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Exploring the utility of routine hip DXA scan to assess Kellgren Lawrence hip OA grading and identify risk factors of progression to total hip replacement in the Busselton healthy ageing study

Abstract

Introduction/Objective: Osteoporosis and hip osteoarthritis (HipOA)/hip replacement often coexist. Hip bone density (DXA) provides an opportunity to screen for HipOA. This study aims to identify factors associated with progression to total hip replacement (THR) in the Busselton Healthy Ageing Study.

Methods: Over a median follow-up of 7.9 years, 145 participants had THR. These were matched with 445 controls (no THR). Kellgren-Lawrence (KL) HipOA grading was performed on DXA images of both hips. Associations were assessed using conditional logistic regression analysis (stratified by matched case–control groups) adjusting for age, sex and BMI.

Results: The study included 590 participants (59.2% male; mean age 59.9±5.2, range 47.1-68.9 years). Those with THR had significantly higher baseline femoral neck BMD(FNBMD) (lowest values of either hip: 1.005 vs 0.941 g/cm^2, p<0.001), higher baseline OA grades (Highest Grade: 1.63 vs 0.93, p<0.001; bilateral composite Combined Grade: 2.79 vs 1.54, p<0.001). Regression analysis showed highest KL Grade (either hip) increased odds of THR by 2.26/1-unit increase (95% CI 1.80–2.84), FNBMD and lowest hip BMD increased THR odds by 2.14/1-SD (95% CI 1.65–2.76) and 2.02/1-SD (95% CI 1.56–2.62), respectively. A combined model of highest KL Grade (OR 2.21/1-unit (95% CI 1.74–2.80) and lowest FNBMD (OR 2.08/1-SD (95% CI 1.58–2.73) had lowest AIC (850.71).

Conclusions: KL grade and BMD, assessed via a single DXA scan, are significant risk factors for future hip replacement in middle-aged adults. Predictive models using both scores could help identify high-risk patients for targeted interventions. Future research should focus on developing and validating these models.

Key words: dual-energy x-ray absorptiometry; hip osteoarthritis; bone mineral density; Kellgren-Lawrence grading Hip OA Grading; Total Hip Replacement.

Volume 11 Issue 2 - 2026

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Received: May 14, 2026 | **Published:** June 09, 2026

Introduction

Arthritis and osteoporosis are among the world's leading causes of pain and disability. These highly prevalent conditions are major reasons for the use of health and allied health services, community assistance programs, and formal and informal care. Under the Australian National Health Priority Area of arthritis and musculoskeletal conditions, national action is focused on osteoarthritis (OA), rheumatoid arthritis, juvenile arthritis and osteoporosis. Both osteoporosis and osteoarthritis are common diseases in older people and impact on quality of life associated with ageing. These conditions are imminently preventable and or treatable. There is a strong association between osteoarthritis and osteoporosis and osteoporosis and the rate of total hip replacement (THR).[1–4]

We rarely perform hip X-rays to screen for onset of OA of the hip due to cost and radiation risk. OA can have significant impact on a person's life, due to ongoing pain, physical limitations and depression [5]. In Australia, OA accounted for 19% of the total burden of disease due to musculoskeletal conditions in 2015 (Australian Institute of Health and Welfare (AIHW)). OA is the most common form of arthritis and the most common condition leading to knee and hip replacement surgery. Hip replacements, which is expensive and invasive, also increase with age and is used to treat both arthritis and osteoporosis associated hip fracture.[2–4]

Dual energy x-ray absorptiometry (DXA) is regularly performed as part of routine screening for osteoporosis, measuring bone mineral density (BMD) at the hip, the lumbar spine and the forearm. The DXA images focussed on the hip have been demonstrated as reliable in assessing the presence and severity of OA of the hip using much lower radiation than traditional X-rays.[6,7] Thus, routine DXA hip scan provide an opportunity to assess OA, and to identify individuals at high risk for hip replacement to enable early intervention. There are multiple tools for OA grading on hip X ray including the widely used, reliable and validated Kellgren-Lawrenc[8] criteria to grade the presence of hip OA (Grade 0; normal to Grade 4; severe).

