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Effects of Lower Limb Amputations on Bone Health of Amputees: Study from A Developing Country

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ABSTRACT

***Objective*:** To measure the Bone mineral density in young adults with traumatic or non-traumatic lower limb amputation using a DEXA scan.

***Study Design*:** Comparative cross-sectional study.

***Place and Duration*:** Armed Forces Institute of Rehabilitation Medicine, Rawalpindi Pakistan, from Jul to Dec 2021.

***Methodology*:** Adults of age ≥18 years, admitted in the amputee ward of Armed Forces Institute of Rehabilitation Medicine with lower limb amputation (traumatic or non-traumatic, unilateral or bilateral, new or follow-up cases), were included. All patients were undergoing a DEXA scan for the first time since amputation. Patients were divided into three groups: Transtibial Amputation-Group (TTA), Transfemoral Amputation-Group and Ankle/Foot Amputation-Group. Z-scores were documented for the lumbar spine (L1-L4) and neck of the femur (NOF). Z-scores at NOF were documented on amputated as well as non-amputated sides.

Results: A total of 47 patients participated in the study. All were male. Mean age of patients was 30.8±7.1 years (Range: 21-48 years). The majority of the patients 28(59.6%) had left lower limb amputation. Out of 47 patients, the TTA-Group comprised 37(78.7%) patients, the TFA-Group comprised 3(6.4%) and the ankle/foot group comprised 5(10.7%) patients. A statistically significant difference in Z-scores at NOF between the amputated and non-amputated sides in TTA (p<0.001).

***Conclusion*:** A significant number of lower limb amputees suffer from reduced BMD. This is the well-identified risk factor for neck of the femur / hip fractures. Healthcare professionals must understand the significance of identifying amputees with low BMD.

Keywords: Bone mineral density, DEXA scan, Osteoporosis, Osteopenia, Transfemoral amputation, TFA, Transtibial amputation, TTA, Foot amputation.

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INTRODUCTION

Limb amputation not only incurs physical disfigurement, but it also carries long-lasting effects on functional mobility, QOL, psychological and socioeconomic aspects of an amputee's life. It can be a pre-planned non-traumatic amputation (like dysvascular, tumour, infection), or it can be traumatic amputation.[1] Globally, there were 57.7 million individuals with traumatic limb amputation in 2017, and prevalence was higher in East Asia and South Asia.[2] In Pakistan, due to the lack of any registry maintaining epidemiological data at the national/provincial level, the burden of disease with respect to limb amputations cannot be established.[3]

Patients with lower limb amputations, either traumatic or non-traumatic, have to face many medical challenges.[4] Amongst these, reduced bone mineral density (BMD) has been discussed less often.[5] Bones are composed of organic (mainly type I collagen) and mineral (hydroxyapatite crystal) components, with mineral components playing a major role in maintaining bone strength.= BMD is the measure of bone health, and dual-energy x-ray absorptiometry (DEXA) is preferably used to measure BMD. T and Z-scores are the measures used to define BMD. [7]

Following amputation, the lower limb undergoes accelerated loss of BMD with an elevated risk of osteoporosis and hip fractures.[6] Owing to the two decades of active war on terror in Pakistan, the number of amputations has shown significant rise resulting in an increasing cohort of lower limb amputees nationwide. Loss of BMD become very relevant in this cohort of young patients who are eager to return to their previous activity level.[8] Various

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studies have highlighted the importance of bone health of amputees. [7-9] In Pakistan, to date, there has been no published study analyzing BMD in this unique cohort. Our study aims to measure BMD with a DEXA scan in young adults who underwent lower limb amputation.

METHODOLOGY

The comparative cross-sectional study was carried out at the Indoor Amputee Ward Armed Forces Institute of Rehabilitation Medicine (AFIRM), Rawalpindi Pakistan, from July to December 2021, after approval was obtained from the Institutional Review Board (IRB reference number 03/2021). WHO calculator was used for sample size calculation, taking the prevalence of foot amputation as 10.6 % out of the approximately 1 million unilateral lower-extremity amputations and absolute precision of 9%.10

Inclusion Criteria: Adults aged 18 years or more, admitted in the amputee ward of AFIRM with lower limb amputation (traumatic or non-traumatic, unilateral or bilateral, new or follow-up cases), were included.

Exclusion Criteria: Individuals with a history of ischemic heart disease, peripheral arterial disease, smoking, alcohol, rheumatoid arthritis, ankylosing spondylitis, bilateral hip disarticulation, taking steroids, oral anticoagulants, and chronic proton pump inhibitors were excluded.

