

**Original**

# CAPILLAROSCOPY OF FINGER NAILFOLD AS A TOOL FOR STUDYING PERIPHERAL CIRCULATION DISORDERS IN HAND-ARM VIBRATION SYNDROME

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## Abstract

Two hundred and ninety-four vibration-exposed workers were examined for hand-arm vibration syndrome (HAVS) or vibration disease (VD) for the worker's accident compensation. Most subjects were male. Their ages ranged from 24 to 68 years. Duration of vibration exposure ranged from 3 to 30 years. After acclimatization at 25°C to 27°C for at least an hour, the nailfold capillaries of the ring (or middle) finger were studied with a light microscope. A cold provocation test (5°C, 10min) was then performed. The morphological findings of the nailfold capillaries were classified based on the criteria by Fagrell & Lundberg. A hundred and eighty subjects were diagnosed as VD and 75 as nonVD, even without taking the capillaroscopic findings into consideration. The classification of the capillaroscopic findings retrospectively investigated were as follows, i.e. in 98 VD subjects 40 cases were stage A, 42 stage B, and 16 cases stage C. In 26 non VD subjects 13 cases were stage A, 10 stage B, and 3 cases stage C, respectively. When the borderline of VD and nonVD existed between stage A and stages B and C, the sensitivity was 59.2%, specificity was 50.0%, and false positive and negative were 50.0% and 40.8%. Among 95 VD subjects, relationship between capillary stages and recovery rates (%) of the skin temperatures during the cold provocation test was also studied. The recovery rate in stage C was not always lower than that in stage A. Similarly, the wave heights of plethysmograms were not always of differential diagnostic use as the skin temperatures as far as the present classification of capillary stages was adopted. Among them, the arteriography of fingers and hands had been independently performed in 57 cases. Despite the use of vasodilator, markedly delayed perfusion of the finger tips was observed in 28 cases. Their capillary stages were A in 12 cases, B in 11 and C in 5. In effect, the peripheral microcirculatory stage in VD should be carefully evaluated in combination with appropriately selected examinations including finger nailfold capillaroscopy.

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## — Key words —

capillaroscopy, hand-arm vibration syndrome (HAVS), occupational Raynaud's phenomenon

## Introduction

The objective evaluation of peripheral circulatory disorders is essential for the diagnosis of hand-arm vibration syndrome (HAVS) or vibration disease (VD) especially in the case of worker's accident compensation. However, to confirm directly the Raynaud's phenomenon in such workers in daily clinical practice at an occupational disease clinic or hospital is very rare. For the purpose of quantitative evaluation of this pathological state, the cold provo-

cation test has been adopted by the Ministry of Labour of Japan. This test reflects changes and distributions of the skin temperature of the fingers and hands and it is more effectively implemented when thermography is combined<sup>1)</sup>. Plethysmography and arteriography reflect digital arterial blood flow, although the latter is invasive. In contrast, the capillaroscopic examination is able to noninvasively investigate both morphological and hemodynamic states of the superficial microcirculation.

In this report, the nailfold of the fingers of vibration-exposed workers with the complaints of vibration-induced white finger (Raynaud's phenomenon), numbness, pain, and so on, was used for studying morphological changes of finger nailfold capillaries, and the clinical usefulness of this approach was studied with reference to skin temperature measurement, its recovery, and plethysmography during the cold provocation test and the arteriography of fingers and hands.

### Subjects, apparatus and methods

#### Subjects

During 3.5 years, 294 workers in forestry, mining, construction industries, concrete plant and so on had a detailed examination for VD for the worker's accident compensation. Most of the subjects were male. Their ages ranged from 24 to 68 years. Profiles of these workers are shown in the table (Table 1). According to the diagnostic criteria of VD by the Japanese Ministry of Health, Labour and Welfare, 180 subjects were diagnosed as VD and 75 subjects as non VD without taking the results of capillaroscopy into consideration. The capillaroscopic recordings from 98 VD subjects were retrospectively compared with those of 26 nonVD subjects.

#### Capillaroscopy and diagnostic criteria

After acclimatization at 25°C to 27°C for at least an hour, the nailfold capillaries of the ring (or middle) finger were studied with a light microscope (a FSC Photographic Apparatus of Cutaneo-Mucous Blood Vessel, Fuji Kogyo Co. Ltd., Tokyo) with a magnification of 53x. The capillaroscopic findings were recorded with a Polaroid Camera. The morphological finding of the nailfold capillaries were classified based upon the criteria by Fagrell & Lundberg<sup>2)</sup>:

Stage A: dot or comma shaped appearance with good tonicity, with less tonicity and/or marked dilatation and sometimes micropools of the capillaries,

Stage B: indistinct capillaries (e.g. edema, sclerosis) and/or capillary hemorrhages, and

Stage C: only a few or no visible capillaries.

