

## RAYNAUD'S PHENOMENON OF FINGERS AND TOES AMONG VIBRATION-EXPOSED PATIENTS

NORIKUNI TOIBANA<sup>1</sup>, NOBUHIDE ISHIKAWA<sup>1</sup>, HISATAKA SAKAKIBARA<sup>2</sup>  
and SHIN'YA YAMADA<sup>2</sup>

<sup>1</sup>*Department of Internal Medicine, Tokushima Kensei Hospital, Tokushima, Japan*

<sup>2</sup>*Department of Public Health, Nagoya University School of Medicine, Nagoya, Japan*

### ABSTRACT

Eleven patients with Raynaud's phenomenon of the toes as well as the fingers were encountered among about 1,000 vibration-exposed patients. They consisted composed of four chain-saw operators, five rock drillers, a stone quarrier and a welder in a shipyard. All the cases were examined carefully for differential diagnosis, but there were no particular abnormalities in hematological, immunological and homodynamic examinations. The rock drillers, quarrier and welder had direct vibration exposure of the foot, which was considered to be responsible for their Raynaud's phenomenon of the toe. Four chain-saw operators, who had been little exposed to vibration of the foot directly, were examined further on skin temperature of fingers and toes every three hours except at night and in a 30-min cold provocation test at 5°C. The skin temperature of both their fingers and toes was lower than in age-matched healthy controls. The chain-saw operators started to work in the 1960's and early in the 1970's, when the chain saw vibration level was high. It is, hence, considered that they were exposed to strong vibration of the hand from chain saws, and then suffered severe Raynaud's phenomenon of both fingers and toes.

Key Words: Vibration, Raynaud's phenomenon, Finger, Toe

### INTRODUCTION

Loriga<sup>1)</sup> was the first to report Raynaud's phenomenon of the fingers due to hand-arm vibration among quarriers in 1911. Many reports followed on Raynaud's phenomenon of the finger among workers who use vibrating tools such as chain saws, rock drills, and chipping hammers etc. There have also been several reports of patients with Raynaud's phenomenon of the toe.<sup>2-7)</sup> Mills reported in 1942 a pneumatic hammer operator with Raynaud's phenomenon of the toe.<sup>2)</sup> Most cases reported were pneumatic hammer or drill operators who used their foot on the tool and had direct vibration exposure of the foot. Hence, their Raynaud's phenomenon of the foot has been attributed to exposure of the foot to vibration.

The authors also encountered some cases with Raynaud's phenomenon of the toes among vibration-exposed patients with vibration syndrome. In the present study, these cases were examined carefully for differential diagnosis. Particularly Raynaud's phenomenon of the toes of chain-saw operators, who had been little exposed to vibration of the foot directly, were discussed in detail in the present study.

### SUBJECTS AND METHODS

---

Correspondence: Dr. Norikuni Toibana, Department of Internal Medicine, Tokushima Kensei Hospital, 4-1-9, Shimosuketo, Tokushima 770, Japan

Data on patients with Raynaud's phenomenon of the toes were collected from about 1,000 patients with vibration syndrome treated over a 10-year period at four hospitals by the authors and cooperators in Japan. The cases were limited to patients whose Raynaud's phenomenon of the toe was confirmed by a doctor directly or through color photos. Consequently, eleven patients with Raynaud's phenomenon of the toes were identified. The eleven subjects were closely questioned about past history of diseases, present symptoms, history of symptoms relating to vibration syndrome, working conditions including operation of vibrating tools, and the like.

Clinical examinations were done to exclude complications, particularly secondary Raynaud's phenomenon: blood pressure, ECG, immunological and hematological examinations, urine test, etc. The subjects were also examined carefully for chronic obstructive arterial diseases. Their feet were inspected by a doctor, and the ankle pressure index (API) was measured at rest and after jogging 500 m at a rate of 100 m/min, using Doppler rheometer according to Ueno.<sup>8)</sup>

The present cases included four chain-saw operators without exposure of the foot to vibration. The four chain-saw operators were further examined on skin temperature of the forehead, right finger (digit 2) and right toe (digit 2) under two conditions. First, skin temperature was measured at 12, 15, 18, 21, 6, 9, and 12 o'clock, excluding nighttime, in a room with air temperature controlled between 26°C and 27.5°C, together with four age-matched healthy controls (mean age; 60.0, vs. 59.5 for four chain-saw operators). The initial test value at 12 was omitted from analysis. Second, skin temperature was measured when four patients and ten age-matched controls (mean age; 59.7) were at first in a room at 25°C, then in a cold room at 5°C for 30 min, and again in a room at 25°C for 60 min. During the measurements subjects wore light uniform clothing.

