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ASSOCIATION BETWEEN OCCUPATIONAL PHYSICAL ACTIVITY AND QUANTITATIVE BONE ULTRASOUND IN SAWMILL WORKERS

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SUMMARY: A small number of studies have examined the relationship between bone health and level of physical load. We explored the effect of occupational physical activity on skeletal status in younger sawmill workers using ultrasonic indices of bone density. In a cross-sectional study, we measured bone density with quantitative ultrasound (QUS) in 128 sawmill workers (89 men and 39 women), mean age 39.1 +/- 10.8 years. Back strength was measured by dynamometry. Information on occupational and leisure physical activity, joint pain, education and smoking were obtained with the questionnaire. All QUS bone parameters and back strength were significantly higher in men than in women. A T score for quantitative ultrasound index (QUI) of - 2.2 or lower was found only in two men and one women. QUI did not significantly differ based on presence of parameters of physical occupational activity (carrying loads exceeding 5 kg, repetitive movements, physical exertion while working and non-sitting position at work). When controlling for age, gender and body mass index, participants with higher smoking index had significantly lower QUI ($p=0.004$). Physical workload was not significantly associated with QUI. In our working population, some lifestyle habits, such as smoking, had a greater impact on bone health than physical occupational activity.

Key words: quantitative ultrasound, occupational activity, occupation, smoking, bone density, back strength

INTRODUCTION

It is well established that physical activity has beneficial effects on growing bone and that it also protects from the bone loss (Damilakis *et al.*, 1999). However, there are discrepancies in those findings, possibly because the physical activity is particularly important for prevention of bone loss in older population, whereas high levels of physical activity at younger age might lead to hormonal imbalances and reduced peak bone mass, which could be seen in female athletes (Mudd *et*

al., 2007). There are also conflicting data in the literature about the impact of occupation on bone health during working life, in terms of its physical activity level. Some results indicate positive associations between physical occupational activity and bone mineral density (BMD) (Damilakis *et al.*, 1999). On contrary, several other studies have not found such associations (Coupland *et al.*, 2000, Mickelsfield *et al.*, 2003) and one has determined lower BMD in men with high level of occupational activity (Walker-Bone *et al.*, 2014). It appears that the impact of occupation on bone also depends on the length of exposure. In one study, occupational physical activities at age 42.6 years was associated with spine BMD, while total lifetime exposure was not (Mickelsfield *et al.*, 2003). Similarly, in other study the only signifi-

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cant positive associations with BMD was standing position in job at age 30 (Coupland et al., 2000).

Sawmill workers are primarily exposed to noise and dust. However, many activities in sawmills are controlled manually and include lifting, carrying, pulling, etc. That is why work in sawmill could be considered as one with high physical workload and consequently could be categorized as high-risk for joint disorders (Rahman et al., 2019). However, most of mentioned physical activity in sawmill workers involve both muscle contraction and gravitational loading, which both exert the positive effects on bone density. The job in sawmill is also predominantly walking or standing, which together with the physical activity classify this job as potentially favorable for bone density. It is important to note that the benefits of physical activity on bone health depend on other lifestyle habits, like smoking and nutrition and on general health and hormonal status.

In most studies on influence of physical occupational activity on skeletal status, bone measurements have been determined with dual energy x-ray absorptiometry (DXA) (Al-Bashaireh et al., 2018, Bernaards et al., 2004, Coupland et al., 2000). Quantitative ultrasound (QUS) can provide useful information not only about density but also about bone structure. A number of studies have reported QUS parameters to be significantly associated with bone structure independently of BMD (Lin et al., 2015, Wuster et al., 2005). There are also several studies, which examined the impact of general physical activity or smoking on bone density using QUS (Dionyssiotis et al., 2010, Oral et al., 2006, Bernaards et al., 2004).

Since there are conflicting data in the literature on the effects of occupational exertion on bone health, in this study we examined the association of present occupational physical activity and bone density in sawmill workers using ultrasonic indices of skeletal status.

MATERIALS AND METHODS

Subjects

The study protocol was previously described in detail in the publication about the respiratory

health in the same study group (Ljubičić Čalušić et al., 2012). Briefly, the study population comprised sawmill workers from two sawmills located near Zagreb, Croatia. They all worked five days a week, eight hours per day. Response rates in both sawmills were 92 % and 86 % respectively with total number of 89 men and 39 women participated in the study. Informed consent was obtained from all subjects included in the study. Participants were recruited on a voluntary basis and the study was approved by the Ethics Committee of the Institute of Medical Research and Occupational Health.

