

ORIGINAL ARTICLE

The effect of hand-arm vibrations on distal forearm bone mineralization

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Competing interests:

The authors have declared that no competing interests exist

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Summary

A prolonged, mainly professional, exposure to hand-arm vibration (HAV) may cause a complex chronic disorder of the upper extremities known as Hand-Arm Vibration Syndrome (HAVS).

Besides vascular and neurological injuries, such exposure to HAV may cause various bone disorders in the form of cystic changes, exostoses, aseptic necrosis, osteoarthritis, spontaneous fractures and osteoporosis.

The objective of this study was to examine whether there were any changes in the bone mineral density in the distal forearm in persons professionally exposed to HAV.

In a group of 31 workers professionally exposed to vibrations (29 men and 1 woman) with neurological and/or vascular signs of HAVS, the bone mineral density of the distal part of the radius of both hands was examined by dual X-ray absorptiometry (DXA). The control group consisted of 25 healthy subjects with no history of HAV exposure. Osteopenia was found in 14 subjects (45.16%), which makes a statistically significant difference compared to the control group ($p=0.017$), where osteopenia was found in 3 subjects (12.0%). Osteoporosis was not found in any of the subjects. Analyzing the value of T score for the dominant (-0.81 ± 0.58 SD) and non-dominant hand (-0.62 ± 0.68 SD) in our patients, we found no statistically significant difference in the average T score values of the dominant and non-dominant hand ($p=0.269$).

Changes in bone density at the distal radius are common in persons occupationally exposed to HAV. Distal forearm DXA examination in workers occupationally exposed to HAV can help diagnose HAVS.

Keywords: Vibration disease, bone density, DXA

INTRODUCTION

A prolonged, mainly professional, exposure to hand-arm vibration (HAV) may cause a complex chronic disorder of the upper extremities known as Hand-Arm Vibration Syndrome (HAVS) (1). Besides vascular and neurological injuries, such exposure to HAV may cause damage to bones, joints, muscles and tendons of the upper extremity (2,3).

HAVS related impairment is disabling, since patients experience functional, social, emotional, and psychological disability (4). Prevalence among vibration exposed workers varies between 8.4% and 18.1% depending on the vibration exposure factors (vibration magnitude, frequency, direction, and exposure duration), environmental factors (temperature, moisture), biomechanical factors (hand coupling forces, hand and arm postures), and individual factors (genetics, tobacco use, age, sex, hand and arm injury history) (5,6).

Various bone disorders, in the form of cystic changes, exostoses, aseptic necrosis, osteoarthritis, spontaneous fractures and osteoporosis are caused by vibration (7,8). Changes are most common in bones and joints of the wrist, metacarpophalangeal and elbow joints, while changes in the shoulder joint, spine, and other joints are less common, depending on the direction of vibration propagation. Low-frequency impact vibration can be transmitted to the upper arm and cause symptoms in the elbow and shoulder, while high-frequency impact vibration can cause symptoms in the wrist and hand (9,10).

Bone-joint changes are diagnosed by X-ray examination, primarily of the hands and wrists, elbow and shoulder joints. Changes in bone mineral density (BMD) can be determined by dual X-ray absorptiometry (DXA) testing (11).

The objective of this study was to examine whether there were any changes in the bone mineral density in the distal forearm in people professionally exposed to HAV.

MATERIAL AND METHODS

A group of 31 workers professionally exposed to hand-arm vibrations (29 men and 1 woman), with average exposure to vibrating tools of 23.23 ± 7.11 years, have undergone distal forearm dual x-ray absorptiometry (DXA) in order to evaluate bone mineral density of the distal part of the forearm of both hands, using an OsteoSys DEXXUM-T osteometer. The distal part of the forearm is divided into 3 regions of interest (ROIs): the "ultra-distal" radius consisting of a 15-mm section adjacent to the end plate of the radius; the proximal region termed the "33%" radius consisting of a 20-mm section one-third of the distance between the ulnar styloid and the olecranon; and the intermediate region consisting of the remaining section between the 2 aforementioned sites (12). In our study, we evaluated bone mineral density of the "ultra-distal" radius. All patients had been previously investigated for

vibration-related symptoms and signs by an occupational medicine specialist and had shown neurological and/or vascular signs of HAVS. The control group consisted of 25 healthy subjects with no history of hand-arm vibration exposure.

