Evaluation of the Coil Planet Centrifuge Method as a Screening Test in the Health Examination System to Detect Vibration Hazards among Forest Workers

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Abstract: The coil planet centrifuge (CPC) test, a sensitive method for detecting minute changes in osmotic fragility of red blood cells (RBC), was applied to 788 forest workers in parallel with the conventional health examination for vibration hazards. Although the RBC of the examinees with or suspected of vibration hazards tend to be osmotically more resistant than the RBC of healthy subjects when evaluated on a group basis, comparison of the results between the CPC test and the vibration hazard examination disclosed that the changes are not remarkable enough to identify the affected individuals from the mass of the non-affected. Thus, the validity of the CPC test as a screening measure to detect the earliest signs of vibration hazards appears to be rather limited, even though this conclusion does not necessarily rule out the possibility that positive changes in CPC findings might be observed in severe cases of vibration hazards.

Keywords: Coil planet centrifuge—CPC—Forest workers—Traumatic vibration disease—Osmotic fragility of RBC—Vibration hazards—Woodcutter

INTRODUCTION

Since the 1950’s vibration hazards have been a serious problem among forest workers, especially operators of vibration tools such as chain saws\(^1\). The current system of health examination for vibration hazards as defined by the the Labor Standards Bureau\(^2\) consists of two-stage examination. The first stage, to screen out the suspects, includes inquiry into occupational history and subjective symptoms, orthopedic/neurological inspection and palpation, dynamometric tests, blood pressure measurement, a nail pressure test and skin temperature measurement as well as tests of pain and vibration sense. The second stage, a detailed examination, comprises peripheral neurocirculatory tests (e.g., provocation for Raynaud’s

* Deceased on June 7, 1979.
phenomenon and measurements of skin temperature, pain and vibration sense on exposure to cold) as well as tapping and further dynamometric tests. X-ray photography may be undertaken when considered necessary. Based on the findings, the doctor in charge will classify the examinees into Category A (healthy subjects), B (borderline cases) and C (those in need of medical treatment including rest). While the cold provocation test for Raynaud's phenomenon by immersion of the hand into cold water is a reliable diagnostic measure\(^1,3,4\), the test per se is painful to the examinees. Accordingly, test measures that do not cause too much distress to the examinees have been sought. Coil planet centrifugation (CPC\(^5\)), a sensitive method for detecting changes in osmotic fragility of red blood cells (RBC) in the peripheral blood, was considered as a possible candidate because RBC are subjected to vibration during the operation of the tools.

Evaluation of the CPC test was made in the present study to ascertain whether or not this method is effective for screening out those affected by exposure to vibration. Application of the CPC test in other fields of occupational medicine was recently described in reporting the relationship between this technique and hematological findings in lead-exposed workers\(^6,7\).

**Materials and Methods**

The study was carried out during two winter seasons, 1978 and 1980. The examinees were 788 forest workers (282 subjects in the 1978 study and 506 subjects in the 1980 study) in Miyagi Prefecture, Japan, of whom about 68% were aged 40-59 years. They were predominantly chain-saw workers (with a few bush cleaner operators) with service histories of around 10 years (more than 50% of the examinees had served five to 15 years). In the first stage of the two-stage health examination for vibration hazards as defined by administrative notice\(^2\), blood samples were taken in the morning from the cubital vein of those who volunteered. A portion, after being anti-coagulated with Na/K-EDTA, was subjected to hematological studies (red and white blood cell counts, hemoglobin concentration and hematocrit) by the conventional methods as well as the osmotic fragility test with the coil planet centrifugation system (CPC\(^5\)). Liver function tests (GOT, GPT, \(\gamma\)-GTP, CHE, ALP, TG and TC) and serum protein determination were carried out with the rest of the blood samples by the conventional methods. Those with abnormal hematological and/or liver function findings were excluded. In a preliminary study, it was confirmed that no significant modification in CPC findings will take place when the blood is anti-coagulated with Na/K-EDTA immediately after sampling and examined within six hours thereafter. For the CPC test, the blood samples were coded and studied in a blind fashion so that the test could be conducted with no information on the results of the vibration hazards examination.

The CPC system\(^5\) was a product of Miki Engineering Co., Tokyo, Japan, and
consisted of a coil preincubator, a CPC centrifuge and a colorimetric scanner. Standard coils with 30–150 mOsm osmotic gradient with sodium chloride (Biomedical Systems Ltd., Tokyo, Japan) were employed. Three marker points, i.e., the starting, maximum and end points of hemolysis (HSP, HMP and HEP, respectively), were recorded in terms of mOsm after standardized procedures\(^5\). Hw (width of hemolysis) is defined as the difference in mOsm between the HSP and the HEP. As the distribution was confirmed to be normal for all four indices in a preliminary analysis, the results were expressed in terms of means±standard deviations (M±SD) in a unit of mOsm.

Statistical evaluation of the results was made either by the Student’s t-test or the \(\chi^2\)-test.

