© Kamla-Raj 2016
PRINT: ISSN 0972-0073 ONLINE: 2456-6802
Anthropologist, 24(3): 702-710 (2016)
DOI: 10.31901/24566802.2016/24.03.03

Paleopathological Patterns of Degenerative Arthropathy: Prevalence of Limb-Joint Osteoarthritis in Joseon People Skeletons

Dong Hoon Shin[1], Go-Un Jung[2], Chang Seok Oh[1], Myeung Ju Kim[3], Eun-Kyoung Shin[4] and Yi-Suk Kim[2*]

[1]Department of Anatomy, Seoul National University College of Medicine, Seoul, Republic of Korea
[2]Forensic Anthropological Laboratory and Department of Anatomy, Ewha Womans University School of Medicine, Seoul, Republic of Korea
[3]Department of Anatomy, Dankook University College of Medicine, Cheonan, Republic of Korea
[4]Department of Social Welfare, Dankook University, Republic of Korea

KEYWORDS Osteoarthritis. Limb-Joints. Paleopathology. Joseon Skeletons

ABSTRACT This study was performed to assess degenerative osteoarthritis (OA) in human skeletons from 15th to 19th century Joseon tombs of South Korea. The researchers performed anthropological examinations of OA in selected limb joints of Joseon skeletons and considered possible reasons for the revealed aspects of OA by focusing on lifestyle or occupational activity during that time. A total of 140 skeletons unearthed from Joseon tombs were evaluated and any pathological lesions in the articular surfaces of limb joints were carefully examined by gross inspection. Most of joints correlated linear degenerative changes over time, however, OA prevalence of knee joints was much higher in middle-aged group. The prevalence of OA at limb joints revealed in this study provides insights into the mobility patterns of pre-modern Korean people. Knowledge of OA in pre-modern samples will enrich our understanding of the developmental interactions that provide the basis of the disciplines of epidemiology and demography.

INTRODUCTION

Osteoarthritis (OA) is by far the most commonly identified pathological condition, which resulted from breakdown of protective cartilage and underlying bone, in ancient skeletal remains (Cunha 1996; Waldron 1991; Yu et al. 2015). Paleopathology enhances our understanding of historical epidemiological data concerning chronic diseases such as OA (Van Saase et al. 1989; Debono et al. 2004; Martin et al. 2013). The skeletal modifications caused by OA involve degenerative changes in diarthrodial joints, which are further characterized by a loss of cartilage and accompanying bony lesions due to direct interosseous contact (Lieverse et al. 2007). The arthritic involvements of OA include marginal lipping (osteophytes), erosive change (porosity), and eburnation (polishing) on the joint surfaces (Jurmain and Kilgore 1995; Lieverse et al. 2007).

**Address for correspondence:*
Dr. Yi-Suk Kim
Department of Anatomy,
Ewha Womans University
School of Medicine, 911-1,
Mok-5-dong, Yangcheon-gu,
Seoul 158-710, Republic of Korea
Fax: 82-2-2650-5716,
E-mail: jwkiss@ewha.ac.kr

A previous epidemiological study proposed multiple risk factors of OA: age, inheritance, obesity, trauma, abnormal biomechanics, and alterations in joint shape (Cushnaghan and Dieppe 1991; Finzel et al. 2014). In fact, differences and similarities in the prevalence of OA reflect the specific activities of the subjects investigated (Larsen et al. 1995; Yu et al. 2015). For instance, the prevalence of OA is known to be different among different historical ethnic groups. In the study of Inoue et al. (2001), the prevalence of hip OA was higher in Caucasians than in Asians of ancient times. This suggests that different lifestyles such as knee bending (Asians) or chair sitting (Caucasians) might be responsible for the discrepancy in OA prevalence between the two ethnic groups. Anthropologically speaking, OA may provide evidence of specific activity and mechanical stress levels of the individuals, and is therefore very relevant to human adaptation and culture (Bridges 1992).

The relationship between OA and mechanical stress experienced by individuals throughout their lives has also been reported from the perspective of cumulative wear-and-tear effects on the diarthrodial limb joints (Lieverse et al. 2007). Paleopathological research has also considered the location of joints, bilateral asymmetries, and sex-based variations when studying OA (Cushnaghan and Dieppe 1991; Jurmain and Kilgore 1995). In the present study, the researchers assessed OA findings in human skeletons from 15th to 19th century Joseon tombs of South Korea. The researchers undertook anthropological examinations on OA, especially in selected limb joints of Joseon skeletons, and then pursued possible reasons for our findings by focusing on lifestyle or occupational activity during that time. Knowledge of OA in pre-modern Korean samples will enrich our understanding of the subsequent developmental interactions that provide the basis of the disciplines of epidemiology and demography.