## RESULTS

The present eleven cases were composed of four chain-saw operators (case 1–4), five rock drillers (case 5–9), a stone quarrier (case 10) and a welder in a shipyard (case 11), as shown in Table 1. Chain-saw operators (case 1–4) had been little exposed to vibration of the foot, while others (case 5–11) operating rock drills or chipping hammers had got direct vibration exposure of the foot by resting it on the tool.

Seven of among eleven patients noticed the first occurrence of Raynaud's phenomenon in the fingers and toes almost at the same time (Table 1). The others experienced Raynaud's phenomenon in the fingers first and then in the toe. More than half of the patients had frequent attacks of blanching in the fingers and toes in winter (Table 2). In seven patients the blanching extended to all the fingers, including the thumb and all the toes. The frequency and location of blanching in the feet seemed to correlate with those in the hands.

They had no past history of severe ailments and no experience of lead or arsenic poisoning (Table 3). Case 7 and 10 were under treatment for hypertension. Case 9 had a history of spinal fracture from falling down, but after one-month hospital he had no trouble working. Other patients had no particular past history affecting circulation conditions in the lower extremities.

The laboratory data indicated no hematological disorders like cryoglobulinemia, collagen diseases like rheumatoid arthritis, and no metabolic diseases like diabetes mellitus (Table 3). But cases 1 and 3 had slight liver trouble, probably due to alcohol abuse. The ankle pressure index was within the normal limit, suggesting no chronic obstructive arterial diseases in the foot (Table 4).

## RAYNAUD'S PHENOMENON OF FINGERS AND TOES

Table 1. Age, operation of tools and onset of Raynaud's phenomenon in eleven cases with Raynaud's phenomenon of fingers and toes.

Case	Age	Tool	Age at beginning of tool operation	Age at onset of Raynaud's phenomenon		TOT (hours)	Vibration exposure of the foot
				Finger	Toe		
1	56	CS	25	40	50	4,500	(-)
2	58	CS	30	31	31	1,600	(-)
3	59	CS	41	46	46	6,000	(-)
4	65	CS	47	59	59	10,000	(-)
5	60	RD	36	40	57	4,000	(+)
6	76	RD	26	34	34(?)	15,000	(+)
7	55	RD	18	32	32	20,000	(+)
8	51	RD	19	36	36	20,000	(+)
9	55	RD, SC	22	55	55	27,000	(+)
10	61	CB, CH, SC	32	50	53	15,000	(+)
11	60	AC, CB	39	40	53(?)	1,400	(+)

TOT, total operating times; CS, chain saw; RD, rock drill; SC, stone crusher; CB, concrete breaker; CH, chipping hammer; AC, air chipper

Table 2. Location and frequency of blanching attacks

Case	Location				Frequency	
	Finger		Toe		Finger	Toe
	Right	Left	Right	Left		
1	1-5	1-5	1-5	1-5	frequent	frequent
2	1-5	1-5	1-5	1-5	frequent	frequent
3	2-5	2-5	4, 5	4, 5	frequent	frequent
4	1-5	1-5	1-5	1-5	frequent	frequent
5	1-5	1-5	1-5	1-5	frequent	frequent
6	1-5	1-5	1-5	1-5	frequent	frequent
7	1-3	1-3	1-3	1-3	frequent	sometimes
8	1-4	1-4	1-4	1-4	frequent	sometimes
9	-	2	-	2	sometimes	rare
10	-	3, 4	-	3, 4	sometimes	rare
11	4	-	4	-	sometimes	rare

Table 3. Past history of diseases and results of laboratory examinations

Case	Past history of diseases	Smoking Index	Laboratory examination		
			Blood chemistry	RA	Autoantibody
1	—	820	slight liver trouble	—	—
2	—	660	—	—	—
3	—	0	slight liver trouble	—	—
4	—	1020	—	—	—
5	—	860	—	—	—
6	—	0	—	—	—
7	hypertension	800	—	—	—
8	—	505	—	—	—
9	spinal fracture	420	—	—	—
10	hypertension	770	—	—	—
11	gastric ulcer	840	—	—	—

