ORIGINAL RESEARCH PAPER

TRAINING-INDUCED CHANGES IN AEROBIC AND ANAEROBIC CAPACITY AND RESTING HORMONAL STATUS IN BLOOD IN ELITE MALE AND FEMALE SPEED SKATERS

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Abstract

To date, there is only one published study with the use standardized ergometry exercise tests regarding effect of long lasting training period on a change of physical fitness among international level male and female speed skaters (van Ingen Schenau JG, 1992). This study showed high level initial performance and lack of its improvements despite trainings. That phenomenon might be resulted in inadequate training modalities, accumulation of fatigue or simply such high initial fitness, that it was impossible to improve it. Our study was aimed to examine the responses of several biomechanical and physiological parameters to preparatory training period (4 months) with incising predominance of strength-velocity exercises over time course. The results showed minor, non-significant improvements of some parameters of anaerobic and aerobic capacity in the males. In females there was no change in aerobic capacity, and those in anaerobic one were lower than in males. After the period in both sexes resting blood cortisol was elevated and testosterone- to- cortisol ratio, was declined, that suggest shift of protein metabolism toward catabolism. We suspect that among females their adverse hormonal status may have been responsible for, general lower expected training effects.

Key words: *speed skating, gender, training, physical capacity, hormones.*

Introduction

Speed skating is a sport discipline that requires concurrent excellent aerobic and anaerobic capacities because starting distance ranges from 500 to 10.000 m. Obviously, some skaters specialize in races at shorter distances, while the others at longer ones. Nevertheless, for each speed skater a contribution of strength-velocity and endurance exercises in a whole preparatory training period (PTP) plays a crucial role. For that reason various laboratory exercise tests was incorporated for evaluation physical capacity and prediction of skating performance. The two main exercise tests anaerobic and aerobic one allows to examine maximal power output and aerobic threshold respectively. For speed skating practice, laboratory exercise tests were incorporated in the 80s and 90s of the last century. Geijsel et al. (1984) fund high correlations between power output realized during supra-maximal bicycle test lasting 30s (Wingate) and based on ice and air frictions and calculated power output generated during skating racing on 500m and 1500m. Nemoto et al. (1988) reported, that maximal oxygen uptake (VO_2 max) when expressed as l/min recorded during incremental graded test, allowed to distinguish top level skaters from those less skilled and successful, however, anaerobic and aerobic thresholds and absolute VO_2 max did not correlated with performance on races on various distances within each group.

Several laboratory studies conducted among athletes of various sport disciplines, especially in track and field, showed higher physical abilities in males, and these differences were often expressed as sex-related differences in scores of sportsmanship. The similar relationships between ergometry tests and scores of on-ice skating performance. Male speed skaters generated higher external power output and are fasters that their female counterparts on various distances due to greater skeletal muscles mass in male athletes. However, that predominance in anaerobic power are somewhat lower, when maximal power output is related to total body mass (Watts/kg) and it additional decreases when this parameters is expressed as power/lean body mass. In speed skating interesting direction of the changes between sexes has been found for anaerobic effort oxygen consumption (liter /minute) per relative external power (P/body mass). These parameters are similar in both sexes, but the oxygen consumption related to P/lean is higher in male skaters (Van de Groot. 1983). Blunting of sex-related differences in muscles power were (power adjusted to muscle mass) was found in speed skaters during 30s and 150s supra-maximal cycling (Van Ingen Schenau et al. 1988). The similar phenomenon was noted among male and female ice hockey players (Gilenstam et al. 2011).

To date, there is only one study on the changes of physical fitness among elite speed skaters throughout their training period. That early investigation showed very minor fluctuations of maximal anaerobic power output and VO_{2max} in elite speed skaters examined at three different occasions, in the February, May and September (Van Ingen Schenau et al. 1992). That indicated that elite speed skaters sustained almost the constant high fitness levels over the long entire pre-competitive period. Presumably, their mean maximal power output generated in Wingate in February was so high, that it was impossible to improve it despite increasing trainings volume from 10 to 20h per week. There are no other investigations on this topic, hence, our study aimed to examine the effect of 4-monthly preparatory training period on changes in maximal power, endurance ability and resting hormonal status in blood among elite Polish female and male speed skaters. This period has been characterized itself by increasing contribution of strength-velocity exercises decreasing volume on changes in maximal power.

