Correlates of Hip Cartilage Defects: A Cross-sectional Study in Older Adults

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ABSTRACT. ***Objective.*** Knee cartilage defects are a key feature of osteoarthritis (OA) but correlates of hip defects remain unexplored. The aims of this cross-sectional study were to describe the correlates of hip cartilage defects.

Methods. The study included 194 subjects from the Tasmanian Older Adult Cohort who had right hip short-tau inversion recovery magnetic resonance imaging (MRI). Hip cartilage defects were assessed and categorized as grade 0 = no defects, grade 1 = focal blistering or irregularities on cartilage or partial thickness defect, and grade 2 = full thickness defect. Hip pain was determined by Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC). Hip structural changes were measured on MRI, and hip radiographic OA (ROA) was assessed. Leg strength and physical activity were assessed using dynamometer and pedometers, respectively. Data were analyzed using log binomial and linear regression.

Results. Of 194 subjects, 24% (n = 48) had no defects, 34% (n = 66) had grade 1, and 41% (n = 80) had grade 2. In multivariable analyses, any hip defects were associated with greater hip pain [prevalence ratio (PR) 1.20, 95% CI 1.02–1.35] and lower mean leg strength (men; mean ratio 0.83, 95% CI 0.67–0.98). Grade 1 defects were associated with hip bone marrow lesions (BML; PR 1.42, 95% CI 1.03–1.96) and high cartilage signal (men; PR 1.84, 95% CI 1.27–2.70), but not with hip pain or other structural findings. Grade 2 defects were associated with greater hip pain (PR 1.40, 95% CI 1.09–1.80), hip BML (PR 1.45, 95% CI 1.15–1.85), hip effusion cross-sectional area (PR 1.14, 95% CI 1.01–1.30), hip ROA (men; PR 1.60, 95% CI 1.13–2.25), and steps/day (PR 0.97, 95% CI 0.96–0.99).

Conclusion. Grade 2 defects in both sexes and grade 1 defects (mostly in men) are associated with clinical, demographic, and structural factors relevant for OA. Damage to the hip cartilage could be one of the major causes of rapid disease progression and pathophysiology of hip defects. The topic needs further study. (J Rheumatol First Release June 1 2016; doi:10.3899/jrheum.151001)

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Cartilage defects are one of the key features involved in the progression of osteoarthritis (OA) and can be assessed non-invasively by using magnetic resonance imaging (MRI). Specifically, cartilage defects of the knee have been found to be associated with pain[1,2], bone marrow lesions (BML)[3,4], cartilage volume[5], meniscal damage[6,7], subchondral bone area[8], and radiological OA (ROA)[9], and they predict greater risk of knee replacement[10]. Evidence suggests that these could be related to body mass index (BMI)[11], muscle strength, and physical activity[12].

The role of defects at other sites, including the hip, has been poorly studied. There was no association between hip pain and hip cartilage defects in subjects with symptomatic hip OA[13]. However, in a case-control study, acetabular

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defects correlated with severe hip pain[14]. Apart from these few small studies, no other clinical or demographic data exist for hip cartilage defects, to our knowledge; however, these defects have been shown to be associated with BML. Neumann, *et al* reported that 76% of middle-aged subjects had a hip cartilage defect at either femoral or acetabular sites and these positively correlated with hip BML[15]. Register, *et al* demonstrated a correlation between hip defects and acetabular BML in asymptomatic subjects[16].

Assessment of other significant OA features, such as cartilage volume, are challenging for the hip joint[5], and those with hip cartilage defects have lower cartilage volume[17]. Another imaging marker, change in hip cartilage signal intensity (high cartilage signal), could be an indicator for early cartilage pathology. It associates with knee pain[18] and hip BML[19], but few studies have explored this concept, and its association with hip cartilage defects remains unknown. Further, it is not known whether synovitis/effusion that commonly coexists with knee cartilage defects[20] demonstrates similar associations with hip cartilage defects. There are some studies examining the link between radiological hip OA and cartilage damage. For instance, Roemer, *et al* demonstrated that those with severe cartilage damage had higher Kellgren-Lawrence (KL) grade[13]. Comparably, Kumar, *et al* also found a positive association between KL grade and hip cartilage defects[14]. Nonetheless, these studies had a small sample size and were conducted in subjects with moderate to severe hip OA.