Smoking Index: number of cigarettes per day  $\times$  years

Autoantibodies: anti-NF, anti-DNA, anti-RNP, anti-SS-A, anti-SS-B, anti-Centrom, anti-Scl-70

Table 4. Blood pressure, ECG and ankle pressure index

Case	Blood pressure	ECG	API at rest		API after walk	
			Right	Left	Right	Left
1	142/86	WNL	1.2	1.2	1.2	1.3
2	124/86	WNL	1.2	1.2	1.2	1.2
3	134/78	WNL	1.2	1.1	1.2	1.2
4	146/84	WNL	1.0	1.0	1.1	1.2
5	140/76	WNL	1.0	1.0	1.0	1.0
6	102/60	WNL	1.1	1.1	0.9	1.0
7	142/78	WNL	1.0	1.0	1.0	1.0
8	130/90	WNL	1.1	1.2	1.2	1.2
9	152/86	WNL	1.1	1.1	1.3	1.2
10	158/84	WNL	1.1	1.1	1.2	1.2
11	140/70	WNL	1.2	1.2	1.2	1.2

WNL: within normal limit

API: ankle pressure index. The abnormal values are below 0.7 at rest and lower after walk.

Four chain-saw operators included in the present study were further investigated. The history of symptoms of Raynaud's phenomenon and their working conditions were as follows.

## RAYNAUD'S PHENOMENON OF FINGERS AND TOES

## Case 1: aged 56

The patient began to work with chain saws in 1969. He operated a chain saw for 5 to 6 hours per day, for 240 to 250 days per year. In 1974 at the age of 40, he first experienced Raynaud's phenomenon in his fingers. He also had a strong feeling of coldness in the lower extremities. In 1975 he quit his chain-saw work and underwent treatment. In 1988 he started chain-saw work again, although he still had Raynaud's phenomenon of the fingers. One year later in 1989, at the age of 55, he noticed Raynaud's phenomenon not only in the fingers but also in toes.

## Case 2: aged 58

The patient was engaged in chain-saw work since 1962. He operated a chain saw till late at night, sometimes for nearly 10 hours per day, because he was paid on a piece-rate basis. The number of working days per year was 240. After one and a half years, in the winter of 1963, at the age of 31, Raynaud's phenomenon appeared in both fingers and toes. The attack often occurred in the winter, when he was washing his face, when driving before the heater had warmed up the air, or when riding his bicycle. He quit work in 1980.

## Case 3: aged 59

The patient used a chain saw for 7 years from 1971 till 1977, sawing for 4 to 6 hours a day, 200 to 250 days a year. In the winter of 1976, at the age of 46, he experienced Raynaud's phenomenon in both the fingers and toes. In 1977 he quit chain-saw work and changed his occupation in the mountains, but Raynaud's phenomenon continued to occur frequently in both fingers and toes in winter.

## Case 4: aged 65

The patient had operated chain saws since 1960. He worked 170 days a year, because he was also engaged in part-time farming. During his working, chain-saw operation averaged 6 to 8 hours. He operated a log collecting machine for a short time. Then, in the winter of 1982, at the age of 59, he experienced Raynaud's phenomenon in both fingers and toes simultaneously. Since then, it manifested almost everyday on cold days, and sometimes spread to the soles of the feet. Consequently, he stopped using chain saws in 1984.

All the chain-saw operators under study here started to operate chain saws in the 1960's or early 1970's, when the vibration level of a chain saw was very high. They experienced the initial onset of Raynaud's phenomenon at the age of over 30 after they used a chain saw consistently for about 5 hours per day. Case 2 had a rather short total operating time of 1,600 hours before the first attack of Raynaud's phenomenon, but he worked very hard for nearly 10 hours per day. These patients experienced Raynaud's phenomenon of fingers and toes almost simultaneously, except case 1. The attacks of blanching in the fingers and toes were very frequent in winter, and included all the digits except in case 3.

Fig. 1 shows diurnal change of skin temperature among chain-saw operators and age-matched healthy controls. There was no significant difference at the forehead, but skin temperature of the finger and toe was lower in the patients than the controls during the daytime. Fig. 2 gives the skin temperature change in a cold room at 5°C for 30 min. In the cold room skin temperature of the finger and toe dropped more in the patients than in the controls. When they returned to a room at 25°C, the recovery of skin temperature of the patients was delayed as compared with the controls.