Data collection

Data were collected using an interviewer-administered questionnaire, designed for this study. The questionnaire consisted of several parts: general data, education, work history, occupational physical activity and load, occupational environment and exposure data, health disorders associated or not associated with work environment, psychosocial factors and lifestyle. The parts of questionnaire related to work conditions and physical activity were prepared according to the Environment protection Agency (EPA) and National Institute for Occupational Safety and Health (NIOSH) Manual on air quality in buildings (Environmental Protection Agency, 1991) and according to Guidebook on Occupational Safety at Manual Cargo Transfer (Public Gazette, 2005). Assessment of physical occupational activity included the questions about: a) Handling the heavy objects (more than 5 kg); b) Repetitive motions of hands and elbows more than 2 hours during working time; c) Self-assessment of physical exertion in the workplace (as low, medium or high); d) Position at work as predominantly sitting, standing or walking. Working conditions associated with loading heavy objects, greater physical exertion, more repetitive movements and non-sitting position were considered as beneficial for bone density. History data included information of present or past diseases (including bone fractures), drug consumption, and presence of joint and/or muscular pain longer than 3 months. Smoking habit was expressed as smoking index for current smokers (number of cigarettes smoked per day multiplied by number of smoking years). Subjects who never smoked and ex-smokers were

designated as nonsmokers. All ex-smokers quit smoking at least 1 year before enrolment in this study. Work experience was expressed as years of employment at the present workplace in the sawmill but also as total years of employment. Education was defined in two categories: unqualified workers, with primary school and qualified workers, with secondary school. Leisure time physical activity was recorded as present or not present. Body mass index (BMI) was calculated from height and weight according to the formula: weight (kg) / height (m)².

Dynamometry

The back strength was recorded using a portable Lafayette-Adult Back and Leg Dynamometer Package Model 32527 A-3 (Lafayette Instrument Company, Lafayette, USA). The package includes a 600-pound pull dynamometer, foot chain, solid aluminum lifting bar with handgrips and a lifting platform. The pull dynamometer has a range of 50 to 600 pounds, in 5-pound increments. The back dynamometer has an adjustable handgrip chain and a scale for quick and reliable reading. The chain was adjusted so that the gripping bar met the knee height of the subject at the measured posture. The subject stood on the platform, grasped the gripping bar at both ends and kept the leg straight. The body was bent forward around the hip joint, and the subject extended his/her trunk around the hip joint by pulling the bar upwards to maximum voluntary force, then the force value was recorded. Each strength item was measured two times for each subject, and the mean of two readings was used as the result. The precision error of the measurement was 3.5 %. Original measurement units of the system are pounds, which were converted to kilograms by multiplying the number of pounds by 0.45.

Quantitative ultrasonography

We used the Sahara ultrasound bone densitometer (Hologic, Bedford, MA) to measure the broadband ultrasound attenuation (BUA; dB/MHz) and the speed of sound (SOS; m/s) of the heel (non-dominant side). The quantitative ultrasound index (QUI) is a mathematical combination of both BUA and SOS and we used it as the

main indicator of bone mineral density (*Nairus et al., 2000*). T scores for QUI were calculated using Croatian QUS normative data (*Kraljević et al., 2007*) according to the formula: $(P-YA)/SD_{YA}$ (P = patient result, YA = young adult mean value, SD_{YA} = standard deviation of young adult population). Since World Health Organization (WHO) criteria (*World Health Organization, 1994*) cannot be directly applied to the QUS, we used a QUI T score ≤ -2.2 as a criterion for diagnosing low bone mineral density, with the Croatian population as referential. A threshold of -2.2 was suggested for Sahara ultrasound devices to define participants as having osteoporosis at the hip or being at high risk of fracture (*Hans et al., 2003*). To compare the bone values of our participants, we used Croatian QUS normative data obtained from the general population of men and women of the same age (*Kraljević et al., 2007*).