OA is a disease of the whole joint, and hip cartilage defects may associate not only with hip BML but also with other factors that influence structural progression. Given these deficiencies in current data, the objective of the present study was to describe the cross-sectional correlates of hip cartilage defects in a community-based sample of older adults.

MATERIALS AND METHODS

Subjects. The Tasmanian Older Adult Cohort (TASOAC) is an ongoing prospective, population-based cohort, and the study design has been extensively described[19,21]. The TASOAC study included a baseline visit and 2 followup visits (phase 2 and phase 3), which were about 2.6 years apart. A hip protocol was added in the latter part of phase 2 of the TASOAC study. In the current study, a sample of 245 consecutive participants who had a hip STIR (short-tau inversion recovery) MRI scan at phase 2 and/or phase 3 were included. Of these 245 participants, 30 were lost to followup at phase 3, and 17 did not have a STIR MRI sequence at phase 2; hence the total number of participants who had a phase 2 and phase 3 hip MRI scan was 198. Of these 198, hip cartilage was not adequately visible in 4 MRI, leaving 194 subjects with complete data. Written informed consent was obtained and the Southern Tasmanian Health and Medical Human Research Ethics Committee approved our study.

Clinical and hip pain measures. Height, weight, and BMI were measured using standard protocols. Hip pain was determined using a hip-specific Western Ontario and McMaster Universities Osteoarthritis (WOMAC) Index pain score. WOMAC uses a 10-point scale from 0 (indicating no pain) to 9 (indicating severe pain). Hip pain (5 items) was assessed using the following questions: "Referring to your hips only, how much pain did you experience when walking on flat surface, going up and down the stairs, at night while in bed, sitting or lying, and standing upright." These 5 items were summed to create a total hip pain score, with a possible range from 0 to 45[22].

Physical activity. Steps/day were assessed at phase 2 and phase 3 by pedometers (Omron HJ-003 and HJ-102 Omron Healthcare). Each participant was instructed to wear the pedometer for 7 consecutive days. This was repeated 6 months later to take into account seasonal variations. Mean steps per day were calculated as the average of both timepoints[23]. Steps/day were further categorized as sedentary (< 5000); low active (5000-7499); somewhat active (7500-9999), and active (10,000+ steps)[24].

Muscle strength. Muscle strength (leg strength) was measured simultaneously in both legs using a dynamometer (TTM Muscular Metre). This test examines isometric strength, predominantly of the quadriceps and hip extensors[25].

Imaging details. The right hip was imaged in the sagittal plane using a 1.5 Tesla G.E. signal whole-body magnetic resonance unit with a phased-array flex coil. The following image sequence was used: STIR 2-dimensional fast spin echo sequence; repetition time 4340 ms, inversion time (TI) 130 ms; echo time 28.4 ms; field of view 20 cm; 15 partitions, and 512 × 512 pixel matrix. Sagittal images were obtained at slice thickness of 3.5 mm with an interslice gap of 1.5 mm. All MRI measures were conducted using OsiriX imaging software (University of Geneva).

Measuring hip cartilage defects. Hip cartilage defects were assessed using OsiriX (Figure 1) on high-resolution workstations (Mac: 1440 × 900 and monitor: 1920 × 1080). DC (experienced radiologist, MD) and GJ (rheumatologist with > 20 years' experience) trained HA to measure hip cartilage defects. GJ and HA adapted a previously published grading system for assessing knee cartilage because it was validated, reliable, and linked with all key features of knee OA[1,3,7,9,10]. Hip defects were identified as any change in the cartilage and were categorized as grade 0 = normal cartilage, grade 1 = focal blistering or irregularities on the cartilage surface or a partial thickness defect, and grade 2 = full-thickness defect with bone ulceration and/or exposure of bone. If more than 1 defect was present at 1 site, the highest score was used. In a reliability study of 40 subjects with re-measurements after 4 weeks, the intrarater agreement (κ) was 0.89. Further, the interrater reliability (κ) assessed by 2 readers (n = 40) for presence of defects and defect categories was 0.84 and 0.63, respectively. These measures were conducted by HGA and Dr. Ming Lu, an orthopedic surgeon with 7 years' experience in reading MRI scans.

