Bone Mineral Density, Body Composition, Physical Activity Level, Muscle Strength and Smoking Status in Adults Men After Spinal Cord Injuries

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Research Article

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Abstract

Background

In this cross-sectional study we aimed to investigate the association of physical activity level, muscle strength, body composition and smoking status with bone mineral density in adults men after spinal cord injuries.

Methods

The study covered 50 men after spinal cord injuries aged 35.6 ± 4.9 years (25 wheelchair rugby players and 25 without sports training). Bone mineral density was measured by densitometry. Body Mass Index and body fat percentage was calculated. Fat mass and fat-free mass were estimated from somatic. An interview method using the Global Adult Tobacco Survey. Muscle strength- maximal hand grip strength was measured using a Jamar dynamometer.

Results

The active men after SCI were significantly higher bone parameters BMD prox, BMC dis and prox, and T-score prox (large effect). Of all the variables analysed, the strongest relationships with bone parameters were consistently found for PA, FM, and age. The strength of bone status relationships with PA is mostly higher than that of the relationships with FM except BMD dis (F = 4.4 *v.* 12.4). The BMC parameter proved to be the most reliable (for both dis and prox) and the highest values of R^2 corr were found, ranging at 7–8% of the analysed set of traits exhausting the variance of this parameter. HGS and AS in years proved to be relevant only for BMD dis. Age when injury occurred (years) proved to be relevant only for T-score prox. Nonsmoking activity men after SCI had the most advantageous values of means BMD in forearm.

Conclusion

Despite its high injury rates, rugby can be considered a sport that has a beneficial effect on BMD. Physical activity level in the form of 5 and more years wheelchair rugby training has been shown to be the strongest factor affecting bone health. Active smoking especially in rugby players influenced lower averaged BMD values.

Background

Spinal cord injury (SCI) is a crippling neurological condition resulting in severe dysfunctions of the entire body [1]. Osteoporosis is a debilitating secondary complication of complete SCI [2, 3]. Bone mineral density (BMD) of the in different parts of the skeleton and extremities declines precipitously in the first 2 years after SCI. Hip BMD declines rapidly for the first several months, then declines more slowly until reaching equilibrium at 12 to 16 months postinjury [4]. The loss of BMD at the femur and tibia during the first year of SCI can occurred significantly earlier than that of the hip BMD [1, 5]. Lumbar spine BMD generally does not decline and may even increase after SCI. [6]. One study showed that patients with SCI have diminished knee and hip BMD [7]. There are few data on BMD changes in the upper limb including the forearm [8]. For SCI patients, it is the upper limbs that become the primary driver of wheelchair locomotion. It is recommended to monitor the BMD in early-stage SCI patients, combined with detection of factors contributing to lower BMD [1].

Physical activity (PA) after a spinal cord injury is considered to be not only an important factor in rehabilitation or a means to enable maximum independence, but also its importance in preventing weight loss and weakening of bone tissue is indicated [9, 10]. During physical exercise bone adapt to mechanical loads generated by mechanical usage including the muscle contraction. Is known a direct role of muscle mass on bone structure and bone strength [11]. Muscle strength, hand grip strength (HGS) may be associated with increasing BMD in men after SCI [12]. In healthy population of men showed associated HGS with forearm BMD [13, 14].

The effect of sports activity on BMD in wheelchair athletes is of growing interest to scientists. However, the findings vary. This is because various factors affecting BMD of wheelchair players with SCI have been analysed, including age, somatic features (body weight, tissue composition) [15, 16], type of sport, area of injury, length of the injury and time needed to resume sporting activity after the injury. Some BMD studies of men after SCI have been conducted by age groups (up to the age of reaching peak bone mass and sometimes at the moment of physiological loss of BMD with age) while others have focused on athletes after SCI (wheelchair basketball, wheelchair rugby, tennis) [10]. Importantly, it has been demonstrated that the sooner patients with SCI started sports training after rehabilitation, the faster the higher BMD values were recorded in the lower limbs, trunk and skeleton regardless of age and sport [10]. The beneficial effect of physical exercise on bone health is due to the load that provides osteogenic stimuli. The increase in mechanical stress exerted on bones in athletes results in a higher BMD compared to the general population [17].

