).

The comparative analysis of ergometric parameters between groups of forward players (U-18 and I-RP) revealed a number of changes in the characteristic of differences in the course of 7-month training period (figure 3). After the completion of the specific preparation period by forward players (U-18), only the value of P_{max} holding was convergent. The time-to-reach P_{max} in group of forward players (U-18) was statistically longer ($p \geq 0.001$), whereas all remaining parameters were of lower value. After the 1st competition period statistically significant changes ($p \geq 0.01$) were noted between the values of LA_{max} and ΔLA. Higher range of anaerobic glycolysis activation was observed in forward players (I-RP) at relatively insignificant differences in the level of P_{max} and W_{TOT}. In the analysed period, forward players (U-18) improved their parameters of power and work and at the same time they improved their anaerobic metabolism (improved energetic effectiveness). After intensive, consecutive period of preparation (III measurement), insignificant decrease of P_{max} and W_{TOT}, as well as increased activation of anaerobic glycolysis (expressed in similar values of LA_{max} and ΔLA in both groups) was observed. High loads and intensity resulted in decreased level of abilities for undertaking work of anaerobic type (U-18). Considerable increment of energetic cost of this type of work was noted. These changes decreased the effectiveness of glycolytic anaerobic work, which is expressed in the W_{TOT} decline.

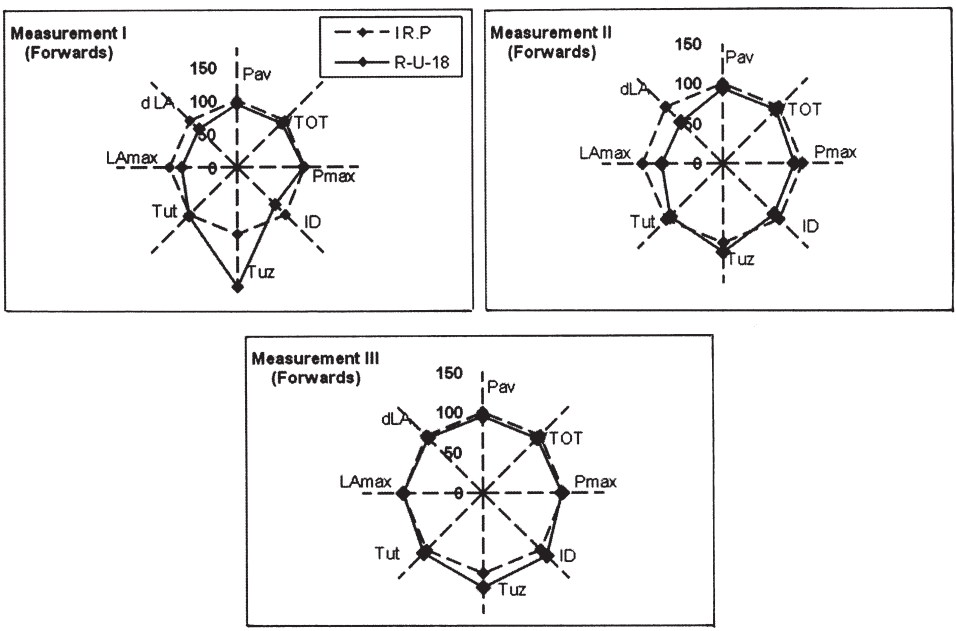

Figure 3. The characteristic of mutual correlation expressed in percentage values U-18 vs. I RP (forwards).

CONCLUSIONS

1. On the basis of analysis of changes observed in parameters values of 30-s test performed on cycle ergometer, a considerable increment of energetic cost of performed work before the direct preparation period for World Championship was noted. The obtained increment of power and total work performed was not adequate to the energetic cost. Therefore it may be hypothesised that excessive physical effort related to frequent participation of young players in hockey games may result in unfavourable changes as far as their adaptation to work of anaerobic character is concerned.

2. The comparative analysis of anaerobic capacity level alternations in young hockey players, members of Polish National Team in the course of 7-month preparation period for World Championship revealed the following:

– considerable increment of parameters of power and work observed after the 1st competition period (I to II measurement) in relation to the ones recorded after the period of specific preparation;
– increment of P_{max} and W_{TOT} values within September-December period accompanies the increment of effectiveness of the leading metabolic source (anaerobic glycolysis) for this type of work – decline in LA increment with accompanying increment of the level of ergometric parameters;
– intensification of competition period (games) resulting in lower effectiveness of anaerobic metabolism and stabilisation of ergometric parameters accompanied by increased energetic cost (LA_{max} and ΔLA increment with constant values of P_{max} and W_{TOT}).

3. The employment of a single 30-s exercise test performed on cycle ergometer for the purpose of anaerobic endurance assessment is limited. This test however may be used in diagnostics of effectiveness of anaerobic processes. Decreased concentration of lactate in blood in consecutive periods of training process with maintenance of stable values of power and total work performed would indicate improved effectiveness of performed work. The opposite situation indicates unfavourable changes in this sphere. In the studied group of hockey players, members of Polish National Team (U-18) both of the above occurred. The early recognition of unfavourable direction of metabolic adaptation remodelling, which occurs in response to accumulating training and competition loads, allows for a necessary correction of this training process. For this purpose, the employment of the 30-s cycle ergometric test is fully justified.

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Shortcuts applied in the work

P_{max}	maximal power
P_{av}	average power
W_{TOT}	total work performed
T_{uz}	time-to-reach P_{max}
T_{ut}	P_{max} holding time
ID	power decline index
LA	the lactate concentration in the blood
ΔLA	the lactate concentration in the blood increment after the completion of test

VARIABILITA PARAMETRŮ ANAEROBNÍ VYTRVALOSTI 17–18LETÝCH HOKEJISTŮ BĚHEM SPECIALIZOVANÉ ČÁSTI PŘÍPRAVNÉHO A SOUTĚŽNÍHO OBDOBÍ

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SOUHRN

Cílem studie bylo posoudit změny úrovně anaerobní kapacity hokejistů, členů reprezentačního družstva Polska do 18 let, v průběhu sedmiměsíční přípravy na Mistrovství světa. Výzkumný soubor tvořilo 26 hokejistů (věk 17–18 let), členů reprezentačního družstva Polska a zároveň studentů Sportovní hokejové školy Polské federace ledního hokeje v Sosnowieci. Na základě analýzy změn v hodnotách parametrů třicetisekundového testu prováděného na bicyklovém ergometru před závěrečnou přípravou na MS bylo zjištěno značné zvýšení energetického výdaje při vykonané činnosti. Dosažený přírůstek výkonu a celkové množství vykonané práce neodpovídalo energetickému výdaji. Využití třicetisekundového testu na bicyklovém ergometru k hodnocení anaerobní vytrvalosti je omezené. Tento test však lze využívat při diagnostice efektivity anaerobních procesů.

Klíčová slova: anaerobní vytrvalost, lední hokej, tréninkové období

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