Assessment of hip effusion. Hip joint effusion was assessed manually by 1 observer (HGA). HGA selected the MRI slice with the largest effusion and then assessed the maximum cross-sectional area (CSA). The intrarater agreement (κ) for presence of hip effusion was 0.84 and the intraclass correlation coefficient (ICC) for hip effusion CSA was 0.97.

Hip BML and high cartilage signal. BML were identified as areas of increased signal intensity adjacent to the subchondral bone on the femoral head and/or the acetabulum, and maximum BML CSA was assessed. The ICC for hip BML was 0.98[19]. High cartilage signal was defined as a high signal intensity band within the cartilage either adjacent to a hip BML or at any location on the STIR MRI slice if there was no BML present. High cartilage signal was graded as 0 for absent and 1 for present with an intrarater agreement (κ) of 0.88[19].

Radiological assessment. Anteroposterior weight-bearing radiographs of the pelvis were obtained. Hip radiographs were read by 2 trained readers using the Osteoarthritis Research Society International grading system. The radiographic features of joint space narrowing (JSN) and osteophytes of the right hip were graded on a 4-point scale, ranging from 0 to 3, where 0 = no disease and 3 = most severe disease by using an Altman's atlas[26]. The intraobserver reliability for radiographs was carried out in 40 subjects and the ICC scores ranged from 0.60 to 0.87[5,27]. A non-zero score of either JSN or osteophytes was regarded as evidence of hip ROA. Thus, after combining JSN and osteophytes score, the presence of hip ROA was defined as a total score of 1 or greater.

Statistical analyses. Student's t test and chi-square tests were applied to

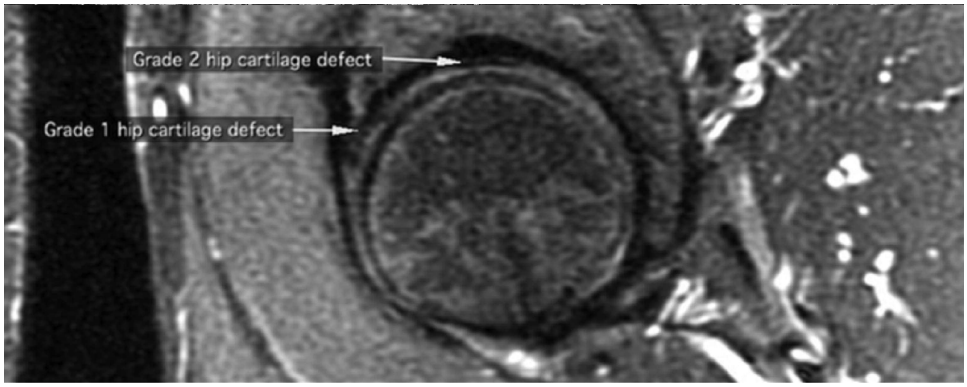

Figure 1. Assessment of grade 1 and grade 2 hip cartilage defects on sagittal short-tau inversion recovery magnetic resonance imaging.

determine the differences in means and proportions. Based on total WOMAC score, which ranged from 0-45, hip pain was divided into 3 categories: category 0 comprised subjects with no pain; category 1, subjects with pain score < 4; and category 2, subjects with pain score ≥ 4. Hip BML and effusion were dichotomized as 0 = no BML/effusion and 1 = BML/effusion > 0. Log binomial regression (a generalized linear model with log link and binomial error) was used to estimate associations with the binary outcome hip cartilage defects. Linear regression was used to estimate associations with continuous outcomes. All models were adjusted for age, BMI, and hip BML (as required) because these factors produced at least 10% of change in the coefficient of the study factor. Results are presented stratified by sex (when the interaction of study factor with sex was statistically significant) or additionally adjusted by sex. Data on subjects at phase 2 and phase 3 were combined in analyses (194 subjects with MRI at both phases), and the correlation between repeated measurements on individuals was taken into account by adjusting standard errors using the sandwich (robust) estimator of variance[28,29]. An assessment was made of the fit of all the final models, with careful attention paid to the scaling of covariates and of the response variable in linear regression. Intrarater and interrater reliability was computed using weighted κ. All statistical tests were 2-sided, and p values < 0.05 were considered significant.

