REVIEW ARTICLE

Prevention Strategy for Vibration Hazards by Portable Power Tools, National Forest Model of Comprehensive Prevention System in Japan

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Abstract: In the 1950s, the introduction of portable power tools into the production process of many industries began on a large scale around the world and resulted in many cases of occupational vibration syndrome after the 1960s. There was an urgent worldwide need to undertake preventive steps, medical assessment and therapy. At the end of 1964, our investigation began in Japanese national forests, and then in mines and stone quarries. The Japanese Association of Industrial Hygiene established a “Committee for Local Vibration Hazards” (1965), and many researchers in the medical and technological fields joined this Committee. After 10 years, a comprehensive system for the prevention of vibration syndrome was established in the national forestry. It consists of 1) improvements in vibrating tools, 2) hygienic regulation of operation time with an alternative working system, 3) health care system involving early medical checks, early therapy and age limitations in operation of vibrating tools, 4) protection against cold in the workplace and while commuting, and 5) education and training for health and safety. The prevention strategy for vibration syndrome in our national forests is to establish a comprehensive prevention system in cooperation among researchers in the medical and technological fields, workers and administration. The Ministry of Labor presented that strategy as good model of prevention for other industries (1976). New designs for this model were developed and adapted according to the special conditions of each industry. Thus comprehensive system for prevention of vibration syndrome developed successfully from the late 1970s to 1980s in Japan.

Key words: Prevention strategy, Vibration hazards, Portable power tool, National forest model, Statistics of vibration hazards

Introduction of Portable Power Tools and Health Hazards

Design of portable power tools

Portable power tools were designed to decrease a high expenditure of human energy in tool operation and bring about higher productivity. Machine tool technology has given
the world, for example, engine or electric motor-driven chain saws to replace hand saws and hatchets, compressed air driven rock drills, pneumatic hammers instead of hammers, mauls, drills and chisels, electric motor- or pneumatic-driven grinders to replace files, sandpapers and grindstones, and pneumatic-driven impact wrenches instead of screw drivers, wrenches and spanners (Fig. 1). Other examples are riveters, breakers, tampers, rammers, sanders, vibrating knives and shears.

Introduction of portable power tools

In the late half of the nineteen century, pneumatic-driven portable tools were introduced in the mining and construction industries, and then electric motor-driven tools in the metal industries. After World War II, small motor- and pneumatic-driven tools were introduced widely in many industries.

Among new technical innovation in the 1950s, the introduction of portable power tools began on a large scale around the world. These were mainly drilling tools (rock drills, chipping hammers etc.), cutting tools (chain saws and bush cutters, etc.), fastening tools (impact wrenches, etc.) and grinding tools.

Advantages for production and risks to health

The introduction of portable power tools served to increase production and decrease the expenditure of human energy, resulting in higher productivity. Rock-drilling experiments, for example, showed that human energy expenditure decreases one third to one sixth, and production increases two to three times. It may mean that productivity rises from four or six to twelve times (Fig. 2). In practice, from the viewpoint of safety, productivity is about one half in experimental production. Moreover, that large increase in productivity is accompanied by a decrease in accidents.

However, the following health risks persist.

(1) Risks from technological factors

The technological risks are high levels of vibration and noise, and weight. Weight relates to the human-engineering risk in operation.

High-level vibration exposure causes a contraction of
peripheral blood vessels in the hand. After long-term exposure, hypersensitivity to cold occurs in the hands, feet and then the body through autonomic nervous dysfunction. Also, Raynaud’s phenomenon appears in fingers and then toes. The vibration effect causes histological changes in the blood vessel walls of the hand, that is, hypertrophy of the median muscular layer, which involves a narrowing of blood vessel lumen, and hypertrophy of connective tissues in the adventitia of blood vessels. These result in a loss of elasticity of vessels and decrease of circulatory blood volume and coldness in the hand. The vibration energy effect across blood vessels is a shear force which acts on the vessel walls and may injure the intima cells of vessels to increase coagulability, while cold exposure increases blood viscosity with constriction of vessels. Thus, combined effects of vibration with cold exposure are very important factors in causing peripheral circulatory disturbances. More attention must also be paid to combined effect of vibration and cold in terms of causing of elevated autonomic nervous dysfunction as mentioned below1, 2).

