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# Predicting radiographic hip osteoarthritis from range of movement

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## Abstract

*Objectives*. The primary objective was to test the hypothesis that new attenders in primary care with hip pain and radiographic osteoarthritis (OA) have a decreased range of movement compared with those without OA. The secondary objective was to define the planes of movement and thresholds that were the most discriminatory for OA.

*Methods*. Men and women aged 40 yr and over presenting with a new episode of hip pain were recruited from 36 general practices across the UK. A standardized radiographic and clinical examination was performed. The discriminating ability of the range of movement for each plane to identify those with radiographic OA was assessed using receiver operating characteristic curves.

*Results*. New hip pain attenders with radiographic OA had restricted movement at the hip compared with those without radiographic change. Restriction in internal rotation was the most predictive and flexion the least predictive of radiographic OA. At this cut-off, restriction in any single plane had a sensitivity of 86% for moderate and 100% for severe OA (specificity was 54 and 42% respectively). Restriction in all three planes had greater discrimination (sensitivity was 33% for mild to moderate OA and 54% for severe OA; specificity was 93 and 88% respectively).

*Conclusions*. Restriction in range of movement was predictive of the presence of OA in these new presenters to primary care with hip pain, and the results of this examination could be used to inform decisions regarding radiography.

KEY WORDS: Osteoarthritis, Hip, Range of movement, Prediction.

Although hip pain is common in the community, population studies have shown that it has only a weak relationship with hip osteoarthritis (OA) [1, 2]. Restriction of the range of motion has been proposed as a useful diagnostic tool [3, 4]. There have been a number of studies assessing the role of joint examination, in combination with other variables, to classify or diagnose hip OA, but these have been based on referral patient populations [5–7]. In such patients, restriction in the range of movement may be of little aid in diagnosis [8, 9].

There are four main reasons why the range of movement needs to be studied in relation to the diagnosis of OA in an unselected population of new hip pain presenters. First, hip pain is difficult to define clinically and restriction of movement may better inform the decision to X-ray and hence avoid unnecessary radiographs. Secondly, the wide normal variation in the range of hip movement and the presence of limitation resulting from other painful conditions means that there is uncertainty whether restriction has a high positive predictive value for painful OA. Thirdly, the actual threshold or cut-off of maximal discrimination for each plane of movement for OA needs to be established. Finally, there are several planes of movement that can be examined, but it is not known whether these provide equivalent information with regard to the diagnosis of OA.

The primary objective of this study was to test the hypothesis that new attenders in primary care with hip pain and radiographic OA have a decreased range of movement compared with those without OA. The secondary objective was to define which movements and thresholds were the most discriminatory for radiographic OA. Such information might inform the

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decision on which attenders with hip pain should be radiographed in the primary care setting.

## Subjects and methods

### *Subjects*

This was a multicentre study of patients presenting with new episodes of hip pain in primary care. General practitioners (GPs) were recruited from all over the UK and asked to enrol consecutive new attenders aged 40 yr or older with hip pain. There were 36 participating GPs, all of whom were members of the Primary Care Rheumatology Society, and so had a particular interest in musculoskeletal pain. The practices were divided between urban and rural areas and had between two and nine partners. Ethical approval was secured locally for each practice before the study began.

### *Definition of hip pain*

As no standardized definition of hip pain exists, a working case definition was derived by a consensus group including the study coordinators and GPs, and was validated by pilot testing. It was defined as pain within a preshaded area on a standardized pain drawing (Fig. 1) which, on clinical assessment by the GP, was not arising from structures outside the hip (e.g. the low back, the trochanteric bursa). The use of a pictorial instrument ensured a standard determination of the area to be regarded as affected by 'hip pain', enhancing the internal validity of the case definition. Replaced hips were excluded as the index joint.

The aim was to study disease as early as possible in its natural history once it was severe enough to prompt a visit to the doctor. As hip pain is a recurrent, episodic problem, a new episode inevitably had to be defined by an arbitrary time cut-off. Thus, based on record review, only those who had not previously attended the GP with the current pain or in the previous 12 months with any hip pain were included.

