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Geographical variation in the provision of elective primary hip and knee replacement: the role of socio-demographic, hospital and distance variables

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ABSTRACT

Background To explore inequalities in the provision of hip/knee replacement surgery and produce small-area estimates of provision to inform local health planning.

Methods Hospital Episode Statistics were used to explore inequalities in the provision of primary hip/knee operations in English NHS hospitals in 2002. Multilevel Poisson regression modelling was used to estimate rates of surgical provision by socio-demographic, hospital and distance variables. GIS software was used to estimate road travel times and create hospital catchment areas.

Results Rates of joint replacement increased with age before falling in those aged 80+. Women received more operations than men. People living in the most deprived areas obtained fewer hip, but more knee operations. Those in urban areas received less hip surgery, but there was no association for knee replacement. Controlling for hospital and distance measures did not attenuate the effects. Geographical variation across districts was observed with some districts showing inequality in socio-demographic factors, whereas others showed none at all.

Conclusions This study found evidence of inequalities in the provision of joint replacement surgery. However, before we can conclude that there is inequity in receipts of healthcare, future research must consider whether these patterns are explained by variations in need across socio-demographic groups.

Keywords access, geographical variation, hip replacement, hospital admission, inequality, knee replacement

Introduction

Inequality in health and healthcare is recognized as an important health policy issue. The UK government has published many white papers and reports over the past decade.[1–4] Recently, the UK Secretary of State for Health announced a comprehensive strategy for reducing health inequalities,[5] addressing unjustified gaps in health status, fair access to NHS services for everyone and good outcomes of care for all.

Joint replacements make a substantial contribution to public health and are among the most common elective procedures. They are cost-effective,[6,7] with good prosthesis survival rates,[8,9] reducing pain, increasing mobility and improving quality of life.[10–17] Previous studies demonstrated evidence of inequalities in the provision of hip and knee replacement. Rates of surgery increase with age then fall in the oldest age groups, and women receive more operations than men.[18–31] More affluent groups receive greater provision of hip[18,19,29,32,33] and knee replacement.[18] Utilization of hip replacement is higher in rural areas,[26,31,34] and US studies found Whites are more likely to get surgery than other ethnic groups.[19,21,22,27,31,35,36]

Many of these studies included all joint operations rather than elective procedures,[19–24,32,35–38] some studies focus only on one socio-demographic domain, statistical methods used in some studies are weak,[38] and only one study explored geographical variation in provision.[36] Finally, with

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the exception of studies examining correlations between hospital characteristics and utilization rates,[38,39] no other studies have looked at whether hospital and distance measures explain inequalities in provision by socio-demographic group. We incorporate such variables into a multilevel regression model using Geographical Information Systems (GIS) methods.[40]

The objectives of our study are to comprehensively explore inequalities in the provision of elective primary hip and knee replacement including provider and distance characteristics and to demonstrate how small-area estimates of provision can be provided to inform local health planning.

Methods

Information on joint replacement operations is provided by the Hospital Episode Statistics (HES) database, which holds information on patients admitted to NHS hospitals in England, either as day-cases or ordinary admissions. Each record relates to one 'finished consultant episode'—the period of time an individual spends under the care of one NHS consultant. Private procedures are excluded from HES as there is no requirement for private hospitals to provide routine data (∼20% of hip and knee operations are carried out in private institutions[41]).

Data on all hip and knee replacement operations occurring in the financial year 2002 were extracted from the HES database held at the University of Bristol. Episodes involving total joint replacement surgery were identified as those with any of the following OPCS4 codes W37, W38, W39 (hip joint) or W40, W41, W42 (knee joint) recorded in any of the procedure fields.

The following exclusions were made to remove potential case-mix issues from the sample as such people are different from those receiving planned elective surgery: revision operations identified as episodes with a primary diagnosis indicating complications due to internal prostheses (ICD-10 codes: T84 or T85); episodes containing a diagnostic code indicating cancers of the hip and knee bones (ICD-10 codes: C40, C795) in any of the diagnostic fields; diagnostic codes indicating fracture of the hip and knee bones (ICD-10 codes: S321, S322, S323, S324, S325, S327, S328, S72, S82); codes indicating other injuries due to trauma, such as transport accidents and falls (external cause ICD-10 codes: V01-V99, W00-W19); and non-elective admissions.