Long-term circulatory disturbances cause nutritional problem in the peripheral nervous system, neuromuscular junctions and tendons. Histological changes, demyelination of peripheral nerve fibers, and onion like hypertrophy of the perineurums are observed in advanced cases. Those changes are irreversible and result in the loss of sensations of touch, pain, vibration and heat, abnormal sensations (numbness and tingling) in the finger and hand which continue long after the end of vibration exposure4, 5).

Vibratory shock on the joints with circulatory disturbance causes deformation, difficulty in mobility, and joint pain. Elbow-joint disturbance sometimes leads to an ulnar nerve dislocation, which causes muscular atrophy and sensory loss in the hands.

High-level noise causes hearing loss. The combined effects of noise and vibration exposure cause a greater contraction of blood vessels in the inner ear than noise exposure alone and aggravate hearing loss9.

Heavy load together with poor working posture during operation also cause muscular and tendon strain, as well as stiffness and pain in the shoulder, neck and back2).

(2) Risks from working conditions

Continuous and long-term vibratory exposure can have severe effect. Limitations on operation time in continuous, daily, weekly and yearly work are necessary for the prevention of vibration hazards. Piecwork rates encouraging longer working days, enhance the likelihood of vibration hazards. Bad footing in working places brings an poor working posture and increases musculo-skeletal strain.

(3) Risks from inadequate health care

Poor health care results in failure to detect find early signs of vibration hazards and preclude chance of early therapy. Vibration syndrome in its advanced stage involves irreversible dysfunctions having grave consequences. Thus, early check ups and early therapy are vital elements of health care.

(4) Meteorological risks

Cold is essential factor in constriction of peripheral blood vessels. Continuous vibration exposure to cold or wet weather aggravates peripheral vasoconstriction, and reinforces hypersensitivity to cold through the elevation of the autonomic nervous system. With insufficient protection against cold, peripheral circulatory disturbance increases winter by winter. Lack of protection against cold at work and in daily life poses severe risks for vibration hazards.

(5) Risks from lack of education

Both manufacturers and workers need information about the risks of portable power tools to the health and safety. Technical and hygienic education in operation is very important for reducing the length of exposure to vibration and muscle strain, and for protection against cold. Lack of such education reduces the chance of early intervention, allowing the unchecked development of vibration syndrome.

The risk factors arise from technical, medical, working, meteorological and educational conditions. In practice, those conditions always combine to produce complicated effects (Fig. 3). This means that portable power tools have many risks by reason of incomplete technological improvements for health and safety. The fundamental approach to the prevention of occupational disease has been to investigate risk factors and, having done so, either to eliminate them or thwart their further development.

The benefits of higher productivity make it tempting for enterprises to introduce tools rapidly without preventive measurements against those risk factors, and resulting in health hazards to the workers. This has been an important lesson from the history of vibration hazards for both the present and future.

Vibration hazards

(1) Pathophysiologica, pathohistological and clinical features

Health disturbances from vibration exposure are described in detail in relation with the risks of portable power tools. Characteristics of those features in relations to functional systems are as follows9.

In the circulatory system, cold hands and Raynaud’s
phenomenon, hyper sensitivity to cold. In the peripheral nervous system, loss of sensation, tingling and pain in the upper extremities. In the musculoskeletal system, loss of manual dexterity, weakness and stiffness in muscles, loss of flexibility in joint movements. In the autonomic nervous system, circulatory disturbances mainly in the hands and feet, specially aggravated hearing loss, hypersensitivity to cold, Raynaud's phenomenon in fingers and toes, heart rate interval changes upon deep respiration and at posture change. In subjective symptoms, sleep disturbance, heavy headedness, irritability, etc. as a results of long-term cold, Raynaud's phenomenon, tingling, pain and muscular stiffness.

Histological changes in blood vessel walls and nervous tissues are irreversible, resulting in the long-term circulatory and nervous dysfunction.

