

# THE ROLE OF NOISE IN THE GENESIS OF VIBRATION-INDUCED WHITE FINGER SYNDROME

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## ABSTRACT

Recent studies reveal that grip forces due to repeated mechanical vasoconstrictions are most significant for the genesis of vibration-induced white finger syndrome (VWF). Therefore, exerted grip force was regarded as a dependent variable in 2 experiments and the effects of noise and vibrations of different weighted acceleration levels were studied. Neither grip forces nor peripheral blood flow as indicated by finger skin temperature were influenced by noise or vibrations. The cause of VWF is therefore presumed to be a concomitant variable which correlates with weighted accelerations and with grip forces as well. A possible factor is the weight of hand-held vibrating tools.

## 1. INTRODUCTION

In the early stages the symptoms of vibration induced white finger syndrome (VWF) are rather unspecific (e.g. numbness). The final stages are characterized by excessive digital vasoconstrictions which are evoked by cold or by emotional stress, typically not during the working hours [3].

Carefully executed epidemiologic studies reveal relative high prevalences of VWF in persons operating hand-held vibrating tools, who are additionally at least temporarily exposed to (seasonal) cold climate. Among them are e.g. forest workers and stone cutters [1].

There are no doubts that frequently experienced vasoconstrictions during occupation cause this specific disease. The analysis of the appropriate work places determined at least 4 factors which are known or at least presumed to cause vasoconstrictions which are indicated in the lab by decreasing skin temperatures. These are

- vibrations where the mechanisms are still not clear,
- exertion of grip forces cause mechanic compressions of the blood vessels,
- noise reduces peripheral blood flow, mediated by excitations of the autonomic nervous system,
- cold climates cause vasoconstrictions as a pure peripheral effect if man is adequately clothed.

To determine the main cause of VWF resp. to assess the weight of those factors which probably contribute to its genesis, the effects of single stressors were separately studied in standardized situations. Subjects were exposed to vibrations where other variables, such as air temperatures, sound pressure levels, posture, exerted grip force were kept constant. As skin temperatures decreased during vibrations in these experiments the latter were believed to cause vasoconstrictions in the acute situation and VWF in the long run.

Recently published papers reveal scarcely correlations between weighted acceleration levels and the extents of vasoconstrictions (as indicated by decreased finger temperatures). Instead, exerted

grip forces were determined as most decisive for actual vasoconstriction and probably for the genesis of VWF as well [4].

But, regarding epidemiologic results, the occurrence of the chronic effect, the incidence of VWF is nevertheless related to the weighted acceleration levels (ISO DIS 5349, 5). These findings lead to the hypothesis that exerted grip forces are - among others - determined by vibrations, and perhaps also by noise, by pushing forces etc.. This assumption was proved in 2 experiments, where exerted grip forces were considered as a dependent variable.

## 2. GENERAL METHOD FOR BOTH EXPERIMENTS

Both experiments were executed in a special chamber with an air temperature of 21 °C. The subjects sat in an upright position in front of a vertical grip. The height of the chair was varied, so that the angle between the upper arm and the forearm was 120 ° when grasping the handle. The temperature of the grip was adjusted to 20 °C. Grip forces as well as skin temperatures at the tips of the 3rd and 4th finger of the exposed right hand were continuously measured throughout the experiments.

The subjects absolved 5 trials in both experiments. After a prephase they exerted a grip force of either 25 N or 50 N which they controlled visually during 30 seconds (control phase). The control instrument for grip force was then turned off and the main phase started. The subjects controlled now for pushing force instead (5 N) using another instrument. But they were requested (to try) to exert the preadjusted grip force until the end of this period. This condition forms the reference trial. In the remaining 4 trials some other stress were applied simultaneously with the onset of the main phase and continued throughout this time. The exertion of grip force without feedback was the main criterion in the present study.

## 3. EXPERIMENT 1

### 3.1 Purpose

Experiment 1 was executed to study the influence of noise, vibrations, and pushing force on exerted grip forces.

### 3.2 Methods

22 healthy, normal hearing and right-handed male students ( $25.1 \pm 2.85$  yrs) participated in 5 systematically permuted trials, which endured 4 minutes each and which were separated by breaks of ever 15 minutes.