However, there is a lack of research on the effects of active lifestyles on the condition of the bones, and other factors that often have an opposite effect on the skeletal system. For example, in the case of athletes, active smoking (AS) is rarely taken into account in health analyses, and studies have shown that this population uses such stimulants. Nicotine use amongst athletes is high and increasing, especially in team sports [18].

Previous studies have mostly shown the effect of nicotine on exercise capacity and tolerance to physical exercise [19]. Nicotine increases muscle blood flow and lipolysis due to enhanced circulating levels of norepinephrine and epinephrine as well as direct action on nicotinic cholinergic receptors in adipose tissue [20]. The effects exerted by nicotine may be beneficial in a wide variety of sports and it is suggested that nicotine is abused by athletes [21]. Cumulative exposure to nicotine metabolites was found in 26% – 56% of sportsmen urine samples that were subjected to screening for tobacco alkaloids

[22]. Few studies have evaluated the effect of AS on bone tissue in athletes. In general, cigarette smoking has been identified as a factor in the reduction of bone mineral content (BMC), consequently increasing the risk of fractures in the general population. The relationship between AS and also passive smoking (PS) in the form of exposure to environmental smoke is explained by the deterioration of bone strength as a result of harmful substances contained in tobacco. It is also indicated that this phenomenon is more noticeable in men than in women [23, 24, 25].

A meta-analysis referring to the effect of smoking on bone condition suggests a reduction of bone mass in active smokers compared to non-smokers. Studies also show a greater decline in BMC among smoking men compared to smoking women [26]. However, the negative effect of smoking on the bones of young men has not been sufficiently studied, and therefore the effects of smoking on the ability to build up a proper peak bone mass remain unclear. An attempt was made to determine the mechanism underlying the bone mass loss due to smoking. Scientists have discovered that the smoker's body synthesizes extremely large amounts of two proteins S100A8 and S100A9, which are conducive to osteoclast production. Researchers believe that this is what lies behind the negative effect of AS on bone density [27]. Therefore, screening and development of practical guidelines for the prevention of osteoporosis in patients after SCI are critical, particularly in those physically active and athletes [28, 29]. In this cross-sectional study we aimed to investigate the association of PA level, muscle strength, body composition and AS status with BMD in adults men after SCI.

Methods

Participants and data collection

The cross-sectional study covered 50 men aged 35.6±4.9 years. The first group consisted of 25 men after SCI, who were players from a wheelchair rugby team. In ASIA Impairment Scale (AIS) in this group were 10 men in Grade A, Type of Injury - complete and 15 men in Grade B, Type of Injury - Incomplete sensors [30]. Training experience was from 5 to 11 years of organized wheelchair rugby training. The frequency of training in this group was 4 training sessions per week including one body weight circuit strength session using sports equipment. Before the SCI, the subjects had not practised any sport. The second group volunteered to participate in the study consisted of 25 men in similar age with spinal cord injuries in wheelchairs, physically inactive (without sports training). In AIS in this group were 13 men in Grade A, Type of Injury - complete and 12 men in Grade B, Type of Injury - Incomplete sensors. From a clinical history and an interview with the men, information was obtained about age when the injury occurred and the period of injury [31]. The inclusion criterion was the lack of contraindications for densitometric examination, written informed consent to participate in the study, the absence of diseases affecting bone metabolism such as thyroid diseases, rheumatoid arthritis, chronic steroid treatment, or rickets. All of the participants were informed about the aims, benefits and procedures of the research project, as well as the possibility to withdraw from the study at any moment without providing an explanation. The inclusion criterion was the written consent of each participant.