Demographic information including gender, age, hand dominance, vibration exposure, smoking status, and alcohol consumption were recorded.

The World Health Organization (WHO) criteria for the diagnosis of osteoporosis were applied, according to which a normal finding means bone density is reduced by 1 SD compared to the values for healthy adults (T-score ≤ -1), reduced bone mass (osteopenia) means bone density is reduced by 1 to 2.5 SD compared to the values for healthy adults (T-score -1 to -2.5), and osteoporosis means bone mass is reduced by 2.5 SD or more from values for healthy adults (T-score ≤ -2.5) (13).

This retrospective, case-control study was performed in accordance with the Helsinki Declaration procedures and Strengthening the Reporting of Observational Studies in Epidemiology (Strobe) Guidelines. The Institutional Ethical Committee approved this study (Protocol No 02/618-1), and subjects were informed of the objective and the procedure of the study and gave their written consent.

Statistical analysis

Data were presented in the form of arithmetic mean and standard deviation, that is, in the form of absolute and relative numbers. The comparison of categorical variables was performed using the Chi-square test. The comparison of age and T-score in relation to the studied groups was performed using the t-test. The hypothesis was tested with a significance threshold of $p < 0.05$. Statistical data processing was performed in the SPSS 21.0 software package.

RESULTS

Patients and healthy controls did not show any relevant age or gender differences, with male gender being dominant in both groups. Descriptive characteristics of the study sample are presented in **Table 1**.

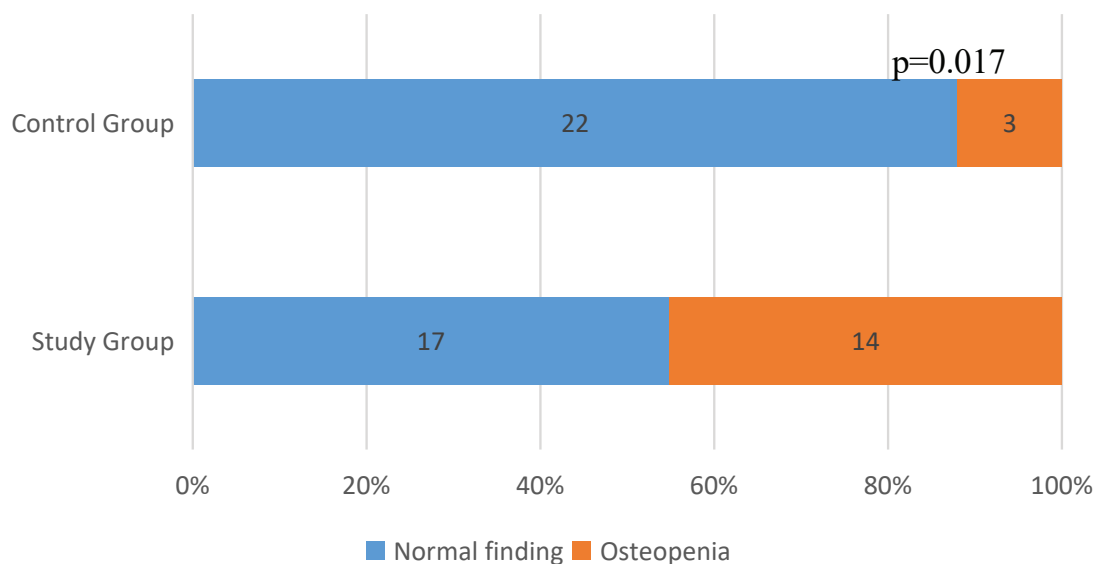
Osteopenia was found in 14 subjects professionally exposed to vibrations (45.16%), which makes a statistically significant difference compared to the control group ($p = 0.017$), where osteopenia was found in 3 subjects (12.0%). Osteoporosis was not found in any of the subjects (**Figure 1**).