METHODOLOGY

Human skeletal remains (n=140) unearthed from Joseon tombs were examined in this study. This type of tomb was first introduced to Korean society as early as the late 15th century and was then rapidly adopted by the upper class nobles in the 16th century. The majority of the Joseon skeletons in this study were collected from the archeological ûelds around Seoul Metropolitan City and the adjacent Gyeonggi province.

Sex estimation was performed by morphological differences manifested in the pelvic bones. To determine pelvic dimorphism, the researchers examined the greater sciatic notch, pre-auricular sulcus, ischiopubic ramus, subpubic angle, subpubic concavity, and ventral arc (Krogman and Iscan 1986). As ancillary indicators, skull structures, specifically the nuchal crest, mastoid process, supraorbital margin, glabella, and mental eminence were checked by standard criteria (Buikstra and Ubelaker 1994).

Age estimation could be done in these cases, only by auricular surfaces of the ilia due to the lack of symphyseal surface in pubic bone and the defects in cranial sutures for evaluating the closure from the minimum of 7 to the maximum of 12 areas, and impossibility of seriation with rib set for evaluating sternal end of fourth rib. The age at death was estimated by auricular-surface degeneration of the pelvis, and various indicators such as the degree of transverse organization, granularity, apical activity, retroauricular activity, and porosity of the articular surface were examined (Lovejoy et al. 1985). The samples were finally categorized into three different groups: young (20 - 34 yrs), middle-aged (35 - 49 yrs), and old (≥50 yrs) adult groups.

Any pathological lesions in the articular surfaces of limb joints were carefully examined by gross inspection. To describe the articular surfaces, all joint sites were classified as shoulder, elbow, wrist, hip, knee, patella-femoral, and ankle. As each joint has specific articular surfaces as variables, the contents and abbreviation of each variable are summarized in Table 1. Grading of the OA changes of articular surfaces was presented using a modified version of the ordinal scale (Jurmain 1991). Evidence of osteophyte, pitting, eburnation, and ankylosis on the evaluated surfaces was also examined (Table 2, Fig. 1).

Table 1: Abbreviations for all variables on the joint sites

Joint site	*Variables*	*Abbreviation*
Shoulder	Glenoid fossa	GF
	Proximal humerus	PH
Elbow	Distal humerus	DH
	Proximal ulnar	PU
	Proximal radius	PR
Wrist	Distal radius	DR
Hip	Acetabular socket	AS
	Proximal femur	PF
Knee	Medial femur	MF
	Lateral condyle of femur	LF
	Medial condyle of femur	MT
	Lateral condyle of tibia	LT
Patello-	Patella surface	PS
femoral	Articular surface of patella	AP
Ankle	Distal tibia	DT

Table 2: Grade of osteoarthritis applied in this study (Jurmain 1991)

Grade	*Definitions*
0	None or slight
1	Moderate degenerative changes; small osteophyte or pitting less than 10% of articular surface
2	Severe degenerative changes; large osteophyte, altered contour of original surface, pitting more than 10% of articular surface, or any eburnation
3	Ankylosis; abnormal adhesion of joint or joint stiffness

Fig. 1. Examples of degenerative changes from limb-joint bony surfaces. (a) Proximal ulna was diagnosed as Grade 1 OA by considering small osteophytes around the rim of the both-side articular surfaces. (b) Lunate surface of acetabular socket was diagnosed as Grade 1 OA, by structure of pitting less than 10% of entire articular surface. (c) Glenoid fossa was significant for confirming this as Grade 2 OA because of its large osteophytes with lipping around the rim of articular surfaces. (d) Posterior surface of left distal humerus was confirmed as Grade 2 OA, by presenting supero-lateral eburnation at right side without any pathological changes.

The chi-square test was used for statistical analysis of differences between both-side joints, sexes, and age groups. McNemar's test was performed for comparison of right and left variables on the same individual, and Fischer's exact test was applied for cells of expected counts less than five for comparison of males and females. Chi-square tests for age-related changes were examined with the linear by linear association option. All statistical significances were set at the level of 0.05 and statistical analysis of data was performed using a statistical software package (SPSS, version 13.0; SPSS Inc., Chicago, IL, USA).

RESULTS

Anthropological evaluation was performed according to the sex and age estimations of Joseon skeletons (77 males and 63 females). Age was estimated by degenerative changes in the auricular surface of hipbone (Lovejoy 1985). The demographic profiles clustered by sex and age estimations are shown in Figure 2. The ratio between male and female almost reached 1:1. The relative ratio of young, middle, and old age groups was 1:6:2.4, respectively.

The estimated ratio of osteoarthritis is summarized in Table 3. Comparing OA prevalence in males and females, OA was seen much more frequently among males at most of the joints, with the exception of the medial condyle of tibia (MT) and distal tibia of ankle joint (DT). In each age group there was a strong tendency of increased OA prevalence in the order of the elbow, wrist, patella-femoral, and ankle joint.