Specific aims

The Busselton Healthy Ageing study (BHAS) is a landmark longitudinal study designed to comprehensively capture prevalent and incident morbidity in an unbiased survey of a general population sample of 'baby boomers' (born 1946 to 1964).[9] We assessed 590 BHAS participants aged 47-69 years at baseline, using a case-control design with 145 cases of incident hip replacement and 445 age,

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gender and BMI category matched controls who did not require hip replacement. We studied:

1. The presence and grade of hip OA by assessing DXA hip images using the Kellgren Lawrence criteria.

2. If hip OA grading and hip BMD at baseline predicts hip replacement over a median follow-up of 7.9 years.

3. To determine if there is a correlation between hip OA grading and total hip and/or femoral neck BMD values.

Study design

Case-control study of incident hip replacement cases with age, gender and BMI category matched controls. Study population were from participants of BHAS who are resident in the City of Busselton local government electoral boundary, in south-western Western Australia.[9] All non-institutionalised residents born between 1946 and 1964 at baseline survey who are listed on the electoral roll were invited to participate (electoral registration is compulsory in Australia), and the study population is predominantly Caucasian.

During the first phase of the study (baseline survey) between May 2010 and December 2015, 5107 participants (~80% of those eligible) were recruited. Of these, 5050 had hip DXA scan (4946 had both hips scanned). Using linked hospital morbidity data, 145 cases of incident hip replacement were identified up to end of December 2020. This case-control study includes these 145 cases and 445 age, gender and BMI category matched controls. All included participants had baseline DXA images of both hips available. The study was approved by the University of Western Australia Human Research Ethics Committee (Number RA/4/1/2203).

Methods

DXA imaging for both left and right hip was obtained using a GE Lunar Prodigy Pro densitometer (GE Health, Madison, WI, USA). To achieve optimal positioning, left and right hips were scanned as two separate scans rather than using the "dual hip function". Scans were analysed using enCORE Version 16 software with manual inspection of regions of interest and adjustment where necessary by two independent reviewers (KZ and MH). Values for femoral neck and total hip BMD (in g/cm^2) are reported for both hips. Calibration of the DXA scanner using a phantom was performed prior to each scanning session according to manufacturer's recommendations. Precision error was less than 2.0% for all measured sites based on repeated scans in a random sample of 30 subjects.

Hip osteoarthritis was classified by the Kellgren-Lawrence (KL) criteria using the DXA images, which assess joint degeneration on a scale from 0 to 4, with higher grades indicating more severe osteoarthritis [8]. Both left and right hips were graded independently by 2 out of 3 reviewers (GM, AC, NH) who were trained on KL grade scoring using an image atlas with and description of criteria for KL grading. A single blinded expert reviewer (CI) scored each patient independently to ensure consistent evaluation by junior readers and to resolve any discrepancy. The readers were blinded to if the participants subsequently had hip replacement surgery after the baseline survey.

Incident THR (not side specific) during the follow-up period was identified using linked data from the Hospital Morbidity Data Collection via the Western Australian Data Linkage System. The following diagnosis codes were used: ICD (International Classification of Diseases, 10th Revision (ICD10) 49,318–00, 49,319–00, and Z96.64.

Other assessments at baseline include anthropometry: body weight and height; BMI was calculated as weight (kg)/height (m)^2.

Statistical analysis

Descriptive statistics were calculated to summarize the characteristics of the study population. Pearson correlation coefficients were used to examine the relationships between KL grades, BMD values, and hip replacement status. We initially performed unconditional multivariate logistic regression models to assess the predictive value of KL grading and BMD for THR, adjusting for potential confounding factors such as age, gender, and BMI. Subsequently, to more appropriately account for the matched case–control design, we used conditional logistic regression with the matched sets (Propensity Case Match) as the stratification variable. Separate conditional logistic regression models were built for the following exposures: Highest KL Grade (of either side), standardized Lowest Femoral Neck BMD (of either side), standardized Lowest Total Hip BMD (of either side), and a combined model including both Highest KL Grade and standardized Lowest Femoral Neck BMD. Model performance was assessed by comparing Akaike Information Criterion (AIC) values.

Statistical significance was defined as a p-value of less than 0.05. All analyses were conducted in R (version 4.4.2, http://www.r-project.org) and verified using SPSS Statistics.