Measures

Kinthropometric measurements

Somatic measurements were performed in accordance with the kinanthropometric methodology adopted in measurements of disabled people [32]. Height was measured with an anthropometer (GPM Anthropometer Siber Hegner, Switzerlandin) with a precision of 0.1 cm in a supine position. Weight of the subject was obtained with a wheelchair medical scale. First, the men were measured in a wheelchair, and then the wheelchair weight was measured separately. Weight of each athlete was calculated as the difference between these measurements. Body Mass Index (BMI) was also calculated. The BMI classification was adopted in accordance with the recommendation of the World Health Organization (WHO). The percentage of the body fat (BF%) was calculated according to Deurenberg et al. [33] using the formula for men. BF content in the weight of the athletes studied was referred to the classification of male body fat content by Gallagher et al. [34]: low <8.0%, standard from 8.0 to 19.9 %, high from 20.0 to 24.9 %, and very high over 25%. Fat mass (FM in kg) and fat-free mass (FFM in kg) were estimated from somatic measurements using formulas adjusted to age, gender and European white population [35].

Methods of bone tissue evaluation

BMC and BMD of the non-dominant forearm in distal (dis) and proximal (prox) part were measured by means of dual-energy X-ray absorptiometry (DXA, Norland, Swissray, Fort Atkinson, WI, USA) The Norland DXA instruction has a here were two measurement points: on the proximal (prox) site (radius + ulna), and distal site (radius + ulna), of the bone according to the adopted densitometry methodology and the recommendations of the International Society for Clinical Densitometry (ISCD). The test protocol was Bone Mineral Density Testing in Spinal Cord Injury [3]. The DXA data were used to calculate the T-score. WHO definition of osteoporosis is based on the T-score. The T-score is a comparison of a patient's BMD to that of a healthy thirty-year-old of the same sex and ethnicity (expressed in standard deviations). T score of −1 and above were considered normal, while T- scores between −1 and −2.5 were considered low BMD [36]. The study was conducted in all people using the same equipment by a team having the necessary qualifications and experience in the research with the above-mentioned method and apparatus. The scanner was calibrated daily against the standard calibration block supplied by the manufacturer to control for possible baseline drift [37].

Measurements of muscle strength

Muscle strength- maximal Hand Grip Strength (HGS) was measured in the non-dominant hand using a Jamar dynamometer and following a standardized protocol [38]. HGS was measured two times with brief pauses between each measurement and the best of measurements was considered the maximum HGS.

Assessment of smoking

An interview method using the Global Adult Tobacco Survey (GATS) Questionnaire Section B (smoking) and Section D1 (stopping smoking). This study assessed quantitative variables such as: total number of active smoking (AS) years of smoking, number of cigarettes smoked per day. A standard global protocol was used to implement GATS. The method of the examinations was consistent with the guidelines of experts of the World Health Organization [39].

Statistical Analysis

All the calculations and analyses were performed using the STATISTICA software (v.12, Stat. Soft. USA). In order to determine the significance of differences between the values of particular variables for active and inactive men after SCI, Student's t test for independent variables was applied. Effect sizes was calculated using Cohen's d= 2t / (df^1/2), (small effect <0.5; medium effect 0.5–0.8; large effect>0.8). Differences between the frequency of low and norm BMD as well as other variables of the analysed were use of the chi-square test. The ANCOVA was applied in order to find relationships between BMD and BMI, body composition, smoking, number of fragility fractures post-SCI, age when injury occurred and the period of injury. The ANOVA test was used to evaluate significance of differences in means BMD in the context of physical activity level and smoking. Statistical significance was set at the levels of $^{*}p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$.

Results

The basic characteristics of the two groups men after SCI (active and inactive) of biometric, somatic, bones parameters and the significance of differences and effect sizes calculated using Cohen's d are presented in Table 1. The groups differed significantly in 10 of 17 analysed parameters. The active men after SCI were slightly older, older age when injury occurred, higher, had smaller BMI (medium effects: 0.5–0.8), had smaller BF (small effect < 0.5), had smaller FM (large effect > 0.8) and significantly higher bone parameters BMD prox, BMC dis and prox, and T-score prox (large effect d > 0.8), (Table 1).