This health hazard is the so-called “White Waxy Disease.” The term was used by Japanese forest workers to describe the awful feeling experienced from cold, paralysis and white fingers. Europeans called the same disease “Dead Finger.” These health disturbances were named “Vibration Syndrome,” and Raynaud’s phenomenon arising from the operation of vibrating tools was named “Vibration Induced White Finger (VIWF or VWF)” at the International Congress on Hand-Arm Vibration.

(2) Reports of vibration hazards

The first report of vibration syndrome caused by portable power tools appeared in Italy\(^6\), and the clinical picture was described in detail somewhat later in the US\(^7\). After these reports, many cases of vibration syndrome were reported in the literature of industrialized European, American and Asian countries. In Japan, cases were reported due to riveting work in a railway car repair work (1937) and then from breaking concrete during rail way repairing (1937), jack hammers in coal mines (1939), riveting in ship yards, chipping in metal factories(1941), and riveting in aircraft factories (1943) etc.

After the World War II, the introduction of new portable power tools and the huge production loads resulted in many cases especially after the 1960s. This period was coincident with the rapid development of the Japanese economy. The chief tools responsible for these health hazards were leg-type rock drills in mining, chipping hammers in metal and stone cutting, and chain saws in tree felling operations.

**History of Prevention of Vibration Syndrome in National Forestry and Other Industries**

Although the vibration hazards were known from the first reports early in the century, systematic prevention was not undertaken until a comprehensive preventive model was established in the national forests in the middle of the 1970s. This model was widely propagated to other industries in the 1980s. A broad historical outline follows\(^8\).

**Academic and social activity**

At the end of 1964, we began to investigate the characteristic clinical features of vibration syndrome and its relation to practical working conditions, and the change in physiological function during the operation of chain saws and bush cutters in the national forests of Central Japan. Considering the results of investigations and the relevant working conditions, we concluded that the high prevalence of these symptoms in this area of Japan was due to the continued daily and year long operation of chain saws with a high level of vibration acceleration.
In March, 1965, we recommended that the Japanese Government (National Forest Agency and Ministry of Labor) establish the following standards: 1) legal recognition of these health hazards as occupational vibration syndrome; 2) a health check system for early diagnosis and therapy; 3) hygienic restrictions on chain saw operation time; 4) an improved chain saw design to reduce vibration, noise and weight; 5) a method to protect against cold; 6) education and training for health and safety.

The Japanese Association of Industrial Health (JAIH) organized the “Research Committee of Local Vibration Hazards” in October of 1965, and this Committee recommended that the Ministry of Labor recognize vibration hazards by chain saw operation as an occupational disease. Many research workers across Japan collaborated in the Committee’s activities. Since then, they have continued to make efforts to prevent vibration hazards in the forestry, mining, construction and metal industries. The Committee issued many recommendations about measurement methods of vibration, guidelines for vibration exposure, improvement of vibrating tools, time regulation of operation, early diagnosis, etc. The Ministry of Labor (1965) and National Personnel Authority (1966) have recognized vibration hazards from chain saw operation as an occupational disease and they have gradually accepted those recommendations.

This Committee issued “Measurement of vibration and vibration exposure guideline” by Miwa (1970) and introduced the ISO Draft 5349 (1974) as a guideline for vibration exposure. That promoted medical and technological cooperation for the prevention of vibration. The Research Committee is still active. The first head of this Committee from 1967 was T. Miura, succeeded by S. Yamada from 1980 and M. Futatsuka from 1994.

The National Forest Agency and the National Forest Workers Union reached agreements through Research Committee’s recommendations. The agreements consisted of time restrictions on chain saw and bush cutter operation (1969), an early-therapy program (1973), improvements in chain saws and bush cutters and hygienic check testing before their introduction (1973), and a health care system (1975). Labor unions in many industries participated in supporting these social reforms. In addition, ILO Contract No.148 on air pollution, noise and vibration (1976) helped to promote such activity.

In order to realize these agreements, the “Committee for Occupational Accidents and Disease in National Forests” was established in 1976. Six experts organized this Committee, and one of the authors, S. Yamada, joined. From 1977 up to the present, under the auspices of this Committee, the “Annual Research Congress of Vibration Syndrome in National Forests” has been held. This Congress has an important role in integrating a great deal of information about vibration syndrome patients as well as health care and prevention systems.