The prevalence of joint OA between both-side joints, sex, and age groups was tested by chi-square test (Table 4). The prevalence in males was significantly higher than that in females, by

Table 3: Prevalence of osteoarthritis (over grade 1)

		Sex* (%)					Estimated age at death* (yr)						
		Male (M)		Female (F)			Young, 20-34(Y)		Middle, 35-49(M)		Old, ≥50(O)		Total (Y+M+O)
Joint site†		R	L	R	L	Total (M+F)	R	L	R	L	R	L	
Shoulder	GF	31.8 (27/85)	38.8 (33/85)	16.5 (14/85)	12.9 (11/85)	100 (85)	3.5 (3/85)	1.8 (1/85)	27.1 (23/85)	29.4 (25/85)	17.6 (15/85)	21.2 (18/85)	100 (85)
	PH	38.1 (8/21)	57.1 (12/21)	4.8 (1/21)	0 (0/21)	100 (21)	0 (0/21)	0 (0/21)	9.5 (2/21)	19.0 (4/21)	33.4 (7/21)	38.1 (8/21)	100 (21)
Elbow	DH	40 (14/35)	20 (7/35)	20 (7/35)	20 (7/35)	100 (35)	0 (0/35)	0) (0/35)	22.9 (8/35)	20 (7/35)	37.1 (13/35)	20 (7/35)	100 (35)
	PU	42.0 (29/69)	30.4 (21/69)	16.0 (11/69)	11.6 (8/69)	100 (69)	4.3 (3/69)	4.3 (3/69)	27.5 (19/69)	14.5 (10/69)	26.1 (18/69)	23.2 (16/69)	100 (69)
	PR	44.4 (4/9)	44.4 (4/9)	11.2 (1/9)	0 (0/9)	100 (9)	0 (0/9)	0 (0/9)	22.2 (2/9)	11.2 (1/9)	33.3 (3/9)	33.3 (3/9)	100 (9)
Wrist	DR	40.6 (13/32)	40.6 (13/32)	6.3 (2/32)	12.5 (4/32)	100 (32)	3.1 (1/32)	3.11 (1/32)	5.6 (5/32)	15.6 (5/32)	28.2 (9/32)	34.4 (11/32)	100 (32)
Hip	AS	31.4 (33/105)	30.5 (32/105)	21.0 (22/105)	17.1 (18/105)	100 (105)	3.8 (4/105)	2.9 (3/105)	27.6 (29/105)	23.7 (25/105)	21.0 (22/105)	21.0 (22/105)	100 (105)
	PF	38.1 (8/21)	38.1 (8/21)	14.3 (3/21)	9.5 (2/21)	100 0	0 (0/21)	0 (0/21)	23.8 (5/21)	19.0 (4/21)	28.6 (6/21)	28.6 (6/21)	100 (21)
Knee	MF	26.7 (8/30)	33.3 (10/30)	20 (6/30)	20 (6/30)	20 (30)	100 (1/30)	0 (0/30)	23.3 (7/30)	30 (9/30)	20 (6/30)	23.3 (7/30)	100 (30)
	LF	44.4 (8/18)	38.8 (7/18)	5.6 (1/18)	11.2 (2/18)	100 (18)	0 (0/18)	0 (0/18)	22.2 (4/18)	22.2 (4/18)	33.3 (6/18)	27.8 (5/18)	100 (18)
	MT	23.1 (3/13)	23.1 (3/13)	30.7 (4/13)	23.1 (3/13)	100 (13)	7.7 (1/13)	7.7 (1/13)	30.8 (4/13)	23.0 (3/13)	15.4 (2/13)	15.4 (2/13)	100 (13)
	LT	33.4 (9/27)	29.6 (8/27)	22.2 (6/27)	14.8 (4/27)	100 (27)	3.7 (1/27)	3.7 (1/27)	26.0 (7/27)	22.1 (6/27)	26.0 (7/27)	18.5 (5/27)	100 (27)
Patello-femoral	PS	44.8 (13/29)	31.0 (9/29)	10.4 (3/29)	13.8 (4/29)	100 (29)	0 (0/29)	0 (0/29)	24.1 (7/29)	20.8 (6/29)	31.0 (9/29)	24.1 (7/29)	100 (29)
	AP	48.0 (12/25)	44.0 (11/25)	4.0 (1/25)	4.0 (1/25)	100 (25)	0 (0/25)	0 (0/25)	16.0 (4/25)	16.0 (4/25)	36.0 (9/25)	32.0 (8/25)	100 (25)
Ankle	DT	26.1 (6/23)	39.1 (9/23)	26.1 (6/23)	8.7 (2/23)	100 (23)	4.4 (1/23)	4.4 (1/23)	21.7 (5/23)	21.7 (5/23)	21.7 (5/23)	26.1 (6/23)	100 (23)

*number of OA joints / number of joints OA observed. †Abbreviations available in Table 1.