Table 1
Characteristics of study population (n = 50)

	Active men after SCI- Wheelchair rugby players (n = 25)	**Inactive men after SCI (n = 25)**	**P-*value***	**Cohen's *d***
	mean± SD			
Age (years)	36.6 ± 5.1	33.9 ± 3.5	0.037*	0.617
Age when injury occurred (years)	23.0 ± 5.1	20.3 ± 2.6	0.019*	0.667
The period of injury (years)	13.5 ± 7.3	13.6 ± 2.9	0.949	0.018
Weight (kg)	77.5 ± 14.0	79.7 ± 11.6	0.548	0.171
Height (cm)	182.2 ± 7.7	176.9 ± 6.8	0.014**	0.729
BMI (kg/m^2)	23.3 ± 3.4	25.4 ± 3.1	0.026*	0.645
BF (%)	21.1 ± 4.6	22.5 ± 3.7	0.049*	0.311
FM (kg)	16.1 ± 6.6	23.0 ± 3.0	0.000***	1.345
FFM (kg)	61.4 ± 8.3	57.7 ± 10.6	0.182	0.388
HGS (kg)	104.0 ± 11.2	92.8 ± 11.5	0.002**	0.944
BMD dis (g/cm^2)	0.454 ± 0.095	0.412 ± 0.057	0.064	0.536
BMD prox (g/cm^2)	0.905 ± 0.089	0.792 ± 0.178	0.007**	0.803
BMC dis (g)	2.185 ± 0.380	1.696 ± 0.176	0.000***	1.651
BMC prox (g)	2.710 ± 0.381	2.069 ± 0.429	0.000***	1.579
T-score dis	0.051 ± 1.419	-0.560 ± 1.578	0.156	0.407
T-score prox	-0.996 ± 1.003	-1.795 ± 0.992	0.007**	0.801
AS (years)	2.6 ± 3.7	4.2 ± 5.1	0.226	0.359
AS (cigarette/day)	4.1 ± 5.3	3.9 ± 4.8	0.225	0.039

Legend to Table 1: AS- active smoking, BMI- body mass index, BF- the percentage of the body fat, BMD- bone mineral density, BMC- bone mineral content, FM- Fat mass, FFM- fat-free mass, prox- proximal part of forearm, dis- distal part of forearm; Student's t-test P value reported for continuous variables. Statistical significance was set at the levels of *p ≤ 0.05, **p ≤ 0.01 and ***p ≤ 0.001.

There were significant differences (p < 0.01) in the prevalence of low bone mineralization between the two groups men after SCI. A higher percentage with low BMD were among inactive men at both bone points by 36%. There were more overweight men in the inactive group (Table 2).

Table 2
The frequency of occurrence of proper and decreased bone mineral status, category of BMI and BF, AS in wheelchair men after SCI (*Chi2 test, level of significance p)*

	Reference ranges	Active men after SCI- Wheelchair rugby players	Inactive men after SCI	Chi ^{2} (p)
		%		
BMD dis	**Low BMD**	**20**	**56**	6.876 (0.009)**
	Norm BMD	80	44	
BMD prox	**Low BMD**	**44**	**80**	7.089 (0.007)**
	Norm BMD	56	20	
BMI	Underweight	8	0	7.700 (0.053)*
	Norm	64	40	
	Overweight	28	48	
	Obesity	0	12	
BF	Low	0	0	1.391 (0.498)
	Standard	44	28	
	High	40	52	
	Very high	16	20	
AS	No	60	56	0.082 (0.774)
	Yes	40	44	

Legend to Table 2: BMI- body mass index, BF- the percentage of the body fat, BMD- bone mineral density, prox- proximal part of forearm, dis- distal part of forearm. Statistical significance was set at the levels of *$p \leq 0.05$, **$p \leq 0.01$ and ***$p \leq 0.001$.

The results of analyses of the relationships of the characteristics studied (BMI, FM, FFM, HGS, PA, AS, age when injury occurred, the period of injury, age as a continuous variable) with individual parameters of bone mineralization status (BMD, BMC, T-score) separately for dis and prox segments are presented in Table 3 (ANCOVA). Of all the variables analysed, the strongest relationships with bone parameters were consistently found for PA, FM, and age. The strength of bone status relationships with PA is mostly higher than that of the relationships with FM except BMD dis (F = 4.4 *v.* 12.4), as shown by the corresponding F test values. The BMC parameter proved to be the most reliable (for both dis and prox) and the highest values of R^2 corr were found, ranging at 7–8% of the analysed set of traits exhausting the variance of this parameter. HGS and AS in years proved to be relevant only for BMD dis. Age when injury occurred (years) proved to be relevant only for T-score prox (Table 3).

