Influence of Local Vibration on Finger Functions of Forest Workers

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Abstract: We physically examined forest workers in the northern part of Fukushima District, Japan. The main purpose of this study was to survey the state of finger functions, especially the differences between the functions of right and left fingers of forest workers. This physical examination was conducted in winter. The items of the physical examination were hand grip strength, finger skin temperature, vibration sensation threshold, nail pressure test of the finger. Subjects were classified into A and B groups on the base of the results of the physical examination. A group is normal or slight disorder, and B group is disorder or illness. Hand grip strength was measured five times at five-second intervals. The decrease ratio of the left hand grip strength was greater than that of the right hand grip strength. Although there were significant differences among each finger of A and B groups, there were no big differences in the skin temperatures of the fingers in each group. Vibration sensation threshold was measured for II, III and IV fingers. The vibration sensation threshold of the index finger was the most sensitive and that of IV finger was the least sensitive. The vibration sensation threshold of the right fingers was more sensitive than that of the left fingers. The reaction times of the nail pressure test of the right fingers were generally faster than those of the left fingers. Forestry workers in Japan become elderly. There are big differences among the physical reactions or strengths of elderly people. Standard values for the measuring items for ageing are needed.

Key words: Hand grip strength, Finger skin temperature, Vibration sensation threshold, Nail pressure test, Dominant hand

Introduction

Local vibration is one of the physical agents of the many types of machines used in forestry working and heavy industrial machinery. Harmful effects with the use of these machines might occur in terms of either physical injury, and health hazards or the impairment of work efficiency and safety.

Previously harmful effects described as vascular spasm of the blood vessels (Raynaud’s phenomenon) in the hands were attributable to the use of vibrating devices such as pneumatic and rotating tools. The definition of this disorder, which is caused by vibrating machines has been expanded to include diseases that affect blood vessels or nerves, bone, joints, and muscles of the finger, hand, arm or shoulder. This complex phenomenon has been designated as “vibration syndrome.”

The chain saw was first introduced by timber workers in Germany before the second world war. With the increasing mechanization of forest work in timber-growing countries,
the chain saw has undergone steady technical development and is now widely used for a variety of work\(^1\)\(^-\)\(^3\).

Forestry workers use vibrating devices such as chain saws and bush cleaners. They are susceptible to the hazards created by local vibration such as white finger phenomena, numbness, and joint disorders in the fingers or arms. The signs and symptoms arising from the use of chain saws in forestry operations have been reported\(^2\)\(^-\)\(^8\). Hand and finger functions vary according to the native of the jobs, i.e. holding vibrator devices or pulling the trigger. The dominant hand is used more often and more skillfully than the other hand during the course of every day activities and specialized job tasks.

It is therefore natural to expect that the extra activity of the dominant hand would produce a greater training effect on the muscles of the dominant hand than on the muscles of the non-dominant hand\(^9\)\(^-\)\(^10\). It is thought that finger functions such as sensation, strength, and task performance are influenced by the states of their jobs and the activities of the hands. It might also be thought that the dominant hand is easily affected by the harmful effects of using chain saw in forestry work.

The purpose of the present study was to mainly survey the state of finger functions, especially the difference between the right-hand and left-hand fingers of forestry workers.

**Subjects and Methods**

Physical examination of workers is done normally once a year in Japan. We physically examined of forest workers. The subjects were 92 male forest workers, aged 24 to 76 years of age, in the northern part of Fukushima District. They were belonging to the Forestry Agency in each area of the northern part of Fukushima Prefecture, Japan. Physical examination was done in winter.

Items of physical examination were body height, weight, blood pressure, hand grip strength, finger skin temperature, finger nail pressure test and so on. At the same time, a questionnaire was given; including questions on the vibration syndrome, general health, and the safety aspects of work.

Blood pressure was measured in the left arm of the subject in a sitting position by using a mercury sphygmomanometer. A Smedly hand dynamometer was used to measure grip strength. Hand grip strengths were measured five times at five-second intervals with a 100% grip effort to estimate fatigue in the hand muscle.

