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Geometric Measurements of the Proximal Femur in UK Women: Secular Increase Between the Late 1950s and Early 1990s

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Abstract. The aim of this study was to determine whether hip axis or femoral length has increased in women in the United Kingdom between the late 1950s and early 1990s. Such an observation would be of interest as it might explain the rise in age-specific incidence of hip fracture observed during these years. We studied two sets of antero-posterior pelvic radiographs of women aged 55–69 years taken during the course of population-based studies in the UK, one in 1958–60 and the other in 1989–91. One observer (S.G.) recorded the following measurements at the right hip: hip axis length (HAL), femoral length (FL) and femoral width (FW). Two summary ratios, HAL/FW and FL/FW were calculated to allow for differences in radiographic technique. HAL, FL and FW were greater in the 1989–91 films compared with those taken in 1958–60. Both HAL and FL expressed as a ratio to FW were also greater in the later films. FL/FW increased by 4.5% ($p<0.05$); HAL/FW increased by 2.3%, though this was not statistically significant. We conclude that there has been a small apparent change in geometric measurements of the hip during the past 36 years. Cautious extrapolation suggests that such a change may explain up to one third of the increase in incidence of hip fracture observed during this period.

Keywords: Epidemiology; Hip axis length; Hip fracture; Osteoporosis; Secular change

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Introduction

There is evidence from a number of population studies that the age-specific incidence of hip fracture has risen over the last 50 years [1–4]. In the United Kingdom, for example, the incidence of hip fracture doubled between 1954–58 and 1983 [1]. The explanation for this secular change is unknown. Possible reasons include a secular change in the level of risk factors for osteoporosis, such as increasing physical inactivity; a birth cohort effect; or increasing frailty amongst the elderly [5].

Recent studies have demonstrated that hip axis length (the distance from the medial aspect of the pelvis to the lateral aspect of the femur along the axis of the femoral neck) is independently associated with an increase in the risk of hip fracture [6]. Reid et al. [7], in a study in New Zealand, found an apparent increase in hip axis length during the past 40 years, and of a magnitude which could have accounted for the increase in incidence of hip fracture. The radiographs evaluated, however, were derived from hospital records and may thus not be representative of the general population.

We studied pelvic radiographs of women from two cross-sectional population surveys conducted 31 years apart. The aim of the analysis was to determine whether there had been an increase in geometric measurements of the hip between the late 1950s and early 1990s and whether this might explain the increased incidence of hip fracture observed in the UK during this time period.

Subjects and Methods

Two groups of antero-posterior pelvic radiographs from women aged 55–69 years, taken 31 years apart during the course of population-based studies, were evaluated.

In 1958–60 the Arthritis and Rheumatism Council's Epidemiology Unit carried out a population-based survey of osteoarthritis in Wensleydale, a rural area in the North of England. A sample of these subjects had antero-posterior pelvic radiography. The main results with regard to osteoarthritis have been published elsewhere [8]. The films have been stored since then and were available to us for study. The radiographs were obtained using portable radiographic equipment. Details concerning the film–focus distance used were unavailable.

The recent radiographs were taken during the course of a population survey of 1035 women for musculoskeletal disease in Chingford, North London [9]. Women aged 45–69 years were recruited from the age–sex register of a large general practice. Pelvic radiographs were taken during 1989–91 using a standard protocol, in 15 degrees of internal rotation and with a film–focus distance of 100 cm. For the purpose of this study a group of 62 films were chosen randomly from the films of those aged 55–69 years.

All measurements were made at the right hip by one observer (S.G.) using a fine transparent ruler. The line of the hip axis was defined as passing through the midpoint of the femoral neck and the point on the femoral head furthest from the midpoint of the neck. The femoral length was defined as the distance along the line of the hip axis from the lateral aspect of the femur to the line joining the superior and inferior extremes of the hip joint (Fig. 1) [7].