Administrative activity

The Ministry of Labor organized “the Committee of Special Medical Examination for the Diagnosis of Vibration Syndrome” (chief: T. Miura) and “the Subcommittee (chief: S. Yamada) of the National Survey for vibration exposure and hazards in private forests” in 1976. At this Committee’s recommendations based on the Survey, the Ministry of Labor in 1976 ordered the legal introduction of the preventive system for vibration syndrome used by the national forest as a good model. Then, it ordered chain saw makers to keep the vibration acceleration level of chain saws below three G by recommendation of the “Technological Committee of Vibration for Safety” in 1977, and this order accelerated improvements in portable vibratory power tools in Japan.

Prevention Strategy; Establishment of Comprehensive Preventive System

Prevention strategy

The strategy of prevention of vibration syndrome is to establish a comprehensive preventive system in close cooperation among researchers in medical and technological fields, workers and administrators. Such cooperation encourages enterprises to make an effort for safety in working conditions and the design of portable power tools. This strategy was pursued successfully in the Japanese national forestry and then in other industries.

The comprehensive prevention system in the national forests consists of the following five elements. 1) Health care system: for early diagnosis, early treatment and consideration of worker aging. 2) Work regulation system: restriction on operation time for chain saws and bush cutters with an alternative job system. 3) Improvement system for portable power tools: new design of chain saws and bush cutters with hygienic evaluation before their actual introduction. 4) Warming system to protect against the cold in the work place and while commuting. 5) Education and training system for hygiene and safety. Those comprehensive systems for the prevention of vibration syndrome constitute the National Forest Model which serves also for other industries.
Improvement system for portable power tools

This is the system for improvements in portable power tools.

(1) Guidelines for vibration exposure

Many patients of vibration syndrome from the 1960s to the 1970s requested urgent improvements in vibration tools. Guidelines for exposure to vibration (1970), recommended by JAIIH on the basis of Miwa's research\(^9\), and ISO Draft 5349 for exposure guidelines (1974)\(^10\) were good references for improvement. Agreement on improvements in chain saws and bush cutters and on hygienic evaluation before their introduction into the job was reached between the National Forest Agency and Workers Union (1973) and brought good cooperation among research, manufacturing and administration personnel. Legal measures by the Ministry of Labor, which ordered the vibration acceleration level of chain saws to be kept below three G (1977) accelerated improvements in many portable vibratory power tools in Japan. Improvements were made to decrease vibration, noise and weight.

(2) History of improvements in national forests

In the first step taken in 1965, the main design for improvement in chain saws, was anti-vibration handles. The vibration acceleration level of chain saws decreased gradually from the late 1960s to the early 1970s from 12 m/s\(^2\) to 5 m/s\(^2\) (frequency weighted acceleration, rms). However this was limited by a trade off between anti-vibration improvements and bad engine balance.

In the second step in 1972 isolation from vibration was achieved when remote control chain saws were designed. For felling, they were set on the stands fastened to the tree trunks. The production per hour fell to 70% of normal, but vibration exposure diminished. Some engineers considered this kind of chain saw to be a step backward because of the lower production levels. This view completely overlooks the health benefit. In reality, workers suffering from vibration syndrome as well as healthy workers can use this type of chain saw without time restrictions and can remain on the job for a much longer time free of disabilities. For cutting trunks, two kind of remote control chain saw were introduced. The first was one with a small carrier and offered ease of operation in restricted working spaces. The second was one with fastened stands for unrestricted spaces. Remote control chain saws worked well during the period characterized by insufficient chain saw engine balance.

