Original article

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Physiological and biomechanical symptoms of physical adaptation to anaerobic and endurance exercises after 3-month period of increased sport activity in female fencers

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Summary

Introduction. The aim of this research was to examine usefulness of biomechanical and physiological indices recorded during two various laboratory exercise tests for estimation of adaptation levels in female fencers over their 3-month period of increased physical activity.

Material and methods. Seven female fencers participated in the studies which were conducted twice, before (on March) and after 3-month period of increased activity (on April). In both cases examined fencers underwent 10-second maximal (anaerobic) test (AT) on the first day. On the second day an incremental graded test (GT) was applied. Both efforts were undergone on cyclo-ergometer. The biomechanical parameters were recorded during AT, and blood samples prior (-15 min) to GT and after (+3 min) it was taken for determination of pH value, blood lactate, cortisol and testosterone levels.

Results. Some parameters of AT improved after training period, but not significantly. 3-month training period resulted in significant rise of pre-GT testosterone and somewhat higher cortisol levels. Pre -GT heart rate and post-GT rating perceived exertion slightly decreased, by 8.4 and 7.5% respectively.

Conclusions. Because in the March the physical fitness was quite well, thus magnitude of post training changes in examined parameters was small except increase of blood hormones. Despite this the results suggest usefulness of both exercise tests for monitoring of training effectiveness. The more reliable applications need the studies conducted on a bigger sample.

Introduction

The fencing belongs to a family of combat sports, and it requires besides psycho-motor abilities also explosive power and physical endurance. Explosive power is generated by lower limbs during ultra short-lasting physical actions, i.e. attacks and counterattacks, which are separated by rest intervals, whereas an appropriate level of endurance is necessary during an all-day fencing tournament. It seems that total energy expenditure during single contest is not high, however, during one day fencing tournament a contestant has to play several fights until he/she comes to the final fight. In addition, fencers use special uniform protecting their bodies from physical trauma, but causes the accumulation of heat and rise of core temperature. For that reason the physical endurance play an important role for sustaining of physical and mental disposition during the whole tournament. Our observation conducted on contestants participating in fencing tournament promote us to apply two not fatiguing laboratory exercise tests, that would be useful for rating of force-velocity and endurance abilities, and for examination of effectiveness of training period.

Several scientific studies was carried out on post training changes in physical and physiological peripheral and central adaptations, that were depended on initial physiological status, training period duration and type of exercises [1-10]. For instance our previous study carried out on professional boxer showed markedly better running performance and lower exercise-induced acute hormonal responses a few days after his retraining [1]. Other studies [9,10] revealed, that interval sprint training resulted in some similar changes typical to those after endurance exercises. It should be stressed, however, that long lasting period of increased physical activity may bring about not only improvement of physical adaptation, that expresses as a better level of physical performance, or blunted physiological responses to efforts of the same workload. Some athletes, whose training tolerance was inadequate to physical loads demonstrated impairment of physical ability compared to that before training, known as underperformance. This is an example of chronic fatigue, known also as so-called overtraining syndrome, which is well described in the scientific literature. Fatigued athletes demonstrate lower resting mood state and when undergoing submaximal exercise test of the same workload, their end-exercise blood lactate is higher [11]. For that reason monitoring of biomechanical and physiological states over long lasting annual training-competitive cycle is recommended.

As to testing anaerobic capacity, the most common tool is supra maximal effort lasting 30 seconds (WINGATE) undergone by lower and/or upper limbs on a cyclo-ergometer [12-14]. During that effort verbal encouragement is given, by researches, that force exercisers to a maximal mobilization and better performance [15-17], especially in subjects of B personality [18]. The same procedure is applied during supra maximal, "all-out" tests lasting, 60 and 90 seconds [19]. Shorter bouts performed on cyclo ergometer (10 and 20s) [20] are recommended by other researches as less fatiguing, better tolerated by athletes, but providing important information about biomechanical features like maximal power output (so-called peak power), the magnitude of power decrement occurring with time-duration of that test (so-called fatigue index-FI), total work output, time required to peak power attainment, time of power sustainment. Shorter successive efforts, 10s runs [21] or 6s cycle ergometer sprints [22] are applied as intermittent tests for determination fatigue and rate of recovery.

Anaerobic efforts utilize mainly phosphagens (PCr) and non-oxidative degradation of glucose (glicolysis) as energy sources. Rapid breakdown of intercellular PCr during maximal exercise results in its partly depletion and decrease of power output, which is lowered at the end of an effort. However those changes are not mutually parallel [20].

