Original Research Article

Occupational Risk Evaluation of Vibration exposed Road Construction Workers of Kolkata: An Ergo-Physiological Analysis

Sugata Das[1], Subhashree Sana[2], Anandi Bagchi[3], Subrata Ghosh[4*]

[1]Department of Physiology, University of Calcutta, West Bengal, India
[2]Department of Physiology, Hooghly Mohsin College, West Bengal, India
[3]Department of Physiology, P R Thakur Govt. College North 24 Pgs West Bengal, India
[4]Department of Physiology, Hooghly Mohsin College, West Bengal, India

Received: 29-11-2021 / Revised: 22-12-2021 / Accepted: 01-01-2022

Abstract

Whole-body vibration is described as the influence of mechanical vibration of the environment on the entire human body. The harmfulness of vibration depends on its intensity, time of exposure, and frequency content. Vibration restricts the blood supply to the hands and fingers, which, depending on the vibration level, can contribute to an ergonomic injury. Long time exposure to vibration develops occupational injuries in the whole body of road construction workers. Therefore, this study aims to evaluate and identify the physiological morbidity of the road contractors of Kolkata, to quantify the body part damages of road contractors due to vibration, and to recommend some suitable preventive measures for avoiding occupational damage. This double-blind study followed STROBE guideline. Here, 56 male road construction workers who were exposed to vibration & 42 other forms of road construction workers of Kolkata were randomly chosen, with age range 30-48years. Their muscle& finger strength, the prevalence of Raynaud's phenomenon, occupational vibration-induced ocular bone injury, and musculoskeletal disorders were evaluated statistically. The results of this study indicate that the experimental group was suffering from poor muscle and finger strength, low back injury, early onset of the white finger, and dry eye disease. FFA, Nailfold capillaroscopy, and DEXA Scan suggeststhe onset of retinal vascular capillary damages, and porosity of bone. ANA results indicatethe presence of higher titer and greater amount of autoantibody amongst the experimental group. However, road construction workers should use anti-vibration shock- proof protection gear and should follow a work-rest cycle of about 10 minutes, when they are exposed to vibration tools.

Keywords: Road construction workers, Raynaud's phenomenon, ocular disease, bone injury, anti-nuclear antibody, MSD.

Highlights

- This study was to investigate the physiological morbidity, hand-arm, ocular, and bone damages during vibration handling.
- Handgrip, Pinch grip dynamometer for muscle strength, Fundus fluorescence angiography (FFA) and tear breakup time for ocular damage, Nailfold capillaroscopy and cold provocation test for finger damage, DEXA Scan for bone damage, and Modified Nordic questionnaire for musculoskeletal disorders were assessed.
- Excessive exposure to vibration for a long time affects different body parts of road construction workers severely.
- The results of this study indicate that vibration not only damages hand-arm but also damages the retina's vascular sheathing and bone morphology as well. Use of recommended PPE may be helpful for road construction workers.
- This study analysis is useful for redesigning ergonomic and vibration-proof equipment for road construction workers to reduce their occupational disorders.

Introduction

Whole-body vibration is described as the influence of mechanical vibration of the environment on the whole human body. In daily normal life, everybody is exposed to the various types of vibration originating from buses, trains, cars, etc.

Many people are also exposed to other vibrationsat their work station including hand tools, machinery, or heavy vehicles. The harmful nature of vibration on the human body depends on its intensity, time of exposure, and frequency. People, who are exposed to vibration at the workplace for a long time, have a likelihood of permanent damage to some parts of their body[1].

Vibration's negative impacts on human health are a big issue. Mechanical vibrations communicated to the human body by power tools and other vibrating instruments can have a harmful influence on particular tissues and blood vessels, create stimulation of internal organs or body parts, and even cause cellular structure damage.Vibration restricts the blood supply to the hands and fingers, which, depending on the vibration level and duration of exposure, can contribute to an ergonomic injury[2]. Hand-arm vibration is vibration transmitted from work processes into workers' hands and arms. It can be caused by operating hand-held power tools, such as road breakers, and hand-guided equipment, such as powered lawnmowers, or by holding materials being processed by machines, such as pedestal grinders. This hand-arm vibration is dangerously transmitted to the upper part of the body, which can cause pathophysiological changes to the cardiovascular, osteoarticular, and nervous systems. Changes in human body systems resulting from exposure to mechanical vibrations are acknowledged as an occupational disease, called vibration syndrome. The workers whose hands are regularly exposed to Hand Arm Vibration may suffer from damage to the tissues of hands & arm, which cause the symptoms collectively known as Hand Arm Vibration Syndrome (HAVS)[3].

