The Influence of Physical Exercise on Psychological Variables during Mental Stress

Albrecht FALKENBACH, Edgar WEBER, Thomas WENDT,
Zentrum der Inneren Medizin, Klinikum der Johann Wolfgang
Goethe-Universität, Frankfurt am Main, Germany
Ichiro WATANABE, Yuko AGISHI
Balneotherapeutic Research Institute, Hokkaido University,
Noboribetsu, Japan

Summary
The effects of physical exercise on psychologic variables during mental stress were evaluated. On each of two different days (for intraindividual control) 20 healthy dental students carried out four (modified) d2-tests (3.5 min available for each test). After two such tests there was a rest period of 5 minutes. During this intermission either a standardized physical exercise was performed or -the other day- (cross over, balanced) the volunteers rested in a sitting position while listening to relaxing music. After the rest period another two d2-tests were carried out. Thereafter a questionnaire ("adjective list", in German) defining 15 subscales (categories of the state of well-being) was completed by all volunteers to quantify parameters of their actual mood. For intraindividual control the results of the subscales obtained on both days were compared by the paired student-t-test. In the test with physical exercise during the break the scores of the subscale being activated were significantly (p < 0.05) higher than in the test with music. The other subscales showed no significant difference. In all tests the scores of the d2-tests reflecting the capability to concentrate showed an increase after the break, which was significantly higher, if physical exercise was performed during the break. Physical exercise can alleviate certain symptoms of mental stress. Feeling more active is the predominant subjective effect.

Key words : Mental stress, Physical exercise, Concentration, Well-being
INTRODUCTION

Prolonged mental stress commonly results in subjective distress and may -after a certain time- contribute to the development of cardiovascular disease (Krantz and Manuck 1984). Arterial hypertension and coronary artery disease are negatively influenced by these "defense-alarm reactions", probably through alterations in hypothalamic functions (Gutmann MC and Benson 1991). A genetic factor may play a role in the generation of hypertension after prolonged stress (Miller and Ditto 1991). Regular physical exercise proved beneficial in the prevention of cardiovascular diseases (Blackburn and Jacobs 1988; Curfman et al. 1985; Leon 1985). Indeed, it has been suggested that one of the mechanisms through which physical activity influences hypertension and coronary morbidity is by moderating stress-related hemodynamic reactions (Streptoe et al. 1990).

Prevention of cardiovascular disease is only reason among others why mental workers are advised to practice sports. The improvement of the state of well-being is another factor speaking in favour of physical activity in mental stress situations (Dishman 1985; Hollmann et al 1989). The present study was designed to evaluate the effects of exercise on psychologic variables (reflecting the state of well-being) during mental stress.

METHOD

20 dental students (13 male, 7 female, mean age 26.8 years) participated in the study. They were tested on two occasions at least two days apart. Before the tests all subjects had attended a 4-hour-course in dental treatment requiring a high level of attention on each of the two days. On both days the test was started in the early afternoon, so that physiologic circadian variations in the sense of well-being did not influence the results. A stress situation was simulated by use of the d2-test, which is usually employed to evaluate the actual concentration capability of the test person. The d2-test of Brickenkamp 1981 consists of 658 signs (letter d or p) in 14 lines. Various attributes are attached to the letters. Defined signs (d with two points) must be marked correctly by the test person. The difference between correctly and wrongly marked signs was taken as the score (result) of the test. In the present study only 15 seconds were allowed for each line, 3.5 minutes for each d2-test. This is less than in the original d2-test (20 seconds / line; 4 min and 40 sec / test) to increase the stressing effect of the test.

This d2-test was filled out four times on each of the two days. After the first two d2-tests (i.e. after seven minutes, maximum 1316 signs) there was a rest period of five minutes. In balanced order during the break either a standardized dynamic physical exercise was performed or -the other day- (cross over) the subjects rested in a sitting position listening to modern relaxing music (Jan Hammer, instrumental). Ten volunteers started with the test setting including physical exercise at day 1 (group 1), the other
ten started with the test with music (group 2). The tests were performed in groups of four to eight subjects.

During the break with physical exercise the following movements were practiced: hopping on the spot (30 sec), bending down (30 sec), knee-bends (30 sec), circular motions of the arms (30 sec), stepping forward with alternating legs (60 sec), shaking arms and legs (60 sec), hopping (twisting) rotating the trunk against the legs (60 sec). By these exercises the heart rate increased to 136 - 156 / min.