As mentioned, examination of endurance abilities needs to apply other test i.e. graded incremental exercise with established modality and time course. That test, if it is not designed as an maximal (sub maximal), its intensity of last bout should be established usually on a such level, that an athlete of mild fitness can perform the entire test until he/she attains a state of exhaustion. In both terms of the study, total effort duration, gradually increasing intensity of the successive bouts, and total workout of the tests should be the same. Based on our experiences regarding laboratory tests which are applied to athletes of various sport event including fencers demonstrating specific type of fitness, we assumed, that standardized supra maximal 10 second test, and non exhausting, incremental graded test would be sufficient for examination of their physical abilities. The aim of the present study was to employ two mentioned laboratory tests for estimating changes in the level of the physical adaptation following 3-month period covering training cycles separated by intermission and minor competitions. That period preceded the main international fencing tournament.

Material and methods

The study involved seven female fencers (epée) of the national level, who were enrolled to the examination of their physical fitness by means of two standardized laboratory physical efforts: 10-second supra maximal exercise test and graded incremental test, both performed, by lower limbs on cyclo-ergometer before noon. That examination was carried out twice, the first in February and the second one, after 3 month training period in June. Both the exercise tests were undergone on two consecutive days, before noon. Anaerobic 10s test (AT) was performed on the first day, incremental graded test (GT) on the next one. Selected indices are widely considered as markers of physical adaptation among athletes. During AT biomechanical parameters like maximal power output (MP), relative maximal power output (RMP, time of maximal power attainment (TMPA), time of maximal power sustainment (TMPS), overall absolute work (OAWO), overall relative work output (ORWO) and fatigue index (FI) were determined. Since power output was recorded with high frequency (1000 Hz), therefore, the results may be presented to the nearest second decimal. The incremental test was consisted of four 3-minute bouts separated by 30-second intermissions. Power output in both studies during four consecutive bouts was increased gradually according to the following sequence: 1.0, 1.75, 2.5, and 3.25 W/kg. Directly before GT and within 4th minute of post GT recovery capillary blood from earlobe was sampled for determination of blood lactate (LA), blood pH, plasma cortisol and testosterone. Value of pH (-log [H+]) was determined using an instrument of Ciba Corning- 248. LA level was determined with use Dr Lange kit. Heart rate (HR) was detected by heart monitor (POLAR) and rating of perceived exertion (RPE) expressed in scores was estimated by Borg scale. Hormones were determined by ELISA kit (DRG-GERMANY). The Shapiro-Wilk test was applied for determination of normality of distribution for each variable. After that the non parametric statistics, Wilcoxon matched pair test and Spearman correlations were used. Before calculations of pH values, that variable was transformed into molar concentration of hydrogen ions [H +], and after that variable was converted to pH again. The study was approval by the Ethical Commission at the Institute of Sport.

Results

The results of examination of anaerobic capacity and physiological responses to incremental graded test are displayed on Table 1. The significance of physiological changes following post incremental grader test is shown on Table 2. Correlation between examined variables are presented on Table 3.

Because of small sample the means of some biomechanical variables of AT recorded during two irrestigations were not significantly different. Also non significant training-induced changes in some physiological parameters of GT at rest and/or after the effort were noted. However, the subjects demonstrated significantly improvement of mean maximal power output and overall work output, whereas time to attainment of peak power tended to decrease. Those positive changes accompanied, however, by a greater decrement of power during the exertion (higher FI) and shorter time of sustainment of the maximal power. That may suggests the phenomenon: the more vigorously undergone anaerobic test at its beginning, the higher end-exercise the fatigue level. Hard to explain, whether that post training change was resulted in specific fencing exercises which were being done during training camp, or whether somewhat higher blood testosterone contributed to those changes. Probably after training period the fencers applied another pacing strategy during performance of AT. Anyway, the biomechanical variables are useful for determination of the influence of training period on anaerobic capacity. It is worth mentioning that one female fencer demonstrated in June somewhat worse anaerobic capacity compared to that in March. Her work output (J/kg) was lower by 4.6%, time of maximal power sustainment (TMPS) was shorter by 39% i.e. that decrement was twice higher than that mean noted in 6 other, and his blood testosterone levels did not changed and was the nearest one (0.8 nmol/) in the group.