To adjust for possible differences in film magnification between the surveys we also measured the femoral width, defined as the shortest distance across the femoral neck, at right angles to the line of the hip axis (Fig. 1).

Reproducibility of these measurements was tested by the original observer (S.G.) reassessing 12 hips at least 5 days after the first reading and a separate observer (T.O'N.) assessing the same 12 films. The mean difference both within observers (Table 1) and between observers (Table 2) varied from 2 mm to 8 mm for all measurements and the confidence limits around the mean difference embraced zero, indicating that there were no systematic differences or bias between observers.

Table 1. Intra-observer agreement: repeat measurement of 12 hips by the same observer (S.G.)

Variable	95% range of agreement	Mean difference (95% CI)
Hip axis length (cm)	(−3.79, 3.95)	0.83 (−1.03, 1.20)
Femoral length (cm)	(−2.38, 3.72)	0.67 (−0.24, 1.55)
Femoral width (cm)	(−1.30, 0.96)	−0.17 (−0.49, 0.16)

Table 2. Inter-observer agreement: Measurements of 12 hips by two observers (S.G. and T.O'N.)

Variable	95% range of agreement	Mean difference (95% CI)
Hip axis length (cm)	(−4.91, 5.24)	0.17 (−1.03, 1.63)
Femoral length (cm)	(−4.17, 5.84)	0.83 (−0.61, 2.28)
Femoral width (cm)	(−1.14, 1.97)	0.42 (−0.03, 0.86)

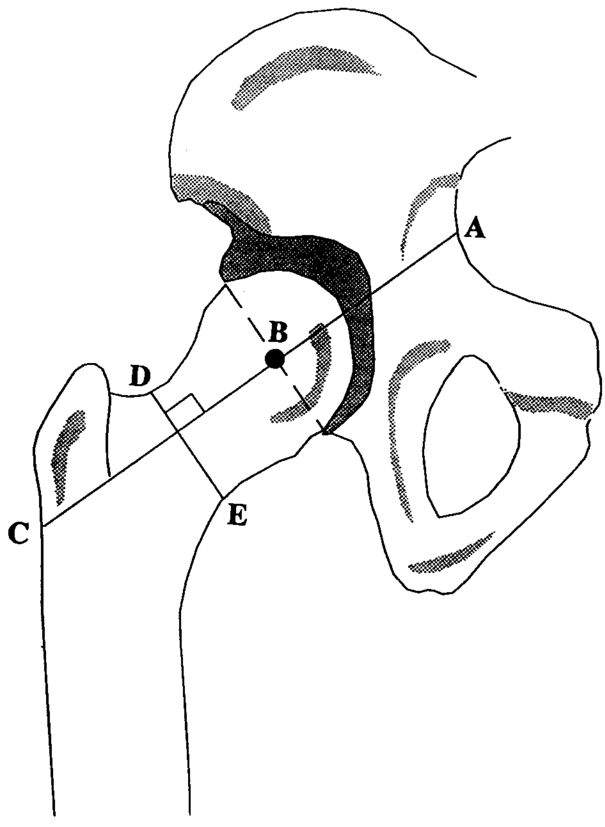

Fig. 1. Right hip joint. Hip axis length (HAL) = AC; femoral length (FL) = BC; femoral width (FW) = DE.

Statistical Analysis

Two summary ratios were defined: hip axis length to femoral width (HAL/FW) and femoral length to femoral width (FL/FW). Absolute differences in hip axis length, femoral length and femoral width, and the summary ratios between the two time periods, were compared using *t*-tests. Analysis of covariance was used to adjust for differences in height between the two populations. A *p* value of less than 0.05 was taken to denote statistical significance. Statistical analysis was performed using GLIM 3.77 [10].

Results

Subjects

Sixty-six radiographs from the 1958–60 study and 62 radiographs from the 1989–91 study were assessed. There was no difference in the mean age of the subjects studied (62.3 years (SD 4.2) vs 62.7 years (SD 5.3)); however, mean height was smaller in subjects in the earlier study (156.8 cm vs 160.6 cm; diff = −3.8 cm: 95% CI −5.9, −1.6).