The skin temperatures of II, III, IV and V fingers were measured using a thermistor thermometer in a room at a temperature of about 24°C. Nail pressure tests were done at II, III and IV finger nails using a Rouken nail pressure tester (Type III, Takei Co., Japan) with an automatic time counter. The nail pressure test consists of pressing the nail for 10 sec with 2 kg of pressure using a metal disc with a diameter of 8 mm, then measuring the time it takes for blood flow to recover after the pressure is reduced. The reaction time of the finger nail pressure test is the recovery time after pressure is reduced. The vibration sensation threshold was measured at II, III and IV fingers at 125Hz with a Rion AU-02B vibration sensation meter (Rion Co., Japan). Method of vibration sensation threshold meter is to put the fingertip on a plate with a 15-mm diameter, which vibrates at 65, 125 or 250 Hz, and increases gradually intensity of vibration until the subject feels the vibration sensation, then measuring the intensity of vibration.

These values were evaluated with reference to the standard values of the Forestry and Timber Manufacturing Labour Accident Prevention Association of Japan\(^11\) to classify the hazard of finger caused by local vibration. According to the results of the state of Raynaud’s phenomenon, finger skin temperature, hand grip strength, nail pressure test and vibration sensation, subjects were classified into A and B groups; A group was normal or slight disorder and B group was disorder or illness.

Statistical analyses focusing on differences among the groups or fingers were conducted by application of a t-test. The relationships between finger functions were analyzed by linear correlation. In this study, a p value of less than 5% was considered to be significant.

**Results**

Table 1 shows the physical characteristics of the subjects. The numbers in A group were 55 people and 37 people in B group. There was no significant difference between the mean age of A and B groups. Mean values of body height and weight of A group were higher than those of B group (p<0.05). Blood pressures of B group tended to be higher than those of A group. Diastolic blood pressure of B group was significantly higher than that of A group (p<0.05).

Table 2 shows working days, working hours, the state of using of chain saw machine and so on. Working days per year and days using chain saw of A group tended to be more than B group. There was a significant difference between both groups in using day of chain saw per year (p<0.01). However, working hours per day and hours using chain saw in a day of A group tended to be less than B group. There was a significant difference between both groups in working...
Mean maximum hand grip strength (± SD) of A group was 41.31 ± 6.73 kg for the right hand (dominant hand) and 41.12 ± 6.48 kg for the left hand (non-dominant hand). Mean maximum hand grip strength of B group was 35.62 ± 5.93 kg for the right hand and 35.41 ± 5.44 kg for the left hand. There were significant differences between hand grips of A and B groups (p<0.01).

Figure 1 shows the relative hand grip strength (hand grip strength/body weight) of A and B groups. The mean maximum values of the relative hand grip strength of the subjects were 64.1 ± 10.2% for the right hand and 63.7 ± 9.3% for the left hand. Hand grip strength decreased with the lapse of time. The decrease tendencies of the left hand grip strengths were larger than those of the right hand. The decrease ratio (D.R.) was calculated by following equation:

\[ D.R. = \frac{(Hg_f - Hg_i)}{Hg_f} \]

where D.R. = decrease ratio

\( Hg_f \) = hand grip strength at first time

\( Hg_i \) = hand grip strength at final time

The decrease ratio of the left hand in A group was 6.72%, while that of the right hand was 2.25%. The decrease ratio of the left hand in B group was 6.98%, while that of the right hand was 4.98%. The decrease ratios of the left hand were bigger than those of the right hand in both groups. Moreover, the decrease ratios of B group were bigger than those of A group of both hands. There were significant differences between the relative hand grip strengths of the right and left hands in A group on the 2nd to 5th times (p<0.01), but in B group on only the 5th time (p<0.05).

Table 3 shows the mean values of skin temperatures at II, III, IV and V fingers of each group. The average values of the finger skin temperatures of A group ranged from 29.7 to
30.5°C. On the contrary, the average values of the finger skin temperatures of B group were lower, and ranged from 26.2 to 26.9°C. In B group, skin temperatures of the right-hand fingers tended to be higher than the temperatures of the left-hand fingers at each finger. Right II finger skin temperature was significantly higher than left II finger skin temperature (p<0.05). In A group, II finger skin temperatures were significantly lower than the values of other fingers at each hand (p<0.01). But, there were no clear tendencies among finger skin temperatures of A group. The correlation coefficients among skin temperatures of the fingers were high and ranged from 0.97 to 0.87 (p<0.01).