*Correspondence
Dr. Subrata Ghosh
Department of Physiology, Hooghly Mohsin College, West Bengal, India

According to data from 2018, vibration syndrome accounted for 2.9 percent of all occupational disorders in forestry, 5.6 percent in mining, 4.3 percent in metals manufacturing, and 8.7 percent in construction industries like road and building.

Vibrations may have a long-term physical influence on the human body. The vibration that occurs in the context of work has a particularly high risk of irreversible injury since the vibration magnitudes can be significant, the exposure lengths can be long, and the vibration exposure might occur on a regular or even daily basis. Vehicle drivers, agricultural workers, road contractors, building contractors are the typical risk group to vibration. Their hand-arm part may be exposed to excessive vibration during work time. Long time exposure to vibration develops occupational injuries in the whole part of body[4]. According to ILO, hand-arm vibrations values are: daily exposure action value of 2.5 m/s^2& daily exposure limit value of 5 m/s^2, whereas whole-body vibrations values are: daily exposure action value of 0.5 m/s^2& daily exposure limit value of 1.15 m/s^2. But the road workers are exposed to vibration beyond the ILO approved limit every day[5]. It is therefore of utmost importance to prevent excessive vibration exposure. So, under these circumstances this study aims:

- To identify the physiological morbidity of the road contractors of Kolkata.
- To quantify the body part damages of road contractors due to vibration.
- To recommend some suitable preventive measures for avoiding occupational damage.

Materials & Methods

Collection of human samples

Double-blind study was carried out in road construction in different areas of Kolkata. Arbitrarily 98 male working labors were randomly chosen for this study. This double blind study was carried out whereby the subjects were divided into two groups. 56 subjects were randomly assigned for Experimental group-A, who were involved with the use of pneumatic hammer and road breaker over the years. Another comparable Control group-B consisted of 42 subjects, who were involved in other forms of work in road construction, but never used pneumatic hammer or breaker. All the above sample collection procedure followed STROBE guideline.

Inclusion criteria

Uninterrupted work experience of minimum 5 years, not taking any medicine 1 month before and during this study, and age range from 30 to 48 years.

Exclusion criteria

Subjects with other occupational disorders prior to the study & subjects who did not agree to volunteer.

Ethical consideration

This study was performed following the ethical guidelines for biomedical research on human participants as directed by ICMR Govt. Of India. All the subjects were explained about the objective and probable impact of the work to volunteer for the study.

Research Design

- The height & weight of all subjects were measured through an anthropometer & weighing machine.
- The Body Mass Index (BMI) of all subjects was calculated by a standard formula. BMI was used to measure the degree of adiposity.
- Muscle strength& finger strength investigation was done by Jamar Hand Grip Dynamometer and pinch grip dynamometer.
- Finger temperature regain time was measured by cold provocation test and thermometer.
- Lacrimation studies were measured by tear breakup time and ophthalmoscope.
- Retinal vasculature and Capillaroscopy were done by Fundus Photography of Eyes.
- Bone mineral density was measured by DEXA Scan.
- Nailfold capillaroscopy was measured for the experimental group &the antinuclear antibodies (ANA) test was done by Immunofluorescence.

Moreover, "Modified Nordic"questionnaire for detecting musculoskeletal disorders was employed in this study to complement the entire findings and to reciprocate their feelings, from a quantitative point of view.

Structured cum schedule interview technique was adopted to elicit the information relating to socio-economic background, health status, activity profile, frequency of performance, total days of performance in a year by the respondents using the PLIBEL questionnaire checklist method.

Statistical Analysis

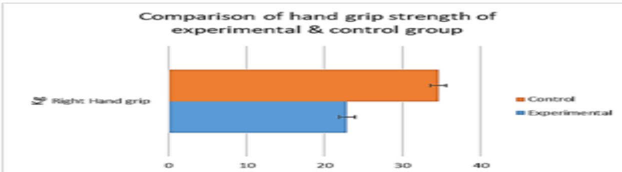
Data was analyzed using the software of Minitab 16. Descriptive statistics of socio-demographic variables were computed as mean and standard deviation. Student t-test was calculated with those data. "p-values<0.05" were considered to be significant.

