Clinics in Surgery

Research Article
Published: 23 Sep, 2021

Correlation between BMD and Physical Activity Scores in Lower Limb Amputees

*Rana Terlemez**

Department of Physical Medicine and Rehabilitation, Saglik Bilimleri University, Sisli Hamidiye Etfal Education and Research Hospital, Turkey

Abstract

Background: Low bone mineral density is one of the common clinical problems in lower limb amputees that may lead to more serious complications.

Objectives: We aimed to evaluate (i) the incidence of low Bone Mineral Density (BMD) in intact and amputated limbs, and (ii) the correlation between BMD and physical activity scores in lower limb amputees.

Study Design: A cross-sectional and non-interventional trial was conducted in lower limb amputees in physical medicine and rehabilitation department of a university hospital.

Methods: Forty-two unilateral lower limb amputees actively using prosthetics were enrolled. Dual Energy x-ray Absorptiometry (DXA) scanning was performed on all patients. Bone Mineral Density (BMD) for the lumbar spine (L1-L4) and bilateral femur (total hip, femoral neck) sites were assessed by using DXA (Lunar Prodigy Advance; GE, Madison, WI, USA). To evaluate the physical activity scores, Trinity Amputation and Prosthetic Experience Scales (TAPES) and Nottingham Extended Activities of Daily Living (NEADL) scales were used.

Results: The rate of low BMD for the total hip and femoral neck on the amputated side were 80% and 83% respectively. The BMD values of the femur sites were found decreased on the amputated side with a statistically significant difference than the intact side ($p<0.001$). Femur Z scores of transfemoral amputees were significantly lower than transtibial amputees ($p<0.05$). There was no correlation between NEADL and TAPES Activity scores and BMD values.

Conclusion: Lower limb amputation, particularly the transfemoral amputation was associated with loss of bone mineral density. It has been observed that the use of prosthesis and active lifestyle alone will not be enough to protect from osteoporosis.

Keywords: Amputation; Bone mineral density; Lower limb; NEADL; TAPES

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Correspondence:
Rana Terlemez, Department of Physical Medicine and Rehabilitation, Saglik Bilimleri University, Sisli Hamidiye Etfal Education and Research Hospital, Istanbul, Turkey,
E-mail: ranakaynar@hotmail.com

Received Date: *27 Jul 2021*
Accepted Date*: 20 Sep 2021*
Published Date*: 23 Sep 2021*

Citation:
Terlemez R. Correlation between BMD and Physical Activity Scores in Lower Limb Amputees. Clin Surg. 2021; 6: 3310.

Clinical Relevance

To our knowledge, this is the first study evaluating the correlation between BMD and physical activity scores in lower limb amputees. Our participants were already active prosthesis user, so we may not have found a correlation between physical activity scores and BMD. Prevention should be targeted on early and rapid weight bearing rehabilitation program, even in some cases it may be necessary to support with medical agents.

Background

Osteoporosis is one of the health problems that the lower limb amputees faced [1]. As a result of long-term unloading, rapid bone mineral density loss occurs after surgery [2,3]. The duration of bed rest, age, sex and the other comorbidities can affect the bone turnover [4]. After the patient becomes ambulatory, amputation level and prosthesis compliance may affect the bone loss especially on the affected side [5].

Some studies have shown the increased bone loss in lower limb amputees [3,6,7]. The etiology of bone loss is uncertain but disuse or underuse of the amputated limb is shown to be main problem. Loss of proprioceptive sense especially from the ankle joint and asymmetrical gait pattern with a shortened stance phase of the amputated limb may cause a less active amputated limb during daily living activities [8,9]. Therefore, lower limb amputees are under the risk of having lower Bone Mineral Density (BMD) and muscle strength.

Amputees may become deconditioned quickly until they are able to use a fitted prosthesis. Flint et al. showed the loss of BMD in active military population despite the rehabilitation program [10]. Also, the energy and time requirement during physical activities are much more according to normal population [11]. Therefore, lower limb amputees are under the risk of reduced physical activity. Goktepe et al. [12] showed that regular exercises were not associated with upper BMD scores below the injury level in spinal cord injured patients. Amputees are considered to be a similar group with spinal cord injured patients from some points like reduced weight load to the affected side. But to the best of our knowledge, there is no study investigating the correlation between BMD and physical activity scores in lower limb amputees.