Material and methods

Preparatory training period lasted from the end of May to the end of September. The studies involved elite four senior female (aged 22-24 ys) and males (22-25ys) speed skaters of the Polish national levels. The study carried out twice. It has been started after completion of the 1st phase and prior to the 2nd phase (1st examination). The 1st phase was characterized by predominance of endurance trainings. These trainings consisted in a great part of cycling on a long distances (daily up to 80-100 km with a speed not exceeding 35km/h) with the use of road bikes, which shape imposed an inclined stances, somewhat similar to that during a competitive run. Throughout that phase groups of males and females were trained separately under supervision of their coaches. After that, came 4-month period of strength-velocity trainings, which involved repeated cycling sprints on shorter distances (2-5km), circuit legs exercises (leg press, squats with a barbell) riding on rollerblades and short lasting uphill runs. That 2nd phase of preparatory training for both males and females covered five repeated 2-3 week training camps, where housed together athletes were accommodated in Training Centers, and had similar training schedule and the same supervision. At the end of that period the whole group was examined again (2nd examination). In both examinations the study lasted two successive days and it included: (the 1st day) estimation of free fat mass (three measures of skin folds thickness: triceps, biceps and subscapula) according to the methodology described by Durnin et al (1974). Determination of resting (08:00) plasma cortisol (C) and testosterone (T) levels with the use of ELISA method, commercial kit provided by DRG-GERMANY and attached to the analytical run control samples as a reference material provided by BIORAD. The hormones were assayed in duplicates, based on these results within assay error were 5.5 and 5.9% for cortisol and testosterone respectively. Anabolic-catabolic indexes were expressed as T: C ratio $*10^2$. Two exercise tests, Wingate 30s and Incremental graded test (IT) were performed forenoon day-by-day in a counter-balanced order on a cycle ergometer (Monark 824E) which was connected on-line with a computer recording a linear speed of flywheel` rotation.

During Wingate test based on the speed and braking force (load), which equaled 7.5% of body mass for both sexes, power output was calculated (authorized software). Biomechanical parameters, maximal power (Watts), work output (Joules), their relative values adjusted to body mass and free fat mass, and time (s) of attaining and sustaining 97.5% maximal power were recorded during the test. Wingate test was preceded by 5-minute warm-up of a moderate intensity; a loud verbal encouragement was used during that test.

IT was continued until volitional exhaustion. It was performed with the unchanged pedal cadence (80 rpm) imposed by an acoustic chronometer. Power output was increased every 3 minutes by the same value, 0.75W/kg for females and 0.90W/kg for males, by the appropriate elevation of the braking force prior to the next stage. Capillary blood lactate (LA, Super GL 2, Dr Müller), maximal VO2 uptake (Metalyzer 3 B Cortex) and rating of perceived exertion (RPE, Borg`s scale) after completing of the last, the most intensive bout of IT were recorded.

Non parametric statistical tests were used, for comparison between groups (U-test, Mann-Whitney), and for comparison between examinations within each group Wilcoxon`s signed rang test was used. The study protocol was approved by the Ethical Commission at Institute of Sport

Results

During exercise tests biomechanical parameters were recorded on-line as follows:

1. P_{max} – maximal power output (the sampling frequency of 1000Hz)
2. W – Total work output
3. T att – time to attainment P_{max}
4. T sus – time to sustain P_{max}
5. FI – fatigue index $(P_{max} – P_{30sec})*100\%/ P_{max}$ (relative decrement of power at the end of Wingate)

6. BM – total body mass
7. FFM – free fat mass
8. VO_{2max} – maximal oxygen uptake

Biomedical and biomechanical variables for female and male speed skaters and results of statistical calculations are displayed in Table 1 and 2 respectively.

Table 1

Post training anaerobic and endurance capacity and the blood hormonal status in elite female speed skaters (n=4)