The subjects rested first 30 seconds, their hands lying on their thighs (prephase). During the following control phase they adjusted a grip force of 25 N. Apart from the reference trial, either pink noise, vibrations (pink noise), pushing force, or pushing force and vibrations were applied during the main phase which endured 180 seconds. The stress of interest in this paper (noise and vibration) is specified in table 1.

	noise	vibrations
reference	<60 dBA	$a_{hw} = 0$
noise	95 dBA	$a_{hw} = 0$
vibration	<60 dBA	$a_{hw} = 7.5$

Table 1: Experimental conditions

Grip forces were averaged over 3 time spaces of the main phase. These are the 90 %-quantile of the 5th - 30th second, all data of the 60th - 119th, and of the 120th - 179th second (periods 1,2,3, see table 2). Regarding finger tip temperatures, the difference between the last 5 seconds of the prephase and the last 5 seconds of the main phase were calculated. The data recorded during noise or vibrations were statistically compared to those of the reference condition.

### 3.3 Results and discussion

According to figure 1 the subjects adjusted their grip forces perfectly to the predefined value of 25 N as long as they controlled it. After the control instrument is turned off, exerted grip forces increase immediately but transiently in any condition. They decrease first rapidly but the declines become gradually less. At the end of the main phase they are 3-5 N below the baseline. Table 2 presents the averaged grip forces and the average decrease of finger-tip temperatures: The data during noise and vibrations are compared to the reference data and  $p < 0.001$  (\*) is regarded as significant.

The initial increase does not exceed +3 N in the reference trial. The consecutive decline is very slow and grip forces average 20 N at the end of the main phase. Finger skin temperatures decrease of 2.0 K indicating reduced peripheral blood flow.

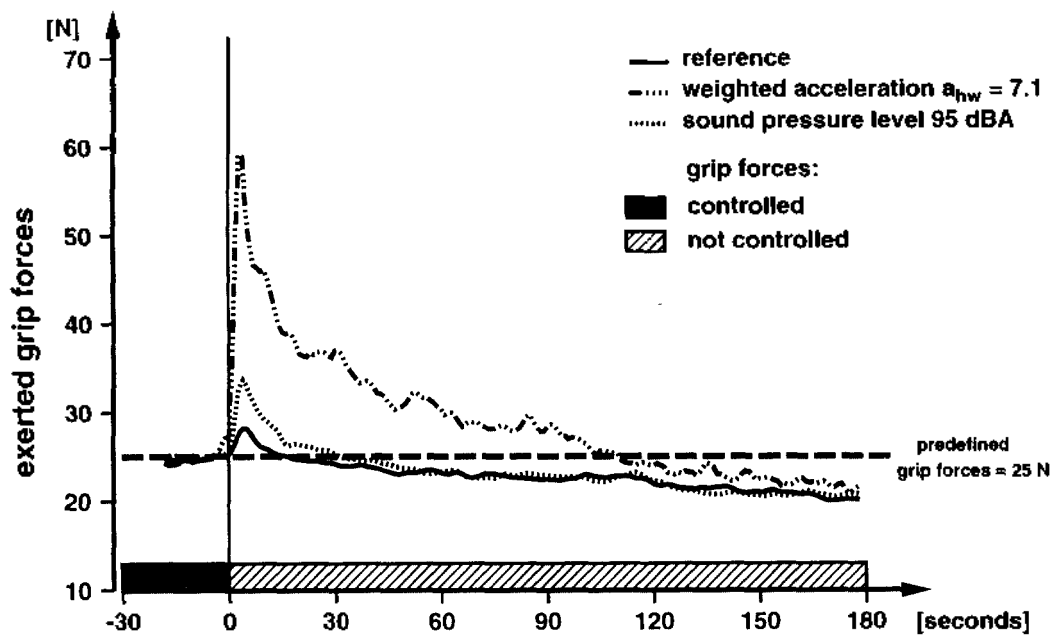


Figure 1: Exerted grip forces under the influence of noise (95 dBA) and vibrations ( $a_{hw} = 7.1$ ). Air temperature 21 °C, grip temperature 20 °C, 22 male subjects (19 - 30 years).

The onset of noise evokes a slightly larger and longer lasting initial increase to not more than +7 N on the average. The consecutive course is almost identical with the course observed in the reference condition and finger skin temperature decrease scarcely more (0.4 K).

