Effects of Bicycle Exercise on Occipital EEG Amplitude in Male Students

Key words: Bicycle exercise—Workload—EEG amplitude—Subjective difficulty rating—Heart rate

Previous studies\(^1\) conducted to develop an objective measure of human mental workload confirmed the utility of occipital midline beta-2 (Ozβ\(_2\)) amplitude. These studies further showed that the Ozβ\(_2\) amplitude was correlated with a subject's mental activity. In applying this to measure the mental workload of workers engaged in mental work, it is first necessary to ascertain whether the Ozβ\(_2\) amplitude is influenced by physical activity, since ordinary mental work must be accompanied more or less by physical activity. The present paper refers to an experiment to determine the effects of bicycle exercise on OzEEG amplitude and heart rate.

Twenty-four healthy male college students (18–22 years of age) served as subjects. Tests were carried out between 2 and 5 p.m. in an air-conditioned room under constant ambient conditions (23.5–25.5°C and 61–76% relative humidity) over a period of thirteen days. Before the experiment, the physical fitness of the subjects was estimated using Vervaeck's index (VI), which is obtained from the formula 100(W+Cg)/L. Where W is body weight in kg, Cg is girth of chest in cm and L is height in cm.

First, as a control, the subject took a 5 min rest on a chair with his eyes open, keeping his mind as blank as possible. The subject was then required to pedal a bicycle ergometer for 5 min at each task load of 50, 60, 70, 80, or 90 watts, taking a 5 min recess between exercises. The exercise period was set at 5 min considering that the physiological and psychological responses of the subjects to moderate physical exercise of this kind would come to a steady level within less than 4 min after the start. Five exercise periods were selected in random order and this experimental session was repeated twice.

During each recess, a subjective rating of task difficulty (SRTD) was recorded using a category scale.\(^1\) The subject was asked to indicate his opinion of the difficulty of performing the task near the end of each task period using an integer from 1 to 9.

Throughout the experiment, the occipital midline (Oz) EEGs were recorded on a magnetic tape using a Medilog-9000 recorder (Oxford). A 10-sec EEG signal without artifacts was extracted from the records in the last one min of the control rest period or each task period. This was based on a previous experiment\(^1\) that showed that the OzEEG amplitude levels in male students changed very little during 5 min of a rest period or a calculating task period. Then the EEG
signals were analyzed in five bands (δ: 2–4, θ: 4–8, α: 8–13, β1: 13–20, β2: 20–30 Hz) by connecting the Medilog-9000 to an EEG-4217 and an MCE-1100 (Nihon Kohden). The average amplitude during each 10-sec period was obtained for each of the five bands by setting the frequency characteristics of the amplifier to a time constant of 0.3 sec for the low range and 30 Hz for the high range.

ECGs of the subject were simultaneously recorded on the same tape by the standard II induction system and heart rate (HR) was obtained by a 30-beat count at nearly the same time as the EEG analysis.

Table 1. Mean OzEEG amplitude±SEM for the rest (R) and mean ΔOzEEG amplitude±SEM (difference between levels at work and at rest) for each bicycle exercise task load.

<table>
<thead>
<tr>
<th></th>
<th>δ µV</th>
<th>θ µV</th>
<th>α µV</th>
<th>β1 µV</th>
<th>β2 µV</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>13.41± .66</td>
<td>10.15± .47</td>
<td>9.29± .64</td>
<td>6.15± .36</td>
<td>3.95± .32</td>
</tr>
<tr>
<td>50W</td>
<td>4.35± 1.13</td>
<td>2.68± .85</td>
<td>1.84± .63</td>
<td>2.93± .56</td>
<td>2.48± .42</td>
</tr>
<tr>
<td>60W</td>
<td>3.06± .87</td>
<td>2.27± .65</td>
<td>1.76± .59</td>
<td>3.10± .54</td>
<td>2.33± .42</td>
</tr>
<tr>
<td>70W</td>
<td>2.39± .65</td>
<td>2.15± .48</td>
<td>1.51± .51</td>
<td>2.89± .42</td>
<td>2.42± .40</td>
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<tr>
<td>80W</td>
<td>3.47± .80</td>
<td>2.63± .53</td>
<td>2.33± .65</td>
<td>3.47± .54</td>
<td>2.85± .45</td>
</tr>
<tr>
<td>90W</td>
<td>2.95± .68</td>
<td>2.47± .51</td>
<td>3.04± .66</td>
<td>3.61± .55</td>
<td>3.14± .39</td>
</tr>
</tbody>
</table>