Three sets of exposure variables were explored.

Socio-demographic variables

Patient level variables are age groups (50–54, 55–59, 60–64, 65–69, 70–74, 75–79, 80–84 and 85+) and sex. Ecological variables were linked to the Census Area Statistics (CAS) ward the patient lives in: Index of Multiple Deprivation (IMD) 2004 deprivation quintiles[42] (weighted to the ward population as each ward varies in size). The index was constructed by the Social Disadvantage Research Centre at the University of Oxford through combining seven domain indices of deprivation using the following weights: income (22.5%), employment (22.5%), health deprivation and disability (13.5%), education, skills and training (13.5%), barriers to housing and services (9.3%), crime (9.3%), living environment (9.3%), rurality (urban ≥10 k; Town & Fringe; village/isolated), ethnic mix of the area (White [≥10% White and ≤0.5% Black, Asian and other], Asian [≥10% White and ≤10% Asian and ≤0.5% Black and other], Black [≥10% White and ≤10% Black and ≤0.5% Asian and other], other [≥10% White and ≤10% other and ≤0.5% Asian and Black] and mixed [all remaining groups]).

Hospital characteristics

A hospital provider code identified the NHS trust performing the operation. We derived: (i) the trust workload by estimating the annual volume of hip and knee replacement operations performed in each hospital in 2002 (quintiles); (ii) if it was an orthopaedic training centre by using information from the British Orthopaedic Association website; (iii) total number of consultants; (iv) number of Trauma & Orthopaedic (T&O) consultants; (v) number of Anaesthetic consultants, for each hospital in 2002, by using the Department of Health (DoH) Census of Medical and Dental Workforce; (vi) number of available and occupied beds; (vii) bed occupancy rate; (viii) number of operating theatres; (ix) number of dedicated day-case theatres were obtained from DoH KH03 and KH12 returns.

Data on hospital characteristics is provided in the form of absolute numbers, e.g. the number of T&O consultants in each NHS trust. Hospital characteristics are not comparable in this format as such information must be related to the population of the catchment area a hospital serves. Using GIS software ArcView 3.3, for each hospital trust, Thiessen polygons were used to create catchment areas based on the area of residence for patients who had a joint operation in 2002.[43] A map of census wards was overlaid with a map of hospital catchment areas, and the proportion of the ward that lies within each catchment area was calculated. Each hospital was assigned the proportion of the population of each ward that lies within its catchment area. Hospital characteristics were then expressed as rates per 100 000 catchment population.

Distance measures

A map of the road network in England was obtained using the DigiMap service at Edina. Ward centroids were the start points and hospitals performing joint replacement were the end points, which were linked to the road network. To estimate road travel times, average speeds were assigned to Motorways, A, B and minor roads, in urban/rural areas.[44] A network path analysis was solved using GIS transportation software Base TransCAD, estimating the minimum road travel time, from each CASward in England to the nearest hospital performing joint replacement.

Statistical methods

The data set was collapsed into a cross-tabulation of counts by 5-year age groups, sex and by all CASwards in England. The number of procedures was available at CASward level, hence explanatory variables included in the model must also be available at CASward level. This was the case for the ecological and distance variables. We created ward level hospital variables as follows. If the centroid of a ward lies in a hospital's catchment area, we allocated the hospital's characteristics to that ward. The denominator was population counts by 5-year age groups, sex and CASward.

The hierarchical structure of the data has individuals in age–sex group i, within CASward j, within district k (the 7969 CASwards nested within 354 districts). A random-intercepts Poisson regression model was fitted using the Multilevel modelling software MLwiN. This controls for evidence of clustering in the data, by allowing the overall rate of joint replacement to vary across wards and districts.[45] Failure to control for evidence of clustering can lead to estimates of standard errors that are spuriously precise and be a potential source of bias. An offset term is included to allow for the size of the population in each ward, age and sex group. Extra-Poisson variation was specified to allow for evidence of overdispersion that remains after controlling for clustering. Analyses are conducted separately for hip and knee replacement.