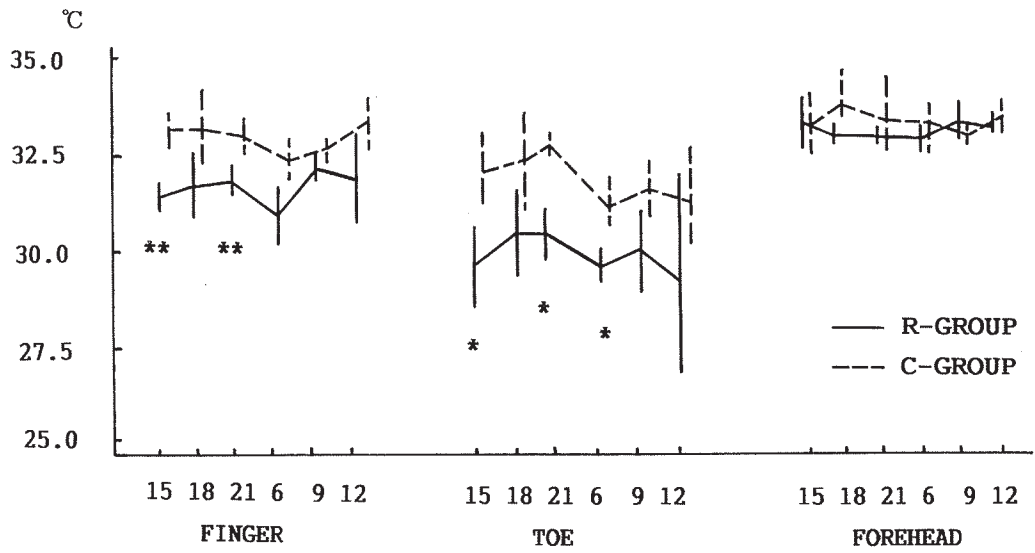


Fig. 1. Diurnal change of skin temperature of the finger and toe (mean  $\pm$  SD). Room temperature was controlled within 26.0°C–27.5°C. \*  $p < 0.05$ ; \*\*  $p < 0.01$ ; statistical differences between the patients and the controls.

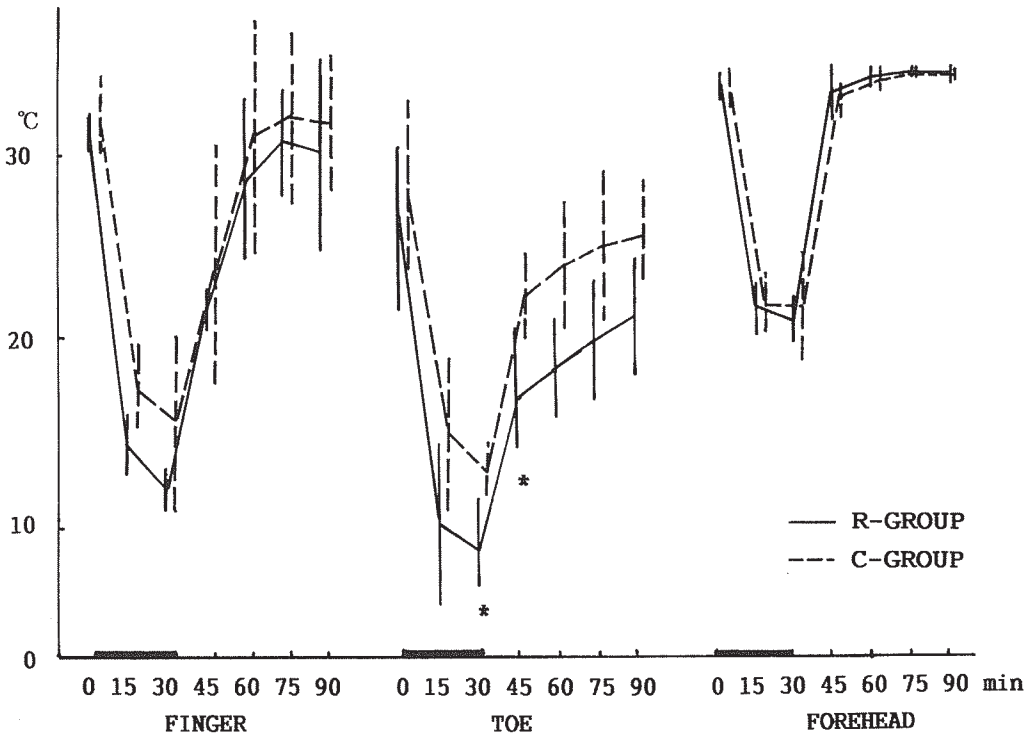


Fig. 2. Skin temperature change with severe cold exposure at 5°C for 30 min (mean  $\pm$  SD). \*  $p < 0.05$ ; statistical differences between the patients and the controls.

