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Does Human Height Have a Correlation with the Risk of Knee Osteoarthritis: A Cross-Sectional Study?

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Abstract

Background: Knee Osteoarthritis (KOA) is more prevalent in Asian population as compared to American and Europeans, and Obesity, measured by Body Mass Index (BMI) is said to be an important risk factor. Body weight alone has been, since ages, highlighted for changes in Body Mass Index (BMI) although BMI has two components: height and weight of the subjects. This study was, therefore, designed to identify the association of height and weight individually with the risk of KOA development.

Method: Eighty non-obese primary KOA subjects were recruited. Anthropometric parameters viz; Height, Weight, BMI, MUAC, TSFT and WHR were recorded. Self- reported VAS score for knee pain and WOMAC scores for pain, stiffness and physical function were recorded to assess clinical severity. X-ray and MRI were performed to assess KL grade and Articular Cartilage Volume (ACV) for radiological severity.

Results: VAS scores had a significant negative correlation with height and positive correlation with BMI. WOMAC pain positively correlated with age and WHR. WOMAC stiffness did not correlate with any of the anthropometric measures. WOMAC physical function and total WOMAC scores had significant negative correlation with WHR. ACV had significant negative correlation with age, BMI and WHR, whereas positive correlation with height. Weight, TSFT and MUAC were not associated with disease severity. Height was the only variable associated with KL grades as it increased with lessening height.

Conclusion: In contrary to all previous studies, Height, not Weight had significant association with the clinical and radiological severity in KOA. Ours would be the first study to report this finding and may offer an explanation that why KOA is more prevalent in Asian population, which is shorter in comparison to American and European.

Keywords: Knee Osteoarthritis; Body Mass Index; Articular Cartilage Volume.

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Introduction

Osteoarthritis (OA) is a persistent debilitating ailment of mobile joints, which most often involves the weight-bearing synovial joints. Sharma et al., (2007) reported OA prevalence between 17%-60.6% based on a community survey in urban and rural areas of India [1]. The rapid increase in the prevalence of this already common disease suggests that OA will have a growing impact on the health care system soon [2]. It is the commonest reason for joint replacement. Among various forms of arthritis, OA is the most quotidian, particularly Knee OA (KOA) followed by hip OA [3]. Due to lifestyle habits, Asians have a higher risk for KOA compared to Americans and Europeans [4].

Pain is the first and predominant clinical feature of KOA. There are a number of scales for assessment of pain such as VAS and WOMAC. The structural changes in KOA are characterized mainly by the progressive erosion and loss of articular cartilage [5]. These changes are often associated with additional structural changes such as subchondral bone lesions, remodelling and cysts, and alterations in the menisci, which include degeneration, tear, and extrusion [6,7]. The first standardized way to determine KOA radiographically is Kellgren and Lawrence (KL) grading which is done by using X- ray. Conventional X-rays have been used and continue to be used to assess some of these changes, particularly in the evaluation of disease progression. However, the use of x-rays to assess and quantify structural changes over time does present some serious limitations, including the fact that this technology does not permit direct visualization of cartilage [8-11]. Magnetic Resonance Imaging (MRI) now allows not only the direct visualization of joint structure but also the quantitative assessment of changes over time. Most of the work has concentrated on the measurement of Articular Cartilage Volume (ACV) and the assessment of changes to evaluate the evolution of OA lesions in cross-sectional and longitudinal studies.

Age, gender and Body Mass Index (BMI) are the most well-known and globally accepted risk factors for KOA, and there is ample evidence in support of these in all the populations [12]. The mechanism and steps involved in the pathogenesis of KOA for each of them have been extensively studied. It is also a fact that whereas age and gender are unmodifiable, BMI may have an important role in modulating the incidence and progression of KOA.

Obesity is suggested to be a causative factor for KOA. Zheng and Chen (2015) conducted a systematic review and meta-analysis to assess the relationship between BMI and the development of KOA by identifying the actual effect sizes. The analysis showed that overweight and obese were approximately 2.5 and 4.6 folds more prone to develop KOA than those with optimal body weight. An increase of 5 kg/m^2 in BMI increases the risk of KOA by 35%. Obesity was found to be an independent predictor of KOA risk and the sub-group analysis revealed that the study country and gender did not predict the effect sizes [13].

