Open Access

Original Article

Patterns of Musculoskeletal Injuries Secondary to Strenuous Physical Training, Assessed on Magnetic Resonance Imaging

Saerah Iffat Zafar, Humza bin Saeed*, Muhammad Asif, Adnan Anwer, Hassan Mahmud Syed*****

Department of Radiology, Combined Military Hospital, Abbottabad/National University of Medical Sciences (NUMS) Pakistan, *Department of Dentistry, Riphah International University, Rawalpindi Pakistan, **Department of Orthopedic Surgery, Combined Military Hospital, Abbottabad/National University of Medical Sciences (NUMS) Pakistan, ***Department of General Surgery, Combined Military Hospital, Abbottabad/National University of Medical Sciences (NUMS) Pakistan

ABSTRACT

***Objective*:** To determine the pattern of musculoskeletal injuries incurred by physical training in patients and training personnel as assessed by Magnetic Resonance Imaging.

***Study Design*:** Cross-sectional study.

***Place and Duration of Study*:** Combined Military Hospital, Abbottabad Pakistan, from Sep 2021 to Jun 2022.

***Methodology*:** Patients from local institutes with rigorous training schedules for their students referred to the Radiology Department of Combined Military Hospital, Abbottabad for musculoskeletal Magnetic Resonance Imaging were included in the study. Data regarding duration of symptoms, and Magnetic Resonance Imaging I findings, site, nature and grading of injury, laterality, and associated features, were recorded for each patient. The nature of injuries, their grading, frequency, and relationship among different types of injuries were assessed.

***Results*:** Stress fracture of the lower limbs was the most common injury associated with physical training, with 28.6% (n=38/105) presenting mostly in the second half of training. Maximum patients presented with the highest grade of stress fractures; it was more common in females, seen in 90% at the time of presentation (n=9/10). Anterior cruciate ligament injury of the knee was the second most common injury (20%-n=21/105). Most patients with meniscal injuries had anterior cruciate ligament injury.

***Conclusion*:** Stress fractures and knee ligamentous injuries are the most common physical training-related injuries. The majority of female patients had stress fractures at their first presentation. Although less common, meniscal injuries were significantly associated with anterior cruciate ligament injury of the knee.

Keywords: Fracture, Ligamentous injuries, Meniscal, Stress fractures, Physical training-related injuries.

How to Cite This Article: *Zafar SI, Saeed HB, Asif M, Anwer A, Syed HM. Patterns of Musculoskeletal Injuries Secondary to Strenuous Physical Training, Assessed on Magnetic Resonance Imaging. Pak Armed Forces Med J 2024; 74(2): 282-286. DOI: https://doi.org/10.51253/pafmj.v74i2.9431*

This is an Open Access article distributed under the terms of the Creative Commons Attribution License (https://creativecommons.org/licenses/by-nc/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

INTRODUCTION

Musculoskeletal injuries (MSIs) comprise approximately 150 diagnoses related to injuries of ligaments, tendons, muscles, bones and joints. Stress fractures constitute a large proportion of MSIs, however with the help of Magnetic Resonance Imaging (MRI), a multitude of stress-related trauma patterns including ligaments, muscles and tendons have been documented.[1,2] MRI forms the gold standard for detecting musculoskeletal injuries due to its exquisite soft tissue, ligamentous and bone marrow details. Its widespread availability, multiplanar imaging and high contrast resolution make it an effective tool for detecting MSIs.[3] Tendon and bone injuries as a result of stress related to excessive physical exertion, in the absence of direct trauma, are sustained due to continuous overload and cumulative microtrauma.[4] MRI has the advantage of not only detecting the degree, nature and site of trauma; it additionally recognises and assesses the adjacent structures for any associated injury- frequently accompanied in non-traumatic MSIs.[5] Many of these injuries remain occult clinically in the acute phase, hence the importance of MR Imaging for early detection.[6]

Grading of stress fractures has important clinical implications in the management of patients. These are based on MRI findings as follows: marrow oedema without macroscopic fracture visualised only on STIR images- Grade I, if appreciable on both T2W/ STIR - Grade II, while findings are appreciated on T1W images as well- Grade III; Grade IV demonstrates a visible fracture line in addition to marrow oedema.[7,8] Ligamentous injuries are graded according to the extent of damage. ACL tear is labelled as partial if it

Correspondence: Dr Saerah Iffat Zafar, Department of Radiology, Combined Military Hospital, Abbottabad Pakistan

Received: 28 Oct 2022, revision received: 19 Mar 2024; accepted: 02 Apr 2024

shows internal signals or bowing and complete if there is a complete disruption in its continuity.[9]

This study is aimed at identifying the trauma pattern associated with training exercises and its relation to the duration of complaints and their occurrence in the period of training, utilising MRI as a diagnostic tool.