Results

Participant characteristics:

The study included 590 participants (Table 1), with a gender distribution of 59.2% males and 40.9% females, and a mean age of 59.9 years (SD ± 5.2), ranging from 47.1 to 68.9 years. The body mass index (BMI) distribution indicated that a significant portion of participants were classified as overweight or obese, with a mean BMI of 28.0 kg/m^2. Males exhibited higher mean OA grades across all measures, with a composite KL score of 1.99 compared to 1.65 in females. Baseline Kellgren-Lawrence Grade distribution for left and right hips in the study cohort is presented in Table 2.

Table 1 Participant characteristics - demographics, KL grades and BMD by hip replacement status and gender

		Total Population			Male			Female		
		Total	No THR	THR	Total	No THR	THR	Total	No THR	THR
	Count	590	445	145	349	262	87	241	183	58
Age (years)	mean (std)	59.9	59.9 (5.2)	60 (5.1)	59.5	59.5 (5.5)	59.7 (5.4)	60.6	60.6 (4.6)	60.4 (4.8)
Height (cm)	mean (std)	169.9	169.8 (8.9)	170.1 (9.1)	175.4	175.4 (6.4)	175.3 (6.4)	161.9	161.8 (4.9)	162.2 (6.5)
Weight (kg)	mean (std)	81.2	79.9 (14.4)	85.3 (15.1)	87.4	86.5 (12)	90.3 (13.8)	72.3	70.5 (12)	78 (14.1)
BMI (kg/m^2)	mean (std)	28	27.6 (4)	29.4 (4.3)	28.4	28.1 (3.5)	29.3 (3.6)	27.6	27 (4.5)	29.5 (5.1)
Left KL Grade	mean (std)	0.8	0.7 (0.9)	1.3 (1.2)	0.9	0.7 (0.9)	1.5 (1.2)	0.8	0.7 (0.9)	1.1 (1.2)

Citation: Inderjeeth C, Inderjeeth D, Hui J, et al. Exploring the utility of routine hip DXA scan to assess Kellgren Lawrence hip OA grading and identify risk factors of progression to total hip replacement in the Busselton healthy ageing study. *MOJ Gerontol Ger.* 2026;11(2):33–37. DOI: 10.15406/mojgg.2026.11.00356

Table 1 Continued....

Right KL Grade	mean (std)	1	0.8 (0.9)	1.5 (1.3)	1.1	0.9 (0.9)	1.6 (1.2)	0.9	0.8 (0.9)	1.2 (1.3)
Left Neck BMD (g/cm^2)	mean (std)	0.98	0.96 (0.13)	1.04 (0.15)	1.01	0.99 (0.13)	1.08 (0.14)	0.93	0.92 (0.13)	0.97 (0.16)
Right Neck BMD (g/cm^2)	mean (std)	0.98	0.96 (0.13)	1.03 (0.15)	1.01	0.99 (0.13)	1.07 (0.14)	0.93	0.92 (0.13)	0.97 (0.16)
Left Hip BMD (g/cm^2)	mean (std)	1.05	1.03 (0.15)	1.11 (0.16)	1.1	1.08 (0.13)	1.17 (0.14)	0.97	0.96 (0.14)	1.01 (0.15)
Right Hip BMD (g/cm^2)	mean (std)	1.04	1.03 (0.15)	1.09 (0.16)	1.1	1.08 (0.14)	1.15 (0.14)	0.97	0.96 (0.14)	1.01 (0.15)