RESULTS

Table 1 summarizes the characteristics of the subjects with

Table 1. Characteristics of the study sample.

Characteristics	Hip Defect Absent, n = 48	Grade 1 Hip Defect Present, n = 66	p	Grade 2 Hip Defect Present, n = 80	p
Age, yrs, mean (SD)	64.1 (6.73)	64.1 (6.84)	0.95	65.5 (7.70)	**0.01**
BMI, kg/cm^2, mean (SD)	27.2 (3.99)	28.2 (4.43)	**0.02**	27.5 (4.20)	0.53
Hip pain†					
Presence‡	40%	48%	0.14	46%	0.81
Men	22%	44%	**0.002**	—	**—**
Women	62%	53%	0.2	—	**—**
Interaction p value, p = 0.003					
Severity §, mean (SD)	1.32 (3.14)	2.10 (4.20)	0.07	2.60 (5.11)	**0.03**
Leg strength, kg, mean (SD)	101 (53.0)	99 (53.0)	0.71	98.0 (48.7)	0.73
Steps per day, mean (SD)	7970 (3526)	7444 (3245)	0.15	7127 (3507)	**0.04**
Any BML	5%	20%	**0.003**	23%	**0.009**
Presence of high cartilage signal	42%	60%	**0.002**	62%	**0.009**
Men	40%	70%	**< 0.001**	—	—
Women	44%	46%	0.81	—	—
Interaction p value, p = 0.008					
Hip effusion†					
Presence*	10%	18%	0.07	20%	0.09
Effusion CSA**, mean (SD)	1.05 (0.79)	1.16 (0.96)	0.31	1.30 (1.01)	**0.02**
Presence of radiological hip OA	28%	30%	0.94	40%	**0.002**
Men	22%	—	—	50%	**0.001**
Women	27%	—	—	27%	0.97
Interaction p value, p = 0.007					

Significant data are in bold face. Results of t tests (continuous variables) and chi-squared tests (categorical variables), with standard errors of means calculated with clustering of observations on subjects at phase 2 and phase 3 taken into account. Two-way ANOVA test was used for estimating sex interactions. † Pain score calculated using Western Ontario and McMaster Universities Osteoarthritis index. ‡ Presence of hip pain defined as grade 0 = no hip pain and grade 1 = pain score > 0. § For subjects with hip pain score > 0. * Presence of hip effusion dichotomized as grade 0 = no effusion or/and effusion CSA ≤ 2.0 cm^2, and grade 1 = effusion ≥ 2.0 cm^2. ** Mean effusion and SD obtained using t test including only subjects with effusion CSA > 0. BMI: body mass index; BML: bone marrow lesions; CSA: cross-sectional area; OA: osteoarthritis.

no defect, and grade 1 and grade 2 defects. Overall, 24% (n = 48) of the subjects had no cartilage defects, 34% (n = 66) had grade 1, and 41% (n = 80) had grade 2 cartilage defects. When a significant sex interaction was found, the data were stratified into men and women. In comparison to those with no cartilage defects, subjects with a grade 1 defect were of similar age, but heavier. Men with grade 1 defects had more hip pain and an increased proportion of high cartilage signal than those without a hip defect. Regardless of sex, subjects with grade 1 defects had more hip BML. In comparison to subjects with no defects, those with grade 2 defects had similar BMI but were older and had a higher hip pain score, higher proportion of hip BML, and high cartilage signal, larger effusion CSA, and took fewer steps per day. The proportion with hip ROA in those with grade 2 cartilage defects was higher in men than in women.

Table 2 presents the cross-sectional associations between categories of hip pain and hip cartilage defects. Those with greater hip pain had greater prevalence of any and grade 2 defects, but grade 1 defects were not associated with any categories of hip pain.

Table 3 summarizes the cross-sectional associations between structural abnormalities and grade 1 cartilage defects, stratified by sex. The prevalence and size of hip BML was greater in men, but no sex interaction was found. Similarly, an association between high cartilage signal and grade 1 defect was found in men, but not in women. Other abnormalities such as hip effusion and radiological aspects were not associated with grade 1 defects.

