Functional and mental working abilities for female after physical load

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Keywords: half period of recovery, heart cycle interval, systolic blood pressure, mental working capacity test.

Summary. Objective. To identify the links between the changes of functional indicators and the level of mental working capacity of athletic and non-athletic females after standardized physical load

Material and methods. The study was performed in the Center for Research of Human Physical Abilities of Lithuanian Academy of Physical Education. Ten athletic and eight non-athletic females participated in the study. During the study electrocardiogram and RR intervals were registered and artery blood pressure was measured. All data were recorded using specialized computer software. Recovery processes were estimated as half periods of recovery indicators. The test of the mental working capacity was performed 5 min. before and after physical load.

Results. Reaction to physical load and recovery were faster of athletic than non-athletic females. The faster recovery (half period T was shorter) was seen in ratio of heart function and regulatory system possibly in order the whole recovery process could be controlled (estimated by ratio T(JT/RR)(s)). Recovery speed, evaluated by its half period, for heart rate T(HR)(s), by systolic blood pressure T(S)(s), by heart metabolic features T(JT)(s), regulatory system impact to recovery of peripheral processes were also higher (shorter half period) for athletic females during bicycle ergometry test. Standardized physical load caused an increase in mental working capacity, accuracy and efficiency for athletic females. For non-athletic females intensity and efficiency of mental working capacity was not changed; accuracy was worse after physical load.

Conclusions. The present study demonstrates that regulatory system of athletic females responded to standardized physical load like to adequate stimulus to organism functional abilities and this can be associated with better results of mental working capacity.

Introduction
The human response to physical load depends on the balanced functioning of major bodily systems. Thus, it is based on the regulatory system – in all brain-controlled levels; the executive system – musculature working under physical load; the supplying system – cardiovascular system which supplies oxygen and energetic material to muscles during exercise and the respiratory system that absorbs oxygen and removes carbon dioxide. A lot of bodily systems are likely to adapt to the variation of load during exercise. Consequently, a number of indicators exist for the measurement of organism’s response to physical load. In practice, the bodily response to physical load is evaluated by the change in the performance of one or another system (1–4). The greatest attention is paid to the change in circulatory process in the work of muscles, a sufficient amount of oxygen and energetic materials’ supplies to the muscles (5). Recently, more frequently research has been carried out to examine exercise as an integrated impact on the organism’s systems (6–8). From this point of view, the computerized integral measurement model of body’s response to physical load, created by A. Vainoras (9), is very informative. According to it, the organism’s response to physical load during the exercise may be measured. This research model may provide help for a sports physician or coach to evaluate sportsmen’s adaptation to physical load and increase the internal reserves of sportsmen’s organisms. This model may be applied not only for the evaluation of body with physical load, but for the rating of the mental performance of the studied as well.

For the organism to function efficiently under mental as well as physical load, the concentration of all organism activity is necessary. The literary sources

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provide only guidelines for the changes in the indicators of different systems with mental workload. The change in heart rate is most frequently considered. Some studies illustrate that heart rate increases and its variability changes performing mental work (10, 11). The rise in women’s heart rate with arithmetic stressors is higher than in that of men’s (12). The biggest changes in heart rate are observed under stress (13). Psychological stress significantly enhances the coefficient of heart rate and is linked to the intensification of sympathetic nervous system at any hour (14). We have not observed the studies about the integrated organism’s response with mental workload. Some authors state that the cardiovascular system with mental workload responds equally to one’s performance with different physical loads. Moreover, fatigue caused by mental work may be reduced by physical exercise (11, 15). The intensification in autonomic nervous system of sportsmen was observed not only experiencing positive or negative emotions, but also feeling different negative emotions (16). After the examination of skin resistance, temperature, cardiovascular and respiratory frequency in volleyball players a high correlation between the increases in vegetative and mental processes was determined (17). In the analysis of mental workload impact, the reduced individual ability to perform a physical task during the task of multiplication was recognized (18). Literary sources do not provide information about the impact of physical workload to the integrated organism’s response and its impact on mental working capacity. On distinguishing the body's possibilities with physical load, the impact of it to the organism with mental workload may be identified. Better athletic women’s response to physical load may lead to better performance level of mental tasks.

The aims of the study were to clarify how the functional indicators and mental working capacity of athletic and non-athletic females after standardized physical load alternate; to identify the links between the changes of functional indicators after standardized physical load and the level of mental working capacity.