The onset of vibrations, however, caused a rather dramatic increase of grip forces which average almost +35 N (moving average over 2 s). The at first rapid decline becomes gradually less and the baseline is reached after about 105 seconds, which is at least 75 seconds later than in the

other 2 conditions. Compared to the reference trial the decrease of skin temperature of 2.8 K is somewhat larger though not significant.

	mean	SD	N	Min	Max
<b>grip forces, period 1 of main phase [N]</b>					
reference	28.0	13.0	22	19.7	84.1
vibration	50.1*	24.8	22	23.7	116.8
noise	30.0	7.4	22	22.8	52.8
<b>grip forces, period 2 of main phase [N]</b>					
reference	21.9	7.1	22	10.8	40.9
vibration	27.0	8.6	22	16.6	49.1
noise	21.8	6.0	22	14.7	34.6
<b>grip forces, period 3 of main phase [N]</b>					
reference	20.2	8.3	22	9.4	45.2
vibration	22.2	8.5	22	9.9	41.1
noise	20.0	6.4	22	12.5	36.7
<b>decrease of finger-tip temperature [K]</b>					
reference	-2.0	2.3	22	4.1	-4.9
vibration	-2.8	1.7	22	0.68	-5.5
noise	-2.4	2.0	22	2.54	-5.5

Table 2

The 'on'-effect in the reference situation results probably from an initial uncertainty due to the offset of the feed-back or to a transient distraction due to the onset of the control meter for pushing force (5 N). If noise occurs, a - still insignificant - startling effect may contribute to the transient increase.

The sound pressure level applied here is undoubtedly beyond the limits where health hazards are avoided. These levels cause noise-induced hearing loss in the long run and evoke extended vasoconstrictions in the acute situation. The latter are mediated by excitation of the autonomous nervous system. If, however, the blood vessels are already mechanically compressed due to exerted grip forces the acoustic stress fails to reduce peripheral blood flow further on via elevated grip force exertion as well as via centrally mediated vasomotor responses. This suggests that noise-induced vasoconstrictions are far less than the mechanic compression of the blood vessels. It is therefore unlikely that noise contributes to the development of vibration-induced white finger syndrome.

Vibrations, on the contrary, induce initially an extensive overshooting increase of grip force exertion, which is significantly larger than in the other trials and - additionally - the increase lasts considerably longer. Therefore, it may be suspected that subjective perception and consecutively the assessment of exerted forces are affected by vibrations. The 'loss of the set value' may be related to the influence of vibrations or merely caused by a startling effect at the onset of vibrations.

Though not significant, skin temperatures decreased slightly more than during the reference trial. The results support - though not strongly - the assumption that vibrations are significant for the genesis of the white finger syndrome. To solve this problem, another experiment was executed and particularly focussed to the effects of weighted accelerations on exerted grip force at 2 predefined levels.

## 4. EXPERIMENT 2

### 4.1 Purpose

This experiment was executed to study the influence of different levels of weighted accelerations on exerted grip forces of 2 predefined levels.

### 4.2 Methods

42 healthy male subjects (18 - 40 yrs) absolved 5 successive, systematically permuted trials which endured 17 minutes each and which were separated by pauses of ever 13 minutes. The

subjects were divided into 2 groups. 20 subjects adjusted a grip force of ever 25 N, 22 adjusted ever 50 N during the control phases (and tried to keep this 'set value' during the main phases).

During the first 3 minutes of each trial the subjects exerted a grip force of 5 N. This 'contact'-phase was followed by 3 identic cycles which endured 180 seconds each and which consisted of again 3 phases. In the first 30 seconds the subjects exerted (still) a force of 5 N, which they controlled visually. In the consecutive 30 seconds (control phase) they exerted the predefined force of either 25 N or 50 N.

The visual control was then turned off but the subjects were requested (to try) to exert the same grip force until the end of the consecutive 120 seconds (main phase). Simultaneously, vibrations were added in 4 experiments. According to the real situation at work but contrary to experiment 1 the onset of the main phase (the onset of vibrations) was announced. One trial was a reference condition where no other stimuli occurred. The very last cycle was followed by a 5 minutes pause.

The weighted acceleration during the main part was  $a_{hw} = 7.1$  in the first trial which was discarded from evaluation. The acceleration levels of the following 4 experiments, namely  $a_{hw} = 0$  (reference), 4.8, 7.1, and 9.5 were systematically permuted.

For statistic comparisons grip forces were averaged over 2 time periods of the main part. These are the 90%-quantile of the 5th - 30th second, and of all the data of the 60th - 119th second (periods 1, 2). The grip forces registered during vibrations were compared to the grip forces as registered during the reference trial. The analysis was performed using a multivariate variance analysis (MANOVA, SAS).

