

Femoral neck bone mineral density in ambulatory men with poliomyelitis

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Abstract

Summary We evaluated bilateral femoral neck bone mineral densities (FNBMDs) in 32 men with poliomyelitis and their matched controls. Men with poliomyelitis had significantly lower FNBMD in both legs, and FNBMD was lowest in their shorter legs. Knee extensor strength and regular exercise were important predictive factors associated with decreased FNBMD.

Introduction People with poliomyelitis (polio) are prone to leg fractures after mild trauma. The flaccid paralysis, asymmetric involvement, and underdeveloped growth of afflicted legs may lead to osteoporosis of either leg, characterized by different patterns. This study aimed to measure their femoral FNBMD and to explore the factors associated with changes in FNBMD in either leg.

Methods We did a prospective study to evaluate bilateral FNBMD with dual-energy X-ray absorptiometry in 32 men with polio (age range, 41–57 years; mean, 47 years) and 32

age- and body mass index-matched controls. Measuring the difference in leg length, we classified the legs of each polio subject as “longer” or “shorter.” In addition, we chose the right leg of each control as a reference leg. We then used the Mann-Whitney *U* test to compare FNBMD of these three groups of legs and searched for the factors associated with FNBMD using stepwise multiple regression analyses. **Results** Compared to the reference leg, men with polio had significantly lower FNBMD in both their longer and shorter legs, by 13% and 23%, respectively. The difference in FNBMD between the two legs of polio subjects was significant. Knee extensor strength and regular exercise were two important factors associated with bilateral FNBMD in men with polio.

Conclusions Men with polio had lower bilateral FNBMD. FNBMD of the shorter leg should be the choice for predicting the risk of hip fracture in men with polio because on average, the shorter leg has lower BMD.

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Introduction

People with disabilities may develop osteoporosis earlier in life with more disastrous outcomes than the general population. Ensuing osteoporotic fractures can cause a vicious cycle of inactivity, increasingly severe loss of function, and new disability. In a study of physically disabled women with spinal cord injuries (SCI), poliomyelitis (polio), or cerebral palsy with a mean age of 50 years, more than 40% had osteoporosis [1]. People who suffer cerebral stroke also experience rapid bone loss and increased risk of hip fracture within 1 year after onset [2]. Silver and Aiello found that one-third of polio subjects have fractures after falling from standing height [3] and most of the fractures occur in the atrophic leg [4]. Susceptibility to falling has been thought the most common reason for fracture, but fails to explain the greater involvement of the atrophic leg. Therefore, it is important to determine whether polio subjects have lower bone mineral density (BMD) on the atrophic leg.

Polio was a common cause of physical disability in children in Taiwan in the 1950s and 1960s. Most of them are now middle aged and currently engage in community walking or an active daily lifestyle. Compared to adults with SCI or stroke, polio subjects have three distinct features; their paralytic legs have flaccid muscle tone, asymmetric involvement, and underdeveloped growth. We hypothesize that all of these characteristics may alter the BMD in either leg, according to different patterns.

To our knowledge, information about BMD and related factors is lacking for the polio population in Taiwan. We therefore carried out this study to measure femoral neck bone mineral density (FNBMD) and to explore the factors associated with low FNBMD in Taiwanese men with polio.

Methods

Participants

We did a prospective study on middle aged men who experienced polio onset before the age of three. All of them had flaccid paralysis of one or both legs. They had no sphincter disturbance. We also recruited age- and body mass index (BMI)-matched healthy men as controls. We excluded from the study those who had paralysis of the arm or who were respirator dependent, those who had a metal implant or a history of fracture in the leg, those who had used glucocorticoids or other medications related to bone metabolism long-

term, and those who had a history of other primary or acquired neuromuscular disease. We obtained approval from the Institutional Review Board of Taipei Medical University Hospital for this study and each participant signed an informed consent form before entering the study.

Subject demographics

We recruited 32 men with polio (the polio group) and 32 healthy controls (the control group) through advertisement between December 1, 2005 and February 28, 2007. Polio and control subjects were matched for age (± 2 years) and BMI ($\pm 5\%$). The ages of polio subjects ranged from 41 to 57 years with the median and mean both at 47 years.

Measurements

A certified densitometry technologist of the International Society for Clinical Densitometry measured all subjects' BMD at the femoral neck with dual-energy X-ray absorptiometry (DXA; Norland XR-36, version 2.5.3 software, Norland Corporation, Fort Atkinson, WI, USA) [5] at a university-affiliated hospital. The instrument had long-term coefficient of variation of 1.2% for BMD and 1.7% for bone mineral content of the femoral neck. The in vitro precision of spinal phantoms was 0.5%. Phantom bone scans were performed daily by the technician and the findings were compared with acceptable ranges from previous runs for more than 1 year. The length of the femoral neck was fixed at 1.5 cm for measurement in accordance with the manufacturer's instructions.

