EFFECT OF AEROBIC FITNESS ON THE PHYSIOLOGICAL STRESS RESPONSES AT WORK

TIINA RITVANEN¹, VEIKKO LOUHEVAARA¹, PERTTI HELIN¹, TOIVO HALONEN², and OSMO HÄNNINEN¹

¹ Department of Physiology
University of Kuopio, Finland
² Department of Clinical Chemistry
Kuopio University Hospital
Kuopio, Finland

Abstract

Objectives: The aim of the present study was to examine the effects of aerobic fitness on physiological stress responses experienced by teachers during working hours.

Materials and Methods: Twenty six healthy female and male teachers aged 33–62 years, participated in the study. The ratings of perceived stress visual analogue scale (VAS), and the measurement of physiological responses (norepinephrine, epinephrine, cortisol, diastolic and systolic blood pressure, heart rate (HR) and trapezius muscle activity by electromyography (EMG) were determined. Predicted maximal oxygen uptake ($VO_2$ max) was measured using the submaximal bicycle ergometer test. The predicted $VO_2$ max was standardized for age using residuals of linear regression analyses.

Results: Static EMG activity, HR and VAS were associated with aerobic fitness in teachers.

Conclusions: The results suggest that a higher level of aerobic fitness may reduce muscle tension, HR and perceived work stress in teachers.

Key words: Stress, Aerobic fitness, Muscle tension, Heart rate, Teachers

INTRODUCTION

Regular physical activity has positive effects on the prevention and rehabilitation of illnesses, such as heart disease, hypertension, osteoporosis, cancer, pulmonary diseases, and diabetes[1,2]. Physical activity has been shown to alleviate state and trait anxiety and to improve physical self-perception and mental well-being [3,4]. In addition, physical activity exhibited marked positive associations with good work capacity and healthy lifestyle [5]. Aldana et al. [6] indicated that employees showing physical moderate activity had about half the rate of perceived stress compared with more passive individuals. On the other hand, Sorensen et al. [7] reported non-significant correlations between physical activity and work ability or perceived physical or mental job stress in police officers during a 15-year follow-up.

The benefits of good aerobic capacity are associated with low blood pressure and heart rate at rest and during submaximal exercise [8,9]. This suggests that aerobically fit individuals require less sympathetic activation to perform the same absolute physical workload than unfit individuals. However, there is no consensus that aerobic power can protect against the kind of stress that is related to lifestyle or occupation [10,11]. Several studies have attempted to investigate the effects of physical fitness on physiological stress responses in simulated mentally demanding tasks in the laboratory [12–16], but only a few have been performed under field conditions [17,18]. Aerobic fitness seems to
moderate stress responses and improve an individual’s capacity for stress coping [13,15,19]. Rejeski et al.[20] reported that physical exercise acutely reduces the reactivity of the blood pressure to psychosocial stress. Boucher and Nugent [12] reported that the absolute response of heart rate (HR) during and after repeated exposures to psychological stress factors is lower in aerobically fit than in unfit individuals. In the study of Szapo et al. [14], the reactivity of heart rate in the mental arithmetic task was independent of the level of aerobic fitness.

Aerobic fitness may also modulate responses of the autonomic nervous system in a real life mentally demanding occupation. Consequently, the aim of the present study was to examine whether aerobic fitness had any effect on physiological stress responses in the work of teachers.

MATERIALS AND METHODS

Study population

The study population comprised 26 healthy high school teachers, 17 women (age range, 35–61 years; mean, 50; SD 8) and 9 men (age range, 33–62 years; mean, 47; SD 6) (Table 1). Two of them smoked, occasionally. The teachers provided their informed consent to participate in the study, and the study protocol was approved by the Ethics Committee of the Kuopio University Hospital.