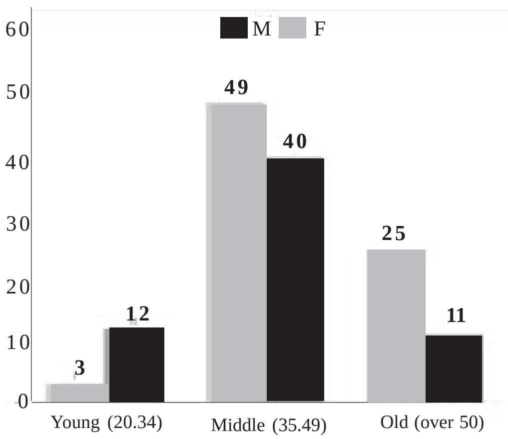

Fig. 2. Demographic profile of current study by sex and age groups. Age estimation is based upon Lovejoy (1985) method

comparing the absolute rates of overall prevalence of degenerative arthrosis in males and females. Significant differences between the sexes were also shown at most of the articular surfaces, including the shoulder joint, proximal ulna of elbow joint, wrist joint, lateral condyle of femur of knee joint, and patellar surface of patellofemoral joint ($p < 0.05$), whereas there were no significant differences between joints on each side. For age group comparisons, the results of chi-square tests showed a significant linear association between degenerative arthrosis and aging ($p < 0.05$).

The joints affected by OA are graphically summarized in Figure 3. Shoulder and hip joints showed the highest OA prevalence of over 20 percent. Among all joints, the elbow joint showed the most remarkable difference in prevalence between right- and left-side limbs. The most rarely affected joints were the ankles on both sides.

The mean intensity grade of affected joints in each age group is represented in Figure 4. Overall, the trend shows that degenerative arthritis in most of the joints increased significantly with advancing age. Among them, the pattern of OA in the lateral condyle in the tibia (LT) exhibited a sharp increase that was not easily observed in any other joints. It is also noteworthy that the patella surface (PS) showed little change regardless of aging.

DISCUSSION

OA is known to occur when the cartilage that cushions the ends of joints gradually deteriorates (Arriaza 2000). When the cartilage wears down completely, the bony end starts to rub with the cartilage of the other side, causing OA in the joints. In general, the degenerative change in joints and bones is influenced by multiple factors including mechanical, biological, and genetic causes (Lieverse et al. 2007). Whereas vertebral OA results from the universal stresses caused over time by bipedalism (Lieverse et al. 2007; Wilczak and Kennedy 1998), OA at limb joints is caused by constant exposure to the

Table 4: Chi-square tests for differences between both-side joints, sex, and age groups

	*Between both sides**		*Between the sexes†*		*Between the ages‡*	
Sites	*Chi-square*	*p-value*	*Chi-square*	*p-value*	*Chi-square*	*p-value*
Glenoid fossa	0.500	0.481	9.235	0.003	7.987	0.005
Proximal humerus	0.167	0.687	13.167	0.000	15.493	0.000
Distal humerus	9.143	0.016	0.025	1.000	18.886	0.000
Proximal ulna	9.143	0.016	8.704	0.004	14.827	0.000
Proximal radius	0.000	1.000	3.192	0.091	6.187	0.023
Distal radius	0.250	1.000	7.986	0.006	17.291	0.000
Acetabular socket	0.056	0.815	2.064	0.163	19.577	0.000
Proximal femur	0.000	1.000	3.840	0.066	11.757	0.001
Medial condyle of femur	0.571	0.453	0.347	0.696	6.457	0.013
Lateral condyle of femur	0.000	1.000	4.702	0.033	10.999	0.001
Patellar surface	0.000	1.000	3.342	0.081	13.936	0.000
Articular surface of patella	0.000	1.000	15.212	0.000	23.426	0.000
Medial condyle of tibia	0.500	1.000	0.546	0.568	0.000	1.000
Lateral condyle of tibia	0.500	0.500	0.764	0.415	3.848	0.063
Distal tibia	0.000	1.000	0.973	0.382	4.597	0.041

*McNemar's test to approximate the binomial exact *p*-value for related samples was performed.
†Fischer's exact test.
‡Chi-square test for trend with Linear by linear association.

activities related to daily living (McAlindon et al. 1999; Martin et al. 2013). The investigation of OA at limb joints of ancient skeletal series therefore provides researchers with a rare opportunity to understand daily life circumstances of premodern peoples.

