Bone Mineral Density Among Individuals With Residual Lower Limb Weakness After Polio

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Abstract

Background: Literature indicates that individuals with long-term residual lower extremity (LE) weakness after polio have decreased bone mineral density (BMD) related to muscle weakness. Where weakness is asymmetrical, bone densitometry measured only on the stronger LE may misclassify BMD.

Objective: To determine (1) whether femoral neck BMD differed from side to side in individuals with asymmetrical LE muscle weakness, and (2) the proportion of individuals at risk for underdiagnosis of low bone density or osteoporosis given unilateral assessment of the femoral neck.

Design: Retrospective study.

Setting: Outpatient postpolio center.

Participants: Patients >18 years old with complete relevant data.

Main Outcome Measures: Bone densitometry T scores, BMD categories based on standard T-score ranges, and side of LE weakness determined by a strength score.

Results: Forty-three patients had at least 1 femoral neck T score and bilateral LE strength scores. Fourteen (32.5%) had bone densitometry only on their weaker LE and 14 (32.5%) had bone densitometry only on their stronger LE. Of the 15 patients with bone densitometry done on both femoral necks, T scores (mean [SD]) were lower in the weaker LE (−1.73 [1.09]) than the stronger LE (−0.88 [1.0]) (P = .001). Classification of low bone density or osteoporosis was more frequent based on T scores taken on a weaker LE (48.3% and 24.1%, respectively) than from T scores from a stronger LE (41.4% and 6.9%, respectively).

Conclusions: In this small sample, using strong-limb T scores resulted in fewer individuals categorized as having low bone density or osteoporosis than when weak-limb T scores were used. Underestimating BMD loss may lead to undertreatment and increased risk of morbidity, mortality, and costs associated with femoral neck fractures in this high-fall-risk group.

Level of Evidence: III

Introduction

Polio affected more than 35 000 people per year in the United States from the late 1940s to early 1950s and up to 350 000 people worldwide by 1988 [1]. A 1994-1995 report of a 1987 survey estimated that there were 1 million polio survivors in the United States, with 443 000 reporting they had paralytic polio [1]. Although there are no current data on the number of individuals in the United States who are living with residual weakness from polio, it is now recognized that 18% to 80% of polio survivors have postpolio syndrome (PPS), depending on the criteria applied [1-3]. PPS is a condition characterized by new or increasing muscle weakness, atrophy, fatigability, and pain—without alternative medical explanation—among individuals whose neurologic and functional status was stable for 15 years or more after recovery from acute poliomyelitis [1,3]. The sequelae related to residual weakness from polio and PPS affect the levels of activity and participation in affected individuals, in addition to putting the individual at risk for the interrelated issues of falls, osteoporosis, and fracture [4-9]. In a sample of 233 polio survivors in the United States, Silver et al found that 64% reported a fall in the past year,
with 35% sustaining associated fractures [6]. In a sample of 50 individuals with PPS in Ireland, Mohammad et al found that 82% reported falls over the past 5 years, with 38% sustaining fractures that were largely attributed to a fall. In their sample, more than half the sample were osteoporotic [5]. They found mean femoral T scores from bone mineral density (BMD) measurements to be lower in the leg with greater muscle weakness (P < .05), with more frequent diagnosis of osteoporosis on that weaker side [5]. In a review of records from a postpolio center in Montreal, Haziza et al found that BMD on the tested hip was correlated to a derived lower extremity muscle strength score on that same side (r = .25-.32, P < .04) [4]. Another study found that side-to-side differences in knee extensor strength accounted for 23% to 29% of the variance in femoral neck bone density in the postpolio group after controlling for multiple other risk factors [10].

The literature indicates that residual lower extremity weakness in the postpolio population is a risk factor for falls and is associated with BMD loss, putting these individuals at risk for the morbidity, mortality, and high costs associated with hip fracture in particular [9]. The International Society for Clinical Densitometry recommends BMD testing for any adult with a condition associated with low bone mass or bone loss, as well as anyone not receiving treatment for whom treatment would be indicated when there is evidence of bone loss [11]. The prevalence of low BMD in individuals with PPS and the risk of falls places individuals with residual weakness from polio among those recommended for BMD testing regardless of age. The evidence supports the ability of different interventions (eg, pharmaceuticals) to prevent fractures among those who are diagnosed with osteoporosis, reducing what are among the highest costs for direct health services.