Differences in Geometric Measurements of the Proximal Femur

The mean hip axis and femoral length measurements were significantly greater in the later films (Table 3); however, the mean femoral neck width was also greater. This in part reflects differences in body size between the two populations, though also differences in the film–focus distance used in the two surveys: an increase in film–focus distance is associated with an apparent decrease in the observed measurements due to magnification.

To take account of any magnification effect we divided both hip axis (HAL) and femoral length (FL) by femoral width (FW) to obtain the ratios, or shape parameters, HAL/FW and FL/FW. Both these ratios were unrelated to body height: beta coefficient (β) = 0.00358 ($p = 0.37$); $\beta = 0.00095$ ($p = 0.77$) for the two ratios respectively (Table 4). Both ratios were greater in the later films, though the confidence interval around the difference in mean HAL/FW failed to exclude zero (Table 3). The significance of the relationship between survey group and both HAL/FW and FL/FW did not change after adjusting for height (Table 4). The results indicate that there has been a small alteration in the shape of the hip over the last 30 years, with an increase in femoral length compared with femoral width and a non-significant increase in hip axis length compared with femoral width. The results are equivalent to a relative increase between the surveys in HAL/FW of 2.3% (diff = 0.08 units: 95% CI −0.18, 0.02) and in the FL/FW of 4.5% (diff = 0.10 units: 95% CI −0.17, −0.03).

Secular Change in Hip Axis and Femoral Length

It seems likely that the observed change in shape parameters is related to an increase in hip axis and femoral length, rather than a reduction in femoral width. Such an increase in hip axis and femoral length between the two populations may be related to: (1) a magnification effect due to differences in film–focus

Table 3. Mean (SD) dimensions of the proximal femur; 1958–60 and 1989–91

Dimensions	1958–60 (*n*=66)	1989–91 (*n*=62)	Mean difference (95% CI)
Hip axis length (mm)	124.4 (9.3)	136.2 (9.9)	−11.8 (−15.20, −8.44)
Femoral neck			
Length (mm)	81.00 (6.8)	90.26 (7.5)	−9.26 (−11.80, −6.76)
Width (mm)	36.64 (2.9)	39.08 (2.3)	−2.44 (−3.36, −1.52)
Hip axis length/ femoral width	3.41 (0.3)	3.49 (0.3)	−0.08 (−0.18, 0.02)
Femoral length/ femoral width	2.22 (0.2)	2.32 (0.2)	−0.10 (−0.17, −0.03)

Table 4. Relationship between body height, survey group and the shape parameters HAL/FW and FL/FW: univariate and multivariate models

Model variables	Dependent variable					
	HAL/FW			FL/FW		
	β	SE (β)	*p* value	β	SE (β)	*p* value
Univariate						
(i) Height	0.00358	0.00401	0.37	0.00095	0.00318	0.77
(ii) Survey group	0.08384	0.05080	0.10	0.09421	0.03980	0.02
Multivariate						
(iii) Height + survey group	0.00180	0.00418	0.37	−0.00135	0.00327	0.76
	0.07705	0.05335	0.15	0.09932	0.04180	0.02

HAL/FW, hip axis length to femoral width ratio; FL/FW, femoral length to femoral width ratio; β, beta coefficient.

distance, (2) differences in body size, or (3) a secular change in measurement. To assess the size of any secular change in hip axis or femoral length we needed to adjust firstly for any magnification effect and secondly for differences in body size.

To estimate the size of the magnification effect we studied the change in femoral width between surveys. Data from a previous study indicated no secular change in femoral width during the past 30 years. We assumed, therefore, that after adjusting for differences in body height, the observed difference in femoral width would provide an estimate of the magnification effect. After adjusting for body height, using an analysis of covariance, the observed difference in femoral width between populations was 1.88 mm, corresponding to an increase in measurement between the earlier and later films of 5%.