For living patients, clinicians have developed an effective diagnosis technique, largely based on signs and symptoms of OA such as pain and swelling in the affected joints. However, only the marginal osteophytes and eburnations could be evaluated in archaeologically obtained OA cases of dry bones (Arriaza 2000). In this regard, we used an ordinal scaling system of degenerative changes to diagnose OA cases in the Joseon skeletons following Jurmain's method (1990). To qualify and quantify the severity of OA, we measured the percentage of the total joint surface area affected by degenerative changes.

In this study, the sex groups showed clear differences in OA frequency at each limb joint. As shown in Table 3, OA prevalence in the upper limbs was much higher in males than in females. This tendency became less pronounced moving farther down to the lower limbs. In fact, the upper limbs are known to be free from the innate mechanical stresses (for example, gravity-induced weight bearing), but more related to physical activities of daily life (McAlindon et al. 1999; Debono et al. 2004; Nguyen et al. 1998;

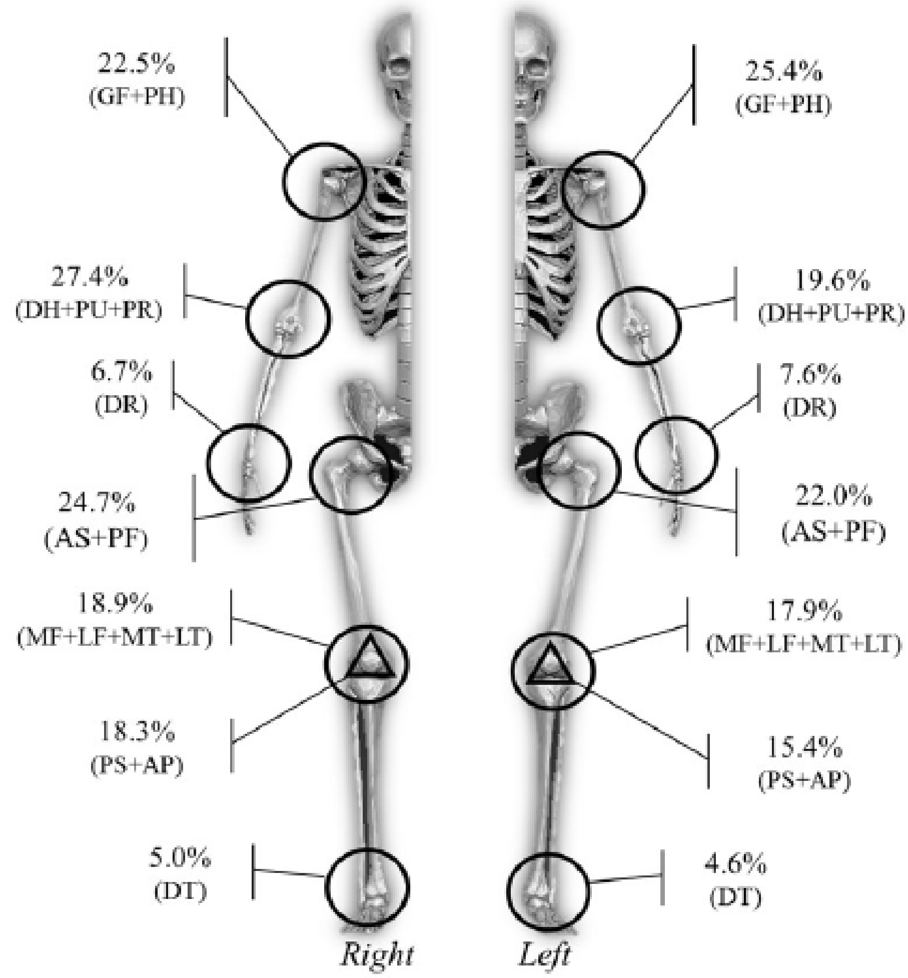

Fig. 3. Joints affected by OA with prevalence rates. Abbreviations available in Table 1