Obesity, therefore, is believed to have the strongest association with the development and progression of KOA among all the known risk factors. This association has been explained by two significant theories: biomechanical and systemic/metabolic mechanisms [14]. The biomechanical theory proposes that axial loading increases due to obesity (local effect) which leads to articular cartilage degeneration. In contrast, the metabolic theory suggests that articular cartilage is adversely affected by some metabolic factors and obesity indirectly acts in terms of the bone dimension, muscle and adipose tissue [15]. Muscle mass or strength has been suggested to play a protective role in OA development [16-18].

Extensive research on BMI and associated health risks has led the use of BMI as the measure of overweight. It is important to note that BMI has two components, the height and the weight of the subject. BMI is calculated by dividing the subject’s weight in kilograms by height in meters, squared. Surprisingly, whereas weight has been, since ages, highlighted for changes in BMI and health risks, the height component is very less spoken off or studied and only recently gaining some significance. Literature seems to be relatively quiet on this issue, and we came across through only three studies done so far, which relates to the association of height with incidence or severity of KOA.

It is well known that, Asians are at higher risk to develop KOA than hip OA [19]. Which is more prevalent in other countries such as United States, England and Germany etc. Human height could be a plausible explanation for this difference because people from different countries grow to different heights. Adult height between ethnic groups also differs significantly and the average height for each sex within a country’s population is significantly different, with adult males being (on an average) taller than adult females. According to the U.S. Centres for Disease Control and Prevention (CDC), the average age-adjusted height for American men is 5' 9" tall, and the average height of an American female is 5' 3.5" tall whereas the average age-adjusted height for Indian men is 5' 4.4" tall, and the average height of an Indian female is 5' 0.2" tall. It has been evident that females are at greater risk to develop KOA than males. Thus, there is a possibility that individuals with shorter height are prone for early development of KOA.

In one of our ongoing prospective randomized placebo-controlled study on Vitamin D supplementation and Quality of Life (QoL) in KOA, we found an incidental finding that has not been reported so far and is being presented here. The study was conducted on non-obese KOA subjects to nullify the metabolic and systemic effects of Obesity. The objective of this study was to assess the association of BMI, Height and Weight individually in non-obese KOA subjects with clinico-radiological severity of the disease.

Materials and methods

The present study was conducted in the Department of Orthopaedic Surgery, King George's Medical University (KGMU), Lucknow, India. The Institutional Ethics Committee has approved this study. 80 Subjects of primary Knee Osteoarthritis (KOA) were recruited. A written informed consent was obtained from all the subjects.

Recruitment of subjects

All the subjects attending Orthopaedic Outpatient Department, KGMU with a complaint of chronic knee pain (knee pain > six months) without any history of knee trauma and knee disease underwent evaluation as per inclusion and exclusion criteria to identify cases of primary KOA.

Inclusion criteria

Subjects of either sex diagnosed as KOA as per American College of Rheumatology (ACR) guidelines [20]:

a) Knee pain with osteophytes on X-ray

b) One of the following:

- Crepitus on knee range of motion
- Age 50 years or older
- Morning stiffness < 30 mins

Exclusion criteria

Secondary causes of OA such as trauma, infection, gout, congenital & developmental disorders affecting knee joint and contraindications to MRI (metal implant, claustrophobia, pregnancy)

Demographics / History

Each of the study subjects was exposed to a detailed personal history using a self-designed and pre-tested proforma. This proforma included demographic details such as age, sex, education, occupation, area of residence, socio-economic status. It also had information related to the history of present illness, clinical symptoms, signs, other relevant clinical information, physical activity pattern etc.

Radiological assessment

X-ray and MRI were performed to assess the severity of the disease. The weight-bearing AP radiographs were obtained in full knee extension, and lateral images in the supine position with the knee flexed to 30°. Kellgren and Lawrence (KL) grade of all the radiographs were recorded. Subjects with KL grade 2 or more were recruited. Each subject had an MRI on 1.5 Tesla whole-body magnetic resonance unit using a commercial transmit-receive extremity coil. Articular Cartilage Volume (ACV) was measured by manually drawing disarticulation contours around the cartilage boundary using independent workstation of semi-automated machine GE Signa Excite Advance 4.5. 3D FSPFR sequence was used to calculate ACV.

Clinical assessment

Swelling, crepitus, pain, stiffness and physical function were assessed under clinical assessment. Symptomatic KOA was considered if the subject had knee pain of more than 6-month duration. The severity of knee pain was ascertained by VAS and WOMAC scores.