METHODOLOGY

The cross-sectional study conducted at the Radiology Department of Combined Military Hospital, Abbottabad Pakistan, from September 2021 to June 2022, after Institutional Ethical Review Board permission (Certificate number CMHAtd-ETH-44-Rad 22).

Inclusion Criteria: Patients of either gender, aged 18-50 years participating in training activities, whether as trainers or trainees, (rigorous physical activities as a part of their curriculum) were included in the study.

Exclusion Criteria: Patients with a history of accidental trauma (not relevant to physical exercises), imaging for non-musculoskeletal complaints, any co-existing disease, were excluded.

All patients reporting to the Radiology Department of Combined Military Hospital, Abbottabad for MR assessment of musculoskeletal trauma sustained during their physical training were included in the study. All patients underwent non-contrast MRI on GE 1.5 Tesla MR machine with T1 and T2 weighted Fast Spin Echo (FSE), Short Tau Inversion Recovery (STIR) and Proton Density (PD) images in multiplanar sequences of the area involved. Patients' complaints, duration of symptoms, term (period of training during which injury was sustained- divided into four terms over two years), laterality and site, and findings, including nature and grading of injury, were recorded. The frequency of type, site and side of injury and their relation to the duration of complaints were recorded.

Statistical Package for Social Sciences (SPSS) version 25.0 was used for the data analysis. Quantitative variables were expressed as Mean±SD and qualitative variables were expressed as frequency and percentages. Chi-square test was applied to explore the inferential statistics. The *p*-value of ≤0.05 was set as the cut-off value for significance.

RESULTS

This study set out to assess the trauma patterns, including stress fractures, ligamentous and other bone injuries, and knee injuries associated with training exercises, and their relation to the duration of complaints and their occurrence in the period of training. There was a high frequency of positive findings in patients referred for MRI to assess MSIs, at 88.5% (n=93/105). The mean age of the subjects was 22.58±5.17 years (range 17-44 years). Young patients (17-25 years) formed the majority of subjects in this study, forming 83.8% (n=88/105) of the total subjects. Most subjects were males, with only 10(9.5%) females referred for MSK MRI (representing the overall low representation of females in these institutes). Most patients were referred for musculoskeletal MRI in the third term of their training (32.4%-n=34/105).

Stress fractures involving lower limbs were the commonest MSI, forming 28.6% (n=38/105) of total injuries detected on MRI, alone or in combination with other injuries, followed by ligamentous injuries of the knee (20%-n=21/105) (Figure).

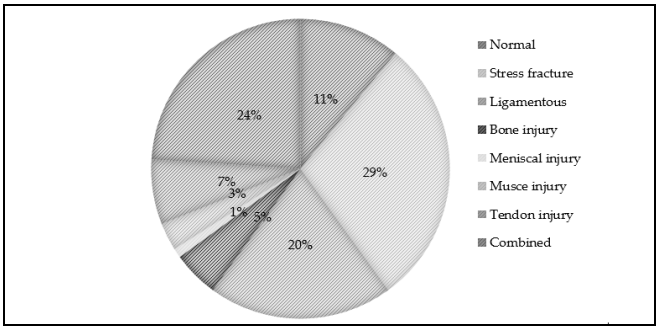

Figure: Frequency of Musculoskeletal Injuries (MSIs) Sustained During Physical Training (n=105)

Other injuries included bone bruise/oedema in association with ligamentous/ soft tissue injuries, ankle ligaments and upper limb trauma (latter seen as a result of direct trauma during training sports such as boxing)-labelled as combined injuries. A significant trend suggested that while Grade I fractures were more common in the 3rd and fourth terms, Grade IV fractures were more commonly observed in the 1st and second terms (p<0.001; Table-I). The duration of symptoms before reporting was between 1-4 months for most of these patients. Stress fractures were highly prevalent among females at the time of presentation (n=9/10; 90%). All of the fractures among females were Grade IV (p=<0.001), while in males, 48.2%(n=14/38) had Grade IV stress fractures (Table-II). Regarding the site of stress fractures, the neck of the femur with or without intertrochanteric region was the commonest (31.5%-n=12/38)- followed by medial tibial condyle and tibial diaphysis (Table-III).