### *Examination*

A standard examination protocol was developed by an iterative process, to minimize observer variability. The aim was to produce a protocol which was easy to learn, quick enough to use in a busy surgery and reliable both within and between observers. Details of the development of the examination routine have been described elsewhere. Good inter-observer reliability had been demonstrated for these movements in a study using a Latin square design [10] with six of the GP participants in the present study. This work showed that, of the six possible planes of movement (flexion/extension, adduction/abduction, internal/external rotation), only three could be measured reliably between primary care observers participating in this study. These were flexion, internal rotation and external rotation. Intraclass

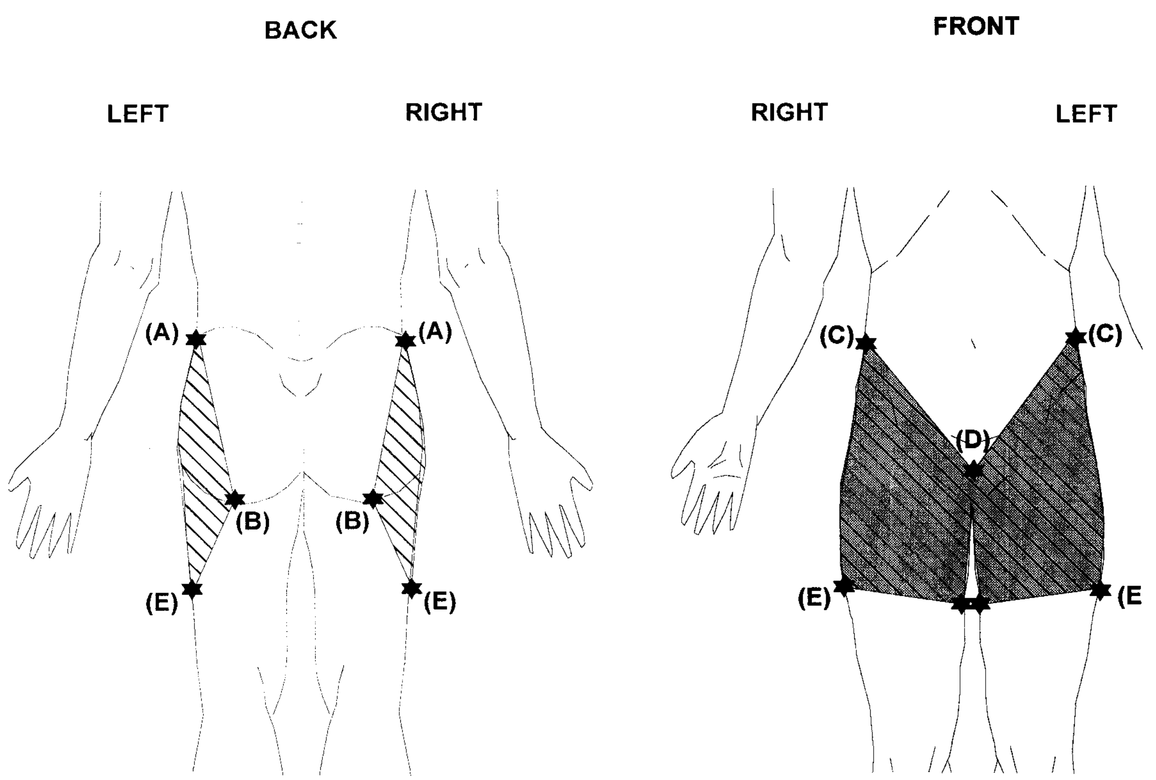


FIG. 1. Standardized pain drawing for hip pain. A, iliac crest; B, ischial tuberosity; C, anterior superior iliac spine; D, pubic tubercle; E, one-third of the way down the spine.

correlation (ICC) coefficients between observers ranged from 0.43 to 0.87. Furthermore, there was no systematic bias between them [10]. Each of the planes of movement was measured using a fluid plurimeter (Dr J. Rippstein, La Conversion, Switzerland) attached to a specially designed footplate. This instrument has an adjustable 360° dial on which the horizontal position of a fluid level can be read. In the neutral position, for each movement, the dial is rotated to zero and the position of the fluid level on the dial is then read at the end of the movement. Flexion was measured with the patient supine, from neutral to maximal passive flexion, with the knee maintained in flexion unless precluded by coexistent knee pain. Sitting internal and external rotation were measured from neutral to maximal passive excursion (Fig. 2).

*Radiographic evaluation*

An anteroposterior pelvis radiograph was requested for each subject; a set of standard instructions was given to the radiology departments used by the recruiting practices. As there is no consensus definition for radiographic OA [11], X-rays were graded both for Croft's modification of the Kellgren and Lawrence grade and for minimal joint space (MJS) [12]. Gradings were made by two independent observers, blinded to the clinical status of the subject, with adjudication of any discrepancies made by a third observer. In a pilot study there was good agreement both within (Croft, kappa = 0.81; MJS, ICC = 0.83) and between observers (Croft, kappa = 0.79, MJS, ICC = 0.75).

