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Impact of mechanical vibration on Human health

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Abstract : The main goal of this study is to determine how mechanical vibrations—which may come from a variety of sources, including vehicles, machinery, waves, and more—affect human health. Mechanical vibrations affect the human body in numerous ways, and the harm they inflict may take many distinct forms. The two primary kinds of impacts are long-term consequences and short-term effects.

Long-term effects of mechanical vibrations on the human body can result in fatigue, drowsiness, and diminished focus. These effects can be caused by continuous exposure to vibrations from sources such as machines or vehicles. Prolonged exposure to mechanical vibrations can lead to chronic health issues that affect the overall well-being of an individual.

On the other hand, short-term effects of mechanical vibrations on the human body are more immediate and can cause mechanical harm to specific organs, including the neurological system, joints, and bones. These effects can occur due to sudden shocks or impacts from sources such as accidents or sudden jolts.

The effect of mechanical vibrations on the human body is assessed using a variety of factors, including amplitude, frequency, duration of action, acceleration, and more (Fliegel et al., 2011). However, because the term "vibration" has different meanings in biology, medicine, and engineering, it's crucial to avoid conflating them.

In engineering, the term "shock" is used to refer to non-periodic excitation that is rapid and severe. A shock wave is an abrupt change in pressure that travels through a medium at a speed faster than the speed of sound. When it comes to the human body, shock forces are typically defined as those that reach their peak levels in less than a few tenths of a second and last no more than a few seconds.

The magnitude of vibrations can have an impact on biological systems, and if the amplitude is high enough, vibrations at all frequencies can affect the human body (Brammer & Von Gierke, 2002) .The response of the human body to vibrations is a primary factor that influences discomfort in a moving vehicle. Many issues related to human health, both in terms of comfort and functionality, can be caused by the vibration of the human body.

As a result, tire and vehicle manufacturers have a strategic relationship with the simulation of the human body in the driving position (Al-Baghdadi et al., 2021). The field of engineering now places a high priority on understanding and mitigating vibrations. This topic has become even more crucial as industries and

automobiles continue to develop. In the modern world, almost every household owns a car, making research on the phenomena of vehicle vibration and its consequences on people of utmost importance.

The mechanical properties of the human body, which is a complicated mechanical system, may be simply changed. Vibration's mechanical and biological impacts on the human body are very intricate and diverse. On the magnitude of forces necessary to mechanically harm the human body, there is, however, little precise information currently on the market. The majority of the time, experimental animals are employed in studies on mechanical injuries to safeguard people.

It is crucial to carefully examine the applicability of findings collected from animal studies to humans, as there are significant differences in size, anatomical structure, and physiological functions between animals and humans (Katu US et al., n.d.). Despite these challenges, research on the impact of mechanical vibrations on human health continues to advance, with the goal of better understanding and mitigating the potential negative effects of vibrations on the human body.

In summary, the effects of mechanical vibrations on human health are a complicated and multifaceted subject that need for careful evaluation of a number of variables, including amplitude, frequency, duration of action, acceleration, and more. Fatigue may arise from vibrations over time.

Keywords : Mechanical vibration , Whole-body vibration, Hand-arm vibration, Low back pain, Cardiovascular effects of vibration, Health effects of vibration exposure

Paper type : Literature review

Introduction

Mechanical vibrations are a frequent occurrence that may affect many biological systems, including the human body, in a variety of ways. Vibrations of any frequency may affect biological systems if their amplitude is large enough (Brammer & Von Gierke, 2002). Mechanical vibrations are produced when a body moves repeatedly in a regular or irregular manner after leaving its resting state. These vibrations may travel through bodies, including living creatures. Variables including the amplitude, frequency, direction, and location of the vibration's entrance point affect how vibrations affect the human body. Vibrations may have harmful effects on the human body, such as lumbar spine problems, a loss of quick, fluid eyesight, and a reduction in the ability to regulate movements precisely and correct them. Low frequency vibrations, however, may also improve vision. When an item vibrates, it may potentially impair eyesight (Santiago et al., 2022).