Variable	Before training period	After training period	Z	p
C (nmol/L)	620±150 (546-790)	768±259 (461-1070)	1.83	0.068
T (nmol/L)	1.7±0.3 (1.3-2.0)	1.8±0.3 (1.3-2.1)	1.07	0.285
T/C*100	0.27±0.06 (0.24-0.37)	0.23±0.12 (0.19-0.43)	0.731	0.465
Biomechanical variables of Wingate				
P_{max} (Watt)	639±111 (539-795)	666±80 (579-769)	1.09	0.273
$p1_{max}$ (Watt/BM)	10.20±0.62 (9.45-10.91)	10.55±0.35 (10.01-11.01)	1.46	0.144
$p2_{max}$ (Watt/FFM)	12.83± 1.11 (11.87-14.43)	13.30 ± 0.54 (12.62-13.98)	1.09	0.273
W (kJ)	15.07±2.51 (12.81-18.56)	15.84±1.67 (13.84-17.92)	1.09	0.273
w1 (J/BM)	241±15 (221-255)	251±10 (243-265)	1.46	0.144
w2(J/FFM)	303 ±25 ((278-337)	316± 11 (305-326)	1.09	0.273
Tatt (sec)	4.30±0.76 (3.26-4.95)	4.03±0.54 (3.37-4.70)	1.09	0.273
Tsus (sec)	3.61±0.28 (3.26-3.88)	3.33±0.74 (2.48-4.10)	0.731	0.465
FI (%)	22.1±1.2 (20.5-23.3)	22.1±1.6 (19.5-23.3)	1.09	0.273
Biomechanical and physiological variables of the incremental graded test				
P_{max} (Watt)	305±37 (260-350)	308±33 (261-338)	1.09	0.273
$p1_{max}$(Watt/BM)	4.89±0.10 (4.81-5.03)	4.88±0.22 (4.66-5.16)	0.365	0.715
$p2_{max}$(Watt/FFM)	6.17±0.17 (6.04-6.40)	6.14±0.11 (6.07-6-29)	0.365	0.715
w1 (kJ/BM)	3.33±0.10 (3.23-3.45)	3.31±0.30 (3.01-3.71)	0.365	0.715
w2 (kJ/FFM	4.20±0.07 (4.14-4.29)	4.20±0.22 (3.97-4.53)	0.00	1.00
VO_{2max} (L/min)	3.36±0.41 (2.90-3.89)	3.35±0.33 (2.94-3.74)	0.00	1.00
$VO_{2\ max}$ (ml/min/BM)	53.65±1.77 (51.7-56.0)	53.08±2.37 (51.5-56.3)	0.00	1.00
$VO_{2\ max}$ (ml/min/FFM)	67.4±2.0 (68.3-70.6)	66.9±1.8 (66.0-68.7)	0.365	0.715
La (mmol/L)	11.8±0.23 (10.6-14.1)	13.8±1.3 (12.9-15.9)	1.46	0.144
RPE (6-20 points)	19.5±0.6 (19-20)	19.8±0.5 (19-20)	0.00	1.00

Table 2

Changes in post training anaerobic and endurance capacity and the blood hormonal status in elite male speed skaters (n=4)

Variable	Before training period	After training period	Z	p
C (nmol/L)	428±83 (357-523)	647±163 (533-889)	1.83	0.068
T (nmol/L)	20.1±0.9 (18.9-21.4)	19.3±2.7 (17.4-23.4)	0.731	0.465
T/C*100	4.5±0.6 (3.2-5.8)	3.1±0.7 (3.0-4.5)	1.83	0.067
Biomechanical variables of Wingate				
P_{max} (Watt)	1017±92 (944-1147)	1055±84 (982-1158)	1.83	0.068
$p1_{max}$ (Watt/BM)	12.58±0.68 (11.71-13.2)	13.00±0.67 (12.11-13.42)	1.83	0.068
$p2_{max}$ (Watt/FFM)	14.01±1.02 (12.61-14.82)	14.42±0.94 (13.14-15.40)	1.83	0.068
W (kJ)	23.84±1.82 (22.39-26.23)	24.98±1.71(23.27-27.18)	1.83	0.068
w1 (J/BM)	295±11 (279-303)	308±17 (283-319)	1.83	0.068
w2(J/FFM)	328±19 (301-345)	341±24 (306-361)	1.83	0.068
Tatt (sec)	3.67±0.53 (2.99-4.51)	3.46±0.74 (2.87-4.22)	0.365	0.715
Tsus (sec)	2.44±0.53 (1.88-2.84)	2.63±0.78 (1.71-3.30)	0.00	1.00
FI (%)	10.6±2.4 (7.3-12.4)	9.9±1.8 (7.7-11.7)	1.46	0.144
Biomechanical and physiological variables of the incremental graded test				
P_{max} (Watt)	432±69 (368-528)	454±73 (370-543)	1.83	0.068
$p1_{max}$ (Watt/BM)	5.31±0.50 (4.97-6.04)	5.59±0.54 (5.07-6.32)	1.83	0.068
$p2_{max}$ (Watt/FFM)	5.90±0.59 (5.33-6.72)	6.20±0.58 (5.74-6.98)	1.83	0.068
w1 (kJ/BM)	3.50±0.35 (3.03-3.96)	3.88±0.78 (3.23-4.76)	2.46	0.144
w2 (kJ/FFM	3.91±0.41(3.47-4.40)	4.31±0.61 (3.68-5.12)	0.731	0.465
VO_{2max} (L/min)	4.97±0.83 (3.92-5.95)	5.12±0.56(4.31-5.44)	0.548	0.583
$VO_{2\,max}$ (ml/min/BM)	61.48±6.11 (55.33-68.21)	63.96 (57.70-68.78)	1.83	0.068
$VO_{2\,max}$ (ml/min/FFM)	69.7±6.4 (62.2-76.2)	68.5±6.2 (61-77.1)	1.83	0.068
La (mmol/L)	12.4±2.5 (9.7-15.7)	14.3±1.4 (12.8-16.2)	1.09	0.273
RPE (scores 6-20 points)	19.5±0.6 (19-20)	19.8±0.5 (19-20)	0.00	1.00