#### Cold provocation test

After the capillaroscopic examination of the finger nailfold, the cold provocation test (5°C for 10 min) was performed. The plethysmography was performed by the Photo-plethysmograph PT-300 (FUKUDA DENSHI Co. Ltd., Tokyo). The skin temperature, its recovery rate (%) and the wave height of the plethysmogram were determined before and after the cooling at time 0, 5 and 10 min.

#### Arteriography of the upper extremities

Among these vibration-exposed workers, 57 subjects were further examined by arteriography of fingers and hands under general anaesthesia. After an intra-arterial administration of Tolazoline as a vasodilator, serial auto-

**Table 1** Profiles of the vibration-exposed subjects

	VD	nonVD	Statistical significance *
n	98	26	
Age (M ± SD) (years)	53.9 ± 7.7	52.4 ± 8.8	n.s.
Vibration exposure (M ± SD) (years)	20.1 ± 8.4	15.5 ± 8.4	P < 0.05
Raynanud's phenomenon	90.8%	19.2%	P < 0.001
Smoker	66.3%	50.0%	n.s.
Occupations			
Forestry	17.3%	19.2%	
Mining	54.1%	38.5%	
Construction industry	14.3%	15.4%	
Concrete plant	6.1%	11.5%	
Others	7.1%	15.4%	

\* Wilcoxon rank sum test and chi-square test

mated arteriograms were taken at two exposures per second following an intra-arterial administration of 60% Urografin<sup>3)-5)</sup>.