We measured the subjects' body weight in the standing position with a standard hospital scale. For orthosis users, we measured the total weight wearing the orthosis and the weight of the orthosis separately. The orthotic weight was then subtracted from the total. Putting a standardized measuring board on the densitometer, we measured the subjects' recumbent body length when lying on the board. We kept the knees from flexing and measured the length from the vertex to the heel of each leg. The side with the longer leg was recorded as body length. According to the difference in leg length, we classified the legs of each polio subject as longer or shorter. Arbitrarily, we chose the right leg of each control as the reference leg for the purpose of analysis. An attending physician with a 5-year experience did all manual muscle testing (MMT, grades 0-5) to rate muscular strength of bilateral hip flexors, knee extensors, and ankle dorsiflexors of each participant, according to the methods endorsed by the medical research council of Great Britain's health system [6].

We assessed all participants' lifestyle with "yes" or "no" (1/0) questions, including cigarette smoking, alcohol consumption, regular exercise, need for an orthosis, as well as need for outdoor and indoor mobility aids. We defined

Table 1 Comparison of characteristics between men with polio and controls

Variables, unit	Polio (<i>n</i> =32)	Control (<i>n</i> =32)
Anthropometry		
Age, years	46.9 (3.3) ^a	47.7 (4.2)
Body weight, kg	61.8 (7.6)	65.3 (6.2)
Body length, cm	162.6 (6.8)*	166.5 (6.3)
Body mass index, kg/m ²	23.4 (2.9)	23.6 (2.4)
Cumulative lifetime cigarette use, 1,000-pack years	1.5 (3.1)*	4.6 (6.3)
Habitual behaviors		
Cigarette smoking (yes/no)	13/19	21/11
Alcohol consumption (yes/no)	20/11	27/5
Regular exercise (yes/no)	12/20	17/15

^a Mean (standard deviation)**p*<0.05 (independent Student's *t* test for body weight, body length, and body mass index; Mann-Whitney *U* test for age and cumulative lifetime cigarette use; Fisher's exact test for category variables)

regular exercise as those who had exercised at least 3 h weekly for more than 3 months. The amount of cumulative lifetime cigarette use was calculated by multiplying the average number of cigarettes smoked daily by the lifetime duration of smoking.

Data analysis

We compared mean body weight, body length, and BMI between groups with two-tailed Student *t* tests. Because the results were not normally distributed (Kolmogorov-Smirnov test, *p*<0.05), we used Mann-Whitney *U* tests to analyze age, cumulative lifetime cigarette use, as well as FNBMD. We compared FNBMD of either leg of the polio subjects with that of the reference leg. We also used Fisher's exact tests to analyze categorical variables. We performed Pearson's correlation coefficients to quantify bivariate relationships

between the average FNBMD of both legs and each variable (age, body weight, body length, BMI, strength of leg muscles, and the need for indoor and outdoor mobility aids). We searched for the predictors of FNBMD for the polio subjects' longer and shorter legs, and for the reference leg of the controls, using stepwise multiple regression analyses. Each predictor was entered into the model at *p*≤0.05 and was removed from it at *p*>0.10.

We analyzed the data with the Statistical Package for the Social Sciences (SPSS, version 13.0, SPSS Inc., Chicago, IL, USA). The differences between the groups and the correlations in the groups were considered significant if *p* values were smaller than 0.05.

Results

All of our subjects with polio had an active lifestyle and were community walkers. Twelve subjects (38%) had regular exercise. Of them, eight actively used their legs during exercise and the others did not. For those who were ambulatory, 13 subjects (41%) needed mobility aids indoors and 16 (50%) needed them when outdoors. Six subjects (19%) wore knee-ankle-foot orthoses on both legs and nine (28%) on only one. Our polio subjects had mean (SD) hip

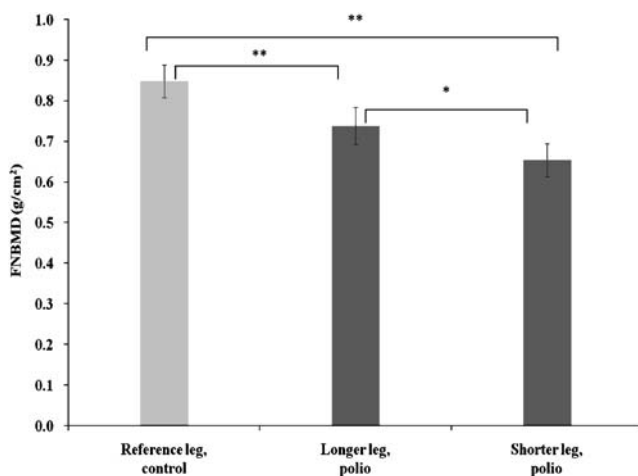


Fig. 1 The difference of femoral neck bone mineral density (FNBMD) between polio and control subjects. The error bars showed a 95% confidence interval. The longer and the shorter legs of each polio subject were treated separately. The reference leg was the right leg of the controls. Compared to the reference leg, both legs of polio subjects had significantly reduced FNBMD. The lowest FNBMD occurred in their shorter legs; ***p*<0.001, **p*<0.005 (Mann-Whitney *U* test)