*Analysis*

The relationship between restriction in a plane of motion and radiographic abnormality was analysed using a number of definitions of restriction. The quintiles of the distributions were chosen as the subdivisions, giving four possible cut-offs for each plane. Analyses were undertaken using two thresholds for radiographic severity: mild to moderate OA, Croft grade $\geqslant 2$; severe OA, MJS $\leqslant 1.5$ mm. The sensitivity, specificity and likelihood ratio were calculated for each restriction threshold for both these grades of OA. As the cut-off became more stringent, as expected, the sensitivity

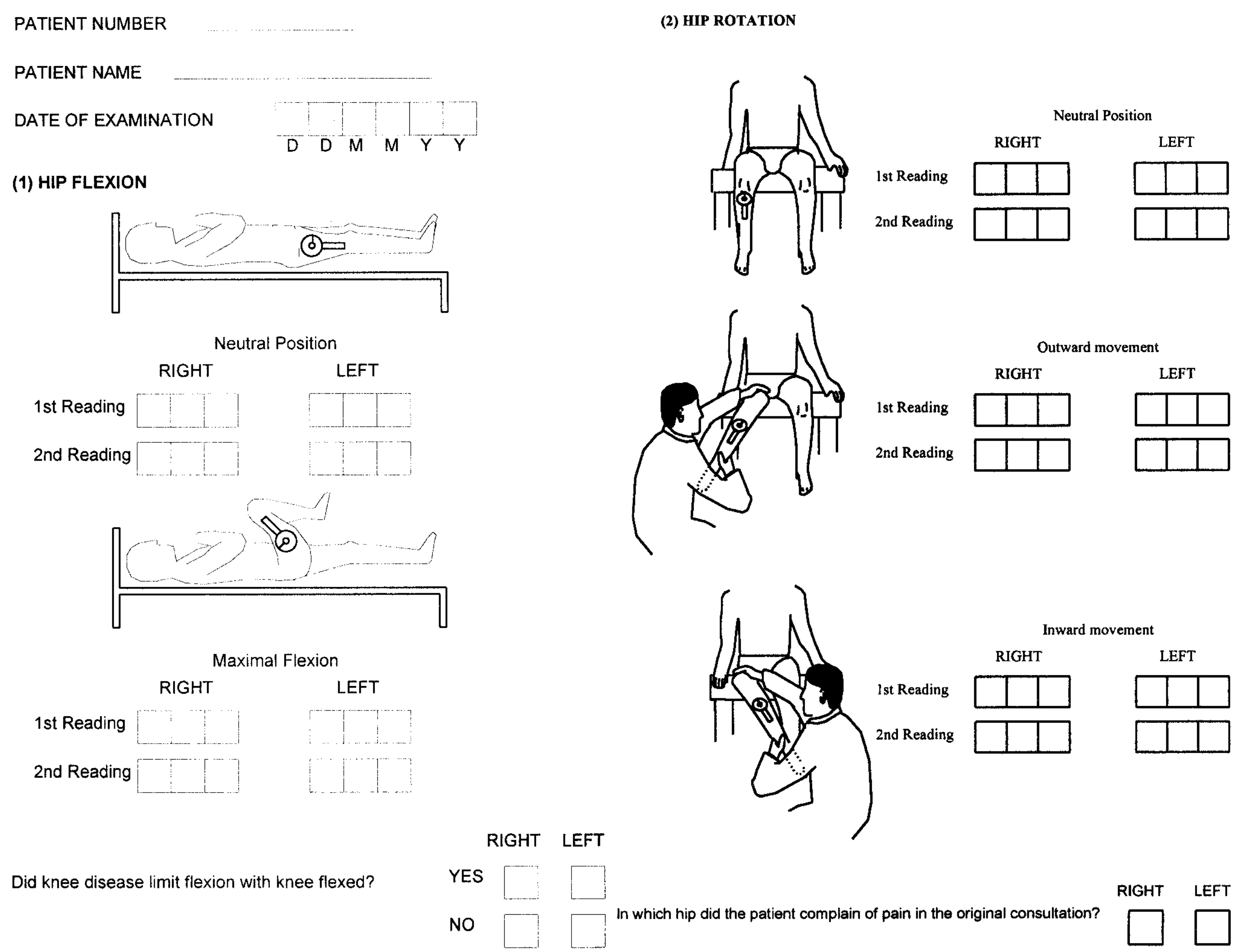


FIG. 2. Hip movement recording form.

decreased as specificity increased. The results were displayed graphically using receiver operating characteristic (ROC) curves, with the optimal cut-off chosen as the shoulder of the ROC curve, at the point of maximum sensitivity and specificity.