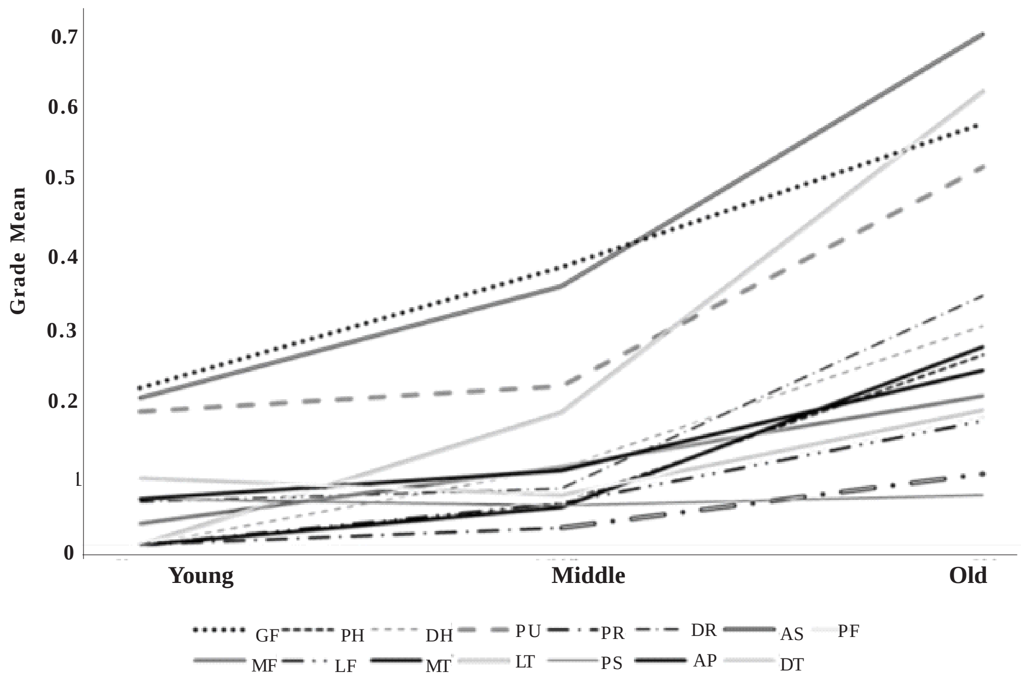

Fig. 4. Grade Mean intensity of the affected joints in each age group. Severity of degenerative arthrosis tends to increase with age in most of joints sites. Abbreviations available in Table 1

Martin et al. 2013). The researchers therefore speculated that the male dominance for OA in the upper limbs in this study might be associated with the men's lifestyle (that is, performing more strenuous work) in pre-modern Korean society (Kim et al. 2013).

The OA prevalence in Joseon people also showed another noticeable pattern in this study. The chi-square tests for aging trends showed that in most joints significant degenerative changes showed a linear correlation over time. However, the OA prevalence in knee joints of Joseon people was much higher in the middle-aged group than in the old-aged group. Considering that knee joint OA was strongly correlated with advancing age in a previous study (Salaffi et al. 2005; Stefanik et al. 2016), further studies should focus on why knee OA was much more prevalent among middle-aged Joseon people than any other age group.

In previous studies on modern populations, the highest OA frequency was reported for knee joints (Cushnaghan and Dieppe 1991; Heine 1926; Park et al. 2003; Waldron 1991; Yu et al.

Table 5: Prevalence comparison between different population groups

Prevalence Ranking	*This study (Joseon)*	*Pre-modern Japan**	*Pre-modern French**	*Modern Germeny†*	*Modern British‡*
1	Shoulder	Elbow	Hip	Knee	Knee
2	Patellafemoral	Patellafemoral	Patellafemoral	Great toe	Hands
3	Hip	Knee	Elbow	Hip	Hip
4	knee	Shoulder	Ankle	Shoulder	Ankle
5	Elbow	Ankle	Wrist	Elbow	Shoulder
6	Wrist	Hip	Shoulder	Acromio-clavicular	Elbow
7	Ankle	wrist	Knee	Sterno-clavicular	Wrist

* Inoue et al. (2001); † Waldron (1991); ‡ Cushnaghan et al. (1991).

2015). When the researchers compared the OA prevalence at each joint in Joseon people with those of different historical and modern populations (Table 5), they found that the OA frequency at knee joints has changed over time and that the tendencies for OA at the knee joints of modern German and British peoples do not match well with those of historical populations (premodern Joseon, Japanese, and French). To explain this discrepancy, the researchers note that OA at knee joints is known to correlate very strongly with obesity (Ortner 2003; Martin et al. 2013); the risk of knee joint OA increases by approximately 15 percent for each kg/m^2 of body mass index above 27 (Sowers 2001). There is also strong evidence that weight loss dramatically reduces the risk of knee joint disease (Felson et al. 1988). Therefore, the increased number of overweight modern peoples might be responsible for the high prevalence of knee joint OA, which could not be observed clearly in historical peoples including the Joseon skeletal series.

Development of OA in a dominant limb is another issue of interest. In short, different stresses on dominant and non-dominant limbs affect the development of OA in a different way. In general, the joint exposed to the dominant use is expected to show a much higher prevalence of OA (Ortner 2003; Lutsky et al. 2016). In this study, however, there were no significant differences between left and right side at all joints. This is consistent with one modern study in which no specific differences of OA prevalence were observed between right- and left-sided joints (Neame et al. 2004).