## DISCUSSION

The present eleven patients with Raynaud's phenomenon of the toes were encountered among about 1,000 patients with vibration syndrome treated at the authors' and cooperators' hospitals. The present patients were only limited cases whose Raynaud's phenomenon was recognized by physicians directly or through color photos. It is generally difficult to visually identify Raynaud's phenomenon of the toes. Hence, there may well be more patients with Raynaud's phenomenon of the toes.

Raynaud's phenomenon is commonly divided into primary and secondary syndromes. The latter includes some blood disorders, collagen diseases, poisoning, and chronic obstructive arterial diseases as well as vibration syndrome. In the present study, clinical examinations were performed to exclude such diseases, and confirmed that the present patients had no hematological disorders, collagen diseases, metabolic diseases, and chronic obstructive arterial diseases in the foot.

There are several reports on Raynaud's phenomenon of the foot in workers handling vibratory tools.<sup>2-7)</sup> Almost all of the cases involved had direct vibration exposure of the foot. The first report by Mills<sup>2)</sup> in 1942 was of a pneumatic hammer operator. Hedlund<sup>6)</sup> found six cases (22.2%) among twenty-seven miners using rock drills. Their feet were exposed to vibration. Direct exposure of the foot to vibration can be a cause of Raynaud's phenomenon of the toes. In the present study there were five rock-drillers, a quarrier and a welder who had been exposed to vibration by resting their feet on the tool. Their Raynaud's phenomenon of the toes was probably ascribable to direct vibration exposure of the foot.

However, the present study also included four chain-saw operators who only rarely had been exposed to vibration of the foot. They were severe cases with vibration syndrome, because the blanching attacks were very frequent in winter, and all digits were affected, except in case 3. And the skin temperature of both their fingers and toes was lower than in age-matched healthy controls, in accordance with another study.<sup>8)</sup> They all started chain-saw work in the 1960's or early 1970's, when the vibration level of chain saws was high, 50–100 m/s<sup>2</sup>. They used such chain saws very hard for more than 4 hours a day, and subsequently experienced Raynaud's phenomenon in both fingers and toes. No collagen diseases, chronic obstructive diseases, and other diseases causing secondary Raynaud's phenomenon were found in the present clinical examinations for differential diagnosis. It is, therefore, assumed that they were intensely exposed to strong hand-arm vibration from chain saw operation, and then suffered severe Raynaud's phenomenon not only of the fingers but also of the toes.

Vibration exposure of the hand can cause vasoconstriction in the contralateral hand<sup>10,11)</sup> and also in the foot.<sup>12)</sup> It was recently demonstrated that hand-arm vibration activates skin sympathetic nerve activity which consists of vasomotor and sudomotor bursts, and leads to vasoconstriction of the finger and toe.<sup>13,14)</sup> It has been also reported that operation of a chain saw decreases the blood flow in the foot.<sup>15)</sup> Sakakibara et al.<sup>9,16)</sup> indicated the existence of circulatory disturbances both in the upper and lower extremities in patients with Raynaud's phenomenon of fingers, and mentioned that long-term repeated vasoconstriction of the foot induced by hand-arm vibration through the sympathetic nerve system may, together with a cold working environment, contribute to circulatory disturbances of the foot. It is thus possible that hand-arm vibration causes circulatory disturbances in the foot, and worst of all, Raynaud's phenomenon of toes. Strong vibration probably affects the foot more easily.

Another possibility is that the chain-saw operators might have primary Raynaud's disease or a predisposition to it. The first occurrence of Raynaud's phenomenon of case 2–4 took place after almost the same length of exposure in both the finger and toe. But all the cases



experienced Raynaud's phenomenon of both fingers and toes after heavy operation of chain saws with strong vibration in the 1960's and early 1970's. On the other hand, there were no chain-saw operator patients with Raynaud's phenomenon of toes who started to use chain saws after the late 1970's, when chain saw vibration levels were decreased. Hence, the authors considered that such intense exposure to strong hand-arm vibration from chain saws was the main cause of Raynaud's phenomenon of the toes in the present patients, though they might have been predisposed to Raynaud's phenomenon.