The purpose of this study was to evaluate (i) the incidence of low BMD in intact and amputated limbs, and (ii) the correlation between BMD and physical activity scores in lower limb amputees.

Methods

Study design

A cross-sectional and non-interventional trial was conducted in lower limb amputees in physical medicine and rehabilitation department of a university hospital.

Study population

Unilateral lower limb amputees admitted to our outpatient clinic were enrolled. Informed consent was obtained from each patient. Forty-two patients, aged between 18 to 50 years with unilateral lower limb amputation were included in the study. All participants were actively using prosthetics. Bilateral amputees, amputees from joint level and patients with a metabolic disease affecting the BMD were excluded. Patients with a condition to avoid DXA scanning like metal implants or pregnancy were excluded, too.

Outcome measures

Bone mineral density: Dual Energy X-ray Absorptiometry (DXA) scanning was performed on all patients. BMD for the lumbar spine (L1-L4) and bilateral femur (total hip, femoral neck) sites were assessed by using DXA (Lunar Prodigy Advance; GE, Madison, WI, USA). The low BMD is defined with a Z score greater than 1 SD below the mean (Z< -1.0). In this study we did not use the terms osteopenia or osteoporosis. Because these terms are typically associated with T score measurements [13].

Trinity amputation and prosthetic experience scales: In order to measure physical activity, a section was extracted from the Turkish version of Trinity Amputation and Prosthesis Experience Scales (TAPES) was used [14]. Topuz et al. [15] showed that this version is valid and reliable in 2011. The Activity restriction section of this scale was used, which has 12 questions in total. Each question scored with a 3-point Likert scale. The total score that can be obtained from this section ranged between 12 to 36 points. The questionnaire was short and easy to use, taking no more than 5 minutes for the patients to finish.

Nottingham extended activities of daily living (NEADL): Functional independence was assessed by using the Nottingham Extended Activities of Daily Living (NEADL) scale [16]. The NEADL scale was developed for stroke but is used widely as an outcome measure in rehabilitation area. Sahin et al. [17] showed that the Turkish version of NEADL is valid and reliable in 2008. NEADL evaluates the independence in daily living activities in 4 subsections; mobility, kitchen, domestic, leisure time activities. In total NEADL consists of 22 questions. Responses were evaluated on 0 to 3 score scale and ranged between 0 to 66 points.

Statistical analysis

Statistical analyzes were performed using SPSS version 20.0 software. Descriptive analyzes were given using mean, standard deviation and median for normal non-dispersive variables. In the cases where the data showed normal distribution, t test was used in independent groups. Pearson Correlation analysis was used to correlate the measured data with each other. Interrelationships of the measured data were examined by Intraclass Correlation Coefficient Test. The P-value was below 0.05 were considered statistically significant.

Results

Forty-two consecutive lower limb amputees were enrolled (8 females, 34 male). Twenty-five of the cases included in the study were transtibial amputees and 17 were transfemoral amputees. The mean age ± SD was 26.3 ± 11.3 years. The mean duration after amputation was 9.7 ± 3.4 years. The mean Body Mass Index (BMI) was 23.4 ± 4.1 kg/m^2. The rate of normal-weighted and under-weighted patients were 71.4% and 11.9% respectively. None of the patients were obese (Table 1).

The rate of low BMD for the total hip and femoral neck on the amputated side were 80% and 83% respectively. These rates on the intact side were 19% and 23.8% respectively. The rate of low BMD for the lumbar spine was 16.6%. The BMD values of the femur sites were found decreased on the amputated side with a statistically significant difference than the intact side (p<0.001) (Table 2).

Femur Z scores for both total hip and femoral neck of transfemoral amputees were significantly lower than transtibial amputees (p<0.05). There was no significant difference for lumbar spine scores according to amputation level. When physical activity scores were compared according to amputation level, no significant difference was found between the two groups (Table 3).