In the third step, the main design objective was to get good engine balance. In 1973, rotary engine chain saws (exhaust volume: 60 cc and 35 cc) were put into practical use at a low vibration level of 0.8 m/s\(^2\). But the heavy weight of the engine, firing trouble in cold conditions, and the high temperature of exhaust gases posed difficulties. The appearance of rotary engine chain saws encouraged engineers in the field of reciprocated engine chain saws. Their group research on improvements is interesting. In 1983, opposed twin-cylinder reciprocable engine chain saws appeared with the same low vibration level as the rotary engine chain saw. The prototype of an opposed twin-cylinder chain saw was made by engineers in Sweden in 1962\(^11\). But they had to abandon the project because the engine was too bulky and at least 30% heavier than a single-cylinder saw. Other problems involved the ignition system, manifolds, and the distribution of cooled air. In 1981, Japanese engineers succeeded in producing a practical design after attempts. The firing of opposed cylinders was controlled by microelectronics. The new version (30 cc x 2) had the same weight and size as a single-cylinder chain saw (60 cc) with low levels of vibration acceleration and noise. Operators in forests praised its ease of operation and low vibration and noise levels. The US Agriculture Department tested this twin cylinder chain saw in 1985 and gave good evaluation by reason of its low vibration level\(^12\). These new designs encouraged better engine balance in engineering of existing reciprocable engine chain saws.

In terms of human engineering, high risks were posed by the excessive weight of chain saws and the resultant ill effects on the musculoskeletal system and posture while felling trees and snedding on steep slopes. For Japanese workers with small physique, the introduction of light weight chain saws was urgent. First, weight reduction in 60 cc displacement engines, and then bantam chain saws improved rapidly. In the 1980s, bantam chain saws with a 35- to 40-cc displacement and a weight of only 4 to 5 kg and low vibration (2.2 m/s\(^2\) to 1.2 m/s\(^2\)) were developed for artificial forests. The result was the abandonment of snedding exclusively by hand tools, which had been reintroduced in the 1970s to avoid the effects of the high level of vibration and heavy weight of chain saws. Shifting operations from natural forests with large-diameter trees to artificial forests with trees of small diameter further promoted the use of bantam chain saws (Fig. 4).

Handle warming of chain saws were engineered by using electric power generated from engine rotation. It produced good effects, i.e., preventing loss of sensation and decreasing blood flow which caused coldness in the hands. Introduction of the new chain saw with warming handle spread rapidly in northern areas of our national forests.

More recently, bush cutters with a small battery and light-
weight motor, and with an opposed twin-cylinder engine have been developed with low vibration and noise.

(3) Hygienic evaluation for improvements

We have sought to evaluate all kinds of already existing and new chain saws and bush cutters from the viewpoint of hygiene for long-term practical tree felling, cross cutting and sneddng, and bush cutting in the mountain forests by request from the National Forest Agency. Indexes to the physiological and subjective evaluation of the effects of chain saw and bush cutter operations were vibratory sensation, skin temperature, muscular strength, finger dexterity and subjective symptoms (Fig. 5). From those tests, we recommended improvements in newly designed chain saws and bush cutters. The combined effect of low vibration level and warming were helpful in the prevention of vibration hazards\(^1\).

Now workers can select good chain saws and bush cutters adapted to the tree diameter, kinds of jobs and weather conditions.

**Work regulation system**

This system is concerned with the regulation of operating time of chain saws and bush cutters combined with an alternative work system. In the 1960s and 70s, the vibration acceleration level of chain saws was high and improvements were difficult. Continuous operation greatly decreased local circulation in the hands and increased static muscular strain in the arms, shoulders and neck. There was a great need for hygienic limitation on operation time.

(1) Epidemiological investigation

An epidemiological investigation into the relation between worker complaints (numbness, pain and Raynaud's phenomenon) and operating hours and days among 6,210 chain saw operators and 7,775 bush cutter operators was conducted by the Committee of National Forest Agency in 1967. The rate of complaints was at 40% among chain saw operators and even higher in the groups with over 2 hr operation per day, 100 days per year and 300 hr per year. These results suggest that about 2 hr a day of operation is the tentative limit required for prevention\(^1\).

(2) Operating time study

Tuji\(^1\) of the Institute of National Forests investigated total cutting time by chain saws per day among many local forestry offices in the late 1960s. Values of total cutting time ranged from about 100 to 200 min. From the late 1950s to early of 1960s, the national forests had a two-worker system and a single-worker system for chain saw operation. The total cutting time was slightly longer in the single-worker system. Total cutting time consisted of felling, cross cutting and
snedding. Values of felling and cross cutting time were about equal to snedding time, ranging below 100 min or so. The work load on hands, arms and shoulders in snedding is higher than in felling and cross cutting in terms of the strain from supporting the weight of a chain saw in a forward bending posture. From those results, it was considered possible to keep the operating time of chain saws within the range of 100 min to two hr if hand tools were used for snedding or an alternative two-worker system was adopted.