To determine if combinations of movements were more discriminatory than restriction in a single plane, a further analysis was performed. The number of planes with restricted movement, based on the optimal cut-off defined above, was derived for each subject. The sensitivity, specificity and likelihood ratios were then compared by the number of planes with restricted movement. Finally, a multivariate analysis was performed using logistic regression to adjust for the potential confounding effects of age and sex on the relationship between range of movement and radiographic change. Analysis was performed using Stata statistical software (release 5.0 for Windows 95; Stata Corporation, College Station, TX, USA).

## Results

The demographic data of the study population are summarized in Table 1. The median age of the study sample of new hip pain attenders was 63 yr and two-thirds were female.

The range of movement for each plane is shown in Table 2 by age and gender. In this population of hip pain patients, external rotation showed no variation with age or sex, but the data suggest a greater restriction in flexion and in internal rotation for males and those aged over 63 yr, the median age. The quintiles of the distribution for all subjects are shown in Table 3 and the relationship between these thresholds and the presence of OA is illustrated as ROC curves for the prediction of mild to moderate OA (Fig. 3) and severe OA (Fig. 4). The movement with the best discrimination for both radiographic definitions was internal rotation. The area under the curves as shown, in general, were substantially larger for severe than for moderate OA. Indeed, internal rotation below the third quintile threshold (28°) identified all subjects with severe OA.

The shoulder of the ROC curves allows the point of best overall discrimination to be identified. From these data, this corresponded consistently to the second quintile threshold (40th percentile) for each of the examination measures (internal and external rotation both $\leqslant 23°$, flexion $\leqslant 94°$). At this cut-off, the likelihood ratio for the detection of OA was between 1.9 and 2.9 for each of the three movements.

The influences of combining restrictions using the second quintile cut-offs in more than one plane for mild to moderate OA are shown in Table 4 and for severe OA in Table 5. The results were similar for both grades of OA. The presence of restriction of any one movement at the second quintile was sensitive for both mild to moderate and severe OA but the corresponding specificities were low (54 and 42% respectively). As the stringency of threshold increased, with increasing number of planes with restriction there was a progressive gain in the likelihood ratios. Thus, the improvement in specificity outweighed the loss of sensitivity.

The association between radiographic change and movement restriction index at these cut-offs was analysed after adjusting for possible confounders of age (by quartile), gender and body mass (by tertile). The results (Table 6) showed only weak relationships, with wide confidence intervals between restriction of flexion and external rotation. However, restriction in internal rotation remained strong, particularly for severe disease. Interestingly, movement in this plane was little influenced by age (Table 2).

TABLE 1. Characteristics of the study population

| | |
|---|---|
| Number of patients | 195 |
| Age (yr): median (IQR) | 63 (54, 71) |
| Females: *n* (%) | 132 (68) |
| Height (m): median (IQR) | 1.64 (1.59, 1.71) |
| Weight (kg): median (IQR) | 71 (63, 83) |
| Body mass index (kg/m$^2$) | 26 (24, 30) |

IQR, interquartile range.

TABLE 2. Distribution of range of movement in the planes examined

| Plane | All subjects ($n = 195$) | Males ($n = 63$) | Females ($n = 132$) | Age 43–63 yr ($n = 98$) | Age 64–86 yr[a] ($n = 97$) |
|---|---|---|---|---|---|
| Flexion | 98° (84°, 110°) | 96° (86°, 104°) | 100° (82°, 112°) | 102° (92°, 112°) | 92° (80°, 106°) |
| External rotation | 26° (20°, 32°) | 25° (20°, 31°) | 26° (20°, 34°) | 26° (20°, 34°) | 24° (18°, 32°) |
| Internal rotation | 28° (20°, 34°) | 22° (16°, 30°) | 30° (21°, 36°) | 30° (20°, 36°) | 26° (18°, 34°) |

Values are median (interquartile range).
[a]Dichotomized at median.