After the break the next two d2-tests were filled out. On both test days the increase (according to the learning effect) of the scores before and after the break was compared (Wilcoxon-test).

Subsequently, the "adjective list" ("Eigenschaftswörterliste", Debus and Janke 1987, in German) was completed on both days (Table 1). This "adjective list" was employed for the assessment of the actual sense of well-being after the fourth d2-test. This commercially available questionnaire is comprised of 161 adjectives each to be answered with yes or no. Between four and twenty of these items are summarized for the quantitative definition of 15 subscales, which are listed in TABLE 3 (in English translation). For an intraindividually control the results of the subscales on both days were compared by use of the paired student-t-test. Differences were considered significant, if the p-value was lower than 0.05.

**Table 1  Test setting**  Twenty volunteers filled out four d2-tests on each of the two days. The four d2-tests were interrupted (after the second d2-test) by either physical exercise or - the other day - by rest in a sitting position listening to relaxing music (cross-over design, balanced order). On each day the "adjective list" was filled out after the 4th d2-test by all subjects to evaluate their actual state of well-being.

| physical exercise | 2x d2-test | rest with music | 2x d2-test | adjective list |

**RESULTS**

The scores of the two d2-tests before and the two d2-tests after the break are listed in Table 2. To take into account the learning effect ("ceiling effect") of the test, the results of both test days are shown separately, further subdividing the volunteers into two groups having performed the test with physical exercise at day 1 (group 1) or at day 2 (group 2), respectively.

Comparing intraindividually the results before and after the break the increase of the scores was greater in the test with physical exercise during the break in all subjects of
Table 2  Scores (mean ± standard deviation) of the two d2-tests before and the two d2-tests after the break. Group 1 performed the test with physical exercise at day 1, the test with music at day 2. Group 2 started with the test with music at day 1 and performed the test with exercise at day 2.

<table>
<thead>
<tr>
<th>Group 1</th>
<th>Before break</th>
<th>After break</th>
<th>Group 2</th>
<th>Before break</th>
<th>After break</th>
</tr>
</thead>
<tbody>
<tr>
<td>day 1:</td>
<td>717 (± 131)</td>
<td>physical exercise</td>
<td>870 (± 124)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>day 2:</td>
<td>890 (± 152)</td>
<td>rest with music</td>
<td>960 (± 142)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>day 1:</td>
<td>609 (± 63)</td>
<td>rest with music</td>
<td>704 (± 123)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>day 2:</td>
<td>706 (± 112)</td>
<td>physical exercise</td>
<td>808 (± 148)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Group 1 and in seven of the ten subjects of group 2. Summarizing all data the increase of the score (before → after the break) was significantly higher in the test setting with physical exercise during the break compared to the test with music.

*Being activated* was the only subscale of the ”adjective list” showing a significantly better result (p < 0.05) in the test setting with physical exercise being performed during the break. The score (mean ± standard deviation) of the subscale being activated (maximum score 19) was 9.65 (±6.05) in the test with physical exercise and 6.2 (±5.32) in the test with music.

*Being concentrated, inactivated, tired, self-reliant and depressed* was positively (yet not significantly) influenced (p < 0.2) by the physical activity compared to the test without exercise. The scores of most subscales showed a favourable trend in the test with physical exercise, which means that in all positive subscales (being activated, concentrated, extroverted, self-reliant, in high spirits) the scores were higher, whereas in most of the negative subscales (being inactivated, tired, benumbed, introverted, touchy, depressed) the scores were lower in the test with physical exercise compared to the test with music. The number of items defining each of the subscales and the results (mean ± standard deviation) are listed in Table 3. To give all information the P-value of the paired student-t-test was cited, even if no significant differences were found.

**Disscussion**

The concentration capability of the subjects was better, if the tests were interrupted by physical exercise. In the ”adjective list” only the score of the subscale being activated was significantly higher in the test with exercise compared to the test with music during the break. In tendency most of the other subscales also showed a positive influence of physical exercise, however no significant differences were found.
Table 3 Results of the 15 subscales (mean ± standard deviation) of the adjective list (and p-values of the paired student t-test). The number of items defining each of the 15 subscales are put in parentheses behind the respective subscale (in English translation).