To permit direct comparisons in hip axis length between the two surveys the 1958–60 HAL and FL values were adjusted firstly by this magnification factor and secondly by body height. After making these adjustments the difference between centres, and thus the presumed secular increase, was 3.1 mm for hip axis length and 3.9 mm for femoral length.

Discussion

Our data confirm the findings from an earlier study of an apparent increase in geometric measurements at the hip between the late 1950s and the early 1990s [7].

There are a number of methodological issues to be considered in interpreting the results of this study. One of the main advantages was that the subjects were drawn from population samples of Caucasian women. The populations differed, however, in a number of respects (Chingford: suburban, southern England; Wensleydale: rural, northern England), and it is possible that these or other environmental differences rather than temporal change may have accounted in part for the observed findings. Subjects in the later survey were taller; however, this did not appear to explain the observed changes in geometric measurements.

Because of the difference in radiological technique used in the two surveys the crude measurements of both hip axis and femoral length were not directly comparable. Our main conclusions are therefore based on the ratios of these lengths to femoral width. It is possible that the differences in ratios between films may be due to a reduction in femoral width. This seems unlikely, however, as in the only previous published study available there was no change in femoral width in films taken 35 years apart [7].

The increase in ratios between the surveys was greater for femoral length compared with hip axis length. The reason for this is unclear. One explanation is that mild disease at the hip joint which could affect hip axis length may have been more marked in the earlier films, though the prevalence of hip osteoarthrosis in both groups was low (<5%). Another possibility is that the increase occurred predominantly at the proximal femur and thus was more apparent in the measurement of femoral length.

How do these results compare with the New Zealand data? Comparing the later films in both studies (1990s), the absolute values for the ratios were larger in the UK, though the percentage change between the early and later films was smaller (HAL/FW 2.3% vs 4.0%; FL/FW 4.5% vs 5.2%) [7]. It is possible that minor differences in measurement technique, such as placement of the femoral neck point, could have accounted for the absolute differences in measurement. The smaller percentage difference in ratios may reflect the slightly shorter time difference between films in this compared with the New Zealand study and the younger age of those studied (62 vs 70 years).

How may our findings be interpreted? There are no prospective data concerning the effect of femoral length on the risk of hip fracture. Our conclusions are therefore based on the observed changes in hip axis length. Although the apparent change in hip axis length was not statistically significant the measurement is closely correlated with femoral length, for which the change was significant, and thus the increase in hip axis length is likely to be real.

If, as in a previous study, it is assumed that the absolute femoral width measurement has remained constant over the last 30 years, and taking into account differences in body size, the increase in hip axis length between surveys was estimated at 3.1 mm. While not statistically significant the difference is equivalent to 0.3 standard deviations of the hip axis length measurement as determined from the earlier films. Faulkner et al. [6] reported that the risk of hip fracture increased nearly twofold for each standard deviation change from the mean value. Our data are thus consistent with an approximate 20%–25% increase in risk of hip fracture as a result of the change in hip axis length. Using UK data, Boyce and Vessey [1] reported a twofold increased incidence in hip fracture between 1954–58 and 1983, while Spector et al. [2] found that the age-specific incidence of hip fracture (aged 44 years and over) increased by about 61% in women between 1968 and 1985. Thus the observed increase in hip axis length may explain up to one third of the increased incidence of hip fracture. This is smaller than the twofold increase as determined in a previous study and highlights the importance of factors other than hip geometry, such as changes in levels of physical activity, in explaining the recent secular rise in incidence of hip fracture.

In summary there is evidence of a small apparent increase in geometric measurements of the femur between the late 1950s and early 1990s. These changes are less marked than have been previously reported. Cautious extrapolation of the data suggests that the increase in hip axis length may have contributed approximatley one third of the secular increase in the age-specific incidence of hip fracture observed during this time period.

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