Table 3
The strength of relationships of major determinants of biological bone mineralization status with all bone parameters (results of ANCOVA analyses, age- continuous variable)

	Distal part			**Proximal part**		
	Mean Square	**F**	**p**	**Mean Square**	**F**	**p**
	BMD			**BMD**		
Age	0.0187	4.4065	0.042	0.0200	1.0525	0.311
BMI	0.0040	0.9469	0.336	0.0000	0.0000	0.997
FM	0.0524	12.3762	0.001	0.0034	0.1806	0.673
FFM	0.0009	0.2038	0.654	0.0153	0.8067	0.374
HGS	0.0277	6.5387	0.014	0.0458	2.4068	0.129
PA level	0.0248	5.8588	0.020	0.0273	1.4346	0.238
AS (years)	0.0188	4.4290	0.042	0.0000	0.0015	0.969
AS(cigarette/day)	0.0001	0.0298	0.864	0.0012	0.0615	0.805
Age when injury occurred (years)	0.0008	0.1810	0.673	0.0076	0.3972	0.532
The period of injury (years)	0.0037	0.8647	0.358	0.0245	1.2896	0.263
F (p)	**3.86 (0.001)**			**2.02 (0.063)**		
R^2 adj.	**0.3446**			**0.1574**		
	BMC			**BMC**		
Age	0.7125	10.7676	0.002	1.1286	8.6875	0.005
BMI	0.0011	0.0169	0.897	0.0407	0.3131	0.579
FM	0.3340	5.0474	0.030	0.2534	1.9510	0.170
FFM	0.0510	0.7711	0.385	0.0884	0.6806	0.414
HGS	0.0407	0.6154	0.437	0.0001	0.0009	0.976
PA level	1.9906	30.0817	0.000	2.4309	18.7125	0.000
AS (years)	0.0898	1.3563	0.251	0.1138	0.8762	0.355

Legend to Table 3: AS- active smoking; BMI- body mass index; BMD- bone mineral density; BMC- bone mineral content; FM- fat mass, FFM- fat-free mass; HGS- hand grip strength; F - Ronald A. Fisher's test; p - p –value, level of statistical significance; PA – physical activity; R^2 adj. - the adjusted R-squared values of determination.

	Distal part			Proximal part		
AS(cigarette/day)	0.1019	1.5405	0.222	0.1144	0.8806	0.354
Age when injury occurred (years)	0.0002	0.0029	0.958	0.0015	0.0117	0.915
The period of injury (years)	0.0036	0.0545	0.817	0.0443	0.3407	0.563
F (p)	**7.66 (0.000)**			**6.71 (0.000)**		
R^2 adj.	**0.5503**			**0.5120**		
	T-score			**T-score**		
Age	9.0586	6.9990	0.012	4.8020	6.7670	0.013
BMI	0.0494	0.0382	0.846	0.5171	0.7288	0.398
FM	0.0436	0.0337	0.855	0.4467	0.6295	0.432
FFM	2.1621	1.6705	0.204	0.5850	0.8244	0.369
HGS	2.1749	1.6804	0.202	0.9284	1.3084	0.259
PA level	0.0211	0.0163	0.899	0.8249	1.1624	0.287
AS (years)	1.4895	1.1508	0.290	0.0126	0.0177	0.895
AS(cigarette/day)	2.9625	2.2829	0.138	2.1602	3.0442	0.089
Age when injury occurred (years)	2.9193	2.2555	0.141	3.1759	4.4756	0.041
The period of injury (years)	1.7777	1.3735	0.248	0.0006	0.0009	0.976
F (p)	**5.24 (0.000)**			**4.28 (0.001)**		
R^2 adj.	**0.4377**			**0.3759**		

Legend to Table 3: AS- active smoking; BMI- body mass index; BMD- bone mineral density; BMC- bone mineral content; FM- fat mass, FFM- fat-free mass; HGS- hand grip strength; F - Ronald A. Fisher’s test; p - p –value, level of statistical significance; PA – physical activity; R^2 adj. - the adjusted R-squared values of determination.