Table 2 Pearson's correlation (*r*) of average femoral neck bone mineral density (FNBMD) and continuous variables, in both polio and control groups

Variables	Polio (<i>n</i> =32)	Control (<i>n</i> =32)
Age	-0.30	-0.03
Body weight	0.10	0.41*
Body length	0.43*	0.28
Body mass index	-0.16	0.19

FNBMD was measured in both legs in polio subjects and only in the right leg in controls

* *p*<0.05

Table 3 Pearson's correlation (*r*) of femoral neck bone mineral density (FNBMD) on each leg, muscular strength, and the need for indoor mobility aids in men with polio

	Knee extensor strength	Indoor mobility aid
Longer leg (<i>n</i> =32)		
FNBMD	0.51***	-0.44*
Knee extensor strength		-0.64***
Shorter leg (<i>n</i> =32)		
FNBMD	0.47**	-0.31
Knee extensor strength		-0.28

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.005$

flexor strength of grade 2.9 (1.9), knee extensor of grade 2.7 (1.9), and ankle dorsiflexor of grade 3.0 (1.9) in their longer legs. In their shorter legs, these were grades 1.8 (1.7), 1.7 (1.5), and 2.1 (1.8), in that order.

Table 1 shows a comparison of individual features of both groups. Considering the risk factors for low BMD [7], both groups had similar age, body weight, and gender. No difference in the frequency of cigarette smoking, alcohol consumption and regular exercise between the polio and control groups was observed; however, our polio subjects had less cumulative lifetime cigarette use (Table 1, $p < 0.05$). Even though, as shown in Fig. 1, men with polio had mean FNBMD of 0.739 (95% confidence interval, 0.693–0.785) g/cm² on the longer leg and 0.655 (0.614–0.695) g/cm² on the shorter one, both were significantly lower than the 0.849 (0.808–0.889) g/cm² of the reference leg ($p < 0.001$). The difference between the longer and the shorter leg was also significant in the polio subjects ($p < 0.005$).

As shown in Table 2, the average FNBMD of both legs had a positive correlation with body length in the polio group ($p < 0.05$) and with body weight in the control group ($p < 0.05$).

Table 3 lists the correlation of FNBMD of either leg with knee extensor strength and the use of mobility aids among the men with polio. We used the strength of the knee

extensor because it had the strongest correlation with FNBMD compared to other leg muscles (data not shown).

Table 4 shows the optimal models for predicting FNBMD of the longer and the shorter legs of the polio group, as well as for the reference leg. Knee extensor strength and regular exercise were two important factors and these explained 29–37% of the variance in FNBMD in men with polio. Concerning the bilateral differences in FNBMDs in the polio group, the difference in knee extensor strength was the only associated factor and it could explain 21% of the variance ($\beta = 0.487$, $t = 3.052$, $p < 0.01$, data not shown).

Discussion

In this study, we found that men with polio had significantly lower FNBMD of the longer leg by 13% and the shorter leg by 23%, compared to the reference leg in control men (Fig. 1, $p < 0.001$). Both figures were higher than the reduction of 10% BMD in subjects with stroke [2, 8] but lower than the 30% in men with chronic SCI [9, 10]. Lower FNBMD may be one of the reasons why polio patients have more frequent fractures with low trauma causes [3]. In addition, the shorter leg had lower FNBMD than the

Table 4 Multiple linear regression to predict the femoral neck bone mineral density in both legs of men with polio (*n*=32) and the controls (*n*=32)

Predictors		β^a	<i>t</i>	<i>p</i> value	Adjusted <i>R</i> ²
Polio					
Longer leg	Knee extensor strength	0.556	3.808	0.001	0.231
	Regular exercise ^b	0.397	2.718	0.011	0.370
Shorter leg	Knee extensor strength	0.497	3.210	0.003	0.174
	Regular exercise	0.376	2.429	0.022	0.293
Control					
Reference leg	Body weight	0.424	2.787	0.009	0.143
	Regular exercise	0.399	2.626	0.014	0.283

Multiple linear regressions is adjusted for variables of age, hip flexor and ankle dorsiflexor strength, body length, body weight, body mass index, cigarette smoking, alcohol consumption, and the need for orthosis as well as indoor and outdoor mobility aids in men with polio; for variables of age, body length, body mass index, cigarette smoking, and alcohol consumption in controls

^a Standardized regression coefficient

^b Category variable, yes=1; no=0

opposite one ($p < 0.005$). This finding may explain the observation that most fractures in polio subjects occur in the atrophic leg [4]. Furthermore, because prediction of osteoporotic fracture using BMD is site-specific [11], FNBMD of the shorter leg may be the choice in clinical practice to predict the risk of hip fracture in men with polio.