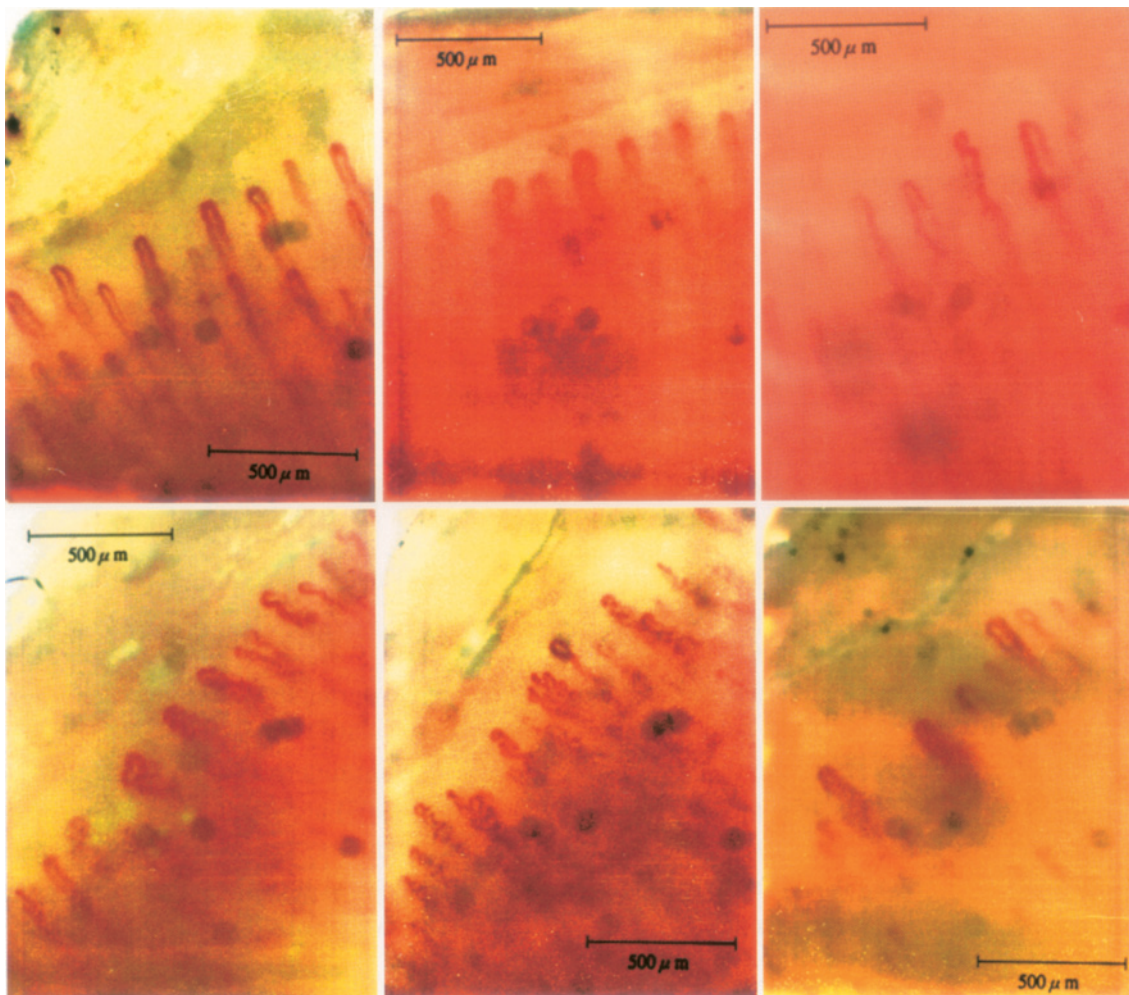
## Results

### Capillary stages and diagnosis of VD

Some examples of the finger nailfold capillaries obtained from vibration-exposed workers were demonstrated in Figure 1. According to the above mentioned criteria<sup>2)</sup>, capillary stages in 98 VD and 26 nonVD subjects were classified as shown in Table 2. The capillaroscopic findings of these subjects were classified according to the worst stage found in the finger. When the borderline of VD and nonVD existed between stage A and stages B and C, the sensitivity was 59.2%, specificity 50.0%, positive and negative predictive values 81.7% and 24.5%, false positive 50.0% and false negative 40.8%.

### Skin temperature and capillary stages

The relationships between capillary stages and recovery rates (%) of the skin temperatures during the cold provocation test were studied in 95 VD subjects (Table 3). The skin temperature and its recovery rate in stage C



**Fig. 1** Demonstrable capillarograms in six male VD subjects

[Top]

left: N.S. (66) Chainsaw for 15 years, 10 cigarettes/day for 36 years.

center: M.N. (29) Jackhammer for 4.5 years, 25 cigarettes/day for 9 years.

right: Y.T. (50) Airpick & jackhammer for 18 years, non-smoker.

[Bottom]

left: S.I. (56) Chainsaw, jackhammer & vibrator for 10 years, non-smoker.

center: F.K. (56) Jackhammer for 16.5 years, non-smoker.

right: M.N. (54) Chainsaw & air pick for 23 years, 20 cigarettes/day for 29 years.

**Table 2** Capillary stages of the finger nailfold in vibration-exposed workers

Stage of capillary morphology *	VD n = 98	nonVD n = 26	chi-square test
A	40 (40.8)	13 (50.0)	n.s.
B	42 (42.9)	10 (38.5)	n.s.
C	16 (16.3)	3 (11.5)	n.s.

Number of subjects (%)

\* Classification by Fagrell, B., &amp; Lundberg, G. (1984)

**Table 3** Finger skin temperatures and their recovery rates (%) during the cold provocation test in 95 VD subjects

Capillary stage	No. of subjects	Skin temperature (°C)				Recovery after cooling (%)	
		Before cooling	Time after cooling (min)			5 min	10 min
			0	5	10		
A	41	32.9 ± 1.9 (23.9 ~ 35.2)	7.9 ± 1.8 (5.5 ~ 11.8)	23.6 ± 4.6 (16.5 ~ 33.4)	27.5 ± 3.7 (20.2 ~ 34.3)	63.4 ± 16.6 (37.4 ~ 93.5)	78.7 ± 13.3 (49.3 ~ 101.0)
B	40	32.4 ± 2.3 (25.1 ~ 35.3)	7.9 ± 1.8 (5.5 ~ 11.8)	22.4 ± 4.0 (15.8 ~ 32.3)	26.2 ± 4.1 (16.7 ~ 33.4)	59.6 ± 15.0 (37.1 ~ 94.5)	74.7 ± 14.4 (42.0 ~ 99.5)
C	14	32.2 ± 2.6 (25.7 ~ 35.7)	7.8 ± 2.5 (5.8 ~ 16.0)	23.6 ± 4.7 (15.3 ~ 32.2)	27.8 ± 4.1 (18.7 ~ 33.3)	65.5 ± 15.4 (37.2 ~ 94.7)	82.6 ± 13.6 (50.8 ~ 100.0)