Data was collected on a structured proforma after obtaining informed consent from all the participants. Basic demographic data included age, gender, height, weight and body mass index. Clinical data comprised level, side, cause and duration of amputation, time from amputation to initial prosthetic gait training, use of gait aids and K-level of prosthetic ambulation. All patients were undergoing a DEXA scan for the first time since amputation. DEXA scan was performed on a Hologic Discovery A, model no. 010-0575 (Hologic, Inc, Bedford, MA, USA). Patients were divided into three groups: transtibial amputation (TTA), transfemoral amputation (TFA) and ankle/foot amputation groups. Z-scores were documented for the lumbar spine (L1-L4) and neck of the femur (NOF). Z-scores at NOF were documented on amputated as well as non-amputated sides.

Amputees were also classified using Medicare Functional Classification Levels (MFCL) based on the patient's functional mobility potential. It comprises five levels (K0 to K5): K0 means the patient lacks the ability or potential to ambulate or transfer safely. K1 means the patient has the ability or potential to use a prosthesis for transfers or ambulation on level surfaces at a fixed cadence (household ambulation). K2 means the patient has the ability or potential for ambulation with the ability to traverse low-level environmental barriers such as curbs, stairs, or uneven surfaces (limited community ambulation). K3 means the patient has the ability or potential for ambulation with variable cadence, can traverse most environmental barriers and may have vocational, therapeutic, or exercise activity beyond simple locomotion (community ambulation); K4 refers to prosthetic ambulation which exceeds basic ambulation skills exhibiting high impact, stress, or energy levels (active adults/athletes/child).[11]

As per standards established by the World Health Organization, the T-score is used to measure BMD and diagnose osteopenia or osteoporosis for postmenopausal women or men older than 50 years.[12] As per the International Society for Clinical Densitometry (ISCD), Z-score is the recommended measure to determine BMD in males < 50 years of age. This study uses a Z-score, which is more relevant to our lower limb amputees. A Z-score of -2.0 or lower is defined as "below the expected range for age," and a Z-score above -2.0 is "within the expected range for age".[13]

Statistical Package for Social Sciences (SPSS) version 23.0 was used for the data analysis. Quantitative variables were summarized as Mean±SD and qualitative variables as frequency and percentages. Independent sample t-test was applied to find the mean differences among the groups. The p-value of ≤ 0.05 was considered significant.

RESULTS

A total of 47 patients participated in the study. All were male. Mean age of patients was 30.8±7.1 years (Range: 21-48 years). Out of 47 patients, the-TTA Group comprised 37(78.7%), the TFA-Group comprised 3(6.4%) and the ankle/foot group comprised 5(10.7 %) patients. Additionally, there were 2(4.3%) patients having bilateral amputation with transtibial amputation on one side and transfemoral amputation on the other side. This accounted for 2x transtibial and 2x transfemoral amputations, considered part of TTA and TFA Groups, respectively. Resultantly, the TTA Group consisted of 39x amputated limbs and 37x non-amputated limbs. The TFA group consisted of 5x amputated limbs and 3x

non-amputated limbs. The ankle/foot amputation group consisted of 5x amputated limbs and 5x non-amputated limbs.

The majority of the patients (n=28, 59.6%) had left lower limb amputation. Trauma (including blast injury, gunshot wound, and road traffic accident) was the leading cause of amputation (n=44,93.6%). Two patients had bone tumours (osteosarcoma and giant cell tumour, each), and one patient had dysvascular amputation secondary to diabetes mellitus. Regarding prosthetic ambulation, most lower limb amputees (n=33, 70.2%) fulfilled the criteria for K-3 level (typical community ambulation). Regarding the need for gait aids / assistive devices for ambulation, only 17 (36.2 %) patients needed assistance. One amongst these was a bilateral lower limb amputee who was using a motorized wheelchair for community ambulation. Higher BMI was associated with lower Z-scores at the total lumbar spine (p-value =0.005) and neck of the femur (p-value < 0.001). Demographic characteristics and clinical characteristics of patients are shown in Table-I.

We compared the mean Z-scores at NOF of our study groups (on amputated as well as non-amputated sides) with BMD diagnosis i-e, "within the expected range for age" and "below the expected range for age". In the TTA Group, out of 39 amputated limbs, 24 had Z-scores within the expected range (adequate BMD) with a mean Z-score of -0.20±1.0 and 15 had Z-scores below the expected range (reduced BMD) with a mean Z-score of -2.62±0.6. Whereas, out of 37 non-amputated limbs, 34 had Z-scores within the expected range for age (adequate BMD) with a mean Z score of 0.07±0.9 and 3 had Z-scores below the expected range for age (reduced BMD) with a mean Z-score of -2.23±0.3. There was a statistically significant difference in Z-scores at NOF between the amputated and non-amputated sides in TTA (p <0.001).

