Accepted, Journal of Clinical Densitometry. Feb 2021

Vertebral anomalies in retired rugby players and the impact on bone density calculation of the lumbar spine

Ian Entwistle[1*], Patria Hume[2], Peter Francis[3], Karen Hind[1].

[1] Department of Sport and Exercise Sciences, Durham University, United Kingdom. [2] Sports Performance Research Institute New Zealand (SPRINZ), Faculty of Health and Environmental Science, Auckland University of Technology, Auckland, New Zealand. [3] Department of Science and Health, Institute of Technology Carlow, Republic of Ireland. *Corresponding author: Mr Ian Entwistle, Department of Sport and Exercise Sciences, Durham University, 42 Old Elvet, Durham, DH1 3HN, United Kingdom. Email: ian.entwistle@durham.ac.uk

Abstract

Introduction: Dual energy X-ray absorptiometry (DXA) lumbar spine bone mineral density (BMD) measurements are subject to artificial elevation in the presence of structural abnormalities that are more common with age and injury, including osteoarthritis, fracture and osteophytes. The aims of this study were to investigate the presence of vertebral abnormalities on DXA scans in retired rugby players and a non-rugby control group, and to explore the effect of vertebral exclusion on BMD diagnostic outcome.

Methods: 87 male retired rugby players and 51 non-rugby controls from the UK Rugby Health Project participated in the study. Lumbar spine, total hip and femoral neck BMD were measured by DXA and scans were analysed pre and post exclusion of anomalous vertebrae. Data were analysed by age group to enable application of T-scores (≥50 y) and Z-scores (<50 y).

Results: From 138 lumbar spine scans, 66 required adjustment. 122 vertebral exclusions were made, and 12 lumbar spine scans (10 in retired rugby athletes) were un-reportable (<2 evaluable vertebrae). Vertebral exclusion significantly lowered lumbar spine BMD across all groups (p<0.01) and lowered the overall lowest T/Z-score. This effect was more pronounced in rugby groups (age <50 y, p<0.001; age ≥50 y, p=0.031) than in the control groups (age <50y, p=0.125; age ≥50 y, p=0.250).

Conclusion: Vertebral abnormalities detected on lumbar spine scans, were highly prevalent and impacted final T/Z-score in this cohort of retired rugby players. Current guidelines recommend exclusion of abnormalities from lumbar spine scans in adults aged ≥50 years. Our findings suggest that vertebral exclusions should also be applied to lumbar spine scans performed in those aged <50 years, particularly in former contact sports athletes, given their high risk for vertebral deformity.

Key words: DXA, Bone density, Sport, Athlete; Spine; Vertebral exclusions

Introduction

Dual energy X-ray absorptiometry (DXA) is the current gold standard for bone mineral density (BMD) assessment in the diagnosis of osteoporosis, given that BMD is a strong predictor of fracture risk (1,2). Population-based data indicates that for every standard deviation reduction in BMD, there is a 1.5 to 3-fold higher risk of fracture (1,3). Along with scans of the total hip or femoral neck, the lumbar spine is also routinely assessed, as recommended by the International Society for Clinical Densitometry (ISCD) and the World Health Organisation (4–6). For both lumbar spine and hip scans, BMD is compared to either the young adult mean or age and sex-matched reference data. In post-menopausal women and men at or over the age of 50 years (≥50 y), a T-score is calculated by comparing the BMD to the young adult mean (4). In premenopausal women and men under the age of 50 years (<50 y), a Z-score is calculated according to age and sex-matched reference data, and adjusted for weight and ethnicity (4).

A high level of scrutiny is required during the scan acquisition and subsequent interpretation of lumbar spine scans to obtain an accurate BMD. This is because lumbar spine BMD can be subject to artificial elevation in the presence of various disease states, most notably osteoarthritis and other degenerative conditions (7). The presence of structural abnormalities such as fracture, osteoarthritis, osteophytes and sclerosis, contribute to the assessed bone density, and result in spurious increase (8). Osteophytes cannot be measured independently of the vertebral body and so elevate the recorded bone density (9). Therefore, it is important that DXA technicians identify and exclude such anomalies from the scan images. It is recommended that adjacent vertebrae with a T-score difference of >1 SD, should be excluded from the lumbar spine bone density measurement. The visible presence of a structural abnormality would also provide a justification for exclusion of a vertebrae (4). There are currently no recommendations for men aged under 50 years, specifically for the use of the Z-score for removal of vertebrae from the clinical evaluation, and this is likely because degenerative changes and artefacts at the spine are more common with age (8).