(3) Physiological effects investigation

A comparative study was made of changes in finger skin temperature and the threshold of vibrotactile sensation during continuous chain saw operation alternating with another job without vibration exposure in all seasons. Skin temperature fell during operation and recovered rapidly when operation stopped and the hand relaxed. Such changes were caused by vibration exposure, hand gripping and cold. They were analyzed according to continuous operating time and atmospheric temperature. Operating times longer than 5 to 7 min caused a greater decrease in skin temperature, especially in winter. The threshold of vibrotactile sensation shifted with vibration during operation. The longer the vibration exposure, the larger the shift in threshold. Recovery of the shift appeared gradually after stopping vibration exposure. If the next interval without exposure to vibration was short, the recovery was insufficient, and the next operation caused an even larger shift. These results were analyzed based on the ratio of total vibration exposure time to total working time. If the ratio was below 0.5, the change in threshold was small. If the next interval without exposure to vibration was equal to or more than the former exposure time, the threshold of vibrotactile sensation decreased in number from 1970 onward. But in 1974 the prevalence was 12.1% and 25.6%, respectively. New patients decreased in number from 1970 onward. But in 1974 the number increased again due to the still high vibration acceleration level of chain saws and the still incomplete time restrictions. A National Forest Agency decision to enforce complete time restrictions remarkably reduced the number of new cases.

Thus, time restrictions played a key role in the early stages of prevention when chain saws had not yet been improved and other preventive methods were insufficient. Since the late 1980s, new controls on the length of vibration exposure over one’s lifetime have been considered because of an increase in the total operating hours accumulated by aging workers.

**Health care system**

This system aims for early diagnosis, early therapy and a consideration of aging.

(1) Early diagnosis

The first model for an early check of vibration syndrome in Yamada’s pilot survey (1965) was tested in many areas and industries by researchers. Their results were incorporated by JAIH Committee in 1969. The Ministry of Labor issued mandatory medical checkups in 1971 at the Committee’s recommendation and revised them in 1976 on the basis of 1972-73 National Survey. A second version was reexamined...
in the 1980s on the basis clinical and epidemiological research in terms of the relations among symptoms, vibration exposure dose indexes and Stockholm Workshop Stages\(^7\text{-}19\). Vibration exposure dose was calculated in the reference to 4 hr energy equivalent and frequency weighted vibration level (ISO: 1986)\(^{10}\). Values of Vibration exposure dose were divided into five indexes (vibration exposure dose index 1 to 5; VDI 1 to 5) according to its level. Stockholm Workshop Scales for Cold-Induced Raynaud’s Phenomenon consist of 4 stages (CIRP stage 0 to 3; CIRP 0 to 3)\(^{20}\) and Sensory Neural Disturbance Stages consist of 4 stages (SN stage 0 to 3; SN 0 to 3)\(^{21}\).

The significance of examination items were tested statistically in relations with VDI, CIRP and SN. Dose dependency is observed in vascular, sensorineural and muscular system, CIRP stage dependency in vascular system and SN stage dependency in sensory neural and muscular system. Higher VDI, CIRP and SN stage relate with many examination items in vascular, sensorineural and musculoskeletal system (Table 1).

Table 1. Examination items and subjective symptoms in VDI 2-5, CIRP 1-3 and SN 1-3 with significant differences from VDI-1, CIRP-0 and SN-0, respectively

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Those results answer the question by Färkkila\(^{22}\) as to whether changes in muscle force form part of the hand-arm vibration syndrome, and they agree with the results by Eckenvall \textit{et al.}\(^{23}\) indicating dose response for both vascular and neurological disorders as well as those by Lundström \textit{et al.}\(^{24}\) for SN stage and by Bovenzi \textit{et al.} for VWF\(^{25}\). The close relation between VDI and examination results with CIRP and SN stages contributed to the establishment of effective examination items in the early diagnosis of vibration syndrome\(^{17}\).