It is also worth considering the fact that rating of quantitative post exercise relative changes in blood acidification are not the same with relation to changes in hydrogen ions concentrations instead those in pH values. That is expressed in Table 2. Surprisingly, some variables recorded during 10s and graded incremental test showed mutual interconnections. For example LA levels recorded during GT correlated with parameters of AT: fatigue index and time of maximal power sustainment (see Table 3). Moreover, between terms changes of some variables (ΔV) also correlated as follows: Δ testosterone/Δ absolute maximal power: 0.725, Δ testosterone/Δ relative maximal power: 0.756*, Δ testosterone/Δ absolute or relative work output: 0.875* Δ post GT cortisol/fatigue index: -0.917*, Other significant correlations between biomechanical Δ variables like power and work are derivatives, hence, their close relationships is obvious.

Tab. 1. Post training period biomechanical parameters recorded during 10s maximal anaerobic exercise test (AT), absolute maximal power, (peak power)-MP, relative maximal power-RMP, time to maximal power attainment -TMPA, time of maximal power sustainment TMPS, overall absolute work output-OAWO, overall relative work output-ORWO, fatigue index-FI, and parameters recorded during incremental graded test (GT): testosterone (T), cortisol (C),lactate (LA), molar hydrogen ions concentrations ([H+]), pH values (-log [H+] in blood, heart rate (HR) and rating perceive exertion (RPE)

Anaerobic test (AT)	Before trainings	After trainings	Differences p value
MP (W)	632±86	658±90	0.03*
RMP (W/kg)	10.15±0.28	10.60±0.60	ns 0.061
TMPA (s)	2.66±0.80	2.39±0.62	ns 0.053
TMPS (s)	2.20±0.63	1.88±0.49	ns 0.11
OAWO (kJ)	5.69±0.81	5.89±0.84	0.04*
ORWO (kJ/kg)	91.14±2.97	93.43±5.26	ns (0.12)
FI (%)	9.86±0.90	10.14±1.57	ns (0.116)
Graded test (GT)	Before trainings	After trainings	Differences p value
Tpre (nmol/L)	2.5±1.5	3.5±1.9	0.03*
C pre (nmol/L)	310±131	494±92	0.02*
C post (nmol/L)	392±103	561±250	ns (0.182)
HR pre (bps)	63.1±7.3	58.4±9.1	ns (0.141)
HR post (bps)	178.3±9.4	178.5±6.8	ns (0.55)
LA pre (mmol/L)	1.8±0.4	1.7±0.4	ns (0.420)
La post (mmol/L)	8.1±0.7	7.8±0.8	ns(0.419)
pH pre	7.387±0.028	7.384±0.032	0.44
pH pre	7.253±0.068	7,263±0.025	0.04*
RPE (Borg scale)	15.7±1.4	14.4±1.8	0.05*

Tab.2. Post GT changes in mean C, LA, [H+] and HR recorded before- and after training period. Differences in plasma cortisol, blood lactate and pH values and heart rate [HR] induced by incremental graded test undergone before – and after training period

Δ variable (work-rest)	ΔC	ΔLA	Δ pH	[H +] pre test	[H +] post test	Δ [H+]	ΔHR
befor trainings (p value)	26.5% ns (0.25)	350% 0.01*	2% 0.04*	0.41*10-7	0.56*10-7	36.6% 0.001*	36.6% 0.001*
After trainings (p values)	14.4% ns (0.45)	358% 0.01*	2% 0.04*	0.41*10-7	0.55*10-7	32.2 0.002*	209% 0.05*

Tab.3 Correlations between selected variables

Correlated variables (V)	summarized data (n=14)	Before trainings (March, n=7)	After trainings (April, n=7)
OAWO/TMPA	-0.785*	-0.643	-0.857*
ORWO/RMP	0.923*	0.964*	0.982*
RMP/TMPS	0.147	0.643	0.143
MP/TMPA	-0.784*	-0.643	-0.857*
RMP/FI	0.633*	0.265	0.655
LApost/Cpost	0.578*	-0.775*	-0.393
LApre/pHpre	-0.786*	-0.661	-0.673
LApost/TMPS	0.460	0.829*	0.250
LApre/FI	-0.416	-0.810*	-0.245
T/Cpost	0.481	0.757*	0.393
Cpre/FI	0.022	0.359	-0.855*