There were no correlations between NEADL and TAPES activity scores and BMD values (p>0.05) (Table 5). Also, Intraclass

Table 1: Baseline characteristics of the patients.

Variables	Patients
Age, mean (years ± SD)	26.3 ± 11.3
Gender, male; female (number)	34;8
Amputation side, right; left (number)	18;24
Amputation level, transfemoral; transtibial (number)	17;25
The duration of amputation, mean (years ± SD)	9.7 ± 3.4
BMI, mean ± SD kg/m^2	23.4 ± 4.1
BMI category, (number)	
• Under-weighted (BMI: <18.5)	5
• Normal-weighted (BMI: 18.5-24.9)	30
• Over-weighted (BMI: 25-29.9)	7
• Obesity (BMI: >30)	0

Table 2: Comparison of BMD scores between amputated side and intact side.

	Amputated side		Intact side		p*
	Mean SD	Median	Mean SD	Median	
Femur neck BMD (g/cm^2)	0.81 ± 0.27	0.91	1.01 ± 0.14	1.00	**<0.001**
Femur total BMD (g/cm^2)	0.78 ± 0.31	0.83	1.06 ± 0.20	1.00	**<0.001**

Table 3: Comparison of NEADL and TAPES activity scores and BMD values by amputation level.

	Amputation Level					p*
	Transtibial		Transfemoral			
	Mean ± SD	Median	Mean	± SD	Median	
NEADL score	54.72 ± 7.95	57.00	48.63	± 11.23	52.00	0.698
TAPES score	28.17 ± 5.15	29.50	25.00	± 7.71	25.50	0.187
Lumbar spine BMD (g/cm²)	1.26 ± 0.16	1.28	1.07 ± 0.21		1.00	0.574
Lumbar spine Z score	0.09 ± 1.13	0.20	-0.29	± 1.05	-0.10	0.810
Femur neck BMD (g/cm²)	0.26 ± 0.18	0.22	0.14 ± 0.33		0.00	0.038
Femur neck Z score	2.02 ± 1.37	1.65	1.57 ± 1.48		1.12	**0.001**
Femur total BMD (g/cm²)	0.30 ± 0.21	0.27	0.27 ± 0.43		0.00	**0.011**
Femur total Z score	2.08 ± 1.48	1.90	1.68 ± 1.66		1.00	**<0.001**

*T test in independent groups; SD: standard deviation

Table 4: Comparison of NEADL and TAPES activity scores and BMD values by gender.

	Gender					p*
	Male		Female			
	Mean ± SD	Median	Mean	± SD	Median	
NEADL score	51.6 ± 9.6	53.00	49.9 ± 13.5		56.50	0.94
TAPES score	26.9 ± 7.0	29.00	23.90 ± 5.7		24.50	0.12
Lumbar spine BMD (g/cm²)	1.2 ± 0.2	1.20	1.2 ± 0.1		1.2	0.91
Femur neck BMD (g/cm²)	0.8 ± 0.2	0.80	0.7 ± 0.2		0.70	0.46
Femur total BMD (g/cm²)	0.8 ± 0.2	0.80	0.7 ± 0.2		0.80	0.37

*Student T test in independent groups; SD: standard deviation

Table 5: Correlation between NEADL and TAPES activity scores and BMD values.

	NEADL score		TAPES score	
	r	p*	r	p*
Lumbar spine BMD (g/cm²)	0.037	0.815	0.076	0.633
Lumbar spine Z score	-0.047	0.766	-0.018	0.911
Femur neck BMD (g/cm²)	0.149	0.347	0.247	0.114
Femur neck Z score	0.076	0.631	0.249	0.111
Femur total BMD (g/cm²)	0.059	0.710	-0.012	0.941
Femur total Z score	0.020	0.898	0.273	0.081

*Pearson correlation test; r: correlation coefficients

Correlation Coefficient test was used to evaluate the consistency between activity scores and BMD values but there was no significant consistency (p>0.05).

Discussion

To the best of our knowledge, this is the first study to evaluate the correlation between BMD and physical activity scores in lower limb amputees. The BMD values of the femur sites were found decreased on the amputated side with a statistically significant difference than the intact side (p<0.001). Also, femur Z scores for both total hip and femoral neck of transfemoral amputees were significantly lower than transtibial amputees (p<0.05). This study showed that there was no correlation between physical activity scores and BMD values.