The need for BMD assessment in individuals with PPS is well supported. However, there is no consensus on how BMD should be assessed. The International Society of Clinical Densitometry and the National Osteoporosis Foundation support measurements at the spine and at 1 hip [11,12], whereas the World Health Organization recommends using only 1 femoral neck [9]. None of these key groups currently recommend assessment of both hips or provides guidelines on which hip to use for femoral neck measurements of BMD. Yet, there is evidence that BMD scores on the weaker lower extremity of those with residual muscle weakness may be lower. If only the hip on the stronger limb is assessed, BMDs requiring therapeutic intervention may be underdiagnosed, thus increasing the fracture risk in those individuals. This study examined all records in the data repository of an international rehabilitation center for polio with the objectives of (1) determining whether femoral neck BMD differed side to side in individuals with asymmetrical residual lower extremity muscle weakness, and (2) determining the proportion of individuals at risk for underdiagnosis of osteoporosis or low bone density given unilateral assessment of the femoral neck, thus leading to possible undertreatment and preventable fall-related fractures.

Methods

Patient Records

All paper and electronic records for participants older than 18 years with a history of polio or PPS who were treated at an international rehabilitation center for polio from 1997 through October 2017 were initially included in this retrospective study. The center is housed in an outpatient facility that is part of a large rehabilitation network and draws patients from around the world although most heavily from the New England area. Eligible participants for this study were those who had complete data on the relevant measures in the center’s electronic data repository. The center’s deidentified data repository (REDCap, copyright 2006-2013, Vanderbilt University, all rights reserved [13]) and the retrospective records review was approved by the network’s Human Subjects Review Committee for securely gathering, storing, and analyzing the center’s patient data.

Procedures

On initial intake, individuals seen at the center brought or released available medical records to the center. Patients also completed questionnaires and were interviewed by center personnel about their medical and social history, the history of their polio experience and current functional status, as well as several patient-reported measures of activity. A physical therapist assessed the strength of 8 lower extremity muscles bilaterally using standardized manual muscle testing [14]. In some instances, additional diagnostic studies were completed, including bone densitometry. Self-report questionnaires on current status and objective tests were repeated during 1 or more subsequent visits to the center when possible.

Outcome Measures

The primary outcome measures for this study were as follows: (1) bone densitometry T scores, (2) BMD categorization, and (3) side of greatest lower extremity weakness based on bilateral lower extremity strength scores. Bone densitometry T scores from the lumbar spine and/or one or both femoral necks were either obtained from patients’ medical records or obtained as part of additional testing. The choice of bone densitometry location (spine or femoral head) and which femoral head (if any) was not controlled but is likely to represent typical practice. Per usual practice, T scores were categorized as normal BMD (> −1.0), low bone density (−1.0 to < −2.5), or osteoporosis (≤ −2.5) [9,11]. A strength score was
generated for each lower extremity as the sum of the numerical grades (0-5) \[14,15\] assigned to hip flexion, knee extension, and ankle dorsiflexion as done in Haziza et al \[4\]. The lower extremity with the greater muscle strength sum score was considered to be the stronger limb. Where repeated visits for an individual resulted in more than 1 set of outcome measures, the lower extremity strength scores closest in date to the first available bone density were used for that individual.

**Statistical Analysis**

Deidentified data from REDcap were exported to Statistical Package for the Social Sciences (SPSS, version 21; IBM Corp, Armonk, NY) for all data analysis. Participant demographics are reported; comparisons between included and nonincluded individuals were done using $\chi^2$ or $t$ tests as appropriate. Paired $t$ tests were done to compare femoral neck $T$ scores from side to side.

**Results**

Of the 121 participant records that were available in the data repository, 43 were included in the study based on at least 1 femoral neck $T$ score and complete strength scores for both lower extremities. Table 1 shows the demographic characteristics of the 43 study participants as well as the characteristics of repository nonparticipants who were excluded because of missing data. There were no statistically significant differences between those included and those excluded because of missing data, with the exception of a greater number of falls in the year before intake among enrolled participants. All 43 participants were found to have strength asymmetry based on their strength scores. Fourteen participants (32.5%) had femoral $T$ scores only on their weaker lower limb, 14 (32.5%) only for their stronger lower limb, and 15 (34.8%) had scores for both limbs.

The BMD diagnoses for all participants are shown in Table 2 using either the only available femoral neck $T$ score or the lower $T$ score for the 15 participants with bilateral bone densitometry. For participants with bilateral $T$ scores, Table 3 shows data for the average $T$ scores for the femoral neck of each lower limb, where $T$ scores were lower in the femoral head of the weaker lower limb ($P = .001$). Based on available data, $T$ scores from participants’ weaker limb would have led to more diagnoses of low bone density (48.3%) and osteoporosis (24.1%) than would have been diagnosed based on $T$ scores from a stronger limb (41.4% and 6.9%, respectively) (Table 4).

**Discussion**

This sample of 43 individuals averaged 55 years since diagnosis of polio. The mean femoral bone density was significantly lower on the side of weakness in those with available bilateral $T$ scores. Of those with $T$ scores on
their stronger limb (Table 4), 14 (48.3%) were categorized as having low bone density or osteoporosis; of those with T scores on the weaker limb, 21 (72.4%) were categorized as having low bone density or osteoporosis.