Material and methods

Subject. Two groups of females participated in the study: ten athletic and eight non-athletic females. The mean age of participants was 23.9±6.44 (mean±SD) for athletic women group and 23.5±2.39 for non-athletic group; the height was 173.1±5.07 cm and 170.63±6.16 cm, weight – 65.4±4.25 kg and 67.13±12.86 kg, respectively. There were no differences in the measured body parameters. Physical load was increased incrementally to fixed 150 W according to the Brooke protocol. The tests were done in the Center for Research of Human Physical Abilities of Lithuanian Academy of Physical Education from September of 2002 till April of 2003 according to the law No. VIII-1679 of Lithuanian Biomedicine Research Ethics legislated on May 11, 2000. All tests were performed between 8 and 10 a.m. Duration of the test was 30 min.

Investigations protocol. During all the tests, 12-lead electrocardiogram (ECG) was recorded and RR intervals were measured during entire test using specialized computer software “Kaunas-Load” (20). Arterial blood pressure was measured each minute of the test using Korotkoff method. The test was divided into six periods: 1) in the state of rest, supine position, RR intervals were recorded and arterial blood pressure was measured; 2) the mental working capacity test was performed, during it the recording of RR intervals was made in sitting position; 3) the bicycle ergometry test using standardized physical load protocol according to Brooke starting from 50 W and increasing by 25 W each minute to 150 W was performed and recording of RR intervals and arterial blood pressure was made in sitting position; 4) the rest after exercise, recovery period was investigated, during it recording of RR intervals and measurement of arterial blood pressure was made in sitting position; 5) the mental working capacity test after physical load was performed during it recording of RR intervals was made in sitting position; 6) at final rest state for 5 min interval the recordings of RR intervals and measurement of arterial blood pressure were made in supine position.

Analyzed functional parameters. In order to evaluate human recovery process after physical load half periods of recovery were introduced – the time interval from time after load stop till any process (parameter) return to a half of its change during load. Following parameters were investigated: half period (T in s) of recovery – a ratio of heart metabolism (evaluated by JT interval) / heart cycle interval (RR interval) – T(JT/RR)(s); half period of recovery of heart rate T(HR)(s); half period of recovery of systolic blood pressure T(S)(s); half period of recovery of JT interval T(JT)(s); half period of recovery of arterial blood pressure pulse amplitude (S-D as reflection of blood pressure regulation in periphery) / systolic arterial blood pressure (S – as result of regulatory systems action) reflected by T(S-D/S)(s) (Fig. 1). Duration of these half periods showed organism dynamic features during recovery after physical loads.

Analyzed parameters of mental working capacity test. The mental working capacity was studied with

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Fig 1. Integrated data with calculated half periods τ(X/2) in text named as T(X), in (s)

the help of corrective test. The female worked for four minutes with special tables of letters, distributed in a casual way. During the first two minutes they crossed out the indicated letters and during the next two minutes they crossed out indicated letters, but if they made the certain unit (fixed context) with other letters, then they underlined them. We analyzed the following parameters of mental working capacity: work intensity (count of reviewed signs during 4 min), accuracy of work (count of mistakes for 500 reviewed signs), and efficiency coefficient Q, which is calculated as

\[ Q = \left( i/10 \right)^2 / \left( i/10 \right) + a, \]

where: \( i \) – count of reviewed signs; \( a \) – count of mistakes.

Statistical analysis. Data were analyzed using mathematical statistical method. Excel 2000 software package was used. Means of parameters and the standard error of the means were calculated. One-way ANOVA tools were used (the data were unbalanced). The aim of investigation was to compare means of studied parameters in case of one factor – sport activity with two levels – with or without sport activities. Significance was set at a level of p<0.05. For estimation of relation between parameters Pearson’s correlation coefficient was used.

Results

Alternation of functional parameters. As we can see in Table 1, parameter T(JT/RR)(s), showing how fast recover the relation of regulatory system and heart activity, is shorter than norm for this age. It means that reaction to physical load was quick. Reaction to physical load was a little faster for athletic females comparing to non-athletic females (p=0.05). Half period of recovery of heart rate T(HR)(s) was also faster after physical load for athletic females. Comparing to age norm, recovery of heart rate was slower for non-athletic females (p>0.05), while for athletic females was equal to age norm. Half period of recovery of systolic blood pressure T(S)(s) was longer than the age norm for both athletic and non-athletic females (p=0.05). Systolic blood pressure of athletic females recovered faster than for non-athletic females. As one can see in Table 1, half period reflecting heart metabolic activity after physical load for athletic females was significantly greater than the half period of non-athletic females and age norm differed (p<0.05). Parameter T(JT)(s) for non-athletic females was greater than parameter T(JT)(s) for athletic females and age norm (p<0.05). Half period of ratio of regulatory system and peripheral recovery evaluated according to the relative pulse amplitude T(S-D/S)(s) after physical load for athletic females was similar to age norm, but significantly lower than half period for non-athletic females (p<0.05). This parameter was significantly greater for non-athletic females as compared to athletic females and age norm (p<0.05).