Univariable analyses were conducted to obtain crude rate-ratios that explore the association between rates of joint replacement and each of the socio-demographic, hospital and distance variables. Multivariable analyses were then fitted to obtain adjusted rate-ratios, using a backwards selection process to remove variables that do not improve model fit. Wald tests are used to explore linear trends. Effect modification is considered to explore *a priori* interactions between age, sex, deprivation and rurality.[18,20,26,34] Random-slopes models are then individually fitted for each socio-demographic variable to see if their effects vary across districts. To produce predicted rates of provision in each district, the chosen models are re-fitted using the Bayesian software WinBUGS to provide estimates of precision around the predictions that incorporate uncertainty arising from the joint estimation of model parameters. Small-area predictions are produced by adding the mean of the linear predictor in each district to the estimate of residual district variation to obtain the overall predicted rate in each district.

Results

Socio-demographic inequalities and distance measures

The crude rate-ratios showed a marked increase with age for both hip and knee replacements, though with a fall off for those aged 80+ (Table 1). The age effect was more marked for knee replacements. Men receive less provision than women for both procedures but this was more marked for hip replacement. For hip replacement, there was weak evidence of a trend with area deprivation, where patients in poorer areas did not receive more procedures, but this was not true for knee replacements where the highest rates were seen in the third deprivation quintile. There was no evidence of differences by ethnicity for either procedure. For hip replacement, non-urban residents received more provision, whereas the reverse was seen for knee replacement. Although there was no effect of distance on rates of knee replacement, paradoxically, those living further away had a greater risk of getting hip replacement.

Multivariable models showed that adjustment for other variables did not have much effect on the patterns of the crude rate-ratios, though in some cases, e.g. gender difference for knee replacement, there was some attenuation.

Evidence of interaction was apparent (online Supplementary material Fig. S2). The effect of gender varied with age. Women received greater provision of hip replacement across all age groups, but this effect was weakest in the youngest and oldest groups. For knee replacement, women received more operations in all age groups except those aged 85+ where men got greater provision. An interaction between deprivation and age was observed for both hip and knee joints. In those aged 50–59, provision increased with increasing levels of deprivation; the most deprived getting more provision. This attenuates with age, and by age 85+, the opposite was seen, with provision 'decreasing' with increasing levels of deprivation; the most deprived received less provision. For hip replacement, the effect of gender was the same across different rurality groups, but was stronger in urban areas.

Table 1 Crude and adjusted rates of admission for primary hip and knee replacement operations (2002) in England by socio-demographic and distance variables