This study is the only one known to compare T scores from both strong and weak lower limbs of individuals who have had polio; however, some comparisons can be made to previous research. Table 5 compares prevalence of low BMD and osteoporosis in the weaker lower extremity to similar data on the weaker lower extremity from Haziza et al and Mohammad et al [4,5]. For reference, the table also includes national data for the U.S. population 50 years of age and older that Wright et al estimated using data from the 2010 U.S. Census and the 2005-2010 National Health and Nutrition Examination Survey [16]. Haziza et al found a similar prevalence of osteoporosis in the weaker limb to that in our sample, whereas Mohammad et al found a higher prevalence of osteoporosis in the weaker limb. Although Chang et al also reported low BMD and osteoporosis in their study of postpolio patients, they referenced the shorter (but not necessarily weaker) limb, and excluded postmenopausal women and all patients older than 60 years, so their data are not used for comparison [17].

All 3 studies in Table 5 show substantially higher proportions of individuals with postpolio and osteoporosis in the weaker limb compared to the national data. The average ages and years since diagnosis in our study (60.2 and 55.4 years, respectively) were similar to the samples of Mohammad et al (58.6 and 53.4 years, respectively) and Haziza et al (56.9 and 52.8 years, respectively). The proportion of patients with osteoporosis in Mohammed et al’s sample was more than twice that of our sample and that of Haziza et al. In looking at other available demographic data, only 43% of Mohammad et al’s sample were daily walkers, and 56% were current smokers. In Haziza et al’s sample, 82% were daily walkers (as compared to 92.5% in our study), and only 17.9% were smokers (compared to 4.9% of our study participants). Physical inactivity and smoking status are risk factors for BMD-related fractures [9], so they may account for some of the differences in the proportions of osteoporosis seen in Table 5. The numbers for low bone density across the 3 studies are not that different from the national data projections. However, those with reduced bone density and residual limb weakness are at higher risk for hip fracture than the general population based on a higher incidence of falls. In our sample, 76.2% reported more than 1 fall in the last year; 64% of Mohammad et al’s patients reported falls in the last 6 months. These numbers agree with those of Bickerstaffe et al, where 73.8% of the postpolio patients (mean age of 57.4 years) reported at least 1 fall in the past year, and those of Silver et al (mean age of 56 years), where 64% reported falls in the past year [6,7]. The frequency of falls in the postpolio population contrasts sharply with studies reporting an incidence of 17% to 23% for annual falls in the general population among those older than 55 years [7].

Recognizing that osteoporosis is multifactorial [9,18], it appears that lower extremity muscle weakness is either directly or indirectly related to BMD. Reduced muscular compressive forces, pain and fatigue associated with PPS, increased risk of osteoarthritis, and reduced levels of inactivity may work together to increase risk [9,18,19]. Summarizing meta-analyses, the World Health Organization Scientific Technical Report proposed a univariate 2.6-fold increase in hip fracture risk for each SD decrease in femoral BMD [9]. Those with low bone density have a 1 SD decrease in BMD; therefore, they have a 2.6-fold risk for hip fracture. Those with osteoporosis have a 2 SD decrease in BMD, and therefore a 6.8-fold (2.62) increased risk. In this study, T scores were lower for the weaker femoral head, and ascertainment of both low bone density and osteoporosis were more frequent according to the weaker limb Tscores. Bone densitometry done only on the stronger limb would undiagnose BMD and, therefore, be likely to lead to undertreatment. Untreated osteoporosis increases the likelihood of femoral neck fracture, leading to mortality, morbidity, and substantial health care costs [9].

**Limitations**

There are several limitations to the study and to the findings. Only 35.5% of the 121 postpolio patients in the database had sufficient data for analysis. The most common missing data were 1 or more of the bilateral manual muscle testing scores used to determine side of greater weakness (hip flexion, knee extension, and dorsiflexion). However, comparison of key demographics did not show any statistically significant differences between included and excluded patients except for a higher number of falls in the past year for the included patients. This may result from the slight increase in proportion of community ambulators in included participants and slight reduced use of assistive devices.