Raynaud's phenomenon of the toe is rare when the foot is not exposed to vibration directly. But the present study suggest that intense exposure to strong hand-arm vibration may lead to Raynaud's phenomenon in the foot in some cases.

## REFERENCES

- 1) Loriga, G.: Il Lavoro Coi martelli pneumatici. *Boll Ispert Lavoro*, 2, 35 (1911).
- 2) Mills, J.: Pneumatic hammer disease in an unusual location. *Northwest Med.*, 41, 282–283 (1942).
- 3) Suzuki, Y., Nishiyama, K., Nagayasu, M. and Nishiyama, S.: A case of the occupational Raynaud's phenomenon observed on the foot of vibrating tool operator. *Acta Shikoku Medica*, 22, 70–72 (1966) (in Japanese with English summary).
- 4) Gomibuchi, R. and Ohi, T.: So-called vibration white finger. *Jpn. J. Traumatol. Occup. Med.*, 15, 177–182 (1967) (in Japanese).
- 5) Hashiguchi, T., Sakakibara, H., Furuta, M., Yamada, S., Horio, K. and Toibana, N.: Raynaud's phenomenon in the lower extremities induced by vibration exposure; report of three cases. *Jpn. J. Traumatol. Occup. Med.*, 36, 651–657 (1988) (in Japanese with English summary).
- 6) Hedlund, U.: Raynaud's phenomenon of fingers and toes of miners exposed to local and whole-body vibration and cold. *Int. Arch. Occup. Environ. Health*, 61, 457–461 (1989).
- 7) Toibana, N. and Ishikawa, N.: Ten patients with Raynaud's phenomenon in fingers and toes caused by vibration. In *Hand-Arm Vibration*, edited by Okada, A., Taylor, W. and Dupuis, H., pp.245–248 (1990), Kyoei Press, Kanazawa, Japan.
- 8) Ueno, A.: Chronic obstructive arterial diseases – its diagnosis and treatment. *Nihon-Iji-Shinpo*, 3358, 13–17 (1988) (in Japanese).
- 9) Sakakibara, H., Hashiguchi, T., Furuta, M., Kondo, T., Miyao, M. and Yamada, S.: Circulatory disturbances of the foot in vibration syndrome. *Int. Arch. Occup. Environ. Health*, 63, 145–148 (1991).
- 10) Nasu, Y.: Changes of the skin temperature caused by local vibratory stimulation in normals and patients with vibration syndrome. *Yonago Acta Medica*, 21, 83–99 (1977).
- 11) Färkkilä, M. and Pyykkö, I.: Blood flow in the contralateral hand during vibration and hand grip contraction of lumberjacks. *Scand. J. Work Environ. Health*, 5, 368–374 (1979).
- 12) Kondo, T., Sakakibara, H., Miyao, M., Akamatsu, Y., Yamada, S., Nakagawa, T. and Koike, Y.: Effect of exposure to hand-transmitted vibration on digital skin temperature change. *Ind. Health*, 25, 41–53 (1987).
- 13) Sakakibara, H., Iwase, S., Mano, T., Watanabe, T., Kobayashi, F., Furuta, M., Kondo, T., Miyao, M. and Yamada, S.: Skin sympathetic activity in the tibial nerve triggered by vibration applied to the hand. *Int. Arch. Occup. Environ. Health*, 62, 455–458 (1990).
- 14) Okada, A., Naito, M., Ariizumi, M. and Inaba, R.: Experimental studies on the effects of vibration and noise on sympathetic nerve activity in skin. *Eur. J. Appl. Physiol.*, 62, 324–331 (1991).
- 15) Hashiguchi, T., Sakakibara, H. and Yamada, S.: Changes of skin blood flow in the fingers and dorsum of the foot during chain saw operation. In *Hand-arm vibration*, edited by Okada, A., Taylor, W. and Dupuis, H., pp.133–135 (1990), Kyoei Press, Kanazawa, Japan.
- 16) Sakakibara, H., Akamatsu, Y., Miyao, M., Kondo, T., Furuta, M., Yamada, S., Harada, N., Miyake, S. and Hosokawa, M.: Correlation between vibration-induced white finger and symptoms of upper and lower extremities in vibration syndrome. *Int. Arch. Occup. Environ. Health*, 60, 285–289 (1988).