In previous studies, BMD differences of femur sites between amputated and intact sides were shown [1,18]. Sherk et al. [6] demonstrated lower BMD values on the amputated femur sites in a smaller patient group, especially in transfemoral amputees similar to our study. The etiology of bone loss still remains unclear but it is likely to be a local phenomenon. BMD may be affected by some factors such as level of physical activity, muscle strength, genetic factors and diet habits [19]. Some authors emphasized that the lack of muscular activity may have a role for bone loss in non-amputees [20,21]. On the other hand, Tugcu et al. [3] reported that muscle strength itself does not seem to be associated with BMD in transtibial amputees. In our study, we implied that level of physical activity itself might not be significantly important for BMD. Similar to Tugcu's study, our participants were physically active with their prosthesis in their daily living activities. Also, the study population was consisted of patients without metabolic disease below the age of 50.

Patients are being advised to do exercises and increase mechanical loading to prevent osteoporosis, especially in healthy population. Although there is not enough data supporting this assumption in disabled people. Goktepe et al. [12] showed that physical exercise was not associated with greater BMD values below the injury level in spinal cord injured patients. In our study we reported similar results in lower limb amputees. On the other hand, Smith et al. [22] reported that mobility status is an independent predictor of BMD at the proximal femur in disabled population. They studied in a wider patient group including spinal cord injured patients, amputees and other neurologic conditions.

The altered and asymmetrical gait pattern of the amputees puts an increased amount of mechanical stress on the intact side. No matter how much attention is given to the prosthesis compliance, the amputated limb is less active during daily physical activities [23]. When transfemoral amputees compared to transtibial amputees, they are under the risk of developing greater bone loss [2,6,10]. In transfemoral amputees body weight skips the proximal femur sites and passes through the prosthesis, directly [24]. We found that femur Z scores for both total hip and femoral neck of transfemoral amputees were significantly lower than transtibial amputees. This finding supports that transtibial amputees may transfer more body-weight to the proximal femur sites. There was no significant difference for lumbar spine scores according to amputation level. Lumbar spine BMD values could be considered as normal, as well other studies [6,12]. Maybe we could find a difference in lumbar spine BMD if we had compared amputees using prosthesis or not.

These findings suggest that the bones of amputees may not be resistant to the high mechanical stress. Amputees are already under a high risk of increased falling [25]. Therefore, it is important to evaluate the bone mass in terms of both early diagnosis and treatment to preserve the quality of life for amputees. To protect patients from fractures, risk level can be identified primarily by using BMD.

The use of DXA to evaluate BMD values is the most widely accepted diagnostic tool [26]. To exclude age-related osteoporosis and postmenopausal osteoporosis, we included premenopausal women and men below age 50. We followed the recommendation of International Society for Clinical Densitometry for using Z score in these populations [27]. Like most of the amputee studies we focused on BMD values. It was our limitation that we did not use bone turnover markers. Sclerostin is a glycoprotein which has recently began to be used more in osteoporosis research. Mechanical loading to long bones decreases the sclerostin levels and induces bone formation [28]. In a recent study Bemben et al. [7] showed elevated serum sclerostin levels in early post-amputation period and they pointed to the rapid bone loss in the first year of amputation. This duration may be the most critical period for preventing bone loss. Future research could be directed these markers even more.

Conclusion

Our findings show that physical activity status of the amputees does not seem to be very important, alone. Amputation level is important for bone loss; but our participants were already active prosthesis user and relatively young. For this reason, we may not have found a correlation between physical activity scores and BMD. It was thought that the bone loss is related the decreased local weight load to the femur proximal sites rather than general limitation of ambulation. Prevention should be targeted on early and rapid weight bearing rehabilitation program and to be supported by daily adequate calcium and vitamin D intake, even with anti-osteoporotic drugs.

Ethical Committee

This study was approved by the committee of the Ethical Board of our university hospital. All cases signed informed consent forms prior to enrollment.

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