Mental working capacity parameters. From Table 2, where parameters of mental working capacity before and after physical load are shown, one can see
that before physical load, mental working capacity was similar for athletic and non-athletic females. After the physical load athletic females worked more intensively – they reviewed more signs, accuracy was better – they were mistaken rarely, efficiency of mental working was increased (p<0.05). Physical load had not significant influence on parameters of mental working capacity for non-athletic females: intensity of mental working capacity was increased marginally, they made more mistakes after physical load, and efficiency coefficient did not change (p>0.05).

**Correlation between mental working capacity parameters and organism functional parameters**

was made in order to analyze the relation of functional parameters with mental working capacity as shown in Fig. 2, recovery of regulatory system and peripheral system for athletic females directly correlated with accuracy of mental working capacity. Faster recovery of peripheral system is associated with accuracy of mental working capacity. Negative correlation for nonathletic females (Fig. 3) was observed between T(HR)(s) and T(JT)(s) parameters and intensity of mental working capacity, and T(HR)(s) and T(JT)(s) with efficiency of mental working capacity. This could show us that slower recovery of heart rate and slower recovery of heart metabolic features T(JT)(s) could cause absence of changes of mental working capacity. Direct correlation between all functional parameters (except T(JT/RR)(s)) and accuracy of mental working capacity shows that slower recovery of functional parameters after physical load caused worse accuracy during mental working capacity.

**Discussion**

Analysis of changes of organism functional parameters after physical load showed that organism reaction to physical load was different for athletic and non-athletic females. Reaction to physical load was faster for athletic females, ratio of heart metabolism (evaluated by JT interval) and regulatory system (RR interval) recovered faster, we think for the reason of all the recovery process, heard rate and systolic blood pressure could be controlled. Thus, physical readiness of athletic females caused better organism adaptation to physical load. This corresponds to proposition of the authors, who investigated organism reaction to physical load (6, 7, 19–21).

The study showed that parameter of mental working capacity was increased for athletic females: they worked more intensively, accurately, and efficiently.

### Table 1. Functional parameters after physical load

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Athletic females</th>
<th>Non-athletic females</th>
<th>Age norm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart metabolism / regulatory system T(JT/RR) (s)</td>
<td>40.6±4.7</td>
<td>50.5±7.3</td>
<td>70±20</td>
</tr>
<tr>
<td>Heart rate T(HR) (s)</td>
<td>71±11.4</td>
<td>97.5±14.2</td>
<td>90±15</td>
</tr>
<tr>
<td>Systolic blood pressure T(S) (s)</td>
<td>151.1±12.0*</td>
<td>167±24.1*</td>
<td>120±20</td>
</tr>
<tr>
<td>Heart metabolic features T(JT) (s)</td>
<td>141.5±18.0**</td>
<td>197.88±31.6**</td>
<td>170±20</td>
</tr>
<tr>
<td>Peripheral system / regulatory system T(S-D/S) (s)</td>
<td>199.8±24.7**</td>
<td>256.25±30.1**</td>
<td>190±20</td>
</tr>
</tbody>
</table>

* p<0.05 comparing athletic or non-athletic females with age norm group.
** p<0.05 comparing athletic and non-athletic females.

### Table 2. Parameters of mental working capacity before and after physical load

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Athletic females</th>
<th>Non-athletic females</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intensity (i – count of reviewed signs)</td>
<td>652.8±31.2</td>
<td>750.9±32.9*</td>
</tr>
<tr>
<td>after physical load</td>
<td>718.4±23.0</td>
<td></td>
</tr>
<tr>
<td>Accuracy (a – count of mistakes for 500 reviewed signs)</td>
<td>10.1±1.4</td>
<td>6.3±1.7</td>
</tr>
<tr>
<td>after physical load</td>
<td>5.5±1.2*</td>
<td>7.0±2.0</td>
</tr>
<tr>
<td>Efficiency Q=(i/10)²/(i/10)+a</td>
<td>54.3±2.4</td>
<td>67.9±3.3*</td>
</tr>
<tr>
<td>after physical load</td>
<td>60.3±3.1</td>
<td>63.3±1.9</td>
</tr>
</tbody>
</table>

* p<0.05 comparing parameters before and after load.
Fig 2. Relation between half periods of recovery for investigated parameters and mental working capacity of athletic females after standardized physical load with positive correlation (r>0.5)