Figure 1 presents a graphical representation of the results of the analysis of variance. Nonsmoking activity men after SCI had the most advantageous values of means BMD in forearm (Fig. 1).

Discussion

In our study, we analyzed the condition of forearm bone tissue in men after SCI. The analysis concerned the impact on bone parameters in forearm: physical activity- wheelchair rugby training, body tissue components (fat mass and fat free mass), active smoking, age when the injury occurred, the period of injury. In our study, the frequency of low BMD among wheelchair rugby players was smaller than inactive men. In both groups of men after SCI, low BMD was particularly active in the proximal part of the forearm. Among wheelchair rugby players, smoking were the strongest factor reducing mean BMD. Condition of forearm bone tissue in men after SCI was has been studied before [8]. The research focuses on the evaluation of BMD after SCI depending on the lifestyle, physical activity [10, 40], diet and supplementation [41]. Studies have evaluated body composition in relation to BMD and BMC men after SCI [15, 42]. Often in study analyzed the determinants of fracture risk among individuals with spinal cord injury [43].

According to research bone loss after SCI occurs especially in the lower extremities. No significant changes in BMD after SCI were found in the proximal and distal forearm [8], radius [40], forearm [44]. However at the same time higher values BMD was active men after SCI with performing upper extremity activities (e.g. wheelchair basketball) that men after SCI inactive [9]. Goktepe et all. [9] compared the bone mineral density of elite paraplegic basketball players with the values obtained from their paraplegic sedentary counterparts. Wheelchair basketball in spinal cord-injured patients was associated with greater bone density in distal radius compared with sedentary paraplegics. Our research of wheelchair rugby players also showed better BMD compared to non-active men after SCI. A higher percentage with low BMD were among inactive men at both bone points by 36%.

Eloumi et al. [45] examined the effects of long-term rugby participation on bone mineral content (BMC) and density (BMD) of male rugby players and to determine if the diverse stimuli elicited by the actions of forwards and backs affect their skeleton differently. They showed that long-term rugby participation, starting at pubertal age, is associated with markedly increased BMC, BMD and bone size at all skeletal sites, except at the head. Similarly, in our study, men performed rugby training 5 years or longer and as analyses show had an effect on significantly better BMD than inactive men.

The musculo-skeletal adaptations, greater in forwards than in backs, could mimic training responses and therefore explain the bone features, localized in specific stressed regions. Sports training for people after spinal cord injuries is often the main factor to prevent the loss of BMD that occurs with age and due to immobilisation. Physical activity based on the intensive involvement of forearms significantly affected the better condition of bone tissue in this location. According to the theory of mechanostat, the effect of pressure forces generated by working muscles is local in nature, which explains the beneficial effect of the upper limbs driving a wheelchair on BMD in wheelchair rugby players. Rugby training also includes resistance exercises, which are an important element of beneficial bone loading [45].

Regular exercises, which load the skeleton with impact forces, are positively correlated with the mechanical bone strength. Athletes of sports characterized by high impact forces, such as rugby, have higher BMD than non-athletes [46]. Participation in regular impact exercises is commonly suggested as a way to reduce the risk of osteoporosis at a later age [40]. Most studies to date have suggested that resuming sports activities at a right time after treatment and rehabilitation is useful in preventing the loss of BMD in wheelchair athletes and can also affect their quality of life [10].

We know from general population studies about the negative impact of smoking on BMD. However, there are very few such studies involving men after SCI. In our study 40% of rugby players were smokers, which translated into the frequency of low BMD. A significant relationship (F = 8,7140; p = 0049) were found between mean BMD and smoking in active and inactive men after SCI. Smokers men had the lowest BMD values.