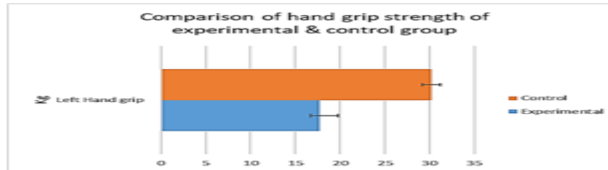
Results

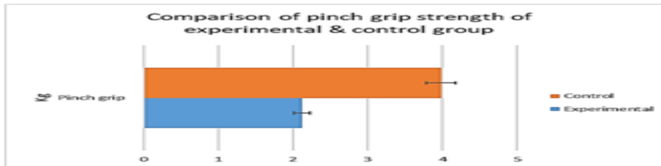
The age range of both the experimental and control group was 30-48 years. Both the groups belonged to the same socio-economic group and had an insignificant value of Height, Weight, and Body Mass Index (BMI) compared to standard values.

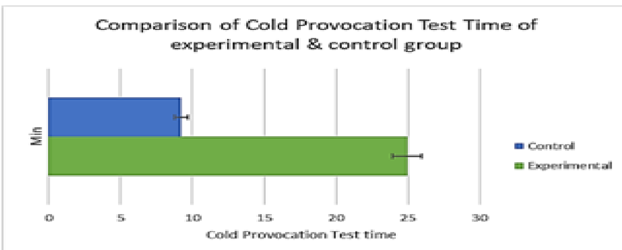
Table 1: Representation of dynamic strength&optical performance parameters between experimental & control group

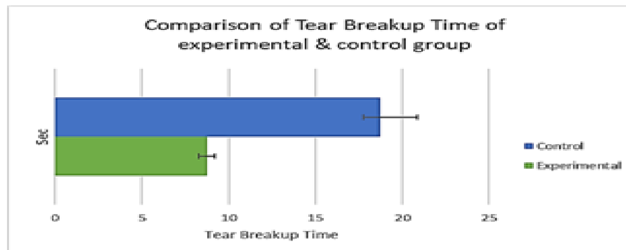
Parameters	Experimental Gr: A		Control Gr: B		p- value (<0.05)
	Mean	S_D	Mean	S_D	
Right Hand Grip Strength (kg) at 45^0	22.86	2.33	34.56	1.99	**0.002***
LeftHand Grip Strength (kg) at 45^0	17.67	2.11	30.21	1.78	**0.001***
Pinch Grip Strength (kg)	2.12	1.83	3.98	2.01	**0.004***
Cold provocation test time (min)	24.94	1.17	9.20	3.11	**0.001***
Tear breakup time (sec)	8.74	1.28	18.75	2.12	**0.001***