TABLE 3. Quintile thresholds for the planes of movement examined

| | Quintile threshold | | | |
|---|---|---|---|---|
| Plane | First (20th percentile) | Second (40th percentile) | Third (60th percentile) | Fourth (80th percentile) |
| Flexion | 80° | 94° | 103° | 113° |
| External rotation | 16° | 23° | 28° | 35° |
| Internal rotation | 16° | 23° | 28° | 36° |

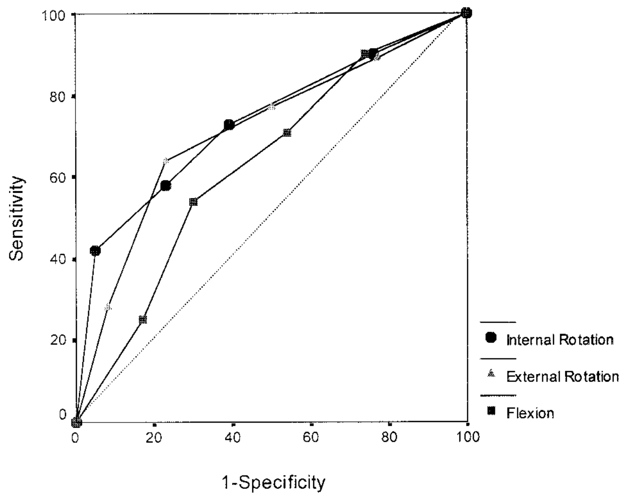


FIG. 3. ROC curve for mild to moderate OA (Croft grade ⩾2). The first and fourth quintile thresholds are marked.

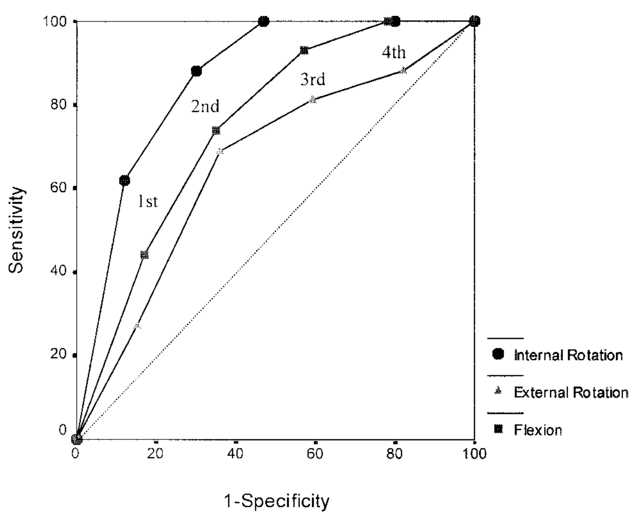


FIG. 4. ROC curve for severe OA (minimum joint space ⩾1.5 mm). The first and fourth quintile thresholds are marked.

TABLE 4. Association between number of planes with restricted movement and presence of OA: mild to moderate OA (Croft grade ⩾ 2)

| Threshold of number of planes with restricted movement[a] | Correct identification of mild to moderate OA | | |
|---|---|---|---|
| | n (sensitivity %) | n (specificity %) | Likelihood ratio |
| 0 | 84 (100) | 0 (0) | 1 (referent) |
| 1 | 72 (86) | 57 (54) | 1.9 |
| 2 | 47 (57) | 82 (77) | 2.5 |
| 3 | 27 (33) | 99 (93) | 5.0 |
| Total | 84 with OA | 166 without OA | |

[a]Defined as below second quintile.

TABLE 5. Association between number of planes with restricted movement and presence of OA: severe OA (minimum joint space ⩽1.5 mm)

| Threshold of number of planes with restricted movement[a] | Correct identification of severe OA | | |
|---|---|---|---|
| | n (sensitivity %) | n (specificity %) | Likelihood ratio |
| 0 | 26 (100) | 0 (0) | 1 (referent) |
| 1 | 12 (100) | 69 (42) | 1.7 |
| 2 | 21 (81) | 112 (69) | 2.6 |
| 3 | 14 (54) | 142 (88) | 4.4 |
| Total | 26 with OA | 164 without OA | |

[a]Defined as below second quintile.