Because of small size of the samples of both sexes results of statistical comparison (Wilcoxon`s signed rank test) did not revealed any post training changes, neither in females nor in males, however, the relative changes were, in general, somewhat higher among males, as was shown in Table 1 and 2. Training period triggered the increase in blood cortisol, by 51.1% and 23.9%, in males and females respectively. Because of very minor changes in testosterone levels, anabolic-catabolic index (T/C*100) decreased by 31.1% in males and by 14.8% in females. In females after training period biomechanical parameters of Wingate test were slightly improved, while those biomechanical and physiological of incremental graded test were the same. In males slightly (by few percents) improvements were noted in scores of both exercise tests. In both group and examination perceptual responses to IT estimated with RPE were the same, the skaters rated the exertion as very, very hard. Based on the total results taken together from the both terms (8 observations within each sex) we found significant gender differences in some variables. As expected, during incremental test the levels of absolute maximal power output and work output were higher in the males group, however, these differences were lower when the variables were expressed as relative values, i.e. when these biomechanical parameters were related to body mass, and lack of the differences appeared when comparison was done for fat free mass. The similar trend was occurred for maximal oxygen uptake during the incremental test. Interestingly, female skates demonstrated two-fold lowed exercise-induced fatigue decrement of power output at the end of Wingate test. Table 3 presents statistical between-sex comparisons.

Table 3

Comparison of sex-related differences in biomechanical and physiological parameters recorded during both examinations

Variables	Z-function	P-value
Wingate test		
P_{max} (Watt)	-3.31	0.001
$p1_{max}$ (Watt/BM)	-3.31	0.001
$p2_{max}$ (Watt/FFM)	-2.15	0.031
w1 (J/BM)	-3.31	0.000
w2(J/FFM)	-2.15	0.031
Tatt (sec)	0.84	0.401
Tsus (sec)	2.57	0.010
FI (%)	-3.31	0.000
Incremental graded test		
P_{max} (Watt)	-3.31	0.001
$p1_{max}$ (Watt/BM)	-2.63	0.011
$p2_{max}$ (Watt/FFM)	0.89	0.372
w1 (kJ/BM)	-1.31	0.189
w2 (kJ/FFM	0.79	0.431
VO_{2max} (L/min)	-3.31	0.000
$VO_{2\ max}$ (ml/min/BM)	-3.09	0.002
$VO_{2\ max}$ (ml/min/FFM)	-0.26	0.793
La (mmol/L)	0.92	0.331

In one of examined female we noted post training decrements in biomechanical parameters of Wingate, incremental graded test and $VO_{2\ max}$ (by few percentages), with strong rise of C level (to 1070 nmol/L) and the highest fall of T/C ratio. These symptoms may suggest development of chronic fatigue and the data influenced mean variables within female group.