Mechanical vibration is the most prevalent type of motion in mechanisms, and it is a characteristic of mechanical energy transmission. The human body is often viewed as a mechanical system composed of sub-masses, stiffness, elasticity, and mechanical resistance (Fliegel et al., 2011). Mechanical vibrations can occur in various circumstances in our daily lives. For example, the heartbeat, peristaltic movement of the digestive system, blood vessel contractions, and muscle contractions are all processes that are caused by natural vibrations in the tissues and organs. Additionally, our bodies are exposed to mechanical vibrations from the external environment during daily activities such as using spinning machinery, shaping machines, forklifts, construction equipment, cranes, trucks, and other components (Herterich & Schnauber, n.d.). These vibrations can transfer energy to the organs and tissues, which can aid the body in carrying out its metabolic tasks effectively (Bernardo-Filho et al., 2018).

Mechanical vibrations, along with noise, unsuitable weather, and poor lighting, are considered as one of the stressors that can significantly impact a worker's comfort, productivity, and health. Vibrations from spinning machinery, shaping machines, transit activities, and other sources can cause mechanical damage, physiological reactions, and subjective responses in humans, and are therefore a subject of human engineering (Katu US et al., n.d.). Achieving a balanced mechanism to reduce the magnitude of vibration on the frame and maintain a constant drive speed has long been a challenge in mechanical design. Vibrations can cause noise, wear, fatigue, and other issues, and reducing vibration can enhance various aspects of mechanical design in fields such as surface engineering, the automobile sector, forestry, and agriculture (Krolczyk et al., 2014).

In recent times, women live longer and spend a significant portion of their lives in the postmenopausal stage, which is characterized by various changes due to the decline in estrogen levels. This hormonal shift can affect different tissues in the body, including bone, nerve, urogenital, and cardiovascular tissues. Osteoporosis, a condition characterized by decreased bone mineral density, can be accelerated by estrogen deficiency, leading to loss of bone matrix in bone tissue. Vibration administered through a vibrating platform is one of the resources used in the treatment of postmenopausal osteoporosis. Daily administration of vibration for 5 to 20 minutes, 2 to 5 times per week, can produce anabolic reactions. However, exposure to vibration can also harm tissues (Bernardo-Filho et al., 2018). Occupational exposure to vibration is often considered a risk factor for conditions such as carpal tunnel syndrome, which is characterized by peripheral nerve injury. Studies have shown that prolonged exposure to vibration with frequencies of 30, 120, or 800 Hz for 4 continuous hours can result harmful effect (Ghayad et al., 2014).

Effect of vibration on Bone and Muscle.

The dynamic reaction of the human body in the context of a driving vehicle can be determined using the biomedical model depicted in Figure 1. This model can also be used to simulate and create vibration isolators for the human body. In the biomechanical model shown in Figure 1, the human body is depicted in an upright, calm stance with a relaxed upper torso, looking straight ahead without side movements, assuming that the foot is on the footplate and the hands are on the lap. The model includes the head, chest, thighs, pelvis, viscera, and legs, with white circles and black circles representing the centres of mass for each body component, and arrows indicating the sites where vibrations are excited. The numbers on the figure represent the joints between two sections.