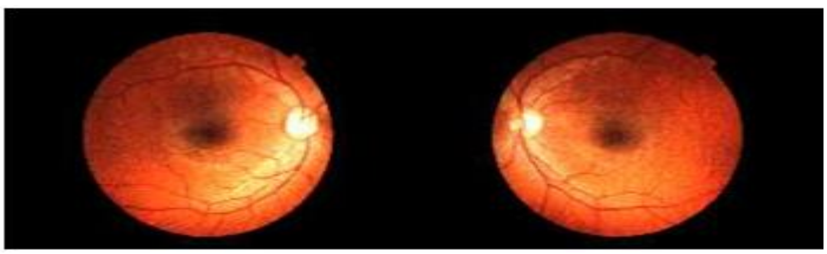




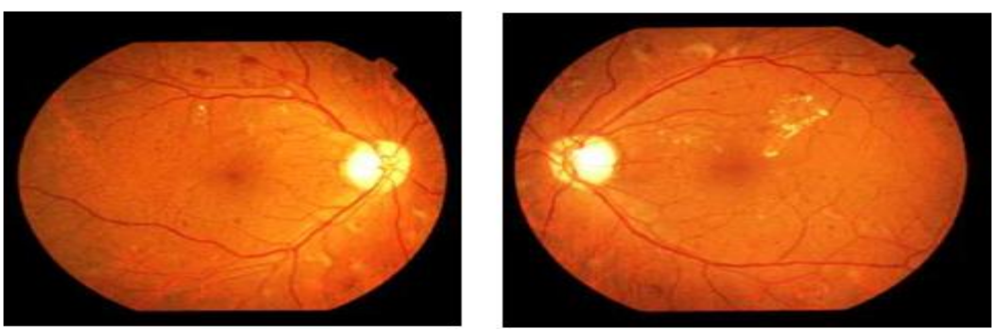




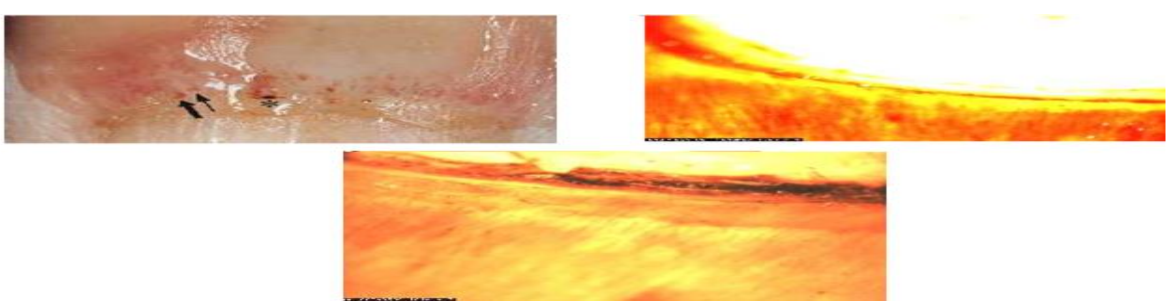




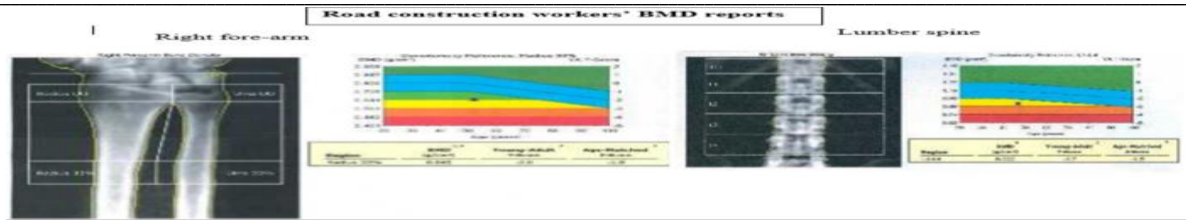
Fundus photographic showing the early retinal damage of Road construction workers(taken by Retinal camera, TRCNW-75f)

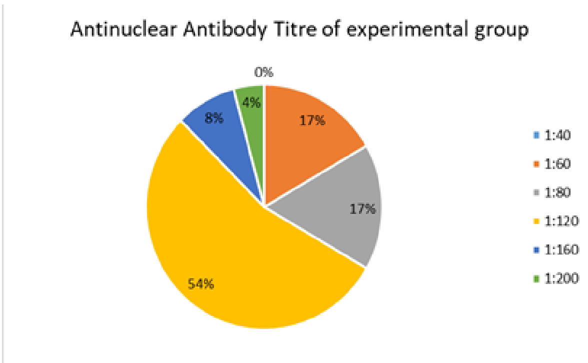


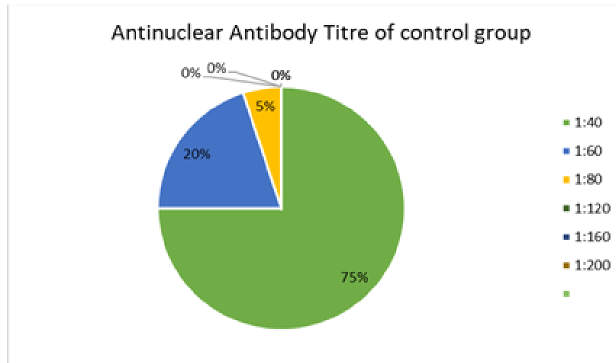
Different grades of retinal capillary damage network