<table>
<thead>
<tr>
<th>during the break:</th>
<th>physical exercise</th>
<th>rest with music</th>
</tr>
</thead>
<tbody>
<tr>
<td>being-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>activated (19)</td>
<td>9.65 (± 6.05)</td>
<td>6.2 (± 5.32)</td>
</tr>
<tr>
<td>concentrated (6)</td>
<td>3.4 (± 2.2)</td>
<td>2.6 (± 1.9)</td>
</tr>
<tr>
<td>inactivated (16)</td>
<td>2 (± 3.4)</td>
<td>4.1 (± 5)</td>
</tr>
<tr>
<td>tired (7)</td>
<td>1.5 (± 1.75)</td>
<td>2.4 (± 2.33)</td>
</tr>
<tr>
<td>benumbed (9)</td>
<td>0.6 (± 1.1)</td>
<td>1 (± 1.1)</td>
</tr>
<tr>
<td>extroverted (9)</td>
<td>3.55 (± 2.09)</td>
<td>2.75 (± 2.17)</td>
</tr>
<tr>
<td>introverted (8)</td>
<td>0.3 (± 0.71)</td>
<td>0.5 (± 0.87)</td>
</tr>
<tr>
<td>self-reliant (8)</td>
<td>4.1 (± 2.6)</td>
<td>3.1 (± 2.2)</td>
</tr>
<tr>
<td>in high spirits (16)</td>
<td>8.7 (± 4.8)</td>
<td>6.9 (± 5.6)</td>
</tr>
<tr>
<td>irritated (15)</td>
<td>2.3 (± 2.85)</td>
<td>1.85 (± 2.15)</td>
</tr>
<tr>
<td>touchy (4)</td>
<td>0.7 (± 1)</td>
<td>0.8 (± 1.2)</td>
</tr>
<tr>
<td>annoyed (7)</td>
<td>0.4 (± 0.6)</td>
<td>0.4 (± 0.5)</td>
</tr>
<tr>
<td>anxious (7)</td>
<td>0.3 (± 0.5)</td>
<td>0.2 (± 0.5)</td>
</tr>
<tr>
<td>depressed (20)</td>
<td>0.25 (± 0.43)</td>
<td>0.6 (± 0.86)</td>
</tr>
<tr>
<td>dreamy (10)</td>
<td>1.2 (± 1.9)</td>
<td>1.2 (± 1.7)</td>
</tr>
</tbody>
</table>

The present study considered subjective parameters only. Although an alternative diversion (listening to music) during the break was used as control, placebo-effects must be kept in mind. Associations with somatic or laboratory parameters have not been investigated, because these measurements (or blood drawing) would have affected the subjective assessment of the actual mental state.

It must be stressed that the test results may have been influenced by the volunteers' general attitude towards physical activity or music. The expectations of the test persons impair the correct answers in the adjective list reflecting the actual sense of well-being.

In spite of these restrictions, we think that the results confirm the daily life experience of beneficial effects of physical exercise in stress situations. The test subjects felt more active, when physical exercise was carried out in the intermission between the concentration tests. Most of the other subscales showed a favourable effect of physical exercise compared to rest with music.
If these results are transferred to the mental work situation of the daily life, it can be concluded that the opportunity to practice sports during rest periods can contribute to an improved sense of well-being of the employees. If the physical exercise is carried out in a group, an improved feeling of homogeneousness may arise. Presumably, improved working results will compensate for the necessary expenditure of time, room and competent teaching of the optimal physical exercises.

How this improvement of the mood is achieved is still speculative. An increased release of endorphines is unlikely, if physical exercise is performed at low intensity only (Brooks et al. 1988; De Meirleir et al. 1986, Schwarz and Kindermann 1989). Changes in the synthesis and secretion of sympathetic hormones and alterations in the sensitivity of their receptors might play a role, but they do not correlate well with the somatic symptoms of mental stress (Cameron et al. 1990). The increased blood flow in the grey matter of the brain (Hollmann et al. 1989) after physical exercise is probably a contributing factor to the improved concentration capability, the influence on the sense of well-being, however, is uncertain.

In various studies the beneficial effects of physical exercise on the brain function and the mood in elderly people and depressive patients have been evaluated (De Meirleir et al. 1986). In healthy people (beside elite athletes) little research has been done in this matter. The positive influence on the sense of well-being by physical exercise is generally acknowledged. The way of action, however, remains to be elucidated.

REFERENCES
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Address: Dr. med. Albrecht Falkenbach
Bereich Physikalische Therapie Zentrum der Inneren Medizin
Klinikum der Johann Wolfgang Goethe Universität
Th. Stern Kai 7
D-60590 Frankfurt am Main