Approximately one third of the UK population over 45 years seek treatment for osteoarthritis (10) and contact sports populations appear to be at particularly high risk. Across multiple injury types, past participation in rugby union and rugby league, particularly at elite level, has been associated with a high cumulative musculoskeletal injury load and a continued impact of previous injuries post-retirement including osteoarthritis (11). The high prevalence of degenerative disease such as osteoarthritis, in retired rugby players (12) appears to occur with premature onset (13). Furthermore, a study of professional rugby players reported a high number of mild to severe vertebral deformities by DXA vertebral fracture assessment (14). Athletes from contact sports including rugby, are reported to have higher lumbar spine bone density compared to athletes from other sports and to non-athlete populations (15,16). However, in these studies, it was not clear if vertebral exclusions were made for vertebral bodies with signs of degeneration or fracture.

The aims of this study were first, to investigate the presence of vertebral anomalies on lumbar spine bone density DXA scans in retired rugby players compared to an age-matched control group, and second, to determine the effect of vertebral deformity exclusion on the bone density outcome.

Methods

This research was performed as a cross sectional analysis of 138 male participants from the UK Rugby Health Project and was approved by the University Research Ethics Committee. The study design and recruitment protocol have been described previously (11). All participants provided signed informed consent prior to taking part.

Participants

Participants were from the United Kingdom, and were either retired rugby players, retired non-contact athletes or non-athletes. All participants in this study were male and aged between 24 and 78 years and retired from competitive sport. Rugby participants (n=87) were drawn from amateur and professional rugby union and rugby league codes. Participants in the non-rugby group (n=51) may have played sport at any competitive level and consisted of retired non-contact athletes (n=30, predominantly cricketers (n=24)) or those that had never taken part in organised sport (n=21). Participants were grouped by age to enable the application of T-scores (≥50 y) or Z-scores (<50 y).

Procedures

Participants received DXA scans (Lunar iDXA^{TM}; GE Healthcare, WI; Encore software v 15.0) of the posterior-anterior lumbar spine (L1-L4) and dual femur (total hip and femoral neck) on one occasion. Participants were advised to abstain from intensive exercise, alcohol and caffeine in the 12 hours prior to scanning. For the lumbar spine scans, the legs were elevated with flexion at the hip and of the knees at 90°, and with the lower legs resting on the iDXA positioning foam block (GE Healthcare, Madison, WI). This positioning enabled a widening of the intervertebral space so that individual vertebrae in the lumbar region were clearly visualised. Positioning for the dual femur BMD scan was assisted using the GE-dual femur positioning device which allowed both legs to be abducted and inwardly rotated 15-25°. Quality assurance using the calibration block was made during the study period, and no drifts were observed. In-vivo precision (CV) for the DXA measurements in adults are 0.4% for lumbar spine BMD, 0.6% for total hip and 1.4% for femoral neck BMD (17).

The scans were performed by an experienced radiographer and an ISCD certified clinical densitometrist. T and Z-scores were evaluated both pre and post exclusion of vertebral anomalies (UK reference population). The presence of vertebral anomalies was determined in consensus between the two experienced densitometrists. T-score (4) or Z-score discrepancies that were greater than 1 SD indicated vertebral exclusion. Vertebrae were also excluded from the evaluation if there was visible evidence of anatomical anomalies based on criteria reported by the ISCD (4). Following removal, scans resulting in less than two evaluable vertebrae were deemed unreportable and were not assigned a T/Z-score. Each participant was assigned a 'hip T/Z-score', which was the lowest score from the femoral neck or total hip and a 'lowest T/Z-score', that is the lowest score of the lumbar spine or hip (4).