Anthropometric measurements

All the subjects were assessed for anthropometric measures viz; Height, Weight, Body Mass Index (BMI), Mid Upper Arm Circumference (MUAC), Tricep Skinfold Thickness (TSFT), Waist-Hip Ratio (WHR). Standard protocols given by National Centre for Health Statistics (National Health and Nutrition Examination Survey III Anthropometric Procedures Manual 2007) were followed for these measurements. The mean values of three consecutive measurements were recorded.

Results

The demographic details of the subjects are presented in Table 1. The average values of anthropometric measurements are presented in Table 2. The correlation of anthropometric measures with clinical parameters showed that age had a significant correlation with WOMAC pain, height and BMI with VAS score and WHR with WOMAC pain, physical function and total WOMAC scores. Weight, TSFT and MUAC did not correlate with clinical scores. Age, BMI and WHR had significant negative correlation with ACV whereas height was positively correlated with ACV Table 3. Anthropometric measures weight, TSFT and MUAC were not correlated with ACV. Table 4 shows the association of anthropometric measures of subjects and radiological severity of the disease in terms of KL grades. Height was the only variable associated with KL grade. The data showed that KL grades increased with lessening height. The remaining variables had no significant association with the disease severity.

Table 1: Demographic profile of the study subjects.

Characteristics	Mean ± SD or Frequency (%) (n=80)
Gender	
Male	32 (40%)
Female	48 (60%)
Age (years)	50.93 ± 12.74
Area of residence	
Urban	67 (83.75%)
Rural	13 (16.25%)
Socio- economic status	
Upper	6 (7.5%)
Upper Middle	37 (46.25%)
Middle/ Lower Middle	24 (30%)
Upper Lower/ Lower	13 (16.25%)
Physical activity pattern	
Sedentary	41(51.25%)
Moderate	38 (47.5%)
Heavy	1(1.25%)
Family history of disease	
Yes	26 (32.5%)
No	54 (67.5%)
Duration of illness	
6 months-1 year	35 (43.75%)
1-3 years	23 (28.75%)
3-6 years	11 (13.75%)
>6 years	11 (13.75%)
Nature of pain	
Mild	9 (11.25%)
Moderate	39 (48.75%)
Severe	32 (40%)

Table 2: Anthropometric Assessment.

Anthropometric measurements	Mean ± SD (n=80)	95% CI
Height (meter)	1.56 ± 0.09	1.54-1.57
Weight (kg)	67.09 ± 13.18	64.20-69.97
BMI (kg/m²)	27.35 ± 4.83	26.29-28.40
TSFT (mm)	11.92 ± 1.32	11.63-12.20
MUAC (cm)	12.86 ± 1.53	12.52-13.19
WHR	0.88 ± 0.10	0.85-0.90

SD: Standard Deviation; BMI: Body Mass Index; TSFT: Triceps Skinfold Thickness; MUAC: Mid Upper Arm Circumference; WHR: Waist- Hip Ratio; CI: Confidence Interval.

Table 3: Correlation of Anthropometric measures with clinical scores and ACV (n=80).

Variables	VAS	WOMAC pain	WOMAC stiffness	WOMAC physical function	Total WOMAC	ACV
Age	0.124	.221*	0.08	0.142	0.171	-.448*
Height	-.378*	-0.123	0.059	-0.216	-0.19	.379*
Weight	-0.09	0.041	0.071	-0.005	0.015	0.057
BMI	.216*	0.125	0.039	0.132	0.137	-.207*
TSFT	0.032	0.074	0.024	-0.016	0.008	-0.061
MUAC	0.038	-0.003	0.044	-0.062	-0.044	0.069
WHR	-0.133	.284*	-0.137	-.223*	-.258*	-.271*

VAS: Visual Analogue Scale; WOMAC: The Western Ontario and Mc Master Universities Osteoarthritis Index; ACV: Articular Cartilage Volume; BMI: Body Mass Index; TSFT: Triceps Skinfold Thickness; MUAC: Mid Upper Arm Circumference; WHR: Waist- Hip Ratio; *Significant p- value.

Table 4: Association of Anthropometric measures with KL grade.