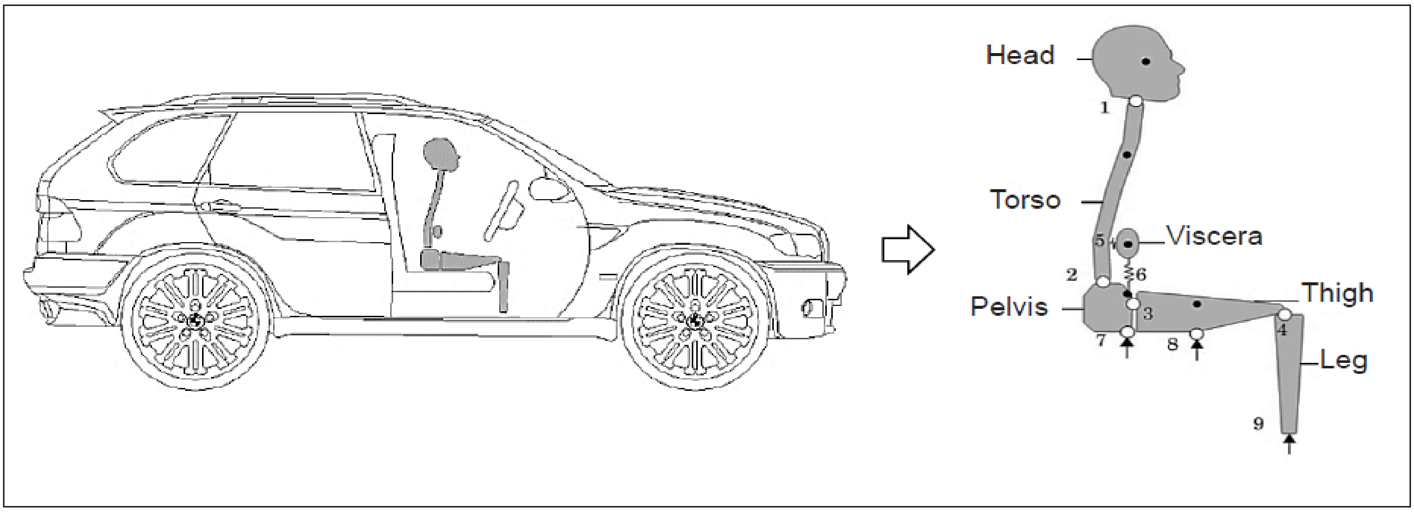


Figure 1 illustrates the geometry of the computational biomechanical model with various human body components and their relationships.

Notably, the seat of a car, which is not explicitly represented in the model, is identified as the main source of vibration in the proposed biomechanical model, as demonstrated in Figure 1. The mobility of the base node in the computational model shape is taken advantage of, and the input excitation is applied in three separate vertical places. In this model, every component of the body is considered as a single, rigid body-like lumped mass, with the viscera and legs not allowed to spin or translate. Translational and rotational springs, as well as a dashpot damper, are used to simulate the connections between body parts in the biomechanical model, allowing for predictions of how the body components will move in relation to one another. The joints between the body sections are modeled using an elasticized version of a fixed link, with torsional stiffness and linear damper coefficient allocated at these joints when employing the flexible form of joints. This enables the mimicry of mechanical characteristics of human biomechanical models, motion descriptions in any location, and the properties of inertia and geometry for a biomechanical model (Al-Baghdadi et al., 2021)

Several studies have looked into the connection between strain under vibrations and human effects, including those by Dupuis and Zerlett (1984) and Dupuis et al. (1988). Some authors come to the conclusion that the relationship between stress and strain under vibration on standing people has only been a minor concern up until now after identifying and describing the essential connections. Few authors, including Reiher and Meister (1932, in Miwa 1968b), Allen (1976), and Yonekawa (1977), have studied the effects of impulsive vibration on standing people. They discovered that the standing person reacts more strongly to increased impulse frequencies and amplitudes. Reiher and Meister found that pulses with longer rise times exhibit reduced effects, but Yonekawa reported that this effect occurs with pulses of shorter length. The effect of impulse duration is presented differently in both research. The subject of applicability for broad application is still up in the air since only sinusoidal, artificial, and specific pulses produced by a step have been investigated (Herterich & Schnauber, n.d.).

In a healthy subject, mechanical vibrations from the environment can be transmitted to the body during simple activities such as walking or running due to the impact of the feet with the ground. Additionally, sports participation in activities such as kicking a soccer ball, hitting/catching a ball with the hands (basketball or volleyball), skiing, or bike riding can induce vibrations and oscillations in the tissues and organs, through the legs or arms. Other sports such as tennis, where a racquet is used to hit a ball, may also result in vibrations being transmitted to the body (Bernardo-Filho et al., 2018).