TABLE 6. Logistic modelling from movements predicting radiographic change: minimal joint space

| | Radiographic grade | | | |
|---|---|---|---|---|
| | Severe OA | | Mild to moderate OA | |
| Predictor | Odds ratio | 95% CI | Odds ratio | 95% CI |
| Gender | | | | |
| Male | 1 | Referent | 1 | Referent |
| Female | 1.4 | 0.5, 4.0 | 1.4 | 0.7, 3.0 |
| Age (yr) | | | | |
| 43–53 | 1 | Referent | 1 | Referent |
| 54–63 | 0.3 | 0.1, 1.4 | 0.8 | 0.3, 2.1 |
| 64–70 | 0.5 | 0.1, 2.3 | 1.0 | 0.4, 2.8 |
| 71–86 | 1.5 | 0.3, 7.6 | 1.5 | 0.5, 4.0 |
| Body mass index | | | | |
| <24.4 | 1 | Referent | 1 | Referent |
| 24.4−28.1 | 1.1 | 0.3, 4.2 | 1.2 | 0.5, 2.9 |
| >28.1 | 0.5 | 0.1, 2.1 | 0.5 | 0.2, 1.2 |
| Flexion restriction[a] | 1 | Referent | 1 | Referent |
| | 2.6 | 0.8, 8.9 | 1.5 | 0.7, 3.2 |
| External rotation restriction[a] | 1 | Referent | 1 | Referent |
| | 1.2 | 0.3, 3.9 | 3.0 | 1.4, 6.2 |
| Internal rotation restriction[a] | 1 | Referent | 1 | Referent |
| | 46.8 | 5.2, 420.0 | 3.6 | 1.6, 8.0 |

[a]Defined as below second quartile.
CI, confidence interval.

## Discussion

In patients newly presenting in primary care with hip pain, we investigated if those with and without radiographic evidence of OA differed with respect to the presence of restriction of three planes of movement. Not surprisingly, the differences observed were more marked for severe than for mild to moderate OA and were most apparent for internal rotation. Restriction to below the 40th percentile for all movements examined proved to be the optimal cut-off, of those analysed, for discriminating between disease groups. Age, in particular, influenced both the likelihood of OA and joint restriction. However, after adjusting for age and the other potential confounders—gender and body mass index—the main findings still held.

There are some methodological issues which must be considered in interpreting the data. First, this was a multicentre study, recruiting patients from several primary care physicians, which would introduce variation in patient attendance and GP referral. We attempted to overcome this by using a standardized approach to defining hip pain. The consensus of the GP participants was to use a standardized approach to anatomical localization (Fig. 1) but also to permit them to use their clinical judgement to decide if the pain was coming from the hip. This approach has the advantage of face validity (for these participants). The study recruited a large number of GPs in an attempt to also maximize the external validity of the findings. Further comparison of the data (not shown) between GPs showed no appreciable influence on the likelihood of radiographic change. In addition, the results from this survey can only be extrapolated to subjects of the category studied here, i.e. new attenders at primary care. In particular, the sensitivity and specificity will vary as the hip pain patients become more selected, as will be the case in clinic referrals.

Secondly, minor differences may have arisen in the examination of the subjects. We have previously shown good inter-observer reliability, as discussed above, for the range of hip movements studied [10]. Although intra-observer reliability was not tested in that study because of the difficulty of blinding, this is likely to be at least as good in clinical practice. Furthermore, it might be expected that any measurement errors are likely to have been random and will have tended to reduce the power of the study to detect a difference, rather than to have influenced the conclusions. While reliable measurement of planes of motion that were not analysed here might improve the prediction of radiographic change, our previous work was unable to demonstrate adequate inter-observer reliability for the movements of adduction, abduction or extension [10]. Finally, errors may have been introduced through errors in radiographic grading, although these were minimized by the use of accepted techniques and the same trained observers, who were blind to the examination results [12].

There have been few previous studies determining whether range of motion is predictive of radiographic change, either in the hip or other joints. In such studies that have been attempted there were methodological problems in three main areas: the validation of measurements, arbitrary criteria of restriction, and the selection of the patient groups used.

First, none of the studies that reported on the usefulness of the range of movement as a criterion for the diagnosis or classification of hip OA quoted validated methods of joint measurement [4–6]. Secondly, the criteria for abnormality in movement were selected arbitrarily and required, for example, restriction of three out of seven movements, plus joint-space narrowing *and* osteophytosis without systematic consideration of item or threshold selection [5]. Finally, as the definitions of restriction were developed for selected patient groups referred to specialist clinics [4–6], this influences their external validity: independent testing of these criteria confirm that they do not perform as well as expected [8, 9].

This study used new presenters with hip pain to examine which validated examination measures can predict radiographic change. A systematic approach was taken to the definition of the best thresholds for discrimination to maximize the robustness of the predictive model. The results support the use of a validated measure of hip movement in predicting the presence of radiographic OA. Further studies to confirm this finding and to test whether restricted hip movement predicts outcome, such as progression to hip arthroplasty, would be appropriate.

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