Early examinations are performed twice annually (in the autumn and spring). They consist of the following items;

1) Physical examination: peripheral circulation (skin temperature, nail press test, plethysmography\(^*\) etc.), peripheral nerve function (touch, pain and vibratory sensation threshold, reflex, radiation of pain, nerve conduction velocity\(^*\) etc.), muscular function (grasping and pinching power, tapping facility, stiffness and muscle pain, electromyogram\(^*\)), skeletal function (pain and limitation in motion of joints, roentgenogram of joints\(^*\) etc.), and hearing level (\*: by doctor's suggestion).

2) Subjective symptoms.

3) History of chain saw or bush cutter operation.

4) Differential diagnosis.

(2) Protection for aging

In 1977, control conditions on aging workers were added. If the chain saw operator is over 55 years of age, he must stop using chain saws to avoid bone and joint aging. Initial use is not allowed after 50 as a rule.

(3) Early treatment

In 1972, a system of hospital treatment with hot spa therapy was organized in Kyushu by Takamatsu \textit{et al.} and soon adopted in other areas. If a worker is recognized as suffering from occupational vibration exposure, he is sent to a hot spa for early therapy, and treatment is controlled by the health care system. This early therapy system has been very effective when started as soon as possible after detecting abnormal signs of vibration syndrome. If early therapy is delayed, it is ineffective, and harmful consequences follow.

\textit{Warming system}

This system is for protection against cold, a condition in the work place and while commuting that plays an important role in the occurrence and development of vibration syndrome.

From 1965 to 1970 we investigated the effects of cold and keeping warm on the physiological function of workers during chain saw operation and while commuting by motorcycle or bus. These results showed that warming is very effective to prevent a decrease in blood flow, loss of hand dexterity, and occurrence of VWF. We recommended that the National Forest Agency introduce warm cottages to working places and provide commuter buses, thus encouraging workers to keep warm at an atmospheric temperature of less than 10°C and to travel by bus or car rather than by motorcycle. Fishing or hunting in cold conditions was also discouraged.

Keeping the chain saw handle warm is very effective to prevent a reduction in blood flow to the fingers and to warm the body. We tested and proved its effectiveness, then recommended that chain saws with handle warmers be used in the central and northern areas of Japan. In these areas, 70% of chain saws had warming handles by 1985.

\textit{Education and training system for health and safety}

This system is for education and training in health and safety. Technical and hygienic education in chain saw operation is very important for avoiding muscle strain and reducing the length of exposure to vibration. It is also valuable for the management of working conditions, improvement of chain saws and bush cutters, and enhancing health care.

Training in Scandinavian lumbering techniques as well as a training system developed at the Bohemian Rehabilitation Center in Czechoslovakia served to improve our education system.

To implement such education and training, the JAIH, the Japanese Medical Doctor's Association and the Association for Prevention of Labor Accidents have cooperated and been of service.

\textit{Cooperation}

Our principles in prevention have been “medical and technological cooperation” in research work and “cooperation among specialists, workers and administrators” in practice and education. We have made consistent efforts based on these principles to assure effective prevention in Japan on the basis of lesson learned from the National Forest Model.

\textit{Health Examination and Disease Incidence in Vibration Syndrome}

The effect of our comprehensive prevention system is confirmed by the results of health examinations and the number of new cases over the long term\(^{16}\).
Number of tested workers and abnormality in examinations

Since 1975, workers tested by compulsory health examinations for early diagnosis of vibration hazards nationwide increased from 21,168 (20.6% in vibration exposed workers) to 79,436 (45%) in 1984 and then decreased to the level of 68,688 (40.8%) in 1990. After the 1980s, that number has been largest in manufacturing followed by mining and forestry. The mean abnormal ratio among the tested workers was 18.4% in 1976 and fell to 5.5% in 1994 in all industries using vibratory tools (Fig. 6).