METHODS AND INSTRUMENTATION

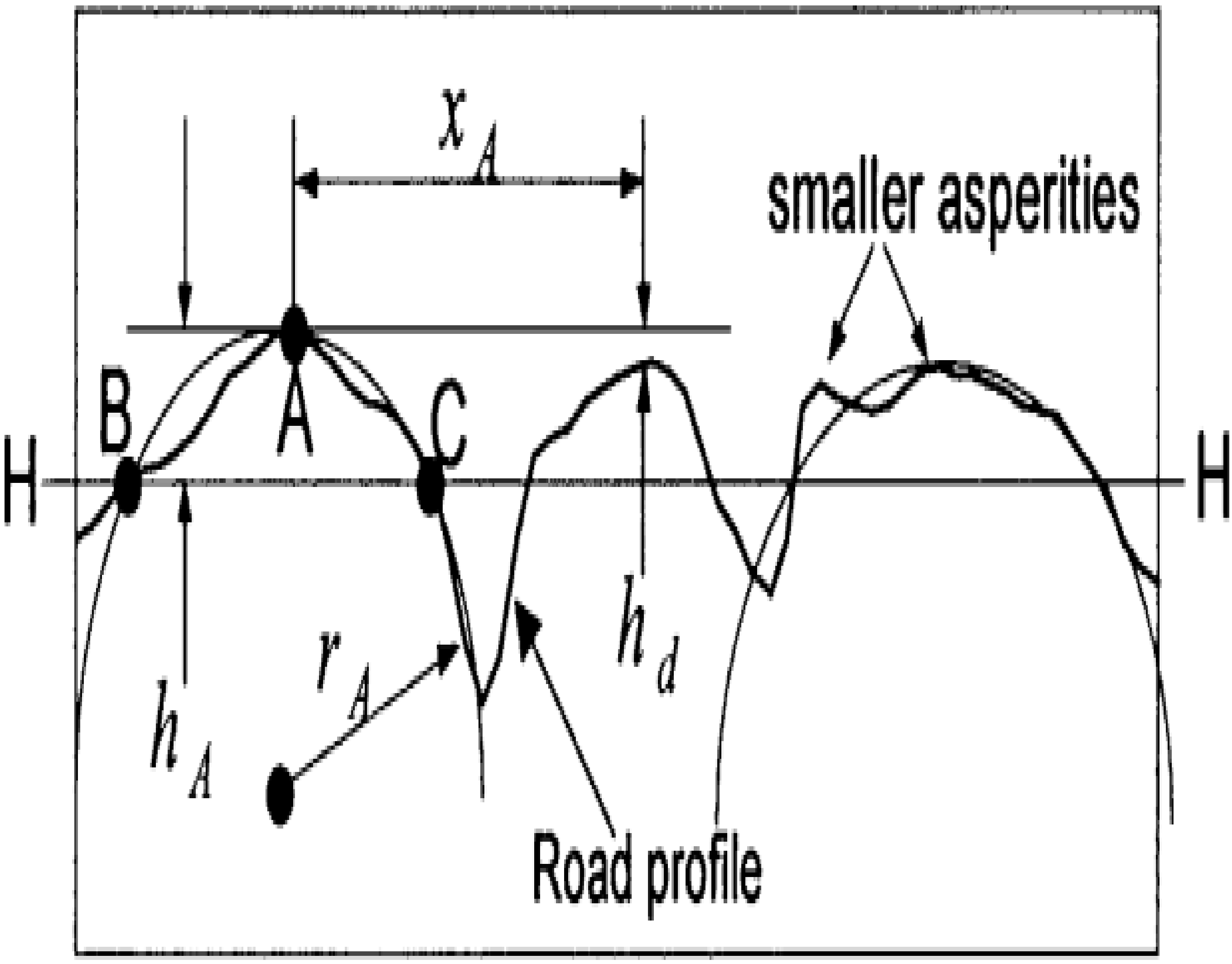
Vibration is a common phenomenon that is characterized by having a frequency, usually measured in Hertz (Hz), which quantifies the number of cycles per second or oscillations per second of a wave. The frequency of vibration is determined by three interrelated variables: displacement, velocity, and acceleration. These variables play a crucial role in the response of organisms subjected to vibration, and there is also a time of vibration exposure, which is a magnitude that can affect the response of organisms (Santiago et al., 2022) .
Quantitative studies are often carried out in the lab in regulated, simulated conditions in order to gain significant data from research of the effects of shock and vibration on people. To prevent affecting the behaviour of the biological system under study, it is crucial to make sure that measuring techniques and equipment are tailored to the specific characteristics of the system (Brammer & Von Gierke, 2002).The goal of field research, on the other hand, is to examine the actual situation in realistic settings at representative workplaces where impulsive vibrations are measured in order to learn more about the vibrations that are transmitted to people or to advance the body of knowledge regarding impulses at standing-only workplaces (Herterich & Schnauber, n.d.).
Numerous techniques, including frequency analysis, weighted acceleration, and the root mean square (rms)-value of the weighted acceleration, as well as others that are suitable for shock analysis, like the calculation of the crest-factor, can be used to evaluate vibration measurements (Herterich & Schnauber, n.d.). These techniques provide the data needed to evaluate how vibration affects organisms.
Martin Kakihata et al.'s research (Martin Kakihata et al., 2019) used the Triplanar Vibration platform to apply vibrations with a frequency of 60 Hz for 10 minutes and an average amplitude of 2 mm. This was used for three days, separated by a week, and followed by a two-day break. Depending on the study design, the total duration of the platform's intervention ranged from 4 weeks for certain groups to 8 weeks for other groups.
Using a GMAC Diesel with a V-8 engine and air shock absorbers, a Cranning Model RD 1500, and an Airshields Transport Incubator, Model TI 100, with a double wall, the measurement of vibration during land transport in a hospital-based mobile intensive-care unit (MICU) was carried out in three phases. A Bruel and Kjaer type 25 16 integrating vibration metre was used to measure vibration. This instrument measures vibration in decibels or root mean square units, which produces an acceleration value corresponding to the energy content of the object (Mechanical Wration in Ambuhnce Transport, n.d.).
Bone is sensitive to mechanical signals, according to research, and whole-body vibrations (WBV) may be utilised to increase bone quantity and/or quality during skeletal maturation. However, safe, efficient, time-