### 4.3 Results and discussion

Grip forces in figure 2 represent the average over the 3 cycles, separately for the 4 acceleration levels. Predefined grip forces were perfectly maintained as long as the subjects controlled it visually. Immediately after the control meter was turned off, however, exerted grip forces increased transiently in any condition. The maximum increase is smallest in the reference condition and largest at the highest acceleration level but these alterations do not exceed 5 resp. 12 N on the average at predefined forces of 25 resp. 50 N. So, the overshooting response observed in experiment 1 is probably a startle effect which can be avoided or at least considerably attenuated by announcing the signal.

Exerted grip forces decrease then rapidly and reach the baseline after 5 to 8 seconds. But they continue to decline throughout the main phase. Though the alterations (the ascents) become gradually smaller, the decrease amounts finally 30 to 40 % as compared to the baseline. This course is almost identic for all the 4 vibration levels (including the reference  $a_{hw} = 0$ ) and there are scarcely any alterations which are related to the vibration level (weighted acceleration). So, it is unlikely that vibrations are directly related to the occurrence of VWF.

The lack of a systematic relation between exerted grip forces and weighted accelerations lead to the conclusion that vibrations do not contribute directly to the genesis of the VWF. Nevertheless, the decisive role of exerted grip force on vasoconstriction on the one hand and the relation between weighted accelerations and the occurrence of VWF on the other hand (ISO DIS 5349, 5) requires extended field studies for the detection of those factors which determine exerted grip force. The search must concentrate on those variables which correlate with weighted acceleration as well as with exerted grip force [5,6]. This could be e.g. the weight of vibrating tools.

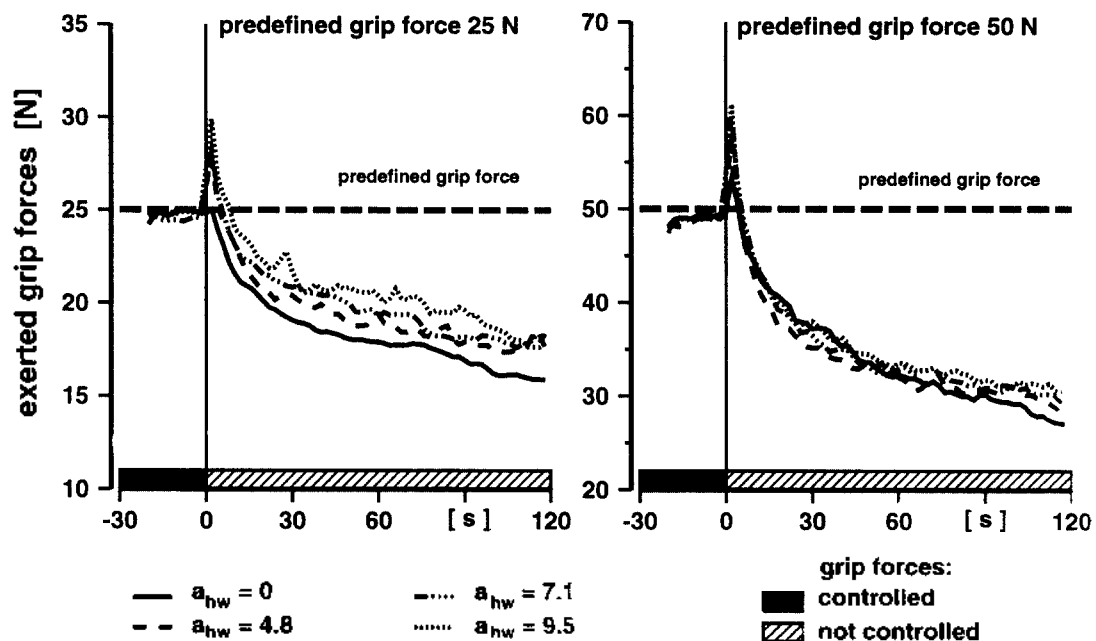


Figure 2: Exerted grip forces under the influence of vibrations ( $a_{hw} = 0, 4.8, 7.1, 9.5$ ), averaged over 3 consecutive cycles. Predefined grip forces: 25 N (20 men, 20-30 yrs) and 50 N (22 men, 18-40 yrs). Air temperature 21 °C, grip temperature 20 °C.

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