Statistics

Data were analyzed using the software Statistica, version 13.0 (StatSoft Inc., Tulsa, USA). The results are shown as mean \pm standard deviation. Distributions of outcome variables were examined for asymmetry and outliers using the Kolmogorov-Smirnov test. Since most variables were distributed normally, parametric functions were used in data analyses. Differences between the means were tested using Student t test and between categorical variables with chi square test. The relationship between two variables was tested with the linear correlation. The multiple regression model was created with QUI as dependent variable and age, body mass index, muscle strength, smoking and physical activity as independent variables. To assess physical occupational activity, a continuous variable was formed from several categorical variables which described working conditions: a) carrying loads exceeding 5 kg (yes/no); b) repetitive motions (yes/no); c) physical exertion while working (yes (moderate, strong)/no); d) non-sitting position at work (yes/no). All positive answers were summed, and then multiplied with the years spent in the current job, in order to form a score, which represented a physical workload at the present job: the higher the score, the higher the workload. In all tests, p value lower than 0.05 was considered significant.

RESULTS

Women were significantly older than men ($p < 0.001$) and they also had longer work experience in the sawmill ($p < 0.008$). As expected, all bone density parameters were significantly higher in men than in women (QUI $p = 0.014$; SOS $p = 0.026$; BUA $p = 0.002$). According to QUI T score (≤ 2.2), two men and one women had osteoporosis. When compared QUS parameters of our participants to those from general population of the same mean age (*Lin et al., 2001*), we found significantly higher BUA ($p = 0.013$) in our men (not presented). Other QUS parameters did not differ significantly between our participants and general population, both in men and women. Back strength was also significantly higher in men compared to women ($p < 0.001$). There were no significant

differences in education level, smoking index and leisure time physical activity between men and women.

There were no significant differences in components of physical occupational activity between men and women except in position at work (Table 2). Most men (76.4 %) and 61.5 % of women had to lift more than 5 kg during working process. Similar percentage of men (59.5 %) and women (66.7 %) performed repetitive movements with hands and elbows more than 2 hours during working process. Approximately half of men and women reported high physical exertion in the workplace. Similar percentage of men and women had to work in sitting or standing position, while significantly more men had to walk during the working process ($p = 0.038$).

Table 1. Age, anthropometry, education, QUS bone parameters, dynamometry and lifestyle variables in men (N 89) and women (N 39)

Tablica 1. Dob, antropometrija, parametri kvantitativne UZV denzitometrije, dinamometrija i način života muškaraca (N 89) i žena (N 39)

Variable	Men Mean + / SD or N (%)	Women Mean + / SD or N (%)	p value
Age (yrs.)	34.9 +/- 11.1	42.9 +/- 10.0	<0.001
Body mass index (kg/m ²)	25.9 +/- 4.3	25.6 +/- 4.5	0.745
Duration of postmenopause (yrs.)	/	2.3 +/- 6.5	/
Work experience in the sawmill (yrs.)	4.8 +/- 4.8	8.1 +/- 8.0	0.008
Total work experience (yrs.)	14.1 +/- 11.0	16.2 +/- 9.7	0.322
Education higher than elementary school	67 (75.3)	23 (58.9)	0.061
Smoking index	213.5 +/- 309.7	116.0 +/- 220.4	0.092
Leisure time PA	46 (51.6)	15 (38.4)	0.168
BUA (m/s)	90.3 +/- 19.0	78.7 +/- 18.8	0.002
SOS (dB/MHz)	1564.8 +/- 37.1	1549.3 +/- 26.5	0.026
QUI	107.7 +/- 21.9	97.6 +/- 16.5	0.014
QUI T score	0.2 +/- 1.2	-0.3 +/- 0.9	0.016
Back dynamometry (kg)	126.8 +/- 45.6	64.7 +/- 34.8	<0.001

PA – physical activity; QUI – quantitative ultrasound index; BUA - broadband ultrasound attenuation; SOS – speed of sound

Table 2. Types of physical occupational activity in men and women working in sawmill**Tablica 2. Vrste fizičke aktivnosti na radu u muških i ženskih radnika u pilani**

Type of occupational physical activity	Men (N 89)	Women (N 39)	p value
Lifting>5kg	68 (76.4 %)	24 (61.5 %)	0.084
Repetitive movements >2h	53 (59.5 %)	26 (66.7 %)	0.073
High physical exertion in the workplace	47 (52.8 %)	19 (48.7 %)	0.268
Dominant position at work:			
- sitting	18 (20.4 %)	7 (17.9 %)	0.653
- standing	45 (50.7)	24 (61.6 %)	0.515
- walking	24 (26.9)	4 (10.5 %)	0.038

Participants who lifted > 5 kg in their workplaces had shorter experience ($p=0.024$) in the sawmill and higher back strength ($p=0.039$) than those who did not lift such heavy load (Table 3). However, they were also significantly younger than participants who did not lift > 5 kg ($p=0.027$) (data not presented in the table). Workers who had jobs without repetitive movements had higher smoking index than those who had not ($p=0.013$). QUI did not significantly differ based on presence or non-presence of any of analyzed category. Participants with lower education (elementary school) had significantly higher smoking index ($p=0.029$) than those with higher education (data not presented in the table). Body mass index was significantly higher in those who predominantly worked in the sitting position ($p=0.005$) (data not presented in the table).