Mean ± S.D. with range in parenthesis

**Table 4** Wave heights of plethysmograms during the cold provocation test in 95 VD and 25 nonVD subjects

Capillary stage	Diagnosis of VD	Number of subjects	Before cooling	After cooling		
				0 min	5 min	10 min
A	VD	41	4.0 ± 1.8 <sup>a)</sup>	1.5 ± 0.9	2.7 ± 1.4	4.1 ± 2.1
	nonVD	12	5.1 ± 2.2 <sup>a)</sup>	1.9 ± 0.8	3.3 ± 2.3	4.3 ± 2.4
B	VD	40	4.2 ± 2.5	1.4 ± 1.1 <sup>b)</sup>	2.8 ± 1.9	4.1 ± 2.5
	nonVD	10	4.4 ± 2.0	2.3 ± 1.3 <sup>b)</sup>	3.6 ± 2.2	4.1 ± 1.6
C	VD	14	5.0 ± 2.6	1.5 ± 1.1	3.1 ± 1.8	4.4 ± 1.7
	nonVD	3	3.8 ± 0.7	2.1 ± 0.7	3.1 ± 1.3	3.6 ± 1.7

M ± SD mV/V, <sup>a)</sup> P < 0.05, <sup>b)</sup> P < 0.05

(severely diseased) group were sometimes higher than those in stage A (slightly diseased) group, that is to say, the parameters in stage C were not always lower than those in stage A.

#### Plethysmography and capillary stages

The wave-heights of the finger plethysmogram were also determined during the cold provocation test. There were statistically significant correlations between skin temperatures and wave heights at all check points before and after test (n=95) (p<0.01). Although there were statistically significant differences of wave-heights between VD and nonVD before cooling in subjects with the capillary stage A (p<0.05) and 0 min after cooling in subjects with stage B (p<0.05), such a tendency was not consistent with those at other check points and those in subjects with stage C (Table 4). When studied as a mass, plethysmography, as well as skin temperature measurement, was essentially of little value as a single test from the differential diagnostic viewpoint as far as the present classification of capillary stages was adopted (Table 3, 4).

#### Arteriographic findings, capillary stages, and physiological parameters

Among 98 VD subjects, the arteriography had been independently performed in 57 cases (Table 5). Slight and mild arteriographic findings were observed in 29 subjects and their capillary stages were A in 15 cases, B in 11 and C in 3 (group I). Despite an intra-arterial administration of vasodilator under general anaesthesia, markedly delayed perfusion of the finger tips or severely diseased finger arteries was observed in 28 subjects and their capillary stages were A in 12 cases, B in 11 and C in 5 (group II). Then, each group was rearranged according to capillaroscopic findings such as group (A) and group (B+C)<sup>2)</sup>. Among these 4 groups, the morphological state of peripheral circulation in group I (A) was the slightest and the group II (B+C) was the severest.

**Table 5** Figner skin temperatures and their recovery rates(%)during the cold provocation test in 57 VD subjects with reference to arteriographic findings

Capillary stage	No. of subjects	Skin temperature (°C)				Recovery after cooling (%)	
		Before cooling	Time after cooling (min)				
			0	5	10	5 min	10 min
Group I (29 subjects with slight and mild arteriographic findings)							
A	15	33.3 ± 1.1	7.9 ± 1.6 <sup>a)</sup>	24.6 ± 5.2	28.4 ± 3.6	65.8 ± 18.4	80.5 ± 13.6
B + C	14	32.8 ± 1.4	9.1 ± 2.7 <sup>a)</sup>	23.9 ± 4.9	27.9 ± 4.4	64.1 ± 17.6	80.2 ± 16.5
Group II (28 subjects with severe arteriographic findings)							
A	12	32.1 ± 2.9	8.0 ± 1.8	23.2 ± 3.6	26.7 ± 3.6	63.1 ± 13.1	77.0 ± 9.5
B + C	16	32.6 ± 2.0	7.5 ± 1.3	22.4 ± 4.3	26.0 ± 4.3	59.8 ± 15.5	73.3 ± 14.3

Mean ± S.D, a) P &lt; 0.05

**Table 6** Wave heights of plethysmograms during the cold provocation test in 57 VD subjects with reference to arteriographic findings