A meta-analysis conducted by Ward et al [23] showed that smokers had significantly reduced bone mass compared to non-smokers who had never smoked and those who had smoked in the past. BMD deficits were particularly evident in the hip, where the bone mass of smokers was one-third SD lower than in non-smokers. The adverse effects of smoking on the health of athletes are therefore wider than just the risk of lung cancer or poorer physical capacity. This topic requires more detailed research and analysis.

Studies have shown that BMD also depends on body composition [47]. In the case of athletes, the fraction of tissue components in the body mass is closely related to the type of sport practiced, training routines, and training experience. In our study, most of the rugby players had a normal BMI or were overweight, which may have been caused by higher muscle mass. There were no cases of obesity among wheelchair players, which, as studies show, is a common occurrence in people after spinal cord injuries [16] and related to insufficient physical activity. In our study, there was no significant relationship of FFM with bone parameters. Previous studies have demonstrated the effect of body composition on BMD and BMC. Elite rugby players are characterized by body mass index (BMI) similar to that in obese people [45], but they differ significantly by their low fat content, high fat-free mass and frequent exposure of the skeleton to stress due to training. Studies suggest the key role of lean body mass in maintaining bone strength and resistance to fractures [46].

Despite the high number of injuries, rugby can be considered a sport that has a beneficial effect on BMD. Athletic training is associated with increased muscle strength. In our study, active men after SCI had a significantly better HGS score than inactive men. In addition, HGS had a significant effect on BMD dis. Previous studies have also shown that long-term practicing of rugby, from adolescence onwards, is associated with significant increases in BMC, BMD and bone size in numerous skeletal locations [42, 48]. Musculoskeletal adaptations represent a response to training loads. However, it is worth noting that smoking can limit the beneficial effect of sports training on bone health. Furthermore, studies have demonstrated that significant changes in body composition are observed at later stages of sports training. Increased fat mass and lower fat-free mass can have a negative effect on the power-to-weight ratio, and can therefore generate lower forces on the skeletal system [42].

This study makes an important contribution to this area of research. In men after SCI especially in physically active people who train regularly, early detection of the risk of low BMD allows to take effective prophylactic measures and reduce the risk of osteopenia, osteoporosis and consequent fractures. The major strength of the study is that a reliable and accurate research methodology was used. The research was conducted by a highly-qualified team with many years of research experience in the field. All data were collected using well selected and internationally recommended research tools. One of the study limitations is the relatively small yet sufficient size of the study group. It cannot provide a full representation of the population of men after SCI at this age. The body tissue composition was evaluated only by the anthropometric method, as it was impossible to perform bioelectrical impedance testing.

Conclusions

Despite its high injury rates, rugby can be considered a sport that has a beneficial effect on BMD. Physical activity level in the form of 5 and more years wheelchair rugby training has been shown to be the strongest factor affecting bone health. Active smoking especially in rugby players influenced lower averaged BMD values. The results of the study support the important role of activating people after SCI. Systematic physical activity promotes good condition of forearm bone tissue which is important for wheelchair locomotion.

Abbreviations

ASI- ASIA Impairment Scale, BMI- body mass index, BF- the percentage of the body fat, BMD- bone mineral density, BMC- bone mineral content, DXA- dual-energy X-ray absorptiometry, FM- Fat mass, FFM- fat-free mass, prox- proximal part of forearm, dis- distal part of forearm, HGS- hand grip strength, ISCD- International Society for Clinical Densitometry; SCI- spinal cord injuries

Declarations

Ethics approval and consent to participate

The work described has been carried out in accordance with the Declaration of Helsinki and Code of Ethics of the World Medical Association for experiments involving humans. The project was approved by the Senate Ethics Committee for Scientific Research of the Józef Piłsudski University of Physical Education in Warsaw (protocol number 01-09/2017). Informed consent was obtained from all the participants.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no conflict of interest.