Table 4 shows the results of nail pressure test of II, III and IV finger nails. Reaction time of right IV finger of A group was the fastest; 0.487 ± 0.170 seconds. On the other hand, the time of left IV finger of B group was the slowest; 0.636 ± 0.295 second. Reaction times of B group were generally slower than A group at each finger (p<0.01).

<table>
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<tr>
<th>Table 4. Reaction times in finger nail pressure test</th>
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<tr>
<td>A group (N=55)</td>
</tr>
<tr>
<td>right finger</td>
</tr>
<tr>
<td>(sec)</td>
</tr>
<tr>
<td>II 0.520 ± 0.216</td>
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<tr>
<td>III 0.524 ± 0.341</td>
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<tr>
<td>IV 0.487 ± 0.170</td>
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<td>Mean ± SD, *p&lt;0.05, **p&lt;0.01.</td>
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Mean ± SD, *p<0.05, **p<0.01.

Reaction times of the right fingers tended to be faster than those of the left fingers in A group. But, there were no significant differences among finger nail pressure test values at each group. The correlation coefficients among nail pressure reaction times of II, III and IV fingers of the left hand ranged from 0.73 to 0.58 (p<0.01, Fig. 2), but the correlation coefficients among fingers of the right hand were rather lower and ranged from 0.63 to 0.28.

Table 5 shows vibration sensation threshold of II, III and IV fingers at 125 Hz. Vibration sensation values of A group ranged from 3.0 to 7.0 dB, and the values of B group ranged from 7.4 to 10.9 dB. There were significant differences between each finger of A and B group (p<0.01). Vibration sensation values of right II finger of A group were the best; 3.05 ± 4.99 dB. On the other hand, the values of left IV finger of B group were the worst; 10.81 ± 7.05 dB. Index finger was the most sensitive and IV finger was the least sensitive in each group. There were significant differences

<table>
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<th>Table 5. Vibration sensation thresholds of fingers</th>
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<tr>
<td>A group (N=55)</td>
</tr>
<tr>
<td>right finger</td>
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<tr>
<td>(dB)</td>
</tr>
<tr>
<td>II 3.05 ± 4.99</td>
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<tr>
<td>III 4.82 ± 5.09</td>
</tr>
<tr>
<td>IV 7.00 ± 5.10</td>
</tr>
<tr>
<td>left finger</td>
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<tr>
<td>(dB)</td>
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<tr>
<td>II 3.46 ± 4.17</td>
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<tr>
<td>III 4.23 ± 4.18</td>
</tr>
<tr>
<td>IV 6.41 ± 4.97</td>
</tr>
<tr>
<td>Mean ± SD, *p&lt;0.05, **p&lt;0.01.</td>
</tr>
</tbody>
</table>

Mean ± SD, *p<0.05, **p<0.01.
among each right-hand finger of A group (p<0.01). But, there were no significant differences between vibration sensation thresholds of left II and left III finger at each group. The correlation coefficients among the fingers of the right hand were over 0.8, and the correlation coefficients among the fingers of the left hand were rather lower and ranged from 0.81 to 0.68. The correlation coefficients among the fingers of the right and left hands ranged from 0.79 to 0.65.

In the relationships among other items of physical examination, there were significant correlation coefficients between finger skin temperatures and reaction times of nail pressure test of the fingers. The correlation coefficients between finger skin temperatures and reaction times of nail pressure test of right II finger were rather higher and ranged from −0.45 to −0.39 (Fig. 3). The correlation coefficients between relative hand grip strengths and vibration sensation thresholds of the right fingers were rather low and ranged from 0.26 to 0.21. There were few significant correlation coefficients among other items.

In this study, there were many middle and elderly workers. The items which showed significant correlation coefficients to age, were body height (r=−0.50), body weight (r=−0.25), blood pressure (r=0.37 and 0.28), vibration sensation threshold (r=0.33−0.41) and relative hand grip (r=−0.24−−0.38). There were a few significant correlation coefficients between age and finger skin temperature or nail pressure test values.