Capillary stage	Number of subjects	Before	After cooling		
			0 min	5 min	10 min
Group I (29 subjects with slight and mild arteriographic findings)					
A	15	4.4 ± 1.8	1.7 ± 1.1	2.8 ± 1.5	4.5 ± 2.0
B + C	14	4.9 ± 2.7	1.9 ± 1.3	3.4 ± 2.3	4.4 ± 2.1
Group II (28 subjects with severe arteriographic findings)					
A	12	3.3 ± 1.4	1.7 ± 0.8	2.8 ± 1.1	3.7 ± 1.5
B + C	16	4.5 ± 2.4	1.4 ± 1.0	2.8 ± 1.9	4.3 ± 2.3

M ± SD mV/V

These morphologically classified group of subjects were then studied with reference to physiological parameters; i.e. skin temperatures (Table 5) and wave heights of plethysmograms (Table 6). Even though there was a statistically significant difference of skin temperature between subjects with stage (A) and stage (B+C) in group I (29 mild and slight arteriographic findings) at time 0 min after cooling ( $p < 0.05$ ), the parameters, such as skin temperature and its recovery rate, wave height of plethysmography, and arteriographic findings were difficult to correlate with the classification of the capillary stages when they were studied as a mass (Table 5, 6).

## Discussion

In the present investigation, clinical diagnostic usefulness of capillary microscopic examination in VD was studied with reference to both morphologically by arteriography and physiologically by the cold provocation test in combination with plethysmography of fingers. In some cases as demonstrated in the figure, it is obviously effective to show directly the abnormalities of capillary vessels (Fig. 1). In spite of our diversified analysis, however, diagnostic usefulness of finger nailfold capillaroscopy was not clearly demonstrated when studied as a mass. Although Fagrell & Lundberg's classification adopted in the present investigation as a standard measure is of value in the case of occlusive arterial diseases of toes and feet such as arteriosclerosis obliterans<sup>2)</sup>, their classification seems to be difficult to apply directly to the VD.

In our earlier studies on arteriography of fingers and hands following an intra-arterial administration of vasodilator in 384 vibration-exposed workers, several findings were observed, such as coiling, tapering, tapering-off, localized stenosis, and stenosis and obstruction with by-pass formation, which indicated mainly organic changes of the finger arteries<sup>3)-5)</sup>. On the other hands, Fagrell & Lundberg established a classification of capillaroscopic findings to foresee the prognosis of necrosis in arteriosclerosis obliterans<sup>2)</sup>. However, tonicity of arteries and arterioles also reflects the state of autonomic nervous function. Cold provocation test reflects peripheral vascular responsiveness to the cold including disorders of nervous function and sclerotic changes of blood vessels. From this viewpoint, in addition to the stage A, B and C or the Fagrell & Lundberg's classification<sup>2)</sup>, there should be further func-



tional classification such as stage 0: dot or comma shaped with good tonicity, stage 1: as in stage 0 but with less tonicity, and stage 2: marked dilatation and sometimes micropools in stage A by Fagrell<sup>6)</sup>.

From the physioanatomical stand point of view, the blood volume entering the capillary beds is regulated by the precapillary sphincters located at the ramificating regions of arterioles and metarterioles, and the blood volume passing through the metarterioles is controlled by the tonus of the structural smooth muscles. Vasomotor activity is highly sensitive to thermal and mechanical stimuli especially in the skin. So, when thermoregulation is important, constriction of precapillary sphincters reduces blood volume flowing through the peripheral capillary beds and the metarterioles seems to serve as the by-passing preferential (thoroughfare) channels in order to conserve heat<sup>7)</sup>. Capillaroscopy gives us information concerning above-mentioned functional and organic changes of microcirculation in the nailfold readily and noninvasively.

Peters described concisely the complaints and distribution of signs and symptoms in fingers and hands in a group of workers exposed to hand-held vibrating tools with an extremely high frequency of 25,000 r.p.m. for one to 72 weeks. In that case, dominant hand was affected and the other hand was symptom free and thus served as a control. Using capillaroscopy, instead of the normal hairpin-like loops, he pointed out decrease in number and decided morphologic changes of nailfold capillaries such as small almost occluded vessels which resembled inverted V's and squares in which the corpuscular flow was sluggish or absent<sup>8)</sup>.