Analyzing the value of T score for the dominant hand (-0.81 ± 0.58 SD) and for the non-dominant hand (-0.62 ± 0.68 SD) in subjects professionally exposed to vibrations, we found no significant difference in the average T score values of the dominant and non-dominant hand in our study ($p = 0.269$) (**Table 2**).

Table 1. Demographic and clinical characteristics

Characteristics	Total	Number of subjects (%) or mean \pm SD		p ¹
		Study Group n=31	Control Group n=25	
Gender				
Male	52 (92.86%)	29 (93.55%)	23 (92.0%)	1.000 ¹
Female	4 (7.14%)	2 (6.45%)	2 (8.0%)	
Age (years)		49.5 \pm 6.1	49.6 \pm 5.6	0.949 ²
Dominant hand				
Right	51 (91.07%)	29 (93.55%)	22 (88.0%)	0.801 ¹
Left	5 (8.93%)	2 (6.45%)	3 (12.0%)	
Smoking status				
Non-smoker	21 (37.50%)	11 (35.48%)	10 (40.0%)	0.944 ¹
Smoker	35 (62.50%)	20 (64.52%)	15 (60.0%)	
Alcohol consumption				
Yes	40 (71.43%)	19 (61.29%)	21 (84.0%)	0.116 ¹
No	16 (28.57%)	12 (38.71%)	4 (16.0%)	

¹ the Chi-squared test, ² t-test

**Figure 1.** Frequency of osteopenia in the study and control group**Table 2.** T score values of the dominant and non-dominant hand in study group

T score	Dominant hand N=31	Non-dominant hand N=31	p ¹
Mean \pm SD	-0.81 \pm 0.58	-0.62 \pm 0.68	0.269
Min-Max	-2.3 - -0.2	-1.7 - 0.7	

¹ t-test

DISCUSSION

Since the time of the first observations of the effect of vibrations on workers' body, which were described by Lariga in 1911, there have been numerous authors who have studied problems related to professional exposure to vibrations and vibration sickness (14).

In our study, there was no statistically significant difference between the examined groups in the distribution of subjects according to the age structure. The average age in the experimental group was 49.5 \pm 6.1 years with the variation interval of 32-61 years, and in the control group it was 49.6 \pm 5.6 years with the variation interval of 35-59 years. This age structure corresponds to the working population.

In the distribution of subjects according to gender, there was a significantly higher number of men (92.9%) in our study in comparison with women (7.1%), while there was no statistically significant difference in the number of subjects according to gender between the examined groups, as male gender was dominant in both groups. This correlates with data in other countries. In

Great Britain male/female ratio of new cases for HAVS from 2010 to 2019 shows that out of 5620 cases 99.7% were male (15). The difference probably reflects a smaller number of women working in job positions that involve exposure to HAV.

Cigarette smoking has been shown to lead to significant bone loss, and is recognized as an independent risk factor for the development of osteoporosis. It has been shown that long-term cigarette smoking can lead to an imbalance in bone turnover, further contributing to a reduction in bone mass and bone length, and an increased risk of fractures (16). However, smoking did not affect the results of our study, considering that the difference between the groups in relation to the smoking habit was not significant, with significantly higher number of smokers, in both examined groups.

Based on the results of a meta-analysis, alcohol consumption was shown to be a risk factor for osteoporosis. Negative effects of alcohol on bone health mainly interfere with the balance of calcium, a vital nutrient for bone health. There is linear association between greater alcohol consumption and bone density loss over time. (17). In our study, the number of subjects who consumed alcoholic drinks was significantly higher than those who did not consume alcohol at all, and even more so in the control group (84.0%) than in the experimental group (54.3%). This could have influenced the DXA findings, but in our study a greater loss of bone mineral density was not registered in the subjects of the control group.