Intensity, 751
- Half period of recovery of heart rate T(HR), 71.0 (s)
- Half period of recovery of heart metabolism / regulatory system T(JT/RR), 40.6 (s)
- Half period of recovery of systolic blood pressure T(S), 151.1 (s)
- Half period of recovery of JT interval T(JT), 141.5 (s)
- Half period of recovery of peripheral system / regulatory system T(SD/S), 199.8 (s)

Fig 3. Relation between half periods of investigated parameters during recovery and mental working capacity of non-athletic females after standardized physical load (dashed lines show negative correlation coefficient, solid lines reflect positive correlation) (r>0.5; r<0.5)

Intensity, 781
- Half period of recovery of heart rate T(HR), 97.5 (s)
- Half period of recovery of heart metabolism / regulatory system T(JT/RR), 50.5 (s)
- Half period of recovery of systolic blood pressure T(S), 167.0 (s)
- Half period of recovery of JT interval T(JT), 197.9 (s)
- Half period of recovery of peripheral system / regulatory system T(SD/S), 256.3 (s)

This could be caused by more harmonious and stronger neuron processes, faster conditional reaction. And this could correspond to references of the authors that physical exercises have impact on mental working capacity (11, 15). Mental working capacity of non-athletic females did not change after physical load, but accuracy of work was worse. The mental working capacity test shows the changes of internal and external inhibition of brains, speed and nature of conditional reaction. It could be said that the changes of these processes were quicker for athletic females.

Relation between organism functions and mental working capacity was different for athletic and non-athletic females. Faster recovery of functional parameters, increase of mental working capacity, direct relation between faster regulatory system recovering

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peripheral processes and increase of accuracy of mental working capacity prove that reaction of regulatory systems for athletic females to physical load was as a stimulus to organism functional abilities. The mental activity of non-athletic females, which had not changed, was related with the longer recovery process of functional parameters. This could depend on a negative relation to parameters of mental working capacity, which could be caused by lower functional abilities of organism. Also slower recovery of heart rate, systolic blood pressure, interval JT(s), lower impact of regulatory system to peripheral recovery have had a direct influence on worse accuracy of mental work.

Thus this study showed that body’s physical abilities had a direct influence on organism’s functions and mental working capacity.

Conclusions
Organism functional parameters after standardized physical load were better for athletic females compared to non-athletic females. Increase in intensity, accuracy and efficiency of mental working capacity was observed for athletic females after physical load. For non-athletic females we observed that intensity and efficiency of mental working capacity have not changed, but accuracy has decreased. Regulatory system of athletic females reacted to standardized physical load like to adequate stimulus to organism functional abilities and this can be associated with better results of mental working capacity. Slower recovery of functional parameters for non-athletic females can be associated with not changed intensity and efficiency of mental working capacity and decrease of accuracy during mental working capacity.

Perspectives
The present study demonstrates that regulatory system of athletic females reacted to standardized physical load like to adequate stimulus to organism’s functional abilities and this can be associated with better results of mental working capacity. We expect that our research may help the athletes to cope both with sports and social life situations. We will try to continue our research in this particular direction.

Moterų organizmo funkcijų ir protinio darbingumo pokyčiai po fizinio krūvio

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Raktažodžiai: atsigavimo pusinio laikas, širdies veiklos intervalas, sistolinis kraujospūdis, protinio darbingumo testas.


Rezultatai. Reakcija į fizinį krūvį bei atsigavimo procesai buvo greitesni sportuojančiųjų merginų palyginus su nesporytuvėmis. Trumpesni atsigavimo pusinio laikai (T) užfiksuoti JT intervalo bei RR intervalo santykinio galbūt dėl reguliacių sistemų įtakos širdies funkcijai ir viso atsigavimo proceso vaidymo svarbą. Kitų stebėtų dydžių atsigavimo pusiniai laikai po veloergometrinio fizinio krūvio buvo taip pat trumpesni sportuojančiųjų meterų – tai širdies dažnis T (HR), sistolinis kraujospūdis T (S), širdies repoliarizacijos trukmė, susijusi su miokardo metabolizmu T (JT), bei santykinės pulsinės amplitudės pusinis atsigavimo laikas T ((S-D)/S). Standartizuotas fizinis krūvis padidino sportuojančiųjų meterų protinio darbingumo charakteristikas, tačiau neturėjo įtakos protinio darbo efektyvumui ir mažino nesporytuvėnų tiriamųjų jo tikslumą.

Išvados. Fizinis krūvis, kaip adekvatus dirgiklis, gerino sportuojančiųjų meterų protinio darbingumo charakteristikas ir koreliavo su funkciniuose, dinaminiai organizmo rodikliais.
References


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