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Authors' contributions

AK, JC- substantial contributions to conception and design; JC- acquisition of data, AK- analysis and interpretation of data; AK, JC- drafting the article; AK, JC- approval of the version to be published and all subsequent versions

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Figures

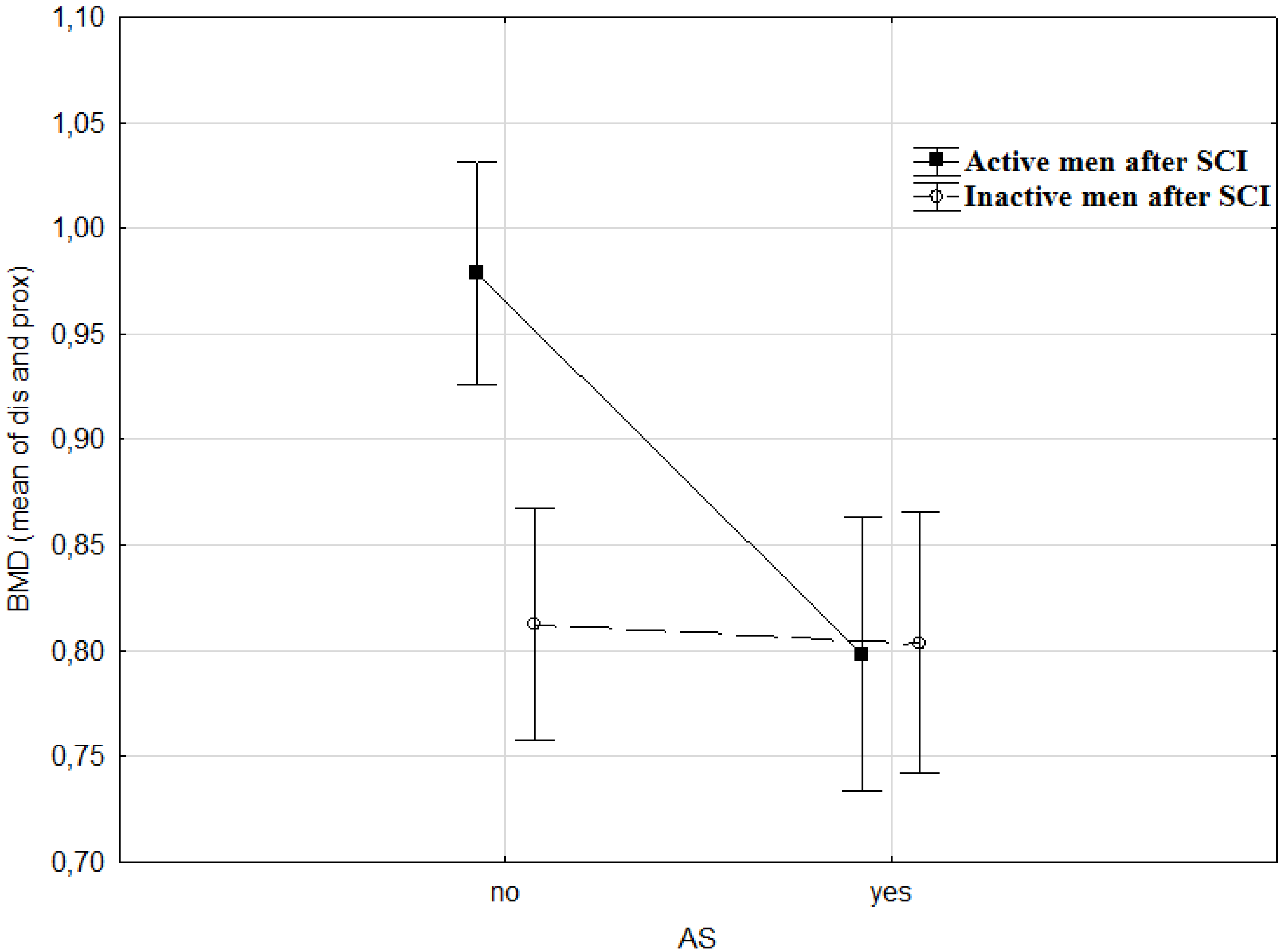

Figure 1

Relationships of PA category and AS with BMD dis (results two-way ANOVA analysis; F=8,7140, p=,0049), vertical lines -0.95 CI - confidence intervals