Discussion

It is worth to note, that for each sport discipline the main issue of physical preparation to competitive period in endurance-velocity trained athletes is an optimal scheduled trainings period undertaken after detraining period. Although regular concurrent aerobic and anaerobic exercises are undertaken during retraining, but first phase of this period is oriented mainly on improvement of endurance capacity, therefore, aerobic exercises predominate in the physical activity. After achievement of required endurance, the next, second stage of preparation is focused on development of strength-velocity abilities with using anaerobic exercises. Finally, a short-term period of reduced activity, so-called taper period directly precedes a competition. Correctly carried out a second phase of the preparation should lead to enhance strength-velocity abilities without loss of previously attained physical endurance, thus, achievement of high speed and good endurance require appropriate training modality. As mentioned earlier, the real effectiveness of trainings utilized throughout the second, strength-velocity period is easy to confirm with using two standardized exercise-tests. It was reported that some biomechanical parameters obtained from off-ice field exercise tests have tremendously predictive power for ice skating performance. Majority studies examine speed running on a short distance. For instance among juvenile females (aged 12ys) practicing ice-hockey, 40-yd dash time was the strongest predictors of skating speed (Bracko and George 2001). More comprehensive examinations among ice-hockey players revealed, that scores of four the laboratory tests, 30-meter sprint, vertical jump, broad jump and 3 hop jump, accounted for a total from 65 to 78% of the variance in on-ice sprint performance (Farlinger et al. 2009; Krause et al. 2012). Likewise, the study in speed skates revealed that higher mean power by 25W results higher mean velocity on ice by 0.5% (Houdijk et al. 2000), therefore we utilized power and endurance tests in our study.

Hormonal changes

Up to date there were only two published results regarding changes in the resting hormonal status induced by training period in speed skaters (Banfi et al. 1993) and the hormonal responses to repeated efforts among three those, who after training period were demonstrated overreaching state (Nederhof et al. 2008). Our study showed training-induced elevation of resting adrenal activity (the increase of C level) and levered T/C ratio that suggests shift of resting metabolism toward protein catabolism. That change is typical for overreaching state after training period, although, biomechanical improvements of physical fitness components recorded during Wingate and incremental graded test were rather small. It is worth to note higher cortisol level among female then in male skaters, both prior to- and after training period. That phenomenon was often reported previously among athletes but not in non-athletes.

Wingate performance

3-month preparatory training period did not significantly change biomechanical parameters of Wingate test in both sexes. Maximal mean power generated by males and females examined by us were markedly lower as compared to those recorded over 20ys earlier in the world class skaters from The Netherlands (Van Ingen Schenau et al. 1988) (males 1103Watts, females769 Watts). The similar predominance presented the other Dutch speed skaters when comparing their relative power (males -14.2 Watts/kg and females 12.6 Watts/kg) (Van Ingen Schenau et al. 1992). As mentioned, the females demonstrated lower work-induced decrements of power output at the end of Wingate test. That lower end-exercise fatigability (FI%) in exercising females may be linked with sex-related differences in proportion between types of muscle fibers (type II and I) (Staron et al. 2000), and the lower work-induced rate of reduction of ATP and PCr, and higher pos-effort rate of phosphagens recovery in women (Esbjörnsson-Liljedahl et al. 1999; Esbjörnsson-Liljedahl et al. 2002). On the other hand, lower cross sectional area of fast twitch fibers (type II) in woman may explain significantly lower relative maximal power express as Watts/free fat mass and somewhat slower reaching peak power (longer Tatt) as were also reported earlier by Billaut (Billaut et al. 2003) . Additional effects of differences in muscle exercise metabolism is significantly lower accumulation of blood lactate in women after completing short-lasting all-out efforts (Esbjörnsson-Liljedahl et al. 2002), however, in our study that parameters was examined only after incremental graded test.

Incremental graded test

The only published data providing information regarding aerobic capacity in elite speed skaters was study conducted among Dutch skaters by van Ingen Schenau GJ (Van Ingen Schenau et al. 1992). He reported VO_2 max accounted an average 63.1 and 55.3ml/kg/min in males and females respectively. These values are comparable with those noted by us.

Comparing pre- and post-preparation variables of Incremental graded test it is worth to note that males demonstrated non-significant, small the improvements, while in females these variables were unchanged. Interesting effects of between sexes comparison of maximal power were found when the variables were related successively to body mass and free fat mass. Absolute power (Watts) was significantly higher in males but no difference was found for the relative values express as Watts/free fat mass. That may indicate that work-efficiency of muscle slow twitch fibers and rate of aerobic metabolism are non sex-dependent.

Conclusions

The study showed that period focused on an improvement of strength-velocity abilities does not diminish aerobic capacity among both groups, but it elicited minor but somewhat better improvement of anaerobic capacity in the males. That is the evidence, that after achievement of good endurance, that ability may be sustained over strength-velocity training period.

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