Table-I: Stress Fracture Grades in Different terms of the Professional Physical Courses (n=105)

		1st	2nd	3rd	4th	N/A	Total	*p*-value
Stress	Grade I	0(0%)	1(25%)	10(76.9%)	1(20%)	0(0%)	12(31.6%)	<0.001*
	Grade III	0(0%)	1(25%)	1(7.7%)	1(20%)	0(0%)	3(7.9%)	
	Grade IV	4(100%)	2(50%)	2(15.4%)	3(60%)	12(100%)	23(60.5%)	
	Total	4	4	13	5	12	38	

Table-II: Stress Fracture Grades for Males and Females (n=105)

		Females	Males	Total	*p*-value
Stress Fracture	None	1(10%)	66(69.5%)	67(63.8%)	< 0.001*
	Grade I	0(0%)	12(12.6%)	12(11.4%)	
	Grade III	0(0%)	3(3.1%)	3(2.8%)	
	Grade IV	9(90%)	14(14.7%)	23(21.9%)	
	Total	10	95	105	

No significant association between the duration of symptoms and the grade of stress fracture could be elucidated.

Among ligaments, the Anterior Cruciate Ligament (ACL) of the knee was the commonest ligament to injure at 68.8%(n=31/45), maximally having partial tears (internal signals, without disruption) at 44.4%(n=20/45). Ankle, hip and upper limb joint ligaments were not commonly injured. Meniscal injuries were uncommon (9.5%;n=10/105). However, these were significantly associated with ACL tears; 90% of patients (n=9/10) with meniscal injuries had ACL tears (*p*=<0.001; Table-IV).

Table-III: Frequency of sites of Stress Fractures (n = 38)

Site	n (%)
Neck of femur (NOF)	4(10.5%)
NOF/ intertrochanteric region	8(21%)
Medial tibial condyle	10(26.3%)
Tibial diaphysis	10(26.3%)
Femoral diaphysis	2(5.2%)
Metatarsal	1(2.6%)
Pelvic bones	2(5.2%)
Calcaneum	1(2.6%)
Total	38(100%)

Table-IV: Meniscal Injuries per Different Grades of Anterior Cruciate Ligament (ACL) Injuries (n = 105)

		Meniscal Injury Absent	Meniscal Injury Present	Total	*p*-value
Knee Injury status	Not Assessed	51(53.7%)	0(0%)	51(48.6%)	<0.001*
	Normal	13(13.7%)	1(10%)	14(13.3%)	
	ACL-I	5(5.3%)	1(10%)	6(5.7%)	
	ACL-II	24(25.3%)	5(50%)	20(27.6%)	
	ACL-III	2(2.1%)	3(30%)	5(4.8%)	
	Total	95	10	105	

DISCUSSION

Radiology is vital in the accurate diagnosis of MSIs of any nature. MRI forms the gold standard for musculoskeletal injury detection due to its high contrast resolution, ability to pick up changes in bone marrow, including subtle bruises and oedema, and demonstration of abnormalities in surrounding structures. Hence, ligaments, tendons, menisci, muscles and bone changes are exquisitely outlined, often masked at clinical examination during the acute phase.[11,12] Additionally, MRI has multiplanar ability and no radiation hazard, making it a suitable modality for detecting and following up these injuries. It is also remarkable for detecting radiographically occult stress fractures and for the grading required for management.[13]

The radiology department of CMH Abbottabad – a tertiary care hospital - receives referrals of patients who sustain stress-related injuries secondary to strenuous physical training. These patients demonstrate a multitude of MSIs predominantly involving lower limbs. In concurrence with the international studies, the preponderance of stress fractures as a consequence of physical training was also found in this study.[14] It was followed by ligamentous injuries in the knee, particularly the anterior cruciate ligament. Stress fractures develop when bones are subjected to abnormal forces to which they fail to adapt by remodelling. This leads to the development of microfractures, and if the activity persists, bone eventually fractures.[15] In this study, the neck of the femur and intertrochanteric region were the commonest sites, followed by tibial diaphysis.