FNBMD is related to body length in men with polio

The average FNBMD of both legs had significant association with body length (Table 2, $r = 0.43$, $p < 0.05$) but not with body weight ($r = 0.10$, $p = 0.60$) in our subjects with polio. This finding did not agree with data for premenopausal Chinese-American women without disability [12] and data for healthy middle-aged men [13]. In the latter study, lean mass was found to be the major factor correlating BMD and body weight [13]. However, because of muscular atrophy and fatty infiltration in the flaccid paralytic legs, our polio subjects may have much more fat mass contributing to their body weight than the controls. The increased fat mass can enhance the leptin-hypothalamus-sympathetic pathway [14] and further lower the BMD. These changes might explain why body weight was not well-correlated with average FNBMD in our polio subjects. In contrast, body length had significant correlation.

Undergrowth of legs and its relation to lower bone mass

As shown in Table 1, the mean body length in the polio group was lower than that in the control group ($p < 0.05$), in spite of their similar age, body weight, BMI, and daily habits. Body length is known to be an indicator for growth and development of children [15], although it is also complicated by genetic and other factors. For our polio participants, body length had a good correlation with muscular strength ($r = 0.47\sim 0.53$, $p < 0.01$, data not shown) and average FNBMD of both legs (Table 2; $r = 0.43$, $p < 0.05$). Thus, the lower body length and the less FNBMD in our polio subjects might both partly result from the lack of development of legs during childhood. Because BMD contributes 70% of strength to bone [16] and most of the bone mass in adults is gained before the age of 20 [17], adequate mineralization of growing bones in children is essential for strong bones in adult life. Therefore, the occurrence of low bone mass in subjects with polio might be partly due to their reduced peak bone mass at a younger age.

Knee extensor strength and regular exercise were two important predictive factors associated with FNBMD

As shown in Table 4, knee extensor strength explained 17~23% of the variance of FNBMD in men with polio ($\beta =$

$0.497\sim 0.556$, $p < 0.005$). Previous literature reveals that muscle strength correlates positively with local bone mass in healthy postmenopausal women [18] as well as in subjects with polio [19] and stroke [20, 21]. Mechanical strain is found to be a strong stimulator for bone formation [22, 23] and muscular contraction put stress on the local bone with site-specific effects [24]. Most of the knee extensors, including the quadriceps muscle, originating from the femoral intertrochanter, may give an eccentric load on the proximal femur during contraction. This anatomical feature might be one of the reasons why knee extensor strength is a major predictor for bilateral FNBMD (Table 4).

After a 22-year follow-up study, Nielsen et al. declared that the risk of osteoporosis increased 1.5-fold during the study period in men with polio [25]. The results of our study showed that regular exercise is positively associated with FNBMD in polio subjects (Table 4; $\beta = 0.376\sim 0.397$, $p < 0.05$). Similarly, stroke subjects with early ambulation or mobility had less bone loss in their paretic leg [8]. Thus, regular exercise could play a role in promoting bone health in men with polio.

Limitations

This study has some limitations. First, because we used MMT to obtain ordinal data for muscular strength, but did not obtain continuous measurements with a dynamometer, some relevant information might be missing in the study. Second, body length is found to be a predictor of bone area or bone size at the femoral neck in Taiwanese men aged 21–70 years [26], and data from DXA measurement may vary with the thickness or size of the measured bone [27]. Therefore, as it is associated with shorter body length, the FNBMD values might be underestimated in our polio subjects. Third, a small number of subjects participated in the study. However, we carefully selected control subjects of a similar gender, age, and BMI for the study. And fourth, being a cross-sectional study, it remains unclear whether the major cause of low FNBMD in our polio subjects is rapid BMD loss or low peak values. Further investigation with a longitudinal study in the future is needed to answer this.

In conclusion, men with polio had significantly lower FNBMD. The shorter leg had lower FNBMD than the longer one. Knee extensor strength and regular exercise were two important predictive factors associated with FNBMD. In clinical practice, FNBMD of the shorter leg may be the choice for predicting the risk of hip fracture in men with polio, and regular exercise can play a role in promoting bone health among them.

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Conflicts of interest None.

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