efficient, and highly compliant strategies are essential if you want to get the best results. Low-level mechanical signals created by WBV have been shown to have an impact on bone in the adult skeleton (Xie et al., 2006).
During sporting activities, our bodies interact with the external environment and experience externally applied forces, which can induce vibrations and oscillations within the tissues of the body (Cardinale & Wakeling, 2005) .

PRECIPITATION OF VEHICLE VIBRATION SOURCES

On the basis of Road

Although many procedures and standards have been proposed to conventionally evaluate the discomfort caused by road roughness on a user in a moving vehicle and develop corresponding acceptance vibration thresholds, in reality there are no comprehensive criteria or methodologies to perform all required analyses. Therefore, taking into account the complexity of the problem and its many facets, it would be beneficial to develop tools and methodologies that provide quantitative and analytical data, particularly information regarding the relationships between the geometry of the road surface and the amount of transmitted vibrations to the vehicle during motion.
IRI, a measure of suspension stroke, is not a great predictor of ride quality. Instead of suspension stroke, as emphasised by Forse'n (1999), ride quality measurements and assessments are preferred based on car floor/seat vibration acceleration as per ISO 2631-1(1997), as shown by benchmarking with vehicle industry practise. Ahlin and Granlund (2001) (Ahlin & Granlund, 2002) provide a technique for calculating reference ride quality.
To evaluate the independent effect of each road roughness parameter using actual road surfaces is difficult. Therefore, the effects were estimated using a tire/road contact model that was previously proposed and improved to estimate the effect of asperity height unevenness as well as other parameters. The road roughness parameters obtained from the road profiles measured using a laser profile meter are depicted in Fig.



The H-H symbol, which stands for a horizontal plane that splits the nominal contact area into two equal portions, was used to separate the profiles. According to Fujikawa et al., who found that the actual contact area between the tyre tread and the pavement is less than 50% of the nominal contact area, the portions above line H-H were considered as asperities. As a result, the characteristics for road roughness shown in Fig. 1 were assessed as follows: The height of the asperity, or hA, is measured from line H-H. The difference in asperity height between the two closest asperities is known as asperity height unevenness (hd). The distance between consecutive asperities, xA, is known as the asperity spacing. Asperity radius rA is the circumference of the arc that connects the three places in Fig. 1: A (the asperity's apex), B, and C (where the profile and line H-H converge). As shown in Fig. 1, several tiny asperities are commonly present in the arcs; however, they are not considered in this study (Fujikawa et al., 2005).