Previously, it has been reported that vibration altered the bone remodeling and affected bone mineralization (18,19). Some studies reported that low frequency (<40 Hz) vibrations of high magnitude might be associated with abnormal radiological findings in the wrist and elbow joints (20,21). Fialova et al., investigated osteoporosis in the proximal segments of the upper extremities by evaluating chest X-ray findings in a group of 107 chainsaw workers. Their results showed a statistically significant difference in the degree of mineralization of the clavicle, compared to a group of 107 healthy men who had never worked with vibrating tools. The authors concluded that osteoporosis was not a rare finding in patients with vibration disease and that it affected both distal and proximal segments of the upper extremities (22). The results of a study by Peelukhana et al. showed that the structural damage was significant for cortical bone while it remained

insignificant for the trabecular bone. Furthermore, the results of this study showed that structural damage was significant at 5D time point for the cortical bone while the trabecular bone remained largely unaffected, with a change in trabecular spacing observed at 20D time point (23). Our results correlate with these data.

This observational study, with its moderate sized, carefully designed groups and well-constructed analysis, is the first one in Serbia that showed the correlation between HAV and low mineral density in the distal part of the forearm. Measuring the bone mass density of the distal radius using DXA, osteopenia was found in 14 subjects (45.16%) in our study according to the WHO criteria, which makes a statistically significant difference compared to the control group ($p < 0.01$), where osteopenia was found in 3 subjects (12.0%). This would confirm the possibility of applying the distal forearm DXA examination in occupationally exposed HAV, bearing in mind that the distal radius is predominantly composed of the cortical bone.

CONCLUSIONS

Changes in bone density at the distal forearm are not uncommon in people occupationally exposed to vibrations. Distal forearm DXA examination in workers occupationally exposed to HAV can contribute to the diagnosis of HAVS. The appropriate assessment and diagnosis ensure adequate treatment primarily in terms of timely cessation of vibration exposure, since, similarly to neurological and vascular disorders, bone mineralization can be repaired upon cessation of exposure to vibration.

Author Contributions:

Conception, interpretation, and work design: Marija Hrković, Tamara Filipović, Anđela Milovanović, Aleksandar Milovanović. Data acquisition and analysis: Dejan Nikolić, Ljubica Nikčević, Jovana Kojović Avramović. Aleksandar Filipović. All authors approved the final version of the manuscript.

Conflict of Interest:

Authors declare no conflict of interest.

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UTICAJ LOKALNIH VIBRACIJA NA MINERALNU GUSTINU KOSTIJU DISTALNE PODLAKTICE

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Sažetak

Produžena, uglavnom profesionalna, izloženost gornjih ekstremiteta vibracijama može izazvati složen hronični poremećaj poznat kao vibraciona bolest. Pored vaskularnih i neuroloških poremećaja, ovakva izloženost lokalnim vibracijama može izazvati razne poremećaje na kostima u vidu cističnih promena, egzostoza, aseptične nekroze, osteoartritisa, spontanih preloma i osteoporoze.

Cilj ovog istraživanja bio je da se ispita da li postoje promene mineralne koštane gustine na nivou distalne podlaktice kod osoba koje su profesionalno izložene lokalnim vibracijama.

U grupi od 31 radnika profesionalno izloženih vibracijama (29 muškaraca i 1 žena) sa neurološkim i/ili vaskularnim znacima vibracione bolesti DXA metodom ispitana je mineralna koštana gustina na nivou distalnog radijusa. Kontrolnu grupu činilo je 25 zdravih ispitanika koji nisu

bili izloženi lokalnim vibracijama. Osteopenija je utvrđena kod 14 ispitanika (45,16%), što čini statistički značajnu razliku u odnosu na kontrolnu grupu ($p=0,017$), gde je osteopenija utvrđena kod 3 ispitanika (12,0%). Osteoporoza nije utvrđena ni kod jednog ispitanika. Analizirajući vrednost T skora za dominantnu ($-0,81 \pm 0,58$ SD) i nedominantnu ruku ($-0,62 \pm 0,68$ SD) kod naših ispitanika, nismo pronašli statistički značajnu razliku u prosečnim vrednostima T skora dominantne i nedominantne ruke ($p=0,269$).

Promene mineralne koštane gustine na nivou distalnog radijusa su česte kod osoba koje su profesionalno izložene vibracijama. DXA pregled distalnog radijusa kod radnika koji su profesionalno izloženi lokalnim vibracijama može pomoći u dijagnostici vibracione bolesti.

Ključne reči: Vibraciona bolest, gustina kostiju, DXA

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