Discussion

Little is known on anaerobic capacity of lower limbs and the change in their power output over training season among adult fencers. The only study on that scope was published long ago [23] and it was conducted among male fencers twice: mild-off-season (preparation period) and mild-in-season (competition period). The results showed that during 20 s Wingate test, somewhat higher mean peak power (809 Watt) in-season was observed compared to that off-season (785 Watt), but that absolute power between term difference was negligible (3%). It completely disappears when comparing mean relative peak power, that was resulted in higher mean body mass on a competition period (73.4 vs 72.2 kg). Explosive strength and power of lower limbs were tested with the use of performance of various type of jumps and shuttle ran test [24]. Other authors tested isokinetic strength of knee flexors and extensors and their peak torque ratio [25]. Whereas in order to determine lower arms selected dynamic parameters which are related to explosive strength and which are in turn beneficial for fencing especially during attacks strength of five muscle groups: adductor pollicis, extensor and flexor carpi radialis, extensor and flexor carpi ulnaris were investigated [26].

In our study the relative differences in mean absolute and relative maximal power recorded in March and June were practically the same (4.1, 4.4%) because of small changes in body mass over the period. As was shown the magnitude of improvements of power and workout demonstrated by female fencers were not high but significant. Some other post-training period changes in TMPA, TMPS and FI recorded during AT should be discussed. The time to attain peak power was shorter ("better") by 10%, but the time to sustain maximal power also was shorter ("worse") by 15%. It seems, that excellent achievement of those both parameters is not easy, hence, AT may be considered as so-called a double conflict task. Taking into account post training changes in TMPA and TMPS, we may conclude, that the adaptation to AT was expressed as more vigorously physical performance at the beginning of the test. Indeed, when comparing the rate of maximal power development (MPD) calculated from MP-to-TMPA ratio from the two studies, its post-period improvement amounts to 16% and between-period difference was significant ($p<0.02$). On the other side, the higher rate of maximal power development at the beginning of the test might affect the higher rate of its impairments during the second part of AT, that expressed as higher FI.

It is interesting that blood testosterone recorded before incremental test (GT) correlates with some biomechanical parameters recorded during AT which was recorded a day before. That confirms our expectation, and well known relationships between circulating the androgen and level of performance of maximal exercises in male athletes [27-29]. As to androgens in exercising females the results are contradictory. Based on numerous studies on circulating androgen investigated among exercising females one may conclude training-induced increase of blood testosterone but chronic, prolonged training may result an adverse effect [30]. Likewise, other authors reported lower basal T in physically young woman, but its acute increase with DHEA-S following exhaustive exercise [31].

Thus, evaluation of an extent of adaptation on the base of incremental graded test was conducted due to the physiological changes and resting blood hormones. 3-month period induced higher resting (pre-exercise) and post-exercise levels of testosterone as mentioned earlier. The increase of blood cortisol pre-and post-test was also recorded but the magnitudes were not so high as blood testosterone. In the consequence relationships between resting anabolic and catabolic status expressed as T/C ratio was somewhat higher after training. Based on that we may suspect that protein metabolism is somewhat shifted towards anabolic process. Other resting and end-GT physiological parameters were similar in both studies. Considering usefulness of employed by us exercise tests it is worth mentioning, that some authors are recently of the opinion that ergometer and treadmill tests, as non-specific ones, are not sufficient for examination of endurance among fencers, because of different type of movements when comparing with fencing bouts [32]. Authors presented fencing-specific endurance test, which allows accurately to determine the level of physical endurance in fencers and to distinguish the elite from non-elite athletes.

Recommendations for the future

Considering the effect of 3-month period covering training and competition on physical abilities we focused only on lower limbs power and endurance ignoring those parameters of dominant fencers` hand, which holds a foil, sabre or épée. An interesting study by Chang et al [26] showed that five muscle group of lower arm are involved in a fencing competition, and the shape of foil handles strongly affects development rate of arm fatigue during a match. In the light of this study, and dependence of hand grip strength on results of competition in some other sports f.i. judo, especially in judo female contestants [33], similar studies in fencers should be taken into consideration in the future. The other problem not tackled in our testing is possible seasonal changes of some psychometric features, like time responses that are related to the place on the ranking list [34,35].

Conclusions

1. Our study suggests usefulness of some biomechanical and physiological parameters recorded during two various standardised exercise tests as biomarkers of effectiveness of training period among male fencers. However, in the light of the recent researches, in addition to the anaerobic and endurance abilities also specific psycho-motor tests seem to be worth incorporating into routine studies.
2. More reliable applications need additional study conducted on a bigger sample of fencers.

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