Anthropometric Measures	KL Grade 2 (n=25) (Mean±SD)	KL Grade 3 (n=34) (Mean±SD)	KL Grade 4 (n=21) (Mean±SD)	p-value
Height	1.60 ± 0.09	1.55 ± 0.10	1.53 ± 0.08	0.027*
Weight	66.88 ± 11.19	68 ± 15.01	65.89 ± 12.68	0.846
BMI	25.65 ± 3.71	28.14 ± 5.23	28.02 ± 4.99	0.117
TSFT	11.83 ± 1.18	11.93 ± 1.38	12.02 ± 1.42	0.883
MUAC	12.80 ± 1.47	13.08 ± 1.52	12.58 ± 1.64	0.49
WHR	0.90 ± 0.10	0.89 ± 0.89	0.84 ± 0.10	0.097

KL grade: Kellgren and Lawrence grade; BMI: Body Mass Index; TSFT: Triceps Skinfold Thickness; MUAC: Mid Upper Arm Circumference; WHR: Waist- Hip Ratio; * Significant p- value.

Discussion

The prevalence of Osteoarthritis (OA) appears to vary between ethnic groups. The prevalence of Tibio-femoral OA (KOA) was significantly higher in the Asian than in the Caucasian skeletal populations [19]. The factors responsible for this difference may be known or unknown risk factors for KOA. Among the known factors in modern epidemiology, only knee-bending [21-24] has so far been said to explain this discrepancy. Any other factor has not been explored so far.

BMI is commonly measured for risk assessment of many health problems. An association of increased BMI has been found with coronary heart disease, Type II diabetes mellitus, hypertension, cancer and arthritis. Individuals with suboptimal BMI also have increased health and mortality risks and are likely to experience compromised psychological health [13,25,26]. The use of BMI is common in clinical practice and biomedical research, however, it is not certainly an ideal indicator of individual health. Limitations of BMI have been highlighted in specific sub-populations including children, teenagers, elderly and ethnic minority patients, and suggested the use of alternative anthropometric measures. Despite these limitations, BMI is easy to calculate and is the commonest tool to correlate the weight of the individuals with health related risks at the population level.

Relationship of BMI and Obesity with KOA is known since ages and is well established. In one of our ongoing study on Knee Osteoarthritis (KOA), we found an incidental finding that has not been reported so far. We did not find any association of weight with KOA, and instead, a significant association was found with the height of subjects. We came across through only three studies so far, which relates to the association of height with incidence or severity of KOA. All these studies are varyingly different from ours are not comparable, and are being presented here.

One of the prospective studies investigated the association of height, weight and BMI with the risk of primary knee and hip replacements in middle-aged women. A significant trend was observed in the association between height and both knee and hip replacements (p<0.0001). They expressed two possibilities for their finding; intrauterine or early childhood factors (such as nutrition in early life) may influence the development of bone and subsequent adult height, and like BMI, the biomechanics can also be a plausible explanation for this association. They explained that the length of the limbs and joint might exert different forces on the articular joint resulting into increased wear and tear [27].

The Beijing Osteoarthritis Study aimed to investigate the association of knee height and pain, with KOA among Beijing residents of >60 years of age. Subjects with radiographic KOA and pain in the same joint were considered for the study and referred as symptomatic KOA. The association of knee height was explored with the knee symptoms independent of structural alterations and a significant association of was observed. The prevalence of symptomatic KOA increased with increase in height and it affects the knee symptoms irrespective of radiographic changes in KOA. The observations were more significant in case of female subjects as compared to males which is in accordance with the female predisposition for KOA and the conception of the female knee joint susceptibility. This study demonstrates the significance of mechanical forces in the assessment of knee symptoms and KOA [28].

The last study we could find was The Northern Finland Birth Cohort 1966 Study, which analysed the association of height with osteoarthritis of the knee and hip: (Welling et al 2017). The individuals having knee or hip OA in the age group of 31-46 years were the cases and those without knee or hip OA were controls in the study. Height and weight of the subjects were recorded as the part of the clinical examination at baseline. An independent samples t-test was performed to compare the average heights of the cases and the controls. The risk of OA in different height quartiles was calculated by Cox regression analysis. The variables adjusted at baseline were education, BMI/weight, leisure-time physical activity, and smoking. This prospective cohort study demonstrated the association between body height and KOA incidence. Subjects with greater height at 31 years were more likely to develop KOA before 46 years of age [29].

In our study, four out of seven anthropometric measures studied (Age, Height, BMI and WHR) had a significant correlation with ACV. The remaining variables and Weight had no significant association with disease severity. We found that the height, weight, TSFT and WHR were significantly different between male and female participants. There was a near to significant difference in BMI between both the genders. The correlation of anthropometric measures with clinical parameters showed that age had a meaningful relationship with WOMAC pain, height and BMI with VAS score and WHR with WOMAC pain, physical function and total WOMAC scores. Weight, TSFT and MUAC did not correlate with clinical scores and ACV.