By industry, the numbers of tested workers and abnormal ratios in early diagnostic examination (in parenthesis) in 1994 was as follows; 16,047 (3.0) in transportation machine production, 10,044 (2.1) in mining, 9,868 (10.2) in agriculture and forestry, 3,940 (4.4) in machine making, 3,822 (4.8) in steel, 2,424 (4.9) in construction, and 1,416 (6.2) in ceramic and stone.

New cases of vibration syndrome

The number of new cases recognized as suffering from occupational vibration hazards in a year in all industries increased from 361 in 1965 to 2,595 in 1978, and then gradually decreased to 941 in 1986, 655 in 1988, 361 in 1990 and 475 in 1994. By industry, the number of new cases in 1969 was highest, i.e., 558 out of 12,000 workers in the national forest industry. That decreased to 31 in 1980, and then to only 7 in 1985. Now there are only a few new cases each year (two cases in 1990). But in private forestry, which has had many difficult problems due to social conditions, the number in 1978 was highest, i.e., 1,431 out of 50,000 workers, and decreased to 821 in 1980, 307 in 1985 and 98 in 1990. As to new cases in other industries, mining had 53 in 1990 and 45 in 1994; stone quarrying 7 and 30; construction 151 and 222, respectively; production had 41 in 1994 (Fig. 7).

The number of cases under treatment in 1990 and 1994 were 5,382 and 3,080, respectively in private forestry; 1,276 and 1,173 in mining; 404 and 279 in stone quarrying; 3,234 and 3,098 in construction. There were 1,095 (1994) in production; 1,387 in other industries; for a total of 11,683 and 9,537, respectively.

The numbers of new cases by the kind of vibrating tool were as follows in 1994; 144 by rock drill operation; 138 by chain saw; 62 by pick hammer; 36 by concrete vibrator; 21 by chipping hammer; 12 by sander; 11 by concrete breaker; 10 by portable grinder; 5 by vibration drill; 5 by impact wrench; 4 by table grinder; 3 by scaling hammer; 2 by portable tamper; 2 by electric hammer; 1 by hand hammer; 1 by sand rammer; 1 by swing grinder; 3 by others. In 1994, there were no new cases by riveter operation, coking hammer, baby hammer, engine cutter, portable bark stripper, vibration shear or jigsaw.

Vibration hazard ranking among occupational diseases

In all mandatory examinations into prevention of occupational diseases, tested worker numbers in vibration are smaller, but abnormal ratios are higher. That is, worker numbers and abnormal ratios (% in parenthesis) for 1993 are 551,138 (4.2%) in organic solvents, 241,294 (0.9%) in special chemical substances, 167,365 (7.9%) in noise, 147,694 (2.3%) in electric radiation rays, 119,687 (1.8) in lead, 73,157 (1.1) in ultra violet and -red rays, 46,692 (5.6%) in vibration, 22,182 (1.9%) by electric cash register and for others 12,423 (1.6%). The numbers of new cases by industry and the order in number of abnormal ratios by occupational disease suggests that prevention of vibration syndrome is
still an important prevention issue in Japanese industry, especially in the construction industry.

Conclusion

Occurrences of occupational disease are always accompanied by the risks in industrial technology, health and safety management by administrators and employers, and education in health and safety for employers, makers and workers. Prevention succeeds by the elimination of those risks.

In Japan, vibration hazards were very serious in the past but improved gradually due to the prevention strategy of the National Forest Model and its new version for other industries from the late 1970s to the 1980s. What of the future in Japan? That depends on learning well the lessons from the National Forest Model for a comprehensive prevention system.

Also in Finland, prevention developed successfully from the 1970s in the forest industry and then other industries. In 7th International Hand-Arm Vibration Congress (1997 in Prague), French researcher summarized a scope of prevention in the world and mentioned about "Lesson from Japan and Finland". He remarked on "Reason of failure in France for the wider use of anti-vibration tools" and introduced "Strategy for the spread of vibration prevention" by INRS (French National Institute for Research and Safety), designed at the end of 1980s. European Communities issued new Council Directive to decrease vibration below 2.5 m/s² in 1989 and modified Directive in 1991 and 1993. In the first decade of the next century, prevention strategy may be spread world wide.

References

Examination results, subjective symptoms, and stages of vibration syndrome. Arberete Och Halsa 5, 165–70.