	THR		*TKR*	
	Crude RR (95% CI)	*Adjusted RR* (95% CI)*	*Crude RR (95% CI)*	*Adjusted RR* (95% CI)*
Socio-demographic characteristics				
Age groups				
50–54	1.00	1.00	1.00	1.00
55–59	2.31 (2.18, 2.45)	2.30 (2.17, 2.44)	3.07 (2.85, 3.31)	3.07 (2.85, 3.31)
60–64	4.08 (3.87, 4.31)	4.08 (3.85, 4.32)	6.27 (5.86, 6.72)	6.27 (5.85, 6.71)
65–69	6.10 (5.78, 6.43)	6.08 (5.76, 6.42)	10.43 (9.76, 11.15)	10.41 (9.74, 11.13)
70–74	6.99 (6.63, 7.37)	6.92 (6.55, 7.31)	13.52 (12.65, 14.45)	13.44 (12.57, 14.36)
75–79	6.81 (6.45, 7.20)	6.69 (6.33, 7.06)	15.09 (14.12, 16.13)	14.95 (13.99, 15.98)
80–84	6.53 (6.16, 6.93)	6.33 (5.97, 6.71)	12.43 (11.58, 13.34)	12.24 (11.41, 13.14)
85+	3.16 (2.94, 3.39)	2.99 (2.79, 3.21)	4.82 (4.44, 5.23)	4.71 (4.33, 5.11)
P linear trend	<0.001	<0.001	<0.001	<0.001
Sex				
Female	1.00	1.00	1.00	1.00
Male	0.73 (0.72, 0.75)	0.77 (0.75, 0.78)	0.85 (0.83, 0.87)	0.91 (0.89, 0.93)
IMD2004				
Least deprived	1.00	1.00	1.00	1.00
2	1.06 (1.02, 1.10)	1.04 (1.01, 1.08)	1.07 (1.03, 1.12)	1.04 (1.00, 1.08)
3	1.07 (1.02, 1.11)	1.05 (1.01, 1.09)	1.17 (1.12, 1.22)	1.13 (1.09, 1.17)
4	1.03 (0.98, 1.07)	1.02 (0.97, 1.06)	1.15 (1.10, 1.20)	1.09 (1.04, 1.14)
Most deprived	0.94 (0.89, 0.99)	0.94 (0.90, 0.99)	1.11 (1.06, 1.17)	1.05 (1.00, 1.10)
P linear trend	0.021	0.036	<0.001	0.006
Ethnic mix of area				
White	1.00	1.00	1.00	1.00
≤10% Asian	1.00 (0.95, 1.04)	1.02 (0.97, 1.06)	0.96 (0.93, 1.00)[§]	0.97 (0.94, 1.01)[§]
≤10% Black	0.96 (0.89, 1.03)	0.98 (0.91, 1.05)		
≤10% other	0.99 (0.93, 1.05)	1.00 (0.94, 1.06)		
Mixed	0.93 (0.89, 0.96)	0.98 (0.95, 1.02)		
Rurality				
Urban >10k	1.00	1.00	1.00	1.00
Town & Fringe	1.10 (1.06, 1.14)	1.07 (1.02, 1.11)	0.98 (0.94, 1.03)	1.00 (0.96, 1.04)
Village/isolated	1.05 (1.01, 1.10)	1.05 (1.01, 1.10)	0.93 (0.89, 0.98)	0.99 (0.95, 1.03)
P linear trend	0.001	0.008	0.003	0.66
Measures of distance to hospital				
Road travel times (min)				
1 (1.79–12.85)	1.00	1.00	1.00	—
2 (12.86–20.07)	1.05 (1.01, 1.08)	1.03 (0.99, 1.06)	1.01 (0.98, 1.05)	—
3 (20.08–30.10)	1.07 (1.03, 1.12)	1.04 (1.00, 1.09)	1.03 (0.99, 1.07)	—
4 (30.11–45.89)	1.15 (1.10, 1.20)	1.10 (1.05, 1.15)	1.02 (0.97, 1.07)	—
5 (45.91–225.76)	1.18 (1.12, 1.25)	1.11 (1.05, 1.17)	0.99 (0.94, 1.05)	—
P linear trend	<0.001	<0.001	0.73	—

THR, total hip replacement; TKR, total knee replacement; RR, rate ratio; CI, confidence interval.

*Hierarchical Poisson regression model fitted in MLwiN allowing for clustering across CASwards and Districts, adjusted for socio-demographic, hospital and distance variables.

[§]Ethnic mix variable simplified to White vs. non-White for knee model.

Hospital characteristics

For hip replacement, provision was greater for hospitals performing a larger volume of operations (Table 2). Hospitals with higher overall numbers of consultants, anaesthetic consultants, operating theatres and dedicated day-case theatres had lower provision rates. Orthopaedic training status, numbers of T&O consultants and bed occupancy rates were not associated with provision. Similar patterns were seen with knee replacement. Multivariable analysis did not change most of the patterns, though it did reverse the association with the number of operating theatres so that an increased rate was now positively associated with greater provision for hip replacement.

Geographical variation

Overall rates of hip and knee replacement varied across wards and districts in England according to the socio-demographic characteristics of those areas. However, there remained geographical variation in provision rates over and above that explained by the variables in the model. Figure 1 displays the overall predicted rate of provision in each district in England, adjusted for socio-demographic, hospital and distance variables, and incorporating estimates of additional unexplained district level variation. Areas with high rates of provision for hip replacements were not necessarily the same areas with high levels of knee provision, suggesting that different factors influence each procedure. Table 3 lists the top 10 districts with the highest and lowest rates of joint replacement.