Fig. 1. Mean ΔOzEEG amplitude (difference between levels at work and at rest) for each bicycle exercise task load.
Vervaeck's index (VI) of the subjects was 89.5 on average (range: 73.1–98.8). The mean OzEEG amplitudes for the rest and exercise periods are shown in Table 1 and Fig. 1. \( \Delta \text{OzEEG} \) amplitude represents the difference between levels at work and at rest. Although the amplitudes of all five bands were higher at work than at rest, none of the amplitudes at work regressed with the task load, indicating that there was no relation between task load and OzEEG amplitude. There was no change in the Oz\( \beta_2 \) amplitude at loads below 90 watts (Fig. 2). At 90 watts there was an increase in the amplitude, but it was lower than the critical level (\( \Delta \text{Oz}\beta_2 \) amplitude=3.5 \( \mu \text{V} \)) for excessive workload found in the previous studies.\(^1\text{--}^3 \)) Thus, physical activity within the range of 50–80 watts appears to have very little effect on the Oz\( \beta_2 \) amplitude. Similarly, Krause et al.\(^5 \)) found

\[ \text{Fig. 2. Mean } \Delta \text{HR (difference between levels at work and at rest) and mean SRTD (subjective rating of task difficulty) for each bicycle exercise task load. Regression coefficient: } t=10.66 \ (p<0.001) \text{ for SRTD, } t=8.95 \ (p<0.001) \text{ for } \Delta \text{HR, } df=8. \]
no effect of static biceps contractions on the power densities of four EEG frequency bands below 20 Hz at C3, C4 and O1 in healthy male subjects. Examining the effect of cranio-facial muscle contraction on the EEG, O'Donnel et al. used biceps contraction as a basis for comparison, assuming that the biceps EMG would not infiltrate the EEG. They found that very strong contraction of the cranio-facial muscles is only moderately reflected in the EEG band ranges above 14 Hz from areas not located over an active muscle. Other studies showed that neck EMG probably does not infiltrate the OzEEG during the performance of a calculating task. In combination, these results indicate that physical activities such as those accompanying ordinary occupational mental work would not have any significant effect on the Ozβ2 amplitude, unless they involved very strong contraction of the neck and cranio-facial muscles or body action over 80 watts.

The mean heart rate (ΔHR, the difference between levels at work and at rest) and the mean SRTD for each bicycle exercise task load are shown in Fig. 2. Both measures regress linearly with task load. The regression coefficient is somewhat higher for SRTD than for ΔHR. And the highest correlation is between the mean values of ΔHR and SRTD (r=0.995, p<0.001). This indicates that both measures will be sufficiently useful for measuring physical workload within the range of 50–90 watts of task load. And it is known that SRTD can be used to measure physical as well as mental workload.

Correlation coefficients between VI and HR or SRTD or Ozβ2 amplitude were computed using individual levels for each rest and task load. Only the following were significant at p<0.05: r=0.405 for HR at rest; r=−0.448 for SRTD at 70 watts; and r=−0.425, −0.466, −0.473 for ΔOzβ2 amplitude at 60, 80, 90 watts. Under this type of physical exercise, the Ozβ2 amplitude is inversely correlated with a subject’s physical condition, since VI is taken as an indicator of an individual’s physical condition. It is, however, an unexpected finding that, in this case, heart rate (except at rest) has no relation to physical condition. In order to determine the utility of heart rate and SRTD in evaluating physical workload, a comparison of these measures with some other indicators of physical strength may be needed.

**References**


National Institute of Industrial Health, 21-1, Nagao 6-chome, Tama-ku, Kawasaki 214, Japan

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