Table 4 presents the cross-sectional associations between structural abnormalities and grade 2 cartilage defects. In these analyses, subjects with grade 2 cartilage defects had a higher prevalence of hip BML and larger hip effusion size compared to subjects with no cartilage defects. Those with grade 2 defects also had a higher prevalence of high cartilage signal [prevalence ratio (PR) 1.30, 95% CI 1.03–1.62], but this association became nonsignificant after adjusting for hip BML, as shown in Table 4. The link between grade 2 defects and radiological hip OA was present only in men.

Table 5 presents the cross-sectional relationship between steps/day and grade 2 cartilage defects. Steps/day and its categories were associated with a lower prevalence of grade 2 defects. These associations persisted after adjustment for age (using the residual method).

Supplementary Figure 1 (available from the authors on request) presents the association between any hip defects and leg strength stratified by sex. Presence of any hip defect was associated with lower leg strength among men (mean ratio: 0.83, 95% CI 0.67-0.98) but not women (mean ratio: 0.91, 95% CI 0.80-1.03).

Table 2. The cross-sectional associations between categories of hip pain and hip cartilage defects.

	Any Hip Defect, PR (95% CI)	Grade 1 Defects, PR (95% CI)	Grade 2 Defects, PR (95% CI)
Hip pain			
Category 0	1.00	1.00	1.00
Category 1	1.00 (0.83–1.20)	1.04 (0.77–1.40)	0.96 (0.70–1.40)
Category 2	**1.20 (1.02–1.35)**	1.22 (0.93–1.60)	**1.40 (1.09–1.80)**

Significant data are in bold face. Independent variable: hip cartilage defects. Dependent variable: hip pain category. Hip pain category 0 includes subjects with no pain. Hip pain category 1 includes subjects with > 0 and < 4 hip pain score. Hip pain category 2 includes subjects with ≥ 4 hip pain score. PR (95% CI) = prevalence ratios adjusted for age, sex, and body mass index and taking into account clustering of observation on subjects at phase 2 and phase 3.

DISCUSSION

This is the first population-based study, to our knowledge, that describes the correlates of hip cartilage defects, and our results are similar to knee defects. Overall, 76% of the population had hip cartilage defects, and correlates of hip defects, in this cohort, appeared to be somewhat influenced by sex. Any hip cartilage defects associated with greater hip pain and men with any defects had lower leg strength. Associations of grade 1 hip cartilage defects were restricted to high cartilage signal (men only) and hip BML. Grade 2 cartilage defects were associated not only with higher hip pain and hip BML but also with hip effusion size and hip ROA (men only). Steps per day was protective of grade 2 cartilage defects.

In unadjusted analyses (Table 1), presence of hip pain and hip pain severity was greater in subjects with grade 1 and grade 2 hip cartilage defects, respectively. In the multivariable analyses, any and grade 2 hip cartilage defects were associated with pain category 2 while grade 1 showed no such associations. Hip cartilage defects were not associated with hip pain category 1. In this study, hip pain was categorized using a cutoff point of 4. Earlier studies have used clinically relevant cutoff points[30,31] and as presumed, those with higher pain score had greater prevalence of cartilage defects. An MRI-based study validating a hip OA score found higher odds of hip pain in those with hip cartilage defects but these links were not statistically significant[13]. Subsequently, a case-control study of 85 subjects with mild to moderate hip OA demonstrated a modest correlation between acetabular defects and hip pain ($r = -0.25$, $p < 0.02$)[14]. Although different methods were applied to classify defects, our findings are consistent with these studies. For instance, Roemer, *et al* classified defects into grade (0-3), and Kumar, *et al*, and Teichtahl, *et al* classified defects into grade (0-2 and 0-1, respectively) by subregions of the femoral head/acetabulum on MRI images[13,14,17]. We categorized hip defects as grade (0-2) and found similar results. In addition, our data imply that those with greater cartilage damage may have a higher probability of hip pain.

The association between hip defects and leg strength is a

Table 3. Cross-sectional associations between structural abnormalities and grade 1 cartilage defects, stratified by sex.