Acutely damaged Nailfold capillaroscopy images of Road construction workers

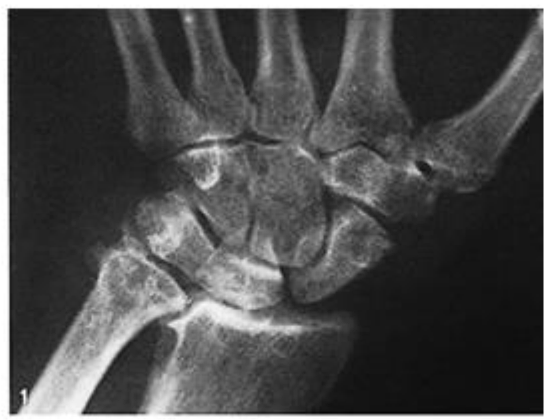




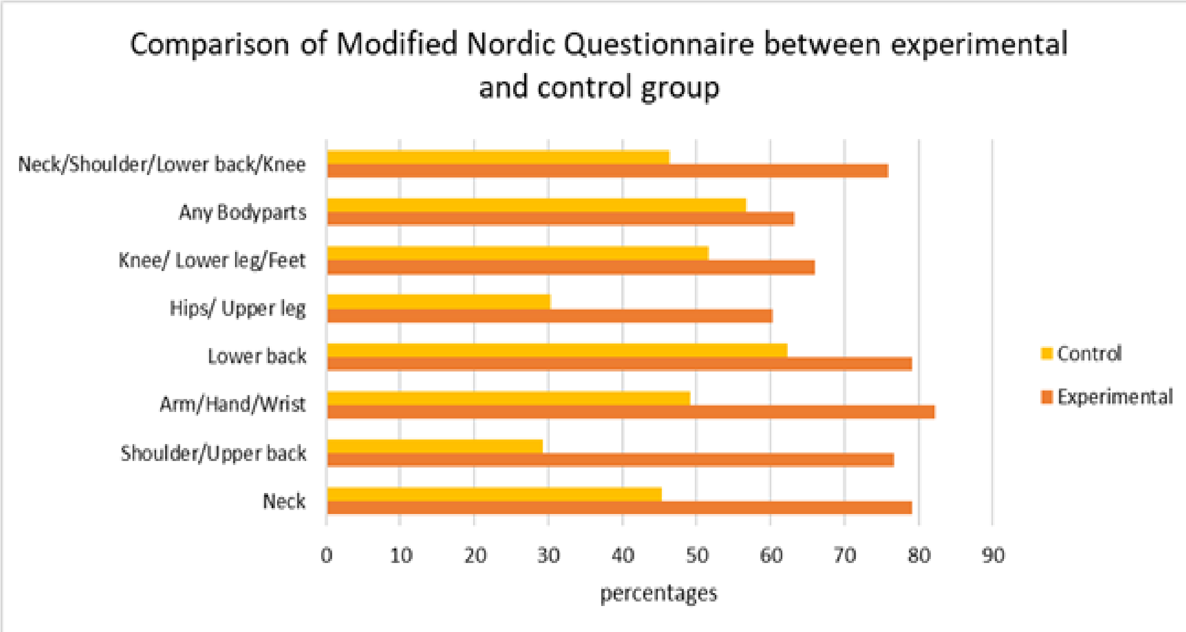


Antinuclear Antibody (ANA) Titer of the experimental and control group

Right fore-arm



Effect of Vibration



Discussion

Road construction and building construction workers are the largest part of the unorganized sector in India. Labors are mostly unskilled and migrant workers. They mostly belong to low socioeconomic status, but the high involvement of construction sectors makes them the most valuable group of India. Around 40 million people are engaged in this industry,regardless of male and female. In construction industries, the workers are found to lack awareness about their safety, working conditions, and wellbeing. They fail to understand the hidden risk at the workstation. Sometimes they are unaware of the actual working hours, factors exposed, occupational hazards, and due to their lack of awareness, they fall into occupational hazards leadingto several injuries. In this study, the main concern is the road construction workers of Kolkata. Road construction workers are primarily exposed to vibrating machinery and equipment, which affects their hand-arm initially and in the longterm affects their whole body.