**Results**

*Absence of aging effects in the CPC findings among examinees*

When the CPC findings in the 1978 study with 282 examinees were classified by five-to-10 year age increments and hemolysis points were compared, no statistically significant difference could be detected among the age groups. Those at 60–69 years of age appeared to have slightly lower values (by 2–3 mOsm) in each of the four indices as compared with the 25–29-year-old examinees, yet the difference was hardly significant (\(p>0.10\)) due to wide variations (CV = 5–8%). This negative observation, suggesting the absence of aging effects on CPC findings as far as studied, was essentially reproducible when the CPC findings in the 1980 study with 506 examinees were analyzed in the same way. Accordingly, no classification by age was considered necessary in further analyses.

*The CPC findings in the presence and absence of vibration hazards*

By the first stage of the two-stage health examination for vibration hazards (for details, see Discussion section) in the 1978 study, 84 subjects (including 16 who reported a history of white finger attacks) among 282 examinees were selected for the detailed examination. In actuality, 62 underwent the examination, and nine were classified as Category C (i.e., vibration hazards requiring clinical treatment) because of cold-provoked Raynaud’s phenomenon, abnormal reaction in skin temperature on exposure to cold and/or tenderness, abnormal X-ray findings and restricted movements in the hand(s) or the elbow joint(s). No muscular atrophy was detected. In the 1980 study, 506 were examined, and 63 (including those with a history of white finger attacks) were selected for the detailed examination because of positive physical abnormalities. Of the 46 who were examined, one was classified as Category C due to elbow joint problems. The CPC findings as classified by the health examination results are shown in Table 1.

Evaluation following the flow of the examination system disclosed that, in the 1978 as well as the 1980 study, both the HMP and the HEP tended to be reduced
in accordance with the steps of the health examination (e.g., the HEP of those with white finger attacks or those in Category C appeared to be lower than that of normal subjects) (Table 1), even though the difference between means was statistically insignificant when analyzed by the t-test ($p>0.05$). As the HSP does not vary, $H_w$ would be larger among those with suspected vibration hazards. The difficulties in obtaining an affirmative statistical evaluation of the HEP decrease ($p>0.05$) among the white finger and Category C groups (Table 1) could be due, at least in part, to the limited numbers of examinees in the two groups concerned. From the relatively small differences in means coupled with large SD's (Table 1), it is also evident, however, that the distribution of the HSP, HMP, HEP and $H_w$ of the most severely affected examinees (i.e., the white finger and Category C groups) overlaps the corresponding distribution among normal subjects, and, therefore, the evaluation on an individual basis is not practical. In other words, the affected, who has history of white finger attacks or would be classified as Category C, can not always be selectively identified in practice among the mass of the non-affected.

### Table 1. CPC findings classified by results of health examination for vibration hazards among forest workers.

<table>
<thead>
<tr>
<th>Group</th>
<th>Number of subjects</th>
<th>HSP</th>
<th>HMP</th>
<th>HEP</th>
<th>$H_w$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1978 study</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal subjects</td>
<td>198</td>
<td>91.5±4.7</td>
<td>77.4±5.2</td>
<td>57.5±4.3</td>
<td>33.9±3.5</td>
</tr>
<tr>
<td>Selectees for detailed examination</td>
<td>84</td>
<td>91.7±4.6</td>
<td>76.6±4.4</td>
<td>57.2±4.0</td>
<td>34.9±3.9</td>
</tr>
<tr>
<td>Examinees of detailed examination</td>
<td>62</td>
<td>91.9±2.9</td>
<td>75.7±3.9</td>
<td>55.7±4.8</td>
<td>34.9±2.9</td>
</tr>
<tr>
<td>1980 study</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal subjects</td>
<td>443</td>
<td>90.9±3.8</td>
<td>75.4±3.5</td>
<td>55.1±3.6</td>
<td>35.7±3.5</td>
</tr>
<tr>
<td>Selectees for detailed examination</td>
<td>63</td>
<td>90.8±4.5</td>
<td>75.0±3.8</td>
<td>54.8±4.2</td>
<td>36.6±3.6</td>
</tr>
<tr>
<td>Examinees of detailed examination</td>
<td>46</td>
<td>90.6±4.5</td>
<td>74.7±4.0</td>
<td>54.4±4.4</td>
<td>36.1±3.6</td>
</tr>
<tr>
<td>Those with white finger attacks</td>
<td>22</td>
<td>90.1±4.7</td>
<td>75.6±4.3</td>
<td>54.4±4.6</td>
<td>35.8±4.7</td>
</tr>
<tr>
<td>Those in Category C</td>
<td>10</td>
<td>90.4±3.2</td>
<td>75.9±2.1</td>
<td>52.7±2.1</td>
<td>36.4±4.8</td>
</tr>
</tbody>
</table>

Unless otherwise specified, the numbers in the table are M±SD (Unit: mOs).  