**Discussion**

Local vibration is a common condition around forest work, heavy industrial machinery and so on. The possible harmful effects of such vibration are a matter of real concern. Harmful effects might occur in terms of either physical injury and health hazards or impairment of work efficiency and safety. Certain aspects of vibration damage have received much attention. Two prime examples are noise-induced hearing loss and so-called white finger syndrome, which is associated with the use of vibrating hand tools.

In the seven-year follow-up study (1978–1985) of white finger symptoms and radiographic wrist findings in lumberjacks, J.Kivekas et al. reported that the prevalence of white finger symptoms was 16.9% in 1978 and 24.9% in 1985 in Finland, and that white finger symptom was still a problem among lumberjacks who started chain saw work before 1970. However, severe damage by local vibration such as white finger syndrome has recently decreased in Japan. One of the reasons is improvement of vibrating hand tools such as chain saws, which became smaller and lighter with a decrease in the grade of the vibration.

The ageing process brings about changes in physical abilities or anthropometry of people. The values for grip strength, forced vital capacity and vertical jump decrease, while blood pressure increases with increasing age, although health states and daily life habits affect physical ability and fitness. Today, forest workers must work till a more advanced age than in the past, because there are fewer young forest workers. The ageing of forest workers has become a serious problem in Japan. In the present study, mean age of forestry workers was 55.3 years old, ranged from 24 to 76 years old. Especially the subjects in B group were old, as shown in Table 1. Blood pressure of B group was higher than A group. Some workers used habitually an anti-hypertension medicine. Elderly people became easily ill with hard work conditions or severe environment. The correlation coefficients between age and certain items were rather high, especially to vibration sensation and relative hand strength.

Mean hand grip strength of A group was about 41 kg and about 35 kg for B group; mean relative hand grip strength (hand grip strength/body weight) was 64% for A group and 62% for B group respectively. A fatigue phenomenon showed up over five repeat measurements of grip strength with the loss being 0.9–0.3 kg for the left hand and 0.7–0.0 kg for the right hand; the values of the relative hand grip strength were 1.6–0.5% for the left hand, and 1.2–0.1% for the right hand.

The experimental results obtained by Hamilton et al. showed that hand muscles became fatigued over three repeat measurements of grip strength, with a loss of approximately 2 kg per grip with a 100% effort, and that the hand grip strength of male sedentary workers (mean age; 38.2 years) was 43.35 ± 7.02 kg. On comparison of the mechanical properties in the dominant and non-dominant hand, the results of Davies et al. indicate that the muscle in the dominant hand has a slower twitch and is less fatigable than the muscle in the non-dominant hand. In the present study, the hand grip strengths of B group were significantly lower than A groups, and the decrease ratios of B group and in the left hand were bigger. Therefore, the hands of B group became easily fatigued as compared with the hands in A group, and the left hand (non-dominant hand) became easily fatigued as compared with the right hand (dominant hand). Comparing the grip strength and relative strength, relative strength is thought to be a better indicator as a reference to body weight.

Standard values or levels of the finger skin temperature,
hand grip strength and so on have been proposed for physical examination of workers using local vibration tools such as forest worker. According to the standard of Forestry and Timber Manufacturing Labour Accident Prevention Association of Japan, finger temperature below 30°C is abnormal, vibration sensation threshold above 7.5 dB is abnormal, and nail pressure test above 2.0 sec is abnormal. Hand grip strength below 45 kg is abnormal for the dominant hand, and below 42 kg is abnormal for the non-dominant hand, and there are the special limit values for grip strength in the case of individuals over 50 years old.

In the present study, physical examination was done in a room with a temperature of about 24°C. The mean values of finger skin temperatures were about 30°C in both hands of A group, and about 26°C in the hands of B group. Finger skin temperatures of B group were significantly lower. There were differences among fingers on vibration sensation threshold. The sensations of II finger were sharper than IV finger. Mean values of vibration sensation of B group were almost below 7.5 dB, especially the values of IV fingers were low. There were similar tendencies in the nail pressure test and finger temperatures, which were thought to show the state of blood circulation. The reaction time in nail pressure test of the right finger of A group was rather faster than the left finger. These values of nail pressure test were generally faster than the standard values. One of the reasons was that many subjects were older. Standard values for measuring items in the elderly for ageing are needed.

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