Statistical analysis

Statistical analysis was performed using IBM SPSS® Statistics, Version 24. Data were assessed for normality visually and using the Kolmogorov-Smirnov test. The number of excluded vertebrae were compared using Mann Whitney U-test. The number of unreportable spines and instances of the lowest T/Z-score arising from the spine were also recorded and compared (Fishers Exact Test). The Related-Samples Sign test was used to compare the paired T/Z-scores from the spine and the lowest T/Z-score. The significance of the difference in the proportions of lowest T/Z-scores being generated by the spine (pre and post exclusion of vertebrae) was assessed with the McNemar's test. The significance of the difference in proportions of participants with ≥ 1 vertebral body excluded from BMD assessment was calculated using Fishers Exact Test. Significance was identified at <0.05.

Results

The study group descriptive results are presented in Table 1. In total, 122 vertebral exclusions were made, 79 in retired rugby players and 43 in the non-rugby group. Following exclusion of vertebrae, 12 scans were un-reportable (eight from the rugby ≥50 y group versus two from the non-rugby control ≥50 y group [p = 0.159] and two from the rugby <50 y group).

Table 2 displays the mean and standard deviation for the Lumbar spine T/Z-score (with and without vertebrae excluded) and the lowest T/Z-score from the lumbar spine or hip. The removal of anomalous vertebrae from the evaluation of the lumbar spine scans significantly reduced the lumbar spine T/Z-score across all four groups. There was a non-statistically significant increase in the incidence of lowest T-score arising from the spine (as opposed to the hip) following exclusion of anomalous vertebrae in each group, other than controls <50 years. The prevalence of the lowest T/Z-score arising from the spine significantly increased when vertebrae with anomalies were removed (47 versus 57, p=0.002). The exclusion of anomalous vertebrae identified an additional two cases of low bone density (T-score <1.0 or Z-score < -2.0).

Discussion

The aim of this study was to determine the prevalence of vertebral anomalies in retired rugby players and to investigate the effect of exclusion of these vertebrae on the lumbar spine T/Z-score and the resultant bone density outcome. In doing so, we found a high prevalence of vertebral anomalies across all study groups regardless of age, and the exclusion of these vertebrae, impacted on the resultant T/Z-score in 62 cases. The highest proportion of anomalies were found in the rugby group over ≥50 y, this group also had the largest number of unreportable lumbar spine scans of any group.

A main finding was that anomalous vertebrae were not limited to those in the over 50 years category. Previous studies demonstrating increased BMD with degenerative change in the spine have largely been limited to older populations (7,9,18,19). Our findings of reduced lumbar spine T-scores following exclusion of anomalies in those over 50 years, together with most (10 out of 12) unreportable spines found in those over 50 years, would be consistent with previous reports that the spine is more susceptible to elevated BMD due to osteoarthritis (19). The impact of this on the overall lowest T/Z-score was significant in the rugby groups of both age categories but not in the control groups. The exclusion of vertebrae with anomalies had the most significant effect on lumbar spine scan Z-score results in the <50 y retired rugby player group. A possible explanation could be the presence of early degenerative changes, which supports reports elsewhere of spine osteoarthritis in male rugby players, also aged under 50 years (13). The risk of osteoarthritis is increased with a previous history of injury (11,20). Rugby players are exposed to a high risk of spinal injury, with a high incidence of cervical and lumbar spine injuries demonstrated in match play and training (21).

The total number of lumbar spine scans producing the lowest T/Z-score was significantly increased following exclusion. However, there were no differences in the proportion of unreportable lumbar spine scans and the scan site producing the lowest T/Z-score between the rugby and control groups of both age categories. Furthermore, there were no differences in the number of vertebrae excluded between rugby and controls groups. The lumbar spine producing the lowest T/Z-score in significantly more cases when vertebrae had been excluded is possibly reflective of the spine BMD being subject to spurious increase from degenerative change particularly more so than the hip (19).