Contrary to all the above studies, Height was the only anthropometric variable associated with KL grade and lesser the height more were the KL grades (radiological severity). Shorter individuals were more prone to developing KOA and had more severe disease both in terms of clinical scores (VAS) and radiological severity (KL grades and ACV).

Whereas we are the first to report this incidental finding, we tried to explore the possible reason for this. In a literature search, we came across a new paper on BMI relating weight to height differently in women and older adults. In this serial cross-sectional survey, an inverse association between height and BMI was found in adults and more so in women with advancing age. The height, weight relationship was analysed by regression using log (weight) as the response and record (height) as the predictor. In early childhood, the excess of weight for height is negligible in shorter individuals, and increases with aging indicating an inversion of BMI and height relation at puberty. They, therefore, theorized that the BMI is dependent on height as taller individuals were gaining more weight in childhood and shorter throughout the lifespan [30]. This perhaps could explain the findings in our study.

Conclusion

In contrary to all previous studies, Height, not Weight, was significantly associated with both the clinical (VAS) and radiological severity (KL grades and ACV) in KOA. This finding is being reported for the first time and is not only interesting but may also pre-empt an explanation that why KOA is more prevalent in Asian population (shorter in height) in comparison to American and European, who are taller and prone to hip OA instead of KOA. Although premature, a very pertinent question thus arises that whether Obesity measured by BMI scales as a risk factor in KOA has been overemphasized and height, which could in itself be an important predictor has been neglected or underestimated so far.

References

1. Sharma MK, Swami HM, Bhatia V, Verma A, Bhatia S, et al. An epidemiological study of co-relates of osteoarthritis in geriatric population of Chandigarh. Indian Journal of Community Medicine. 2007; 32: 77-78.

2. Lawrence RC, Felson DT, Helmick CG, Arnold LM, Choi H, et al. Estimates of the prevalence of arthritis and other rheumatic conditions in the United States: Part II. Arthritis & Rheumatism. 2008; 58: 26-35.

3. Felson DT, Lawrence RC, Dieppe PA, Hirsch R, Helmick CG, et al. Osteoarthritis: New insights. Part 1: The disease and its risk factors. Annals of Internal Medicine. 2000; 133: 635-646.

4. Fransen M, Bridgett L, March L, Hoy D, Penserga E, et al. The epidemiology of osteoarthritis in Asia. International Journal of Rheumatic Diseases. 2011; 14: 113-121.

5. Martel-Pelletier J, Lajeunesse D, Pelletier JP. Etiopathogenesis of osteoarthritis. In: Arthritis and Allied Conditions: A Textbook of Rheumatology Edited by: Koopman WJ, Moreland LW. Baltimore, MD: Lippincott, Williams & Wilkins. 2005: 2199-2226.

6. Berthiaume MJ, Raynauld JP, Martel-Pelletier J, Labonté F, Beaudoin

G, et al. Meniscal tear and extrusion are strongly associated with the progression of knee osteoarthritis as assessed by quantitative magnetic resonance imaging. Ann Rheum Dis. 2005; 64: 556-563.

7. Sowers MF, Hayes C, Jamadar D, Capul D, Lachance L, et al. Magnetic resonance-detected subchondral bone marrow and cartilage defect characteristics associated with pain and X-ray-defined knee osteoarthritis. Osteoarthritis Cartilage. 2003; 11: 387-393.

8. Amin S, LaValley MP, Guermazi A, Grigoryan M, Hunter DJ, et al. The relationship between cartilage loss on magnetic resonance imaging and radiographic progression in men and women with knee osteoarthritis. Arthritis Rheum. 2005; 52: 3152-3159.

9. Ding C, Garnero P, Cicuttini F, Scott F, Cooley H, et al. Knee cartilage defects: association with early radiographic osteoarthritis, decreased cartilage volume, increased joint surface area and type II collagen breakdown. Osteoarthritis Cartilage. 2005; 13: 198-205.

10. Hayes CW, Jamadar DA, Welch GW, Jannausch ML, Lachance LLet al. Osteoarthritis of the knee: Comparison of MR imaging findings with radiographic severity measurements and pain in middle-aged women. Radiology. 2005; 237: 998-1007.