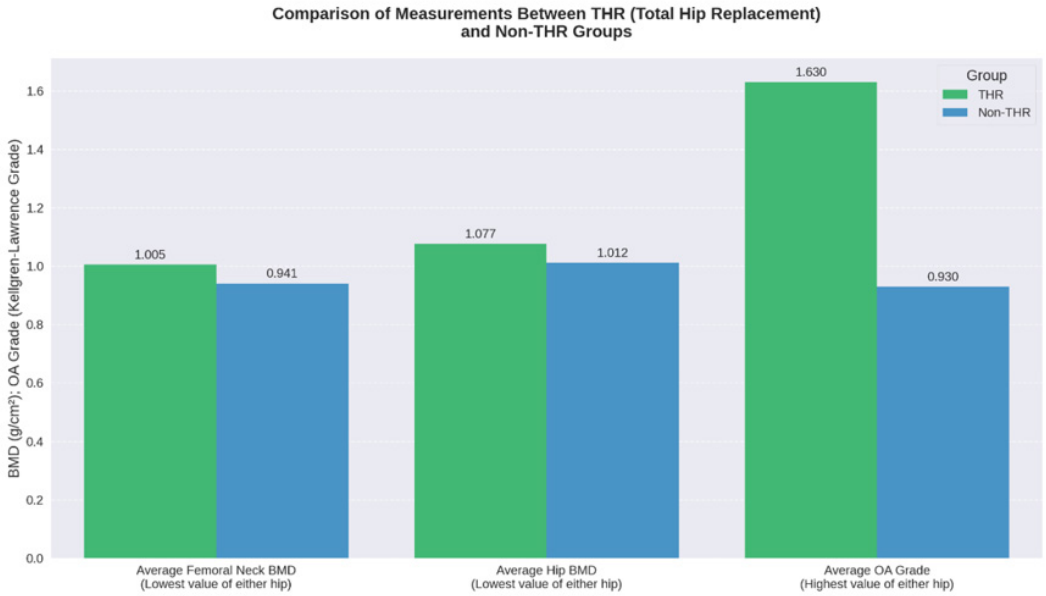

Figure 1 Osteoarthritis grading, BMD and hip replacement.

Table 2 Baseline kellgren-lawrence grade distribution for left and right hips in the study cohort (N=590)

Kellgren Lawrence Grade	Left Grade Count	Left Grade (%)	Right Grade Count	Right Grade (%)
0	285	48.31%	243	41.19%
1	168	28.47%	192	32.54%
2	73	12.37%	82	13.90%
3	60	10.17%	65	11.02%
4	4	0.68%	8	1.36%

Osteoarthritis grading, BMD and hip replacement

Patients who underwent total hip replacement (THR) had significantly higher baseline Kellgren-Lawrence (KL) grades and total hip and femoral neck BMD values for both hips compared to those who did not (Table 1). The mean baseline femoral neck BMD (lowest values of either hip) was higher in the incident THR group than in the non-THR group (1.005 g/cm² vs 0.941 g/cm², $p < 0.001$) (un 1). Additionally, participants who required THR had a higher mean KL grade for the most affected hip (1.63 vs. 0.93, $p < 0.001$) and a higher composite KL score, which represented the sum of left and right hip grades (2.79 vs. 1.54, $p < 0.001$) at baseline.

Correlation analysis:

KL grades were positively correlated with the likelihood of having undergone hip replacement ($r = 0.275$), indicating that higher OA severity could be associated with increased risk.

In the total study sample, there was a weak positive correlation between the OA grade and both the femoral neck and total hip BMD (Table 3). Gender differences in correlation strength were noted, with stronger associations between KL grades and BMD observed in females, whereas the correlations were largely non-significant in males. After accounting for BMI, none of the correlations remained significant (data not shown).

Predictive modelling:

Unstratified logistic regression analysis identified both KL grade and femoral neck and total hip BMD as significant independent predictors of hip replacement, which remained significant after adjusting for age, gender, and BMI.

Conditional logistic regression (Stratified by matched groups):

We then performed a conditional logistic regression analysis to properly account for our matched design. The following models assessed odds of hip replacement, adjusting for age, sex and BMI:

- Highest KL Grade only: For each 1-unit increase in KL Grade, the odds of hip replacement increased by 2.26 (95% CI 1.80–2.84, $p<0.001$).
- Lowest Femoral Neck BMD only (standardized per 1 SD increase): OR=2.14 (95% CI 1.65–2.76, $p<0.001$).
- Lowest Total Hip BMD only (standardized per 1 SD increase): OR=2.02 (95% CI 1.56–2.62, $p<0.001$).
- Combined model (Highest KL Grade + Lowest Femoral Neck BMD, each standardized where applicable):

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- Highest KL Grade: OR=2.21 (95% CI 1.74–2.80, p<0.001), controlling for Femoral Neck BMD.
- Lowest Femoral Neck BMD: OR=2.08 (95% CI 1.58–2.73, p<0.001), controlling for KL Grade.

Among these models, the combined model had the lowest AIC (850.71), indicating the best fit. The results confirm that both OA severity (KL Grade) and Femoral Neck BMD independently contribute to THR risk, even when accounting for the matched study design.