In conclusion, it is crucial to create thorough criteria and procedures to undertake the necessary analyses of road roughness in order to gauge how much pain a user has when riding in a moving vehicle. Ride quality measurements and assessments are ideally based on vehicle floor/seat vibration acceleration as per ISO 2631-1(1997). Suspension stroke, such as IRI (Cantisani & Loprencipe, n.d.), is not a good indication of ride quality. In Ahlin and Granlund (2001), a technique for calculating reference ride quality is described.2002's Ahlin & Granlund Since it is challenging to determine the independent effects of individual road roughness parameters using actual road surfaces, the effects are instead estimated using a tire/road contact model. A number of variables, such as asperity height, asperity height unevenness, asperity spacing, and asperity radius, may be used to assess the road roughness characteristics.

Unbalance In the Engine Causes Vibration

An automobile engine, which are the components that move back and forth in a straight line. These parts include the pistons, connecting rods, and crankshaft. When these parts move, they can cause periodic disturbances or vibrations in the engine, which can then be transferred to the entire automobile. These vibrations can be felt by passengers and can affect the smooth operation of the vehicle. The severity of the vibrations depends on several factors, including the speed of the engine, the size and weight of the reciprocating parts, and the overall design of the engine. In some cases, these vibrations can be reduced through the use of balancing techniques or other design modifications (Gramann, 1999; Katu US et al., n.d.) .

Vibration due to rotating shaft

Numerous engineers find the vibration of rotating shafts to be important, so there is a wealth of literature on the subject. In order to provide a succinct overview rather than a comprehensive study, many significant contributions must be categorically rejected since they are not strictly relevant (Katu US et al., n.d.).

VIBRATION'S IMPACT ON HUMAN PERFORMANCE

There are two different kinds of vibrations produced by engines: torsional vibrations and longitudinal vibrations. Because they operate by reciprocating, engines always experience some torsional vibration. As the piston gets closer to top dead centre (TDC) on the compression stroke, the crankshaft of an engine starts to rotate, increasing the cylinder pressure. Just after TDC, combustion and ignition cause the pressure to rise, and as the piston descends to BDC, the pressure begins to fall. During this combustion stroke, the pressure on the piston creates the tangential force that produces meaningful work and accelerates the crankshaft's rotating speed, while the compression stroke reduces the engine's angular velocity. The crankshaft's speed changes and torsional vibrations at the crankshaft are caused by the changing rotational speed. During operation, the reciprocating and rotating engine parts are subjected to variations in inertial motion and combustion pressure. These variations in inertial motion of the parts during upward and downward motion, as well as variations in combustion pressure, produce unbalanced forces at the engine block, which are measured as longitudinal vibrations in the three orthogonal directions. By reducing unbalanced forces and supporting the engine at the correct mounts, both vibrations may be minimised (Ramachandran et al., 2012).

In addition to the harmful physical and emotional impacts of vibration, this phenomenon also poses health hazards to the whole body (Farrokhi Zanganeh et al., 2021). The comfort of a vehicle's ride is significantly influenced by lateral accelerations (around the roll axis). However, a suspension system for a half-car cannot be used to model these. Due to the need for a 12-degree-of-freedom full car model that included roll vibrations, earlier quarter-car and half-car models—while accurate and correct for their intended use—will not be further discussed in this study (Jayachandran & Krishnapillai, 2013).

Results and conclusion

Studies have shown that exposure to mechanical vibration can have negative effects on human health.

Prolonged exposure to mechanical vibration can cause a range of health problems, including damage to the musculoskeletal system, circulatory system, and nervous system. For example, workers who use hand-held power tools or operate heavy machinery are at risk of developing hand-arm vibration syndrome (HAVS), which can cause nerve damage, vascular damage, and musculoskeletal disorders.

Furthermore, exposure to whole-body vibration (WBV) can also cause health problems, including lower back pain, fatigue, and digestive disorders. Certain populations, such as long-distance truck drivers, construction workers, and heavy machinery operators, are particularly at risk of developing these conditions.

In conclusion, it is important to limit exposure to mechanical vibration and take measures to reduce its harmful effects on human health. This can include using vibration-dampening equipment, taking regular breaks, and using proper posture and ergonomics when working with vibrating equipment.

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