In contrast, some international studies report the latter as the commonest site.[16] It occurred more commonly in the second year of physical training,

probably secondary to continuous microtrauma for a prolonged time. In addition, there was a significant ratio of stress-induced fractures in females in our study, which is also a well-known gender-associated predilection in female athletes for this type of injury.[17] Factors behind these are stated to be mainly anatomical differences between males and females.[18] One of the international studies, citing the significant difference in stress fractures between genders, has recommended separate training structures for males and females.[19] In our study, female patients underwent training at a relatively older age than their male counterparts, which may be another contributing factor in this regard.

Ligamentous injuries, alone or in combination with meniscal tears, effusion or bruises, were common in the knee. In this study, the anterior cruciate ligament (ACL) was the most common ligament involved in knee injuries (partial tear is more common than a sprain or full tear). An American study depicted a significantly high rate of ACL injuries in patients undergoing rigorous physical training professionally compared to the general US population.[20] No significant association with meniscal injury was, however, identified in our study. At the same time, international literature has reported medial meniscal injury as a frequent accompanying injury.[21] Conversely, in almost all meniscal injuries, ACL tear was a significant association in this study. Contrary to international data where lateral meniscus was more commonly associated with ACL tears,[22] this study showed no significant preponderance of either side with regards to meniscal injury (lateral: 50%-n=5/10; medial (40%-n=4/10). Ligaments, tendons, and bone injuries to the ankle and hip joint were seen less commonly. Upper limb injuries were only seen in relation to stress-induced trauma, mainly seen in the context of sports injuries.

LIMITATIONS OF STUDY

This study has the limitation that the evaluation of MSIs was based on a small proportion of patients, in particular of the female patients (owing to the disparity in the number of males and females in these institutes); larger sample size and follow-up is required to accurately assess the pattern trend of MSIs in patients with trauma owing to rigorous physical activities.

CONCLUSION

Stress fractures of lower limbs and anterior cruciate ligament of the knee were the most common injuries found in patients undergoing physical exercises as part of their professional training. Females were particularly prone to stress fractures and presented with the highest severity at first presentation. Meniscal injury, although less common, was significantly associated with ACL tears.

Conflict of Interest: None.

Authors Contribution

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

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

MA & AA: Data acquisition, critical review, approval of the final version to be published.

HMS: Data acquisition, data analysis, data interpretation, critical review, 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.

REFERENCES

1. Jones BH, Hauschild VD, Canham-Chervak M. Musculoskeletal training injury prevention in the U.S. Army: Evolution of the science and the public health approach. J Sci Med Sport 2018: 21(11); 1139-1146. https://doi.org/10.1016/j.jsmas.2018.02.011.
2. Iris D, Jagannath S, Tim JG. Training Load Monitoring and Injury Prevention in Military Recruits: Considerations for Preparing Soldiers to Fight Sustainably. Stren Condit J 2021; 43 (2): 23-30. https://doi.org/10.1519/SSC.0000000000000632
3. Dijksma I, Arslan IG, van Etten-Jamaludin FS, Elbers RG, Lucas C, Stuiver MM. Exercise Programs to Reduce the Risk of Musculoskeletal Injuries in Military Personnel: A Systematic Review and Meta-Analysis. PM R 2020; 12(10): 1028-1037. https://doi.org/10.1002/pmrj.12360.
4. Mujahid M, Younus S, Ali Y, Khattak NA. Occurrence of Musculoskeletal Injuries and Associated Risk Factors in Army Recruits During Military Training. Pak J Rehab 2022; 11(1): 37-46.
5. Ahn JM, El-Khoury GY. Role of magnetic resonance imaging in musculoskeletal trauma. Top Magn Reson Imaging 2007; 18(3): 155-168. https://doi.org/10.1097/RMR.0b013e318093e670.
6. Hoenig T, Tenforde AS, Strahl A, Rolvien T, Hollander K. Does Magnetic Resonance Imaging Grading Correlate With Return to Sports After Bone Stress Injuries? A Systematic Review and Meta-analysis. Am J Sports Med 2022; 50(3): 834-844. https://doi.org/10.1177/0363546521993807.
7. Farshad-Amacker NA, Potter HG. MRI of knee ligament injury and reconstruction. J Magn Reson Imaging 2013; 38(4): 757-773. https://doi.org/10.1002/jmri.24311.
8. Molloy JM, Pendergrass TL, Lee IE, Hauret KG, Chervak MC, Rhon DI. Musculoskeletal Injuries and United States Army Readiness. Part II: Management Challenges and Risk Mitigation Initiatives. Mil Med 2020; 185(9-10): e1472-e1480. https://doi.org/10.1093/milmed/usaa028.
9. Khan K, Khan AA, Ahmad S, Jeilani A, Khan ZR. Bone stress injuries in the Army cadets of Pakistan Military Academy. J Ayub Med Coll Abbottabad, 2008; 20(4): 55-58.
10. Verma R, Singh JP. Magnetic resonance imaging in stress fractures: Making a correct diagnosis. Indian J Musculoskel Radiol 2020; 4 (1): 49-60. https://doi.org/10.25259/IJMSR_18_2020.