Socio-economic status of the individuals must inevitably be considered for scientific interpretation of archaeologically obtained skeletons (Schmeling et al. 2000). Most skeletons examined in this study were collected from tombs encapsulated by a lime-soil mixture barrier (Hoegwakmyo), a unique burial system of the Joseon Dynasty. In general, human samples excavated from such tombs are archaeologically classified as the ruling class people of the pre-modern Korean society (Kim et al. 2012). This is consistent with the fact that grade 3 OA was not found at any of the joints in the current study.

Taken together, the prevalence of OA at limb joints revealed in this study provides insights into the mobility patterns of pre-modern Korean people. The prevalence and distribution pattern of OA presented here will contribute to a comprehensive understanding of the activity pattern of Joseon people and adaptive strategies. Moreover, comparison of the prevalence of OA over historical periods provides insight into the etiology of osteoarthritis throughout history.

ACKNOWLEDGEMENTS

This research was supported by the Basic Science Research Program through the National Research Foundation of Korea (NRF-2013R1A1 A2009306) and the Education and Research Encouragement Fund of Seoul National University Hospital (2015).

REFERENCES

Arriaza BT 2000. *The Cambridge Encyclopedia of Human Paleopathology.* Cambridge, United Kingdom: Cambridge University Press.

Bridges PS 1992. Prehistoric arthritis in the Americas. *Annual Review of Anthropology*, 67-91.

Buikstra JE, Ubelaker DH 1994. *Standards for Data Collection from Human Skeletal Remains*. Fayetteville, United States: Arkansas Archeological Survey.

Caballero B 2007. The global epidemic of obesity: An overview. *Epidemiologic Reviews,* 29(1): 1-5.

Cobb S 1999. *The Frequency of the Rheumatic Diseases*. Bloomington, United States: iUniverse.

Crubézy E, Goulet J, Jaruslav B, Jan J, Daniel R, Bertrand L 2002. Epidemiology of osteoarthritis and enthesopathies in a European population dating back 7700 years. *Joint Bone Spine,* 69(6): 580-588.

Cunha E 1996. Osteoarthritis as an indicator of demographic structure of past populations: The example of a Portuguese medieval sample. In: Perez Perez (Eds.): *Salud, enfermedad y muerte en el pasado*. Barcelona/Spain: Romargraf, pp. 149-156.

Cushnaghan J, Dieppe P 1991. Study of 500 patients with limb joint osteoarthritis. I. Analysis by age, sex, and distribution of symptomatic joint sites. *Annals of the Rheumatic Diseases*, 50(1): 8-13.

Debono L, Mafart B, Jeusel E, Guipert G 2004. Is the incidence of elbow osteoarthritis underestimated? Insights from paleopathology. *Joint Bone Spine*, 71(5): 397-400.

Felson DT, Anderson JJ, Naimark A, Walker AM, Meenan RF 1988. Obesity and knee osteoarthritis: The Framingham Study. *Annals of Internal Medicine,* 109(1): 18-24.

Felson DT 1987. Epidemiology of hip and knee osteoarthritis. *Epidemiologic Reviews,* 10: 1-28.

Finzel S, Sahinbegovic E, Kocijan R, Engelke K, Englbrecht M, Schett G 2014. Inflammatory bone spur formation in psoriatic arthritis is different from bone spur formation in hand osteoarthritis. *Arthritis Rheumatol,* 66(11): 2968-2975.

Fransen M, Bridgett L, March L, Hoy D, Penserga E, Brooks P 2011. The epidemiology of osteoarthritis in Asia. *International Journal of Rheumatic Diseases,* 14(2): 113-121.

Heine J 1926. Über die Arthritis deformans. *Virchows Archiv,* 260(3): 521-663.

Inoue K, Hukuda S, Fardellon P, Yang Z, Nakai M, Katayama K, Ushiyama T, Saruhashi Y, Huang J, Mayeda A 2001. Prevalence of large joint osteoarthritis in Asian and Caucasian skeletal populations. *Rheumatology,* 40(1): 70-73.

Jurmain R 2013. *Stories from the Skeleton: Behavioral Reconstruction in Human Osteology.* Oxford, United Kingdom: Routledge.

Jurmain R 1991. Degenerative changes in peripheral joints as indicators of mechanical stress: Opportunities and limitations. *International Journal of Osteoarchaeology,* 1(3-4): 247-252.

Jurmain RD, Kilgore L 1995. Skeletal evidence of osteoarthritis: A palaeopathological perspective. *Ann Rheum Dis,* 54(6): 443-450.

Kim DK, Kim MJ, Kim Y-S, Oh CS, Lee S-S, Lim SB, Ki HC, Shin DH 2013. Long bone fractures identified in the Joseon Dynasty human skeletons of Korea. *Anatomy and Cell Biology,* 46(3): 203-209.

Kim DK, Kim MJ, Kim Y-S, Oh CS, Shin DH 2012. Vertebral osteophyte of pre-modern Korean skeletons from Joseon tombs. *Anatomy and Cell Biology,* 45(4): 274-281.