This study mainly focused on some of the immediate factorsof the general and occupational health of road construction workers. The Jamar-grip dynamometer is a simple, reliable, and valid assessment tool that has been extensively used for the assessment of upper-extremity strength impairments. Hand-grip dynamometer and pinch gauge readings are extremely useful tools to measure baseline functions of hand and finger muscles. Maintaining muscle strength above the safety margin allows individuals to remain functionally independent for as long as possible. Therefore, good muscle strength acts as a reserve that protects healthy adults[6]. This study aimed to investigate hand-grip and key-pinch strength, particularly at theupper limb positions for both groups,because experimental subjects are exposed to vibration-induced tools very frequently.

A decline in handgrip strength (HGS) is predictive of increased disability and mortality in an individual. Static hand activity influences the muscle activity in the 4 shoulder muscles - the supraspinatus, the infraspinatus (flection) and, to a lesser extent, the deltoid muscles. In the supra and infraspinatus muscles, there was a positive correlation between the degree of the shoulder muscle activity and the intensity of the handgrip exertion in most of the tested arm-positions[7]. HGS is a useful tool for measuring general muscle strength to diagnose sarcopenia, as low HGS is a clinical indicator of poor mobility, low muscle mass, and poor nutritional status. It may be hypothesized that low muscle strength is related to low back pain. So the low handgrip strength values of the road construction workers may suggest that they are suffering from back pain. Low pinch grip strength is indicative of their finger disability. Long-time use of road breaker machinery causesa decreased level of finger strength, which infuture may lead to the development of white finger.

From the emerged data, it is found that the experimental group is suffering from an early stage of Raynaud's phenomenon, and dry eyes, as reflected from their cold provocation test and tear breakup time analysis. In the cold provocation test, road construction workers scored borderline normal values, which may be due to long term exposure to vibration without the use of personal protective gear[8]. Tear breakup time is a clinical test used to assess evaporative dry eye disease. Low tear breakup time indicates that there is a damage of drainage through the lacrimal passages and evaporation, leading to dryness of the eyes[9].

Fundus Fluorescein Angiogram (FFA) image defines construction workers' retinal circulationwith little damage tovascular sheathing, clotted blood spot,and occasional ocular uneasiness, and is also an early indicator of retinal vasculardamage at an early age. After getting abnormal results fromthe cold provocation test, Nailfold capillaroscopy of the construction workers was studied. From the images, it was found that their capillary walls are damaged and morphological changes are seen clearly, indicating that they are suffering from primary Raynaud's phenomenon[10].

Dual Energy X-ray Absorptiometry (DEXA) is the only test that can diagnose osteoporosis or osteoarthritis before a broken bone occurs. This test helps to estimate the density of bones and the chance of breaking a bone. From the DEXA scan images, it is found that they are very much prone to osteoarthritis in the near future. The X-Ray images of the hand reflect their loose bone joints than theirnormal counterpart, causing fragility of bone due to using vibration machinery frequently.

Antinuclear antibodies (ANA) are a group of autoantibodies produced by a person's immune system when it fails to adequately distinguish between "self" and "non-self." The ANA test detects these autoantibodies in the blood.A positive ANA test result means that autoantibodies are present, which suggests the presence of an autoimmune disease, but further evaluation is required. The lower the dilution ratio at which ANA is still detected, the higher the titer and the greater the amount of autoantibody present. The construction workers of this study are more exposed to vibration-induced tools during road breaking. Due to continuous exposure to such vibration tools, their body produces antinuclear antibodies. The use of vibrating tools at work often leads to the development of the hand-arm vibration syndrome (HAVS). It manifests with vascular symptoms like occupational Raynaud's disease, neurologic symptoms like carpal tunnel syndrome – CTS, and musculoskeletal symptoms like impaired grip strength, osteoarthritis, and bone necrosis. Vibration-induced shear stress damage on the vascular endothelium leads to activation of the coagulation cascade. HAVS can lead to disability, occupation difficulties, and poor quality of life. Hand-transmitted vibration significantly worsens dexterity scores in workers exposed to hand-transmitted vibration-induced tools. In HAVS, endothelial damage and dysregulation of arteries caused by vibration lead to the decrease of endothelial-derived relaxing factors such as nitric oxide and increase of endothelial-derived constricting factors such as endothelin-1. Increased oxidative stress and the predominance of α_2-receptor function also contribute to local acral dysfunction. The management of HAVS comprises reduction of vibratory exposure, avoidance of cold exposure, smoking cessation, physical therapy, and medical treatment with a calcium channel blocker. Gripping the handle lightly, allowing the machines or equipment to do the work for the handler, and rotation of tasks among several workers may also help to reduce the risk of injury[11]. It is also found from the evaluation of the modified Nordic questionnairethat they suffer from pain invarious parts of the body due to extreme vibration exposure and awkward posture during working time. Musculoskeletal Disorders are disorders or inabilities that impact the body's mobility (MSD). Workers become fatigued when they are exposed to MSD risk factors due to repetition and stress. The role of construction workers in the conventional industry needs to be recognized and introduction of beneficial plan for the interest of humanity as well as industry is essential.