Aerobic fitness

Maximal oxygen uptake (VO₂max) was estimated according to the submaximal cycle-ergometer test in the laboratory [21]. The target HR was set at the level of 220-age beats/min minus 15% [22]. HR was recorded with the cardiac monitor of Polar Accurex Plus (Polar Electro Ltd., Finland). An Ergoline 900 Cycle ergometer (Ergoline GmbH &Co. KG, Germany) was used in the test. The initial workload was 40 W for the women and 50 W for the men with a pedalling speed of 60–70 revolutions/min. The workload was increased by 10 W for the females and 20 W for the males every minute until the target HR was reached. HR data and workload were analyzed and VO₂max was estimated with the FitWare software (FitWare Ltd., Vantaa, Finland). The rating of perceived exertion (RPE) was inquired with the scale of 6–20 at intervals of 2 min during the test [23]. Exercise tests were performed in the morning between 8:00 and 10:00 am one day after biochemical tests, and muscle activity, blood pressure, HR, and perceived stress were recorded in all subjects.

Physiological stress response

Catecholamine and cortisol excretion

Neuroendocrine reactivity was assessed following the diurnal urine excretion of epinephrine and norepinephrine in a 24-h urine collection. Urine samples were collected in polyethylene containers with 10 ml of 6 mol/L HCl as a preservative and stored in a refrigerator (5°C ± 3°C) during the collection. The volume of 24-h urine was measured and 60 ml of the aliquot was frozen at –70°C until analyzed. The chromatographic system consisted of the Shimadzu LC-10A pump (Shimadzu, Japan), Waters 717 Autosampler (Waters Inst., USA), ESA, Chromsystems HPLC column for urinary catecholamines (# 6100) (Chromsystems Instruments and Chemicals GmbH, Munich, Germany), ESA, Coulochem II detector equipped with Guard Cell (Model 5020), and Analytical Cell (Model 5011) (ESA,

<table>
<thead>
<tr>
<th>Variable</th>
<th>Women n = 17 (SD)</th>
<th>Men n = 9 (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>50 (8)</td>
<td>47 (6)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>163 (5)</td>
<td>177 (6)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>65 (11)</td>
<td>70 (6)</td>
</tr>
<tr>
<td>Body mass index (BMI)</td>
<td>24 (4)</td>
<td>22 (2)</td>
</tr>
<tr>
<td>Work experience (years)</td>
<td>21 (9)</td>
<td>17 (10)</td>
</tr>
<tr>
<td>VO₂max (ml/min/kg)</td>
<td>38 (8)</td>
<td>52 (9)</td>
</tr>
<tr>
<td>Cortisol (mmol/l)</td>
<td>500 (120)</td>
<td>524 (126)</td>
</tr>
<tr>
<td>Epinephrine (µmol/24h)</td>
<td>0.03 (0.01)</td>
<td>0.06 (0.03)</td>
</tr>
<tr>
<td>Norepinephrine (µmol/24h)</td>
<td>0.23 (0.08)</td>
<td>0.26 (0.7)</td>
</tr>
<tr>
<td>VAS (mm)</td>
<td>52 (22)</td>
<td>45 (32)</td>
</tr>
<tr>
<td>DBP (mmHg)</td>
<td>84 (11)</td>
<td>80 (5)</td>
</tr>
<tr>
<td>SBP (mmHg)</td>
<td>137 (20)</td>
<td>134 (9)</td>
</tr>
<tr>
<td>HR (beats/min)</td>
<td>73 (8)</td>
<td>71 (9)</td>
</tr>
<tr>
<td>Static EMG (%)</td>
<td>5 (2)</td>
<td>4 (1)</td>
</tr>
</tbody>
</table>

VAS – visual analogue scale; DBP – diastolic blood pressure; SBP – systolic blood pressure; HR – heart rate; EMG – electromyography.
Bedford, MA, USA). The data were analyzed with a HP Kayak XA computer (Hewlett Packard, USA) equipped with the HP ChemStation chromatography program. An aliquot of sample, standard or control (3.0 ml), was transferred to the vessel, followed by the addition of 100 μl of internal standard and 6.0 ml of dilution buffer. The diluted urine was applied to prepared clean-up columns. The effluent was discarded. Thereafter, the clean-up columns were rinsed once with one column volume of distilled water. Finally, catecholamines were eluted out of the clean-up columns with 6 ml of elution buffer. An aliquot of 20 μl was injected for the HPLC system. The absolute recovery of catecholamines was 81–87%, analytical recovery 89–102%, linear range of the method 0.06–6 nmol/l, intra-assay variation 3–5%, and inter-assay variation 5–7%.