There are several considerations to make when interpreting the results of this study. First, our study focused on vertebral anomalies in former rugby players and therefore further studies would be valuable to explore the prevalence of deformities in other populations. None-the-less, we also found vertebral anomalies in both the <50 y and ≥50 y control groups. It should also be considered that the evaluation and removal of vertebrae in DXA analysis can vary according to technician. In this study, the technician performing the scans was a registered radiographer and vertebral exclusions were verified by two densitometrists, including a certified clinical densitometrist.

In conclusion and based on our findings, vertebral exclusions should be considered for lumbar spine BMD scans performed in individuals under age 50 years, where there is evidence of vertebral anomalies. Currently, recommendations are restricted to over 50 years only and through the use of T-scores (4). Considering the possibility of bone and joint degenerative changes at an earlier age in contact sports such as rugby, DXA scans in these athletes regardless of age, should be performed with careful evaluation to support the exclusion of vertebral anomalies where required, in order to avoid a falsely elevated BMD. Further research would be necessary to focus on athletes under 50 years from other sports to study the number of vertebral anomalies and potentially elevated BMD.

Acknowledgements

The authors would like to thank all UK Rugby Health project participants for their enthusiasm and support of the study, and for their valued time.

Funding has been received from Auckland University of Technology and from the Wolfson Research Institute for Health and Wellbeing, Durham University.

References

1. Kanis JA. 2002 Diagnosis of osteoporosis and assessment of fracture risk. Lancet. 359(9321):1929–36.
2. Lewiecki EM, Binkley N, Morgan SL, Shuhart CR, Camargos BM, Carey JJ, et al 2016 Best Practices for Dual-Energy X-ray Absorptiometry Measurement and Reporting: International Society for Clinical Densitometry Guidance. J Clin Densitom. 19(2):127–40.
3. Marshall D, Johnell O, Wedel H. 1996 Meta-analysis of how well measures of bone mineral density predict occurrence of osteoporotic fractures. BMJ.312(7041):1254–9.
4. ISCD. International Society for Clinical Densitometry Official Positions 2015 ISCD Combined Adult and Pediatric. ISCD Position Paper. 2015. p. 1-21.
5. Blake G, Adams JE, Bishop N. 2013 DXA in Adults and Children. In: Rosen CJ, editor. Primer on the Metabolic Bone Diseases and Disororders of Mineral Metabolism. 8th ed. Ames: John Wiley & Sons; p. 251–63.
6. World Health Organisation. 2007 WHO Scientific Group on the Assessment of Osteoporosis At Primary Health Care Level Summary Meeting Report. Available from: https://www.who.int/chp/topics/Osteoporosis.pdf
7. Yu W, Glüer CC, Fuerst T, Grampp S, Li J, Lu Y, et al. 1995 Influence of degenerative joint disease on spinal bone mineral measurements in postmenopausal women. Calcif Tissue Int. 57(3):169–74.

8. Adams JE. 2013 Advances in bone imaging for osteoporosis. Nat Rev Endocrinol. 9(1):28–42.
9. Pye SR, Reid DM, Adams JE, Silman AJ, O'Neill TW. 2006 Radiographic features of lumbar disc degeneration and bone mineral density in men and women. Ann Rheum Dis. 65(2):234–8.
10. Arthritis Research UK. 2013 Osteoarthritis in general practice data and perspectives. Arthritis Research UK [accessed 3 Feb 2016] Available from: http://www.arthritisresearchuk.org/arthritis-information/data-and-statistics.aspx
11. Hind K, Konerth N, Entwistle I, Theadom A, Lewis G, King D, et al. 2020 Cumulative Sport - Related Injuries and Longer Term Impact in Retired Male Elite - and Amateur - Level Rugby Code Athletes and Non - contact Athletes : A Retrospective Study. Sport Med. (0123456789).
12. Davies MAM, Judge AD, Delmestri A, Kemp SPT, Stokes KA, Arden NK, et al. 2017 Health amongst former rugby union players: A cross-sectional study of morbidity and health-related quality of life. Sci Rep. 7(1):11786.
13. Scher AT. 1990 Premature onset of degenerative disease of the cervical spine in rugby players. South African Med J. 77(6):557–8.
14. Hind K, Birrell F, Beck B. 2014 Prevalent morphometric vertebral fractures in professional male rugby players. Heymann D, editor. PLoS One. 9(5):e97427.
15. Elloumi M, Ounis O Ben, Courteix D, Makni E, Sellami S, Tabka Z, et al. 2009 Long-term rugby practice enhances bone mass and metabolism in relation with physical fitness and playing position. J Bone Miner Metab. 27(6):713–20.
16. Hind K, Gannon L, Brightmore A, Beck B. 2015 Insights into relationships between body mass, composition and bone: Findings in elite Rugby players. J Clin Densitom. 18(2):172–8.
17. Hind K, Oldroyd B, Truscott JG. 2010 In vivo precision of the GE Lunar iDXA densitometer for the measurement of total-Body, lumbar spine, and femoral bone mineral density in adults. J Clin Densitom. 13(4):413–7.
18. Jones G, Nguyen T, Sambrook PN, Kelly PJ, Eisman JA. 1995 A longitudinal study of the effect of spinal degenerative disease on bone density in the elderly. J Rheumatol. 22(5):932–6.
19. Liu G, Peacock M, Eilam O, Dorulla G, Braunstein E, Johnston CC. 1997 Effect of