- a Those who were classified as Category A in the first-stage examination (screening test).  
- b Those who were considered to need detailed examination (second-stage examination) because of positive physical abnormalities.  
- c Those who underwent the detailed examination. The difference in the number of the examinees from that of the selectees indicates the number of selectees who did not appear for the detailed examination.  
- d Those who stated that they had experienced white finger attacks. The examinees in the 1978 study (16 subjects) and those in the 1980 study (6 subjects) were combined.  
- e Those who were classified as Category C (i.e., needing medical treatment). The examinees in the 1978 study (9 subjects) and those in the 1980 study (1 subject) were combined.
Correlation between the health examination results and the variation in the CPC findings was further examined by classifying the examinees into two groups, the normal subjects and the selectees for the detailed examination. The normal range of CPC findings was defined as $M \pm 2SD$, and the CPC findings were considered abnormal when any one of the four indices fell out of the corresponding normal range. The $\chi^2$-test of the classification results revealed no significant difference ($p>0.10$) in the CPC findings between the two groups in the 1978 study, the 1980 study or both combined (Table 2).

### Table 2. Possible correlation between health examination results and CPC findings.

<table>
<thead>
<tr>
<th>Examination results</th>
<th>CPC findings</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal$^a$</td>
<td>Abnormal$^b$</td>
</tr>
<tr>
<td>Normal subjects$^a$</td>
<td>582 (177+405)</td>
<td>59 (21+38)</td>
</tr>
<tr>
<td>Selectees for detailed examination$^b$</td>
<td>127 (71+56)</td>
<td>20 (13+7)</td>
</tr>
<tr>
<td>Total</td>
<td>709 (248+461)</td>
<td>79 (34+45)</td>
</tr>
</tbody>
</table>

The numbers in the table are the combination of the 1978 and 1980 study results together with the 1978 results in the first terms and the 1980 results in the second terms in the parentheses. The $\chi^2$-test of the individual year results and also of the combination disclosed no significant difference ($p>0.10$) in the distribution.

$^a$, $^b$ As under Table 1.

$^c$ The cases when all 4 times (i.e., HSP, HMP, HEP and Hw) fall within the corresponding $M \pm 2SD$ range.

$^d$ The cases other than $^c$.

Correlation between the health examination results and the variation in the CPC findings was further examined by classifying the examinees into two groups, the normal subjects and the selectees for the detailed examination. The normal range of CPC findings was defined as $M \pm 2SD$, and the CPC findings were considered abnormal when any one of the four indices fell out of the corresponding normal range. The $\chi^2$-test of the classification results revealed no significant difference ($p>0.10$) in the CPC findings between the two groups in the 1978 study, the 1980 study or both combined (Table 2).

### DISCUSSION

It has been reported that hepatic disorders$^8$ and hematological diseases$^9,10$ may give rise to changes in CPC findings. Accordingly, hepatic function tests and hematological examinations were carried out in the present study in parallel with the health examination for vibration hazards. The findings in all the examinees in the present study were within normal range (e.g., Hb>14 g/100 ml; GOT<45 Karmen Units; GOT<35 Karmen Units; $\gamma$-GTP 2–29 m Units/ml, etc.) so that the possible modification of CPC findings due to an etiology other than vibration could be ruled out.

To evaluate the screening efficacy of the CPC test in identifying those with possible vibration hazards, blood samples were taken at the first stage of the health examination and subjected to the CPC test in a blind fashion. In other words, the CPC test was performed with no knowledge of the findings of other health examination items; the results were compared after the health examination was completed and the diagnosis was made independent of the CPC test. Thus, any bias due to prior knowledge of related findings could be ruled out. Such precautions are of practical importance, as the HSP, HMP and HEP are not always
clearly identified on the record chart and the identification is sometimes not quite free from subjective judgement. Experience shows that the HEP is most reliable among the three points because of the sharp return to the baseline in the chart.

The analysis on a group basis disclosed that the hemolysis points, especially the HEP, tends to shift toward lower osmolarity (i.e., the RBC become more resistant to osmotic hemolysis) among the vibration suspects as compared with healthy subjects, even though the difference was not statistically significant. It was also observed, however, that the changes in the CPC findings in those with white finger attacks and those classified in Category C (i.e., the most severely affected) are not always remarkable enough to separate them from the mass of the non-affected, when considered on an individual basis. Thus, the value of the CPC test as a screening measure may be rather limited.

Increased osmotic resistance of RBC was reported among the vibration-hazard patients with morphological changes in the fingers (e.g., muscular atrophy)\textsuperscript{11}). Shifts of the hemolysis points toward lower osmolarity were observed in the recipients of compensation for vibration hazards\textsuperscript{12}). Such shifts of the hemolysis points followed by the return to the normal values after therapy have also been reported\textsuperscript{13}). The characteristics common to these four reports is that the subjects studied were affected by vibration so severely that they needed clinical treatment and/or received monetary compensation. The present findings are not necessarily contradictory to these reports, as the first concern of the present study was to evaluate the CPC test as a screening measure, and the results do not rule out the possibility that certain clear-cut changes might be detected in vibration-hazard victims of clinical severity.

\textbf{Acknowledgement}

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\textbf{References}

2) Administrative \textit{Notice No. 609 from the Labor Standards Bureau, the Ministry of Labor, the Government of Japan}, on October 20, 1975.