Venous blood samples were taken from the forearm between 8:00 and 9:00 am for cortisol analyses. The blood samples were aliquoted into appropriate prechilled vacutainer tubes and centrifuged within 1 h. The plasma fractions were frozen and stored at –80°C until the assays were performed. The Immulite 2000 Cortisol method based on the EIA principle with chemiluminescense detection was used to quantitate cortisol levels (Diagnostic Products Corporation, Los Angeles, CA, USA).

**Muscle tension**

Muscle tension was assessed by electromyography, which was recorded bilaterally from the surface of the trapezius muscle (trapezius pars descendes) by a portable ME3000P device. EMG was analyzed by using ME300P software (Mega Electronics Ltd., Kuopio, Finland). The ME3000P device enables the muscle activity to be monitored as averaged fully rectified signals from 15 to 500 Hz with the averaging period of 1 s to give the root-mean-square (RMS) values [24]. The skin was cleaned with an alcohol swab before pairs of disposable surface electrodes were affixed (Ag/AgCl, type M-00-S, N-00-S Medicotest, Ölstykke, Denmark). The electrodes were attached bilaterally to the upper rim of the trapezius muscle with a 2 cm inter-electrode spacing about 2 cm lateral of the midpoint between C7 and acromion. The reference electrodes were attached to the skin approximately 9 cm laterally from the recording electrodes. The positions of the electrodes were defined according to the recommendations of Zipp [25]. EMG was measured during the entire working day (8 h). The RMS values were normalized with a reference voluntary electrical activity obtained during a static submaximal reference voluntary contraction. The achieved normalization values corresponded with about 10–15% of the maximal voluntary contraction (MVC) of the trapezius muscle [26]. EMG levels were analyzed according to the amplitude probability distribution function (APDF) introduced by Jonsson et al. [27]. From a cumulative frequency distribution, the 10th percentile was defined as the static load level.

**Blood pressure and heart rate**

The measurement of systolic and diastolic blood pressure and HR were carried out at 8:00–9:00 am and 15:00–16:00 pm using an automatic digital device (Omron M4, Matsusaka Co., Ltd., Japan). The measurements were taken in the sitting position after a 10-min rest period and the result represented the mean of three measurements completed at intervals of 1 min. Afternoon BP and HR values were used in the analyses.

**Perceived stress**

The perceived psychophysiological stress was assessed using a visual analogue scale. The results of each VAS were expressed in millimetres (scale 0–100 mm, with the end points of “no stress” and “extreme stress”) [28].

**Statistical analysis**

SPSS package 11.0 for Windows was used for statistical analysis. Differences between gender were calculated by t-test. VO₂max is highly age-dependent [21], therefore, VO₂max was standardized for age using residuals of linear regression analyses, labeled by suffix “(res)”. The associations between VO₂max(res) and physiological stress responses were determined by linear regression analyses with the calculation of the Pearson product correlation coefficient separately for the male and female teachers. Covariance analyses of ANOVA were used to calculate the effects of predicted VO₂max(res) and relevant confounders (body mass...
index – working experience, gender) on physiological stress responses and perceived stress. P values below 0.05 were considered significant.

RESULTS

There was a significant negative correlation between static EMG activity, HR and VAS and aerobic fitness in the female teachers ($r = -0.61$, $p < 0.01$; $r = -0.56$, $p < 0.05$; $r = -0.63$, $p < 0.01$, respectively). In the male teachers, the corresponding correlations were negative, but did not reach the level of significance (Figs. 1, 2, 3).

The covariance analysis revealed the significant ($p < 0.01$) effect of the estimated VO$_{2\text{max}}_{\text{res}}$ on HR significant. BMI approached the level of significance ($p = 0.064$), but neither gender nor work experience exerted its effect on HR. The model, which included VO$_{2\text{max}}_{\text{res}}$, BMI, work experience and gender, predicted 39% of HR variance ($F = 4.18$; $p = 0.01$) (Table 2).
With respect to the static EMG activity, the model predicted 37% of the variance ($F = 6.51; p = 0.003$). The effect of $VO_{2\max res}$ was significant ($p < 0.05$), but no effects of BMI, gender or work experience on the static EMG activity were found (Table 2).