Study factor	Men Hip Defect Present, PR (95% CI)*	Women Hip Defect Present, PR (95% CI)*	P Value for Interaction
MRI abnormalities			
Any hip BML, Y/N	**1.42 (1.03–1.96)**	1.20 (0.80–1.76)	0.50
Hip BML CSA	**1.41 (1.11–1.71)**	1.25 (0.81–1.68)	0.56
High cartilage signal, Y/N†	**1.80 (1.04–2.53)**	0.92 (0.63–1.22)	**0.01**
Hip effusion, Y/N	1.03 (0.60–1.83)	0.83 (0.60–1.20)	0.52
Hip effusion CSA	1.00 (0.83–1.21)	1.08 (0.88–1.30)	0.40
Radiological abnormalities			
Radiological hip OA, Y/N	1.20 (0.80–1.82)	0.90 (0.60–1.44)	0.41
Joint space narrowing, Y/N	1.12 (0.62–2.03)	0.80 (0.44–1.41)	0.40
Osteophytes, Y/N	0.90 (0.50–1.60)	1.20 (0.73–1.88)	0.44

Significant data are in bold face. Independent variable: structural abnormalities. Dependent variable: presence of hip cartilage defect. *PR (95% CI) = prevalence ratios (95% CI) adjusted for age, sex, and body mass index, taking into account clustering of observation on subjects at phase 2 and phase 3. †PR (95% CI) further adjusted for presence of hip BML. MRI: magnetic resonance imaging; BML: bone marrow lesions; CSA: cross-sectional area; OA: osteoarthritis.

Table 4. Cross-sectional associations between structural abnormalities and grade 2 cartilage defects.

Study factor	Hip Cartilage Defect, PR (95% CI)*
MRI abnormalities	
Any hip BML, Y/N	**1.45 (1.15–1.85)**
Any hip BML, CSA	**1.42 (1.21–1.66)**
High cartilage signal, Y/N†	1.20 (0.95–1.52)
Hip effusion, Y/N	0.98 (0.65–1.50)
Hip effusion, CSA	**1.14 (1.01–1.30)**
Radiological abnormalities	
Radiological hip OA, Y/N	1.30 (0.96–1.70)
Men	**1.60 (1.13–2.25)**
Women	0.80 (0.45–1.40)
Interaction, p value	**p = 0.04**

Independent variable: structural abnormalities. Dependent variable: presence of hip cartilage defect. *PR (95% CI) = prevalence ratios (95% CI) adjusted for age, sex, and body mass index and taking into account clustering of observation on subjects at phase 2 and phase 3. †PR (95% CI) further adjusted for presence of hip BML. CSA: cross-sectional area; MRI: magnetic resonance imaging; BML: bone marrow lesions; OA: osteoarthritis.

Table 5. Cross-sectional relationship between steps/day and grade 2 cartilage defects.

Study factor	Grade 2 Hip Cartilage Defects, PR (95% CI)*
Steps/day	**0.97 (0.96–0.99)**
Steps/day categories	
0–5000 steps	1.00
5000–7499 steps	0.90 (0.77–1.04)
7500–9999 steps	0.87 (0.74–1.01)
10,000+ steps	**0.77 (0.65–0.91)**

Independent variable: steps per day and steps per day categories. Dependent variable: grade 2 hip cartilage defects. *PR (95% CI) = prevalence ratios with 95% CI, adjusted for age residuals, sex, and body mass index and taking into account clustering of observations on subjects at phase 2 and phase 3.

novel finding. We found that men with hip cartilage defects had lower leg strength. No other study has explored this concept at the hip, to our knowledge, but some data exist for the knee[12,32]. In 87 women, knee cartilage damage in combination with either pain or presence of loose bodies explained 28%-38% of the variation in isokinetic extension strength. In women with knee cartilage damage, synovitis and/or effusion explained 34% variability in isometric flexor strength[12]. In both men and women with lower quadriceps muscle strength, there was a greater prevalence of patella-femoral cartilage damage[33]. The dynamometer used in the TASOAC study predominantly captures quadriceps and hip extensor strength. The associations between leg strength and hip cartilage defects were predominately seen in men, but are similar to the above studies. Our results suggest that hip cartilage defects (like knee defects) associate with muscle strength.