osteoarthritis in the lumbar spine and hip on bone mineral density and diagnosis of osteoporosis in elderly men and women. Osteoporos Int. 7(6):564–9.

20. Wilder F V., Hall BJ, Barrett JP, Lemrow NB. 2002 History of acute knee injury and osteoarthritis of the knee: A prospective epidemiological assessment. The clearwater osteoarthritis study. Osteoarthr Cartil. 10(8):611–6.

21. Fuller CW, Brooks JHM, Kemp SPT. 2007 Spinal injuries in professional Rugby union: A prospective cohort study. Clin J Sport Med. 17(1):10–6.

Table 1: Study group characteristics

		N	Age (y)	Height (cm)	Weight (kg)	BMI (kg/m^2)	Hip T/Z-score
≥50 y	Rugby	31	57.4 ± 7.0	175.7 ± 7.4	94.5 ± 16.5	30.5 ± 4.6	-0.4 ± 1.3
	Non-Rugby	25	62.4 ± 6.6	174.4 ± 5.4	89.4 ± 16.9	29.3 ± 4.7	-0.7 ± 1.0
	p		0.006	0.471	0.264	0.347	-
<50 y	Rugby	56	39.9 ± 6.1	182.9 ± 6.9	102.7 ± 13.5	30.7 ± 4.0	0.4 ± 1.1
	Non-Rugby	26	37.4 ± 7.3	179.6 ± 5.9	84.2 ± 11.6	26.1 ± 3.1	-0.1 ± 1.0
	p		0.136	0.034	<0.001	<0.001	-

Table 2: Bone mineral density pre and post vertebral anomaly exclusion

		N	Lumbar spine T/Z-score			Overall Lowest T/Z score			Mean number of excluded vertebrae per person	Number of participants with ≥ 1 vertebrae excluded (%)
			Pre exclusion	Post exclusion	*p*	Pre exclusion	Post exclusion	*p*		
≥50 y	Rugby	31	0.7 ± 1.5	0.1 ± 1.3	0.006	-0.5 ± 1.2	-0.6 ± 1.1	0.031	1.5 ± 1.3	20 (65)
	Non-Rugby	25	0.5 ± 1.6	0.1 ± 1.5	<0.001	-0.8 ± 1.0	-0.9 ± 1.1	0.250	1.1 ± 1.2	14 (56)
	p								0.247	0.588
<50 y	Rugby	56	0.5 ± 1.4	0.3 ± 1.3	<0.001	0.0 ± 1.1	0.0 ± 1.1	<0.001	0.6 ± 0.9	22 (39)
	Non-Rugby	26	0.2 ± 1.3	-0.1 ± 1.0	0.004	-0.4 ± 1.0	-0.4 ± 0.9	0.125	0.6 ± 0.9	10 (39)
	p								0.873	1.000