Conclusion

It may thus be concluded that probably due to the frequent exposure to vibration tool and machinery, road construction workers are highly affected and suffer from several occupational hazards & illness.Additionally, work-station equipment design is found to be faulty and construction workers suffer from postural dysfunction, pain, and other occupational hazards. Different clinical reports vividly showed their body's illness due to vibration. Lack of awareness on protective gear enhances their illness. Use of anti-vibration shock-proof protective gear may delay the onset of severe injury. Moreover, these workers need to follow a work-rest cycle, where a break after every 10 minutes should be followed, to reduce their ocular, muscular, and bone damages. The employers & the employee federations should be concerned seriously towards development of an ergonomicconstruction worksite on the roads.

Acknowledgments

We are grateful to and express our heartfelt admiration to all ofroad construction workers of Kolkata and our coworkers, for their cooperation and assistance. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of interest

There is no conflict of interest amongst authors.

References

1. Kalc, M., Ritzmann, R. and Strojnik, V., 2020. Effects of whole-body vibrations on neuromuscular fatigue: a study with sets of different durations. *PeerJ*, *8*, p.e10388.
2. Cronin, J.B., Oliver, M. and McNair, P.J., 2004. Muscle stiffness and injury effects of whole-body vibration. *Physical Therapy in Sport*, *5*(2), pp.68-74.
3. Bast-Pettersen, R., Ulvestad, B., Færden, K., Clemm, T.A.C., Olsen, R., Ellingsen, D.G. and Nordby, K.C., 2017. Tremor and hand-arm vibration syndrome (HAVS) in road maintenance workers. *International archives of occupational and environmental health*, *90*(1), pp.93-106.
4. Azmir, N.A., Ghazali, M.I., Yahya, M.N., Ali, M.H. and Song, J.I., 2015. Effect of hand-arm vibration on the development of vibration induces disorder among grass cutter workers. *Procedia Manufacturing*, *2*, pp.87-91.
5. Niu, S., 2010. Ergonomics and occupational safety and health: An ILO perspective. *Applied Ergonomics*, *41*(6), pp.744-753.
6. El-gohary, T.M., Abd Elkader, S.M., Al-shenqiti, A.M. and Ibrahim, M.I., 2019. Assessment of hand-grip and key-pinch strength at three arm positions among healthy college students: Dominant versus a non-dominant hand. Journal of Taibah University Medical Sciences, 14(6), pp.566-571.
7. Sporrong, H., Palmerud, G. and Herberts, P., 1996. Handgrip increases shoulder muscle activity: An EMG analysis with static handcontractions in 9 subjects. *Acta Orthopaedica Scandinavica*, *67*(5), pp.485-490.
8. Pyykkö, I., Färkkilä, M., Korhonen, O., Starck, J. and Jäntti, V., 1986. Cold provocation tests in the evaluation of vibration-induced white finger. *Scandinavian journal of work, environment & health*, pp.254-258.
9. Tsubota, K., 2018. Short tear film breakup time–type dry eye. *Investigative ophthalmology & visual science*, *59*(14), pp.DES64-DES70.
10. Chen, Q., Chen, G., Xiao, B., Lin, H., Qu, H., Zhang, D., Shi, M., Lang, L., Yang, B. and Yan, M., 2016. Nailfold capillary morphological characteristics of hand-arm vibration syndrome: a cross-sectional study. *BMJ open*, *6*(11), p.e012983.
11. Yano, H. and Kinjo, M., 2020. Digital gangrene due to hand arm vibration syndrome. BMJ Case Reports, 13(12).