Table 3 Correlation analysis of femoral neck and hip BMD (lowest of either side) and OA grade

	Left hip OA grade	Right hip OA grade	Highest OA grade of either side	OA grade both hip combined
All (n=590)				
Femoral neck BMD	0.131**	0.132**	0.137**	0.139**
Total hip BMD	0.139**	0.139**	0.145**	0.148**
Males (n=349)				
Femoral neck BMD	0.084	0.067	0.091	0.079
Total hip BMD	0.069	0.049	0.074	0.063
Females (n=241)				
Femoral neck BMD	0.156*	0.181**	0.162*	0.180**
Total hip BMD	0.187**	0.215**	0.196**	0.214**

Values are Pearson correlation coefficient, * P<0.05, ** P<0.01.

Values are Pearson correlation coefficient, * P<0.05, ** P<0.01.

Discussion

This study demonstrates that combining Kellgren-Lawrence (KL) grading and BMD measurements obtained from routine DXA scans provides valuable insights into the risk of hip replacement in a middle-aged population. The interaction is quite complex. The findings indicate that higher KL grades and higher BMD values at the affected hip are significant predictors of total hip replacement (THR), emphasizing the importance of early identification and intervention for patients at increased risk. The conditional logistic regression analyses confirm that higher KL grades and lowest BMD values both significantly increase the odds of THR, emphasizing a complex relationship between OA severity and bone density i.e., osteoporosis as a potential risk factor.

The relationship between hip BMD and OA is much more complex interaction. Patients who underwent THR had higher KL grading and higher BMD, and there is a weak positive correlation between KL grading and BMD, suggesting those with higher BMD are more likely to develop OA, consistent with the findings of previous studies.[10] A possible explanation for the relationship is that obesity and or high impact physical activity increases BMD but increase the risk of HipOA.[11] In addition, features of OA such as osteophytes and subchondral sclerosis, if present in the region of interest of DXA scans, could artefactually increase BMD values.[12] Furthermore, it could be due to comorbid factors, such as in the present study as some associations were no longer significant after adjusted for BMI. The combination of KL grade and low BMD as a risk factor, may possibly reflect the impact of OA on reducing physical activity or the independent risk of hip fracture requiring THR.

The value of DEXA to assess KL grade for hip OA has been demonstrated in previous studies demonstrating reproducibility and diagnostic accuracy.[6] The findings in this study are also consistent with that reported in the literature of the relationship of BMD and knee OA.[13–15]

Gender differences

While males exhibited higher mean OA grades across all measures, the correlation between KL grades and BMD was stronger in females, suggesting that BMD may play a more significant role in predicting hip replacement risk in women. These findings indicate that gender-specific factors, potentially including hormonal differences and bone health, may influence the progression of OA and the need for joint replacement.

Clinical Implications

The positive correlation between KL grades and the likelihood of hip replacement underscores the clinical utility of KL grading of DXA in assessing osteoarthritis (OA) severity as an opportunistic screening tool. Patients with higher OA grades showed a significantly increased risk of undergoing THR, suggesting that KL grading may be a useful tool in clinical decision-making. When combined with BMD assessments (particularly the femoral neck of the affected side), the risk of THR is increased, highlighting the potential for using these combined measures to identify high-risk patients. Incorporating both KL grading and BMD into predictive models could enhance the ability to stratify patients by risk, enabling targeted interventions to delay or prevent hip replacement.

This study demonstrates the value of DXA beyond osteoporosis assessment and its utility in routine screening for early identification of hip OA grading in middle aged men and women. It is potentially a missed opportunity for OA screening and reduces the need for higher radiation and cost associated with traditional x ray screening for a common condition with significant consequences if unidentified and untreated.

Limitations and future research

The observational nature of this study limits the ability to establish causation, and longitudinal studies would be beneficial to track the progression of OA and changes in BMD over time. Additionally, exploring the role of other covariates such as physical activity, vitamin D levels, and lifestyle factors in future research could help clarify the observed associations. Developing and validating predictive models that integrate KL grading, BMD, and other relevant factors will be a crucial next step in improving clinical strategies for managing patients at risk of hip replacement. This is the next planned step in this research project.

Conclusion

This study highlights the potential utility of using routine DXA scans for opportunistic OA grading and BMD measurement to assess hip replacement risk. The findings suggest that a combined approach incorporating KL grading and BMD could inform clinical decision-making and enable early interventions to reduce the need for hip replacement. Further research is needed to refine predictive models and explore additional factors that may influence OA progression and hip replacement outcomes.

Acknowledgments

None

Conflicts of interest

The authors report no potential conflicts of interest relevant to this article.

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