However, longitudinal studies are required to assess cause and effect. Age-adjusted steps/day and doing +10,000 steps/day was associated with a lower prevalence of grade 2 cartilage defects. Any or grade 1 cartilage defects showed no such associations (data not shown). This concept has not been examined at the hip, and the evidence for the knee is being debated. For instance, in an asymptomatic sample, 93% of subjects with a high level of physical activity had knee cartilage lesions[34]. A longitudinal study demonstrated that subjects with a knee BML at baseline and who walked 10,000+ steps/day were more likely to have worsening knee cartilage damage[23]. Another longitudinal study showed physical work capacity was modestly and positively correlated with knee bone area but negatively with knee cartilage volume[35]. Here, physical activity associated with lower prevalence of grade 2

hip cartilage defects. Again, longitudinal studies are required and there is a possibility that subjects with grade 2 defects take fewer steps per day because of hip pain. Owing to the lack of consistency in evidence and no other comparable data at the hip, it is hard to define at this point whether physical activity is helpful or harmful for hip cartilage.

Subjects with a hip BML had about a 1.5 times higher risk of having grade 1 or grade 2 hip cartilage defects. BML have gained much attention and play a key role in OA. At the hip, studies have reported hip BML, articular damage, and cartilage defects in subjects with and without symptomatic hip OA, but these did not document associations between BML and cartilage defects[13,16,36]. Neumann, *et al* demonstrated a strong positive correlation between hip defects and hip BML ($r = 0.44$, $p < 0.001$) in subjects with and without hip OA[15]. Register, *et al* found a positive correlation between hip chondral defects and acetabular BML ($p = 0.009$) in asymptomatic subjects with hip structural changes[16]. Our study is consistent with these findings and demonstrates associations between hip BML and defects in a community-based sample.

Men with a high cartilage signal were 80% more likely to have a grade 1 defect; while men and women with a high cartilage signal were 30% more likely to have a grade 2 defect (PR 1.30, 95% CI 1.03–1.62). However, this association became nonsignificant after adjusting for hip BML. The significance of high cartilage signal intensity at the knee has been described[18,37,38,39]. Our group was the first to outline its association with hip BML[19], to our knowledge, and in this study we demonstrated its association with grade 1 defects, further validating its role as an early marker for cartilage changes. Its association with grade 2 hip cartilage defect was not independent of hip BML. Thus, the association of high cartilage signal with grade 2 cartilage defects is mediated by hip BML, indicating the possibility of underlying causal pathways between these structural changes[19].

Hip effusion CSA was associated with grade 2 defects and these subjects had 14% larger hip effusion. Presence of hip effusion did not associate with hip cartilage defects. Joint effusion at the knee has been linked with progression of cartilage defects[20] but its role in hip OA has not been reported. Joint effusion is an inflammatory process and may directly affect the cartilage matrix or could be a consequence of cartilage damage[40]. Either way, our findings support this hypothesis.

In our current study, men with radiological changes were 60% more likely to have grade 2 hip defects. Grade 1 or any hip defects were not associated with hip ROA. Radiological changes at the hip are part of the diagnosis of hip OA[13,14,41], but less is known about its relationship with hip defects. Earlier studies reported greater cartilage damage with increasing KL grade in subjects with severe hip OA[13]. Further, worsening KL grade was associated with femoral ($r = 0.33$, $p = 0.002$) and acetabular defects ($r = 0.34$, $p = 0.001$)[14]. Our data are highly consistent with both these studies; however, the association between ROA and defects was stronger in men than in women.

This study has some potential limitations. The analyses are cross-sectional. Assessing hip cartilage is challenging and the technique used to assess hip defects was adapted from earlier studies[9]. We acknowledge that we are unable to provide arthroscopic or pathological validation, and those with defects are at a higher risk of OA, but having a defect may not be a precursor for hip OA. During measurements, it is possible we might have missed a small or shallow cartilage defect. However, our reproducibility was high, our previous measures have shown excellent measurement metrics, and as hypothesized, our findings are consistent with earlier studies at the knee and the hip. Lastly, the MRI sequence could not separate synovitis from effusion and associations may vary if each is examined separately.

Grade 2 defects in both sexes and grade 1 defects (mostly in men) are associated with clinical, demographic, and structural factors relevant for OA. Damage to the hip cartilage could be one of the major causes of rapid disease progression, and the pathophysiology of hip defects needs further study.

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