11. Raynauld JP, Martel-Pelletier J, Berthiaume MJ, Beaudoin G, Choquette D, et al. Long term evaluation of disease progression through the quantitative magnetic resonance imaging of symptomatic knee osteoarthritis patients: Correlation with clinical symptoms and radiographic changes. Arthritis Res Ther. 2006; 8: R21.

12. Ding C, Cicuttini F, Scott F, Cooley H, Jones G. Knee structural alteration and BMI: a cross-sectional study. Obesity research. 2005; 13: 350-361.

13. Zheng H, Chen C. Body mass index and risk of knee osteoarthritis: Systematic review and meta-analysis of prospective studies. BMJ open. 2015: 5.

14. Sanghi D, Srivastava RN, Singh A, Kumari R, Mishra R, et al. The association of anthropometric measures and osteoarthritis knee in non-obese subjects: A cross sectional study. Clinics. 2011; 66: 275-279.

15. Hartz AJ, Fischer ME, Bril G, Kelber S, Rupley Jr D, et al. The association of obesity with joint pain and osteoarthritis in the HANES data. Journal of chronic diseases. 1986; 39: 311-319.

16. Toda Y, Segal N, Toda T, Kato A, Toda F. A decline in lower extremity lean body mass per body weight is characteristic of women with early phase osteoarthritis of the knee. J Rheumatol. 2000; 27: 2449-2454.

17. Slemenda C, Brandt KD, Heilman DK, Mazzuca S, Braunstein EM, et al. Quadriceps weakness and osteoarthritis of the knee. Ann Intern Med. 1997; 127: 97-104.

18. Slemenda C, Heilman DK, Brandt KD, Katz BP, Mazzuca SA, et al. Reduced quadriceps strength relative to body weight: a risk factor for knee osteoarthritis in women? Arthritis Rheum. 1998; 41:1951-1959.

19. Inoue K, Hukuda S, Fardellon P, Yang ZQ, Nakai M, et al. Prevalence of large-joint osteoarthritis in Asian and Caucasian skeletal populations. Rheumatology. 2001; 40: 70-73.

20. Altman R, Asch E, Bloch D, Bole G, Borenstein D, et al. Development of criteria for the classification and reporting of osteoarthritis: Classification of osteoarthritis of the knee. Arthritis & Rheumatism: Official Journal of the American College of Rheumatology. 1986; 29: 1039-1049.

21. Cooper C, McAlindon T, Coggon D, Egger P, Dieppe P. Occupational activity and osteoarthritis of the knee. Ann Rheum Dis. 1994; 53: 90-93.

22. Anderson JJ, Felson DT. Factors associated with osteoarthritis of the knee in the first national health and Nutrition Examination Survey (HANES-1). Am J Epidemiol. 1988; 128: 179-189.

23. Felson DT, Hannan MT, Naimark A, Berkeley J, Gordon G, et al. Occupational physical demands, knee bending, and knee osteoarthritis: Results from the Framingham Study. The Journal of rheumatology. 1991; 18: 1587-1592.

24. Kivimaki J, Riihimaki H, Haninen K. Knee disorders in carpet and floor layers and painters.Scand J Work Environ Health. 1992; 18: 310-316.

25. Nuttall FQ. Body mass index: obesity, BMI, and health: A critical review. Nutrition today. 2015; 50: 117-128.

26. Chernenko A, Meeks H, Smith KR. Examining validity of body mass index calculated using height and weight data from the US driver license. BMC public health. 2019; 19: 100.

27. Liu B, Balkwill A, Banks E, Cooper C, Green J, et al. Relationship of height, weight and body mass index to the risk of hip and knee replacements in middle-aged women. Rheumatology. 2007; 46: 861-867.

28. Hunter DJ, Niu J, Zhang Y, Nevitt MC, Xu L, et al. Knee height, knee pain, and knee osteoarthritis: the Beijing Osteoarthritis Study. Arthritis & Rheumatism. 2005; 52: 1418-1423.

29. Welling M, Auvinen J, Lehenkari P, Männikkö M, Karppinen J, et al. Association between height and osteoarthritis of the knee and hip: The Northern Finland Birth Cohort 1966 Study. International Journal of Rheumatic Diseases. 2017; 20: 1095-1104.

30. Sperrin M, Marshall AD, Higgins V, Renehan AG, Buchan IE. Body mass index relates weight to height differently in women and older adults: Serial cross-sectional surveys in England (1992–2011). Journal of Public Health. 2016; 38: 607-613.