Table 3. Differences in experience, QUI, back strength and smoking index based on presence or non-presence of occupational physical activity**Tablica 3. Razlike u stažu, QUI, snazi leđnih mišića i indeksu pušenja u odnosu na fizičku aktivnost na radu**

Type of occupational physical activity	Experience in the sawmill	QUI*	Back strength	Smoking index
Lifting>5kg	p value			
	<i>0.024</i>	0.372	<i>0.039</i>	0.330
Repetitive movements	0.055	0.879	0.228	<i>0.013</i>
High physical exertion	0.906	0.959	0.138	0.146
Non-sitting position at work	0.051	0.539	0.433	0.633

*QUI – quantitative ultrasound index

QUI significantly negatively correlated with age ($r=-0.354$; $p<0.001$) and smoking index ($r=-0.262$; $p=0.005$) (not presented).

Using multiple regression we analyzed whether occupational physical workload, back strength, leisure time PA and smoking predicted QUI. Measure of physical workload was derived from components of physical occupational activity and from the years spent in the particular job. When controlling for gender, age and body mass index, we found that participants with higher smoking index had significantly lower QUI ($p=0.004$) (Table 4). Physical workload was positively but not significantly associated with QUI.

Table 4. Association between quantitative ultrasound index (QUI) and different predictors**Tablica 4. Povezanost kvantitativnog ultrazvučnog indeksa (QUI) i različitih prediktora**

Predictors	Regression coefficient (b)	p value
Gender	-3.79	0.073
Age	-0.49	<0.001
Body mass index	0.73	0.040
Back strength	0.01	0.705
Occupational PA	0.17	0.281
Leisure time PA	0.72	0.793
Smoking index	-0.02	0.004

PA – physical activity

DISCUSSION

In our working population, we found that bone density assessed by QUS was more influenced by lifestyle habit, namely smoking, rather than working conditions and workload. This is generally a consistent finding in most studies on the association between workload and bone density, which are however quite rare. In our relatively young subjects, who on average had good bone density, smoking was the factor that most harmfully affected bone health. Considering a quite high smoking index and the fact that almost half of the participants were active smokers and about 10 % were ex-smokers, the negative impact of smoking is understandable. In Croatia, the rate of smoking is higher in younger individuals below 65 years of age and among people of lower educational level and lower income, which is in accordance with other European countries (*Dečković Vukres et al., 2015*). There is no specific study on association between smoking and occupation in Croatia. However, the study conducted in 14 European countries showed the highest smoking prevalence in metal industry for men (54.3 %) and in cleaners for women (50.7 %), which indicated a higher prevalence among manual workers (*McCurdy et al., 2003*). Very few studies have investigated the relationship between smoking and bone strength parameters measured with QUS (*Bernaards et al. 2004, Lin et al. 2001; Gregg et al., 1999*). *Bernaards et al. (2004)* suggested that smoking was associated with a deterioration in bone quality but

not with a reduction in BMD measured by DXA. Another study showed the effect of smoking on calcaneal QUS in young men, suggesting an interaction between metabolic genes and tobacco smoke in bone deterioration (*Liu et al. 2012*). Bearing in mind that nicotine has been identified as a risk factor for the development of osteoporosis (*Al-Bashaireh et al. 2018*), we can assume that manual workers in general, who usually have a high prevalence of smoking, are at higher risk of losing bone density.