The model for VAS predicted 33% of the variance ($F = 4.07; p = 0.013$). The effects of $VO_{2\max res}$ were significant ($F = 4.72; p = 0.042$), but no other variables made any significant contribution to VAS (Table 2).

The variance analysis showed no significant predictive power of $VO_{2\max res}$ with respect to SBP and DBP or catecholamine and cortisol excretion. The male teachers showed higher epinephrine levels than the female teachers ($F = 4.47; p = 0.048$).

**DISCUSSION**

An interesting observation was the significant association between estimated aerobic fitness and static EMG activity. This finding may indicate that the higher aerobic fitness alleviates muscle tension during work, exerting a positive buffering effect on stress, and thus may reduce musculoskeletal problems, such as tight muscles. Augustine [29] also suggested that physical activity may reduce the tightness of muscles and help to ease stress. Brandon et al. [19] also found a negative relationship between the levels of frontalis EMG and aerobic fitness in subtraction tasks. Several studies have revealed that stress can contribute to static EMG activity at work [30–33].

Another interesting observation was the significant negative association between estimated aerobic fitness and HR. In the analysis of covariance, the significant association still survived, but the model showed that the effect of BMI approached the level of significance. This observation supports previous findings that in general physically active individuals have lower resting and submaximal HR than more passive individuals [8,9], and also suggests that BP is lower in physically fit individuals. The subjects in the present study were normotensive with a narrow BP range, and thus it was not possible to duplicate the above observation. In addition, Georgiades et al. [34] suggested that physical exercise, especially when combined with a weight loss program, may lower BP and HR levels at rest and during conditions of mental stress.

Although the hypothalamic-pituitary-adrenal (HPA) axis is responsive to stress [35–37], no significant links between...
cortisol and work stress have been established [38]. An increased basal activity of the HPA axis with higher urinary, plasma or salivary cortisol levels was reported, but no evidence was found for a low HPA activity in chronically stressed individuals [39–41]. Kirschbaum et al. [42] suggested that the opposite regulation of the HPA axis related to chronic stress could be due to the adaptational and coping processes of individuals. In this study, only the morning cortisol levels were assessed, since the increase in the morning cortisol excretion were shown to be associated with prolonged psychological stress [43,44]. However, no significant associations between aerobic fitness and the levels of morning cortisol excretion were found. There are many confounders, which may affect the morning cortisol level, such as quality of sleep at the previous night and individual activities before blood sampling in the morning. In the future, statistical weighing of the HPA axis status should be assessed.

Gender affected the epinephrine excretion. The higher catecholamine excretion of the male teachers may be explained by the greater body size of men, which has been reported to influence catecholamine output [45]. In the present study, the estimated aerobic fitness was not associated with diurnal catecholamine excretion. Moyna et al. [46] reported that norepinephrine increased in the speech task, but the neuroendocrine response to psychological stressor factors was independent of the level of aerobic fitness.

There was a significant, negative association between aerobic fitness and perceived stress, indicating that a higher aerobic fitness may affect self-confidence and personal appearance. The significant association survived in the analysis of covariance. In the present study, perceived stress was assessed by the simple VAS method, which is widely used to measure the intensity of pain [47], but it has also been used to measure satisfaction and acutely perceived stress [48]. Methodological and terminological differences with regard to the definition of the physical fitness and stress complicate the comparison of reports on the hypothesized relationship between aerobic fitness and stress. As the subjects of the present study were middle-aged, the assessment of VO\textsubscript{2}\text{max} has been shown to be an appropriate method to be used in middle-aged or older individuals [49]. In addition, there are few non-laboratory studies of this issue and thus it is difficult to find similar previous studies to compare our results.

There are certain limitations to the present study related to its relatively small sample size. The cross-sectional design reduces its power to establish causal relationships. In spite of these limitations, the higher aerobic fitness seems to lower muscle tension and HR in the work of teachers. On the other hand in this study, HR was measured only in the resting condition. In future studies, long-term ambulatory HR monitoring during work and leisure time should be undertaken. Proactive strategies for coping with stress, including physical activity, may play an important role before the basic causes of stress can be tackled. Certainly, physiological and psychological benefits associated with the increased physical fitness have major public health implications. Probably the combination of ergonomic and individual measures has the best effect on the promotion of health and work ability of teachers.

REFERENCES