Identification of the weaker lower limb was based on manual muscle testing scores for only 3 muscle groups (hip flexors, knee extensors, and ankle dorsiflexors) and

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<th>Low BMD</th>
<th>Osteoporosis</th>
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<tr>
<td>Current study*</td>
<td>14 (48.3)</td>
<td>7 (24.1)</td>
<td>29</td>
</tr>
<tr>
<td>Haziza et al [4]*</td>
<td>67 (41.3)</td>
<td>41 (25.3)</td>
<td>162</td>
</tr>
<tr>
<td>Mohammad et al [5]*</td>
<td>20 (40)</td>
<td>28 (56)</td>
<td>50</td>
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<tr>
<td>Projected National Data [16]</td>
<td>5.7 m (39.4)%</td>
<td>3.9 m (5.7)%</td>
<td>99 m²</td>
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BMD = bone mineral density.
* Based on weaker-limb femoral T scores.
† Non-institutionalized adults ≥50 years old, adjusted for age, sex and race/ethnicity from National Health and Nutrition Examination Survey and 2010 census based on femoral neck BMD.
‡ m = million.
was not necessarily done at the same point in time as the bone densitometry. We used the complete strength data closest to the time of bone densitometry. Because progressive muscle weakness is one of the symptoms of PPS, strength scores and the side of greater weakness are not necessarily stable [1]. We used the methodology of Haziza et al to generate the side-to-side strength scores, but ascertainment of the weaker limb has varied among studies [4,7,8,19]. Although there might be an ascertainment strategy that better correlates lower extremity strength with BMD, it does not appear that a different strength assessment strategy would substantively affect conclusions drawn from this and other studies.

The patient database used for this study did not include use of bisphosphonates or other medications that might affect BMD. If patients were already being treated, our study may have underestimated the proportion of individuals who fall into the low bone density or osteoporosis categories presuming medication was effective in either increasing BMD or slowing decline.

Clinical Impact and Implications for Future Research

The clinical impact of undetected BMD loss and hip fracture risk in the population of individuals with residual asymmetrical lower extremity weakness after polio is a function of the size of that population. Although new cases in the United States and elsewhere in the world are rare, it was estimated in 1987 that 443,000 in the United States were living with residual paralysis after polio [1]. Of those still living today, 25% to 80% are estimated to have increasing disability due to PPS that may lead to additional loss of BMD through aging and increasing muscle weakness [1,3]. The need to monitor BMD in a weaker hip may go beyond those with residual paralysis after polio. It is estimated that 2.6% of the noninstitutionalized population of the United States (<18 years old) experienced a stroke, with 2% to 3% of the U.S. population reporting disability due to stroke [20]. Ramnemark et al and Lazoura et al found a greater decline in BMD on the affected side of individuals with hemiparesis poststroke by the end of the first year (P < .01) [21,22], thus increasing the potential public health impact if hip fracture risk is underestimated. Guidelines from the International Society for Clinical Densitometry and World Health Organization recommend bone densitometry for such at-risk individuals, but each recommends bone densitometry of only one hip without guidelines as to which hip should be tested [9,11]. Data from our study showed 24% fewer individuals diagnosed with low bone density or osteoporosis based on strong-side T scores as compared to weak-side T score. These data, with the support of past research, indicates that the side of greater weakness should be tested to minimize underdiagnosis, undertreatment, and increased risk of hip fracture. Although our study and other cited studies used strength assessment strategies based on manual muscle testing to determine the weaker lower limb—not clinically feasible to conduct at the time of bone densitometry testing—anecdotal evidence from therapists at our postpolio center strongly suggests that most patients can correctly identify their weaker side when asked. The affected side would be a matter of record and obvious to individuals poststroke with residual hemiparesis. Therefore, we recommend that bone densitometry personnel ask the patient to identify the side of weakness; minimally, the hip on the side of weakness should be scanned.

Confirmation of the findings about side-to-side differences in BMD in additional populations with asymmetric motor loss and increased fall risk is needed to ascertain generalizability of our findings. Studies should include those with both upper and lower motor neuron dysfunction from other neurologic disorders. Further research should also look at whether there is a more sensitive measure of lower extremity strength and whether there is a critical strength score or critical muscle weakness that is associated with reduced BMD.

Conclusion

Of individuals with bilateral femoral neck T scores in this sample, the side of greater lower extremity weakness had significantly reduced T scores compared to the stronger side. Categorizing individuals as having low bone density or osteoporosis based on T scores from the stronger limb resulted in lower proportions in each category. These findings imply that performing femoral neck bone densitometry without consideration as to the side of greater weakness is likely to underestimate BMD loss, potentially leading to undertreatment and increased risk of morbidity, mortality, and costs associated with femoral neck fractures in a high-fall-risk group. The recommendation generated from this study is that bone densitometry be consistently performed on the hip that the patient identifies as the lower extremity of greater weakness.

References


13. Research Electronic Data Capture (REDcap) [computer program], (2006-2013); Vanderbilt University.


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**Disclosure**

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**CME Question**

What relationship was noted in bone mineral density of the femoral neck between the strong and weak lower limbs in patients with postpolio syndrome?

- a. Higher incidence of osteoporosis in the strong limb
- b. Weak limb had higher incidence of osteoporosis
- c. Both limbs showed decreased incidence of osteoporosis
- d. Osteoporosis risk was the same as normal population

**Answer online at** http://me.aapmr.org