In the TFA Group, all five amputated limbs had Z-scores at NOF below the expected range for age (reduced BMD) with a mean Z-score of -3.32±086. At the same time, all three non-amputated limbs had Z-scores at NOF within the expected range for age (adequate BMD) with a mean Z-score of -0.60±0.7. In the ankle/foot amputation group, all five amputated and non-amputated limbs had Z-scores at NOF within the expected range for age (adequate BMD) with mean Z-scores of -0.06±1.1 and 0.34±1.1. However, Z-score comparisons were impossible for the TFA Group (amputated and non-amputated side) and ankle/foot

Table-I: Descriptive Statistics of the Study Parameters (n=47)

Study Parameters	n(%)
Age (Mean±SD)	30.80±7.1 years (Range: 21 to 48 years)
Male Gender	47(100%)
Level of Amputations	
Transtibial (TTA)	37(78.7%)
Chopart	2(4.3%)
Syme	3(6.4%)
Transfemoral (TFA)	3(6.4%)
TTA & TFA	2(4.3%)
Side of Amputation	
Right	17(35.4%)
Left	28(59.6%)
Bilateral	2(4.3%)
Mechanism of Injury	
Mine Blast Injury	28(59.6%)
IED Blast	8(17.0%)
Gun Shot Wound	5(10.6%)
Road Traffic Accident	3(6.4%)
Bone Tumour	2(4.3%)
Diabetes Mellitus	1(2.15%)
K Level of Prosthetic Ambulation	
Pre-prosthetic Phase	7(12.8%)
K2	7(12.8%)
K3	33(70.2%)
Body Mass Index	
Underweight	6(12.8%)
Healthy	25(53.2%)
Overweight	12(8.5%)
Obese	4(8.5%)
Need of Gait Aids/Assistive Devices	
Axillary Crutch	10(21.3%)
Motorized Wheel Chair	1(2.15%)
Elbow Crutch	5(10.6%)
Walker	1(2.15%)
None	30(63.8%)
Presence of Comorbid	
Yes	3(6.4%) *
No	44(93.6%)
Mean Z-score NOF	
Amputation Side – TTA Group (Mean±SD)	-1.13±1.51 (Range:-4.4 to 2.4)
Mean Z-score NOF Non-	
Amputation Side – TTA Group (Mean±SD)	-0.11±1.10 (Range:-2.6 to 1.8)
Mean Z-score NOF	
Amputation Side – TFA Group (Mean±SD)	-3.32±0.86 (Range: -4.0 to -2.10)
Mean Z-score NOF Non-	
Amputation Side – TFA Group (Mean±SD)	-0.60±0.78 (Range:-1.5 to -1.0)
Mean Z-Score NOF Amputation Side–Ankle/Foot	
Amputation Group (Mean±SD)	-0.06±1.1 (Range:-1.1 to 1.3)
Mean Z-score NOF Non-Amputation Side –Ankle/Foot	
Amputation Group (Mean±SD)	0.34±1.1 (Range:-1.3 to 1.7)
Duration of Amputation (Mean±SD)	44.82±50.2 months (Range: 5-264 months)
Time Between Amputation and Provision of Prosthesis (Mean±SD)	10.47±5.0 months (Range: 3-24 months)
Mean Z-score at Lumbar Spine (Mean±SD)	-1.00±1.3 (Range: -3.3 to 1.6)

***** *(2 x Malignancy, 1 x Diabetes Mellitus)*

amputation group (amputated and non-amputated side). Proximal level of amputation correlated with lower Z-scores at NOF on the amputated side only (p-value=0.008). For all lower limb amputees, mean Z-scores at the lumbar spine remained within the expected range for age (-1.00±1.3), suggesting adequate BMD. Table-II shows a comparison of mean Z-scores at NOF for BMD on amputated and non-amputated sides of study groups.

Table-II: Comparison of mean Z-scores (NOF) for Bone Mineral Density on Amputated and Non-Amputated Side of Study Groups (n=47)

Mean Z-score - Amputation side (TTA Group) (mean±SD)	**Study Groups**		***p*-value**
	Within Expected Range (n=24)	**Below Expected Range (n=15)**	
	-0.20±1.0	**-2.62±0.6**	**<0.001**
Mean Z-score - Non-amputation side (TTA Group) (Mean±SD)	**Study Groups**		*p*-value
	Within Expected Range (n=34)	Below Expected Range (n=3)	
	0.07±0.9	-2.23±0.3	<0.001
Mean Z-score - Amputation side (TFA Group) (Mean±SD)	**Study Groups**		*p*-value
	Within Expected Range (n=0)	Below Expected Range (n=5)	
	-	-3.32±086	-
Mean Z-score - Non-amputation side (TFA Group) (Mean±SD)	**Study Groups**		*p*-value
	Within Expected Range (n=3)	Below Expected Range (n=0)	
	-0.60±0.7	-	-
Mean Z-score - Amputation side (Ankle/Foot Amputation Group) (Mean±SD)	**Study Groups**		*p*-value
	Within Expected Range (n=5)	Below Expected Range (n=0)	
	-0.06±1.1	-	
Mean Z-score - Non-amputation side (Ankle/Foot Amputation Group) (Mean±SD)	**Study Groups**		*p*-value
	Within Expected Range (n=5)	Below Expected Range (n=0)	
	0.34±1.1		-