As we have already stated, previous studies have shown a poor correlation between physical occupational activity and bone density. The basic assumption is that physically demanding jobs have a positive effect and that sedentary jobs have a negative effect on bone density. In a study on impact of lifetime occupational physical activity on skeletal status in healthy postmenopausal women, both DXA and QUS parameters were significantly higher in the farmers compared with the controls (1). On contrary, in a sample of 860 adults men and women who had worked ≥ 20 years no significant associations between hip BMD and any of measures of lifetime occupational physical activity was found (5). Two case control studies have reported an increased risk of hip fracture associated with sedentary occupations (*Cooper et al., 1990; Jaglal et al., 1995*). Occupational activity did not appear to markedly increase BMD in postmenopausal women in industrialized countries, but reduced BMD was found in young women with predominantly sedentary occupations (*Coupland et al., 2000*). *Vehmas et al. (2004)* showed that the higher load of the dominant hand may not prevent the bone loss after menopause, assessed by metacarpal cortical index. It is known that physical activity and mechanical forces created by muscle contraction exert the load to bones which impacts bone density, strength and architecture (*Benedetti et al., 2018, Hong et al., 2018, Uzunca et al., 2005*). Intensive occupational physical activity, especially loading activity, may produce benefits such as enhanced muscle strength and coordination. Most of our participants lifted a weight higher than 5 kg during the work process. Those participants had significantly higher back strength, but not significantly higher bone density compared to those who did not lift a weight higher than 5 kg. However, our parti-

participants, especially our middle-aged women, had generally well-preserved bone density, which led to the conclusion that physical exertion at work might still had a positive effect and that without such load, the bone density of our participants probably could have been lower. Since the work experience in the sawmill was relatively short in our participants (approximately 6 years for men and women together), that period was probably not long enough to produce the marked effect on bone density.

Another predictor in our analysis was education, which is an important determinant of health (*Hahn et al., 2015*). There have not been many studies of occupationally defined qualification and bone density, although an inverse relation between years of education and hip fracture was reported in a study of Iranian (*Maddah et al., 2011*) and Chinese women (*Piao et al., 2015*).

Limitations

The limitation of the study is lack of comparative group with sedentary occupational physical activity, which would probably get a better insight into the impact of physical occupational activity on bone. Although we compared our bone results to the general population, we lacked the information on their occupation. However, most studies that analyzed the association between occupation and bone health also did not have a control group (*Coupland et al., 2000, Mickelsfield et al., 2003, Walker-Bone et al., 2014, Lunde et al., 2016*). The next limitation is the relatively small number of participants, but our study sample was uniform according to working conditions and workload and therefore comparable to other studies that analyzed the impact of workload on bone health.

CONCLUSIONS

In our study, like in majority of similar studies, the lack of strong association between occupational physical activity and bone density suggests that mechanisms other than workload are responsible for bone health in working population. Even though we noticed a tendency of slightly better bone density in our sawmill workers compared to general population, the lifestyle habit, specifically

smoking, overcame any major occupational effect on the bone. Since the working population is generally young or middle-aged, we presume that the younger age has a predominant role in preserving bone health from possible negative impact of working conditions. On the other hand, possible beneficial effects of workload on bone density may still not be obvious in those age groups.

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Conflict of interest

All authors declare no conflict of interest.

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POVEZANOST TJELESNE AKTIVNOSTI NA RADU S PARAMETRIMA KVANTITATIVNOG ULTRAZVUKA RADNIKA U PILANAMA

SAŽETAK: Mali broj istraživanja analizirao je povezanost zdravlja kostiju i razine tjelesnog opterećenja povezanog sa zanimanjem. U ovom presječnom istraživanju autori su odredili parametre kvantitativne ultrazvučne (UZV) denzitometrije, u 128 radnika u pilanama (89 muškaraca i 39 žena), prosječne dobi 39,1 +/- 10,8 godina. Snaga leđnih mišića izmjerena je dinamometrijom. Uzeti su podaci o tjelesnoj aktivnosti na poslu i u slobodno vrijeme, bolovima u zglobovima, obrazovanju i pušenju. Svi UZV parametri kostiju i snaga leđnih mišića bili su značajno veći u muškaraca nego u žena. T vrijednost za kvantitativni ultrazvučni indeks (QUI) od - 2,2 ili niža utvrđena je u samo dva muškarca i jedne žene. QUI se nije značajno razlikovao u odnosu na profesionalnu tjelesnu aktivnost (nošenje tereta veće od 5 kg, ponavljani pokreti, teški tjelesni napor tijekom rada i nesjedeći položaj na poslu). Uz kontrolu dobi, spola i indeksa tjelesne mase, ispitanici s višim indeksom pušenja imali su značajno niži QUI ($p=0,004$). Fizičko opterećenje u vezi sa zanimanjem nije bilo značajno povezano s QUI. U našoj radno aktivnoj populaciji neke su životne navike, poput pušenja, imale veći utjecaj na zdravlje kostiju od fizičkog opterećenja povezanog sa zanimanjem.

Ključne riječi: kvantitativna ultrazvučna denzitometrija, tjelesna aktivnost, zanimanje, pušenje, koštana gustoća, snaga mišića

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