Krogman WM, Iscan MY 1986. *The Human Skeleton in Forensic Medicine*. Springfield, United States: Charles C. Thomas Publisher Ltd.

Lankov A 2007. *The Dawn of Modern Korea*. Seoul,Korea: EunHaeng NaMu.

Larsen CS, Ruff CB, Kelly RL 1995. Structural analysis of the Stillwater postcranial human remains: Behavioral implications of articular joint pathology and long bone diaphyseal morphology. *Anthropological Papers of the American Museum of Natural History,* 77: 107-133.

Lieverse AR, Weber AW, Bazaliiskiy VI, Goriunova OI, Savel'ev NA 2007. Osteoarthritis in Siberia's Cis Baikal: Skeletal indicators of hunter gatherer adaptation and cultural change. *American Journal of Physical Anthropology,* 132(1): 1-16.

Lovejoy CO, Meindl RS, Pryzbeck TR, Mensforth RP 1985. Chronological metamorphosis of the auricular surface of the ilium: A new method for the determination of adult skeletal age at death. *American Journal of Physical Anthropology,* 68(1): 15-28.

Lutsky K, Kim N, Medina J, Maltenfort M, Beredjiklian PK 2016. Hand dominance and common hand conditions. *Orthopedics.* doi: 10.3928/01477447-201 60 315-02.

Martin KR, Kuh D, Harris TB, Guralnik JM, Coggon D, Wills AK 2013. Body mass index, occupational activity, and leisure-time physical activity: An exploration of risk factors and modifiers for knee osteoarthritis in the 1946 British birth cohort. *BMC Musculoskeletal Disorder,* 14: 219.

McAlindon TE, Wilson PW, Aliabadi P, Weissman B, Felson DT 1999. Level of physical activity and the risk of radiographic and symptomatic knee osteoarthritis in the elderly: The Framingham study. *The American Journal of Medicine,* 106(2): 151-157.

Neame R, Zhang W, Deighton C, Doherty M, Doherty S, Lanyon P, Wright G 2004. Distribution of radiographic osteoarthritis between the right and left hands, hips, and knees. *Arthritis Rheum,* 50(5): 1487-1494.

Nguyen T, Sambrook P, Eisman J 1998. Bone loss, physical activity, and weight change in elderly women: The Dubbo Osteoporosis Epidemiology Study. *Journal of Bone and Mineral Research,* 13(9): 1458-1467.

Ortner DJ 2003. *Identification of Pathological Conditions in Human Skeletal Remains.* Cambridge, United States: Academic Press.

Rogers J, Dieppe P 1994. Is tibiofemoral osteoarthritis in the knee joint a new disease? *Annals of the Rheumatic Diseases,* 53(9): 612-613.

Salaffi F, Carotti M, Stancati A, Grassi W 2005. Health-related quality of life in older adults with symptomatic hip and knee osteoarthritis: A comparison with matched healthy controls. *Aging Clinical and Experimental Research,* 17(4): 255-263.

Schmeling A, Reisinger W, Loreck D, Vendura K, Markus W, Geserick G 2000. Effects of ethnicity on skeletal maturation: Consequences for forensic age estimations. *International Journal of Legal Medicine,* 113(5): 253-258.

Sowers M 2001. Epidemiology of risk factors for osteoarthritis: Systemic factors. *Current Opinion in Rheumatology,* 13(5): 447-451.

Stefanik JJ, Guermazi A, Roemer FW, Peat G, Niu J, Segal NA, Lewis CE, Nevitt M, Felson DT 2016. Changes in patellofemoral and tibiofemoral joint cartilage damage and bone marrow lesions over 7 years: The Multicenter Osteoarthritis Study. *Osteoarthritis Cartilage* doi: 10.1016/j.joca.2016.01.981.

Van Saase J, Van Romunde L, Cats A, Vandenbroucke J, Valkenburg H 1989. Epidemiology of osteoarthritis: Zoetermeer survey. *Annals of the Rheumatic Diseases,* 48(4): 271-280.

Waldron HA 1991. Prevalence and distribution of osteoarthritis in a population from Georgian and early Victorian London. *Ann Rheum Dis,* 50(5): 301-307.

Wilczak CA, Kennedy KA 1998. Mostly MOS: Technical aspects of identification of skeletal markers of occupational stress. In: KJ Reichs (Eds.): *Forensic Osteology Advances in the Identification of Human Remains.* Springfield, United States: Charles C. Thomas Publisher Ltd., pp. 461-490.

Yu D, Peat G, Bedson J, Jordan KP 2015. Annual consultation incidence of osteoarthritis estimated from population-based health care data in England. *Rheumatology,* 54(11): 2051-2060.

Paper received for publication on December 2015
Paper accepted for publication on June 2016