11. Richards JT, Dickens JF. Multiligamentous Knee Injuries in the Military Tactical Athlete. Sports Med Arthrosc Rev 2019; 27(3): 92-98. https://doi.org/10.1097/JSA.0000000000000253.
12. Haley, CA, Posner MA. Knee Injuries in the Military. Knee Surg 2019; 32(02): 117. https://doi.org/10.1055/s-0038-167701.
13. Bussières AE, Peterson C, Taylor JAM. Diagnostic imaging guideline for musculoskeletal complaints in adults—an evidence-based approach: Part 2: Upper extremity disorders. J Manipulat Physiol Therap 2008; 31(1): 2–32. https://doi.org/10.1016/j.jmpt.2007.11.002.
14. Takkar P, Prabhakar R. Stress fractures in military recruits: A prospective study for evaluation of incidence, patterns of injury and invalidments out of service. Med J Armed Forces India 2019; 75(3): 330-334. https://doi.org/10.1016/j.mjafi.2018.09.006.
15. May T, Marappa-Ganeshan R. Stress Fractures. In: StatPearls. Treasure Island (FL): StatPearls Publishing; 2022.
16. Tins BJ, Garton M, Cassar-Pullicino VN, Tyrrell PN, Lalam R, Singh J. Stress fracture of the pelvis and lower limbs including atypical femoral fractures-a review. Insights Imaging 2015; 6(1): 97-110. https://doi.org/10.1007/s13244-014-0371-z.
17. Wentz L, Liu PY, Haymes E, Ilich JZ. Females have a greater incidence of stress fractures than males in both military and athletic populations: a systemic review. Mil Med 2011; 176(4): 420-430. https://doi.org/10.7205/milmed-d-10-00322.
18. Moreira CA, Bilezikian JP. Stress Fractures: Concepts and Therapeutics. J Clin Endocrinol Metab 2017; 102(2): 525-534. https://doi.org/10.1210/jc.2016-2720.
19. Gam A, Goldstein L, Karmon Y, Mintser I, Grotto I, Guri A, et al. Comparison of stress fractures of male and female recruits during basic training in the Israeli anti-aircraft forces. Mil Med 2005; 170(8): 710-712. https://doi.org/10.7205/milmed.170.8.710.
20. Aguero AD, Irrgang JJ, MacGregor AJ, Rothenberger SD, Hart JM, Fraser JJ. Sex, military occupation and rank are associated with risk of anterior cruciate ligament injury in tactical-athletes. BMJ Mil Health 2023; 169(6): 535-541. https://doi.org/10.1136/bmjmilitary-2021-002059.
21. Ahn J, Choi B, Lee YS, Lee KW, Lee JW, Lee BK. The mechanism and cause of anterior cruciate ligament tear in the Korean military environment. Knee Surg Relat Res 2019; 31(1): 13. https://doi.org/10.1186/s43019-019-0015-1.
22. Naraghi AM, White LM. Imaging of Athletic Injuries of Knee Ligaments and Menisci: Sports Imaging Series. Radiology 2016; 281(1): 23-40. https://doi.org/10.1148/radiol.2016152320.