Vayssairat et al. compared nailfold capillary microscopic findings between 107 vibration-exposed lumberjacks and 115 non-exposed workers. Main findings were a reduced number of capillary loops at room temperature and abnormal spasm of the digital artery in response to cold such as extinction of capillaries, disappearance of reactive hyperemia and appearance of pericapillary edema. They also found statistically significant differences of such findings between lumberjacks with and without Raynaud's phenomenon in addition to the lowering of the finger systolic blood pressure<sup>9)</sup>. When a client worker is desperate for the workmen's accident compensation, however, such a comparison will be rather impracticable since many of our cases, both VD and nonVD, have subjectively complained of Raynaud's phenomenon (Table 1).

Bossnev et al. proposed four categories of capillary microscopic findings in combination with ultrasonic Doppler flowmetry to obtain functional parameter such as spastic type, atonic type, inverse type, and paralytic type in subjects with vibration disease (VD). They reported that spastic type capillary findings were more characteristic for stage II and III VD cases, and its incidence showed a progressive decrease in stage I VD, dystonic vessels with predominantly spastic tendencies were also observed in stage I VD, and atonic changes were more characteristic for autonomous neuropathy<sup>10)</sup>.

Kusumoto classified the morphology of finger nailfold capillary loops into five categories according to the degree of tortuosity<sup>11)</sup>. In his classification, the findings such as disarrangement and paucity of capillary loops, dilatation and micropools, haemorrhage and pericapillary edema were not included<sup>6)8)-10)</sup>. Their subjects seem to be slight or mild VD cases with reference to Vayssairat et al. and Bossnev et al. since tortuosity of nailfold capillary vessels was observed mainly in mild VD cases<sup>9)10)</sup>.

Although the sensitivity and the specificity of capillaroscopic examination are insufficient as a single test at the ambient temperature for practical clinical use, capillaroscopy is noninvasive and an easily acceptable clinical test which visualizes directly the microcirculatory state of finger nailfold of vibration exposed subjects. For the present time being, we are thinking much of the data obtained by routine clinical examinations and cold provocation test, with reference to presence or absence of capillary abnormalities. However, establishment of another new classification is expected to include both functional and organic abnormalities of the finger nailfold capillary loops. In effect, the peripheral microcirculatory state in VD should be carefully evaluated in each case in combination with appropriately selected clinical examinations including finger nailfold capillaroscopy.

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## 振動障害の末梢循環障害研究手段としての爪床毛細血管像の観察

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### —キーワード—

爪床毛細血管撮影, 振動障害, 職業性レイノー症候群

振動障害 (HAVS, VD) の労災認定のために294名の振動曝露労働者の検査を行った。ほぼ全例が男性で、年齢は24～68歳に分布し、振動曝露の期間は3～30年であった。法定の5℃10分の冷水負荷検査に先立ち、最低約1時間、室温25～27℃に順化した後、環指 (又は中指) の爪床毛細血管を光学顕微鏡で観察した。爪床毛細血管の形態学的所見はFagrell & Lundbergの診断基準によりステージA, B, Cに分類した。

被験者は、爪床毛細血管像とは無関係に、診断基準に従って180名が振動障害 (VD), 75名が非振動障害 (nonVD) と診断され、後日毛細血管像の分類に基づいて検討した結果は以下のとおりであった: 98名の振動障害者 (VD) のうち40名はA (軽症群), 42名はB (中等症群), 16名がC (重症群); 26名の非振動障害者 (nonVD) では13名がステージA, 10名がB, 3名がCであった。VDとnonVDの境界をステージAとステージB+Cの間に設定すると、感度は59.2%, 特異度50.0%, 疑陽性率50.0%, 疑陰性率40.8%であった。爪

床毛細血管像のステージ分類が可能であった95名のVDについて冷水負荷テストでの皮膚温及びその回復率、指尖容積脈波の波高との関係についても検討したが、最も症度の重いステージC群の皮膚温回復率は最も症度の軽いステージA群よりも常に低いとは限らないとの結果であり、脈波高についてもこの分類を用いた場合にはVDとnonVDとの間での鑑別診断上の有用性を見出すことは出来なかった。また、この95名のVDのうち57名では手指の動脈造影検査が行われていたが、血管拡張剤の使用にもかかわらず28名では指尖血管網の画出の著しい遅延が認められた。この動脈造影上の重症例28名の中では、毛細血管像のステージはAが12名, B11名, C5名との結果であった。従って、非侵襲的な爪床毛細血管の顕微鏡検査が極めて有用な症例はあるものの、振動障害における手指末梢循環の状態は爪床毛細血管像を含めて、各症例毎に適切に選択された検査法の組み合わせによって慎重に評価される必要がある。