DISCUSSION

This study was conducted to find the effects of lower limb amputations on bone health. BMD is the measure of bone health, and the gold standard for measuring BMD is the DEXA scan.6 T-score is the comparison of the BMD of the patient to a gender-matched, healthy adult of 30 years ago, while Z-score refers to the comparison of the BMD of a patient to a gender as well as age-matched individual.[4,12]

Various independent studies from different parts of the country mainly focused on the epidemiological aspects of amputations. Ahmad *et al*. and Rathore et al. focused on demographics of lower limb amputees in their studies.1,[14] Khan et al. described hind foot amputations secondary to mine blast injuries.[15] Gill et al. highlighted problems related to prosthetic components in their study population.[16]

Our study population was young, with a mean age of patients 30.8 ± 7.1 years, and all were male. Flint JH et al. showed that 98% of the patients with lower limb amputations were male.9 Trauma was the leading cause of amputation (n=44, 93.6%) in our study population, a finding consistent with local and regional studies.[1,3,5,14,16-18]

Most of the lower limb amputations in our study group were transtibial (83 %). This is very important from the prosthetic rehabilitation aspect as retaining the patient's knee joint (where possible) helps in better, energy-efficient and smooth gait with a more natural transition through different phases of gait.

Our results suggested relatively reduced BMD on the amputated side as compared to the non-amputated side in the TTA and TFA Groups. In the TTA Group, out of 39 amputated limbs, 15 amputated limbs had mean Z-scores below the expected range for age (-2.62±0.6). Although the overall mean Z-score on the amputated side was within the expected range for age, it was comparatively lower than the non-amputated side (-1.13±1.51 vs -0.11±1.10). Whereas in the TFA group, all five amputated limbs had Z-scores below the expected range for age with a mean value of -3.32±0.86. This result is consistent with the findings of many studies who independently found that there was an increased loss of BMD ipsilateral to the amputation side.[4,9,20-21]

Our results also showed more reduction in BMD with a higher level of amputation (TFA > TTA Group). Regarding the ankle/foot amputation group, mean Z-scores at NOF remained within the expected range on amputated and non-amputated sides, suggesting better BMD with distal lower limb amputations. Similar results were seen in various other international publications.[4,9,21] This has important clinical implications as reduced BMD at NOF has the greatest predictive power of fracture at NOF, suggesting a higher possibility of fracture NOF compared to controls.[4,7,8,21]

Prosthetic ambulation of all amputees was documented using the MFCL system, and the majority (n=33(70.2%) were typical community ambulators (K-3 level) with the ability to ambulate at variable cadence and traverse most of the environmental barriers. Seven were at K-2 level (limited community ambulation),

and seven were undergoing pre-prosthetic training (not provided with prosthesis yet). Moreover, out of 47 patients, only 17(36.2 %) still needed assistance with gait aids. One amongst these was a bilateral lower limb amputee who was using a motorized wheelchair for community ambulation. This shows the positive attitude and motivation of the young lower limb amputees for prosthetic rehabilitation, with a dedication to reintegrating into the community and the assumption of their family roles.

LIMITATION OF STUDY

We identified various limitations of our study. It was a single-centre study that could not cover the study subjects from all over the country and needed more female patients. There were fewer trans-femoral and ankle/foot amputees than transtibial amputees. A multi-center study with a large sample size covering different regions of the country will surely identify the magnitude of this health issue in amputees.

CONCLUSION

A significant number of lower limb amputees suffer from bone loss. Reduced BMD is a well-recognized risk factor for NOF / hip fractures. DEXA scan remains the gold standard for diagnosis and monitoring of bone loss. Monitoring of bone health needs to be included in long-term medical follow-up of this unique cohort. Early screening will help in timely diagnosis, management planning, prevention of falls, balance training and enhancing quality of life.

Conflict of Interest: None.

Authors Contribution

Following authors have made substantial contributions to the manuscript as under:

RY & UY: Conception, study design, drafting the manuscript, approval of the final version to be published.

ZAG & MTK: Data acquisition, data analysis, data interpretation, critical review, approval of the final version to be published.

OJ & IR: Data acquisition, drafting the manuscript, approval of the final version to be published.

Authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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