For both hip and knee replacements, there was evidence that the effect of some variables varied across districts. For example, the effect of gender varied from a 28% relative reduction for men (Lambeth) to a 20% relative increase (Wansbeck) for knee replacement (see online Supplementary material Appendix).

Discussion

Main finding of this study

This study demonstrates evidence of inequalities in the provision of hip and knee replacement performed in English NHS hospitals. Hospital and distance variables were found to influence provision, but adjustment for these variables did not attenuate inequalities observed for socio-demographic variables. We have shown how one can estimate rates of provision for each district in England and the uncertainty in these estimates, which can be used by local health planners. The pattern of inequalities by variables, such as gender, was found to vary geographically across districts.

What is already known on this topic

Consistent with previous research, we found rates of joint replacement increase with age before falling in the oldest age groups, and women receive more operations than men.[18–31] Prior research demonstrated that in urban areas, women receive higher rates of hip replacement, with the opposite seen in rural areas where men receive greater provision.[26,34] The interaction observed in our study was different; the effect of gender (women receiving more provision) was greater in urban than in rural areas. US studies demonstrated interactions between gender and ethnicity. Women receive greater rates of hip replacement than men except among Black and Hispanic populations,[22] and the difference in knee replacement rates between African-American men and women is greater than between White men and women.[21] Age–sex interactions have been observed where from age 50–84 women receive more knee replacement than men, but then in those aged 85+ there was no longer a gender difference[20] and men have slightly higher levels of provision,[18] consistent with our findings.

For hip replacement, prior studies found that more affluent groups receive greater provision,[18,19,29,32,33] though we found the deprivation gradient to be modest. A recent study[29] found that although evidence of a deprivation effect was apparent, inequalities had narrowed over time, with the proportionate increase in use in those in the least deprived areas falling from 41% to 27% between 1991 and 2001. In line with others, we observed an interaction whereby the deprivation effect is greatest in older age groups.[33] For knee replacement, only one study exists, which found that those in the least deprived areas receive greatest provision (adjusted for age and sex).[18] This is inconsistent with our findings—we found that deprived areas get more operations. Further investigation in our study found that failure to control for clustering in the data causes the association to change direction.

Prior studies on hip replacement found that utilization was higher in rural areas,[26,31,34] as has this study. Others demonstrated that this rurality effect was the same in males and females.[26] US studies found that White Americans were most likely to receive hip replacement,[19,22,27,31,35] although the effect may vary with age[35] where differences are only observed in men and women aged 50+. Rates of knee replacement are found to be higher for Whites than Hispanics and Blacks[21,36] although the difference was smaller between women. Living in regions of higher income diminished the difference between Black and White men.[36] Hispanic women in high-income areas receive higher rates of arthroplasty than non-Hispanic, but the opposite is seen in low-income areas.

Table 2 Crude and adjusted rates of admission for primary hip and knee replacement operations (2002) in England by hospital trust characteristics

	THR		*TKR*	
	Crude RR (95% CI)	*Adjusted RR* (95% CI)*	*Crude RR (95% CI)*	*Adjusted RR* (95% CI)*
Annual hospital trust volume				
1 (1–234)	1.00	1.00	1.00	1.00
2 (238–308)	1.16 (1.10, 1.22)	1.11 (1.05, 1.17)	1.12 (1.06, 1.18)	1.07 (1.02, 1.13)
3 (310–389)	1.13 (1.07, 1.19)	1.08 (1.03, 1.14)	1.05 (1.00, 1.11)	1.06 (1.01, 1.11)
4 (396–564)	1.12 (1.06, 1.18)	1.09 (1.03, 1.15)	1.14 (1.08, 1.20)	1.14 (1.08, 1.20)
5 (570–1076)	1.20 (1.13, 1.26)	1.11 (1.05, 1.18)	1.10 (1.04, 1.16)	1.09 (1.03, 1.16)
P linear trend	<0.001	0.005	<0.001	<0.001
Orthopaedic training centre status				
No	1.00	—	1.00	1.00
Yes	0.97 (0.93, 1.01)	—	0.93 (0.89, 0.97)	0.90 (0.86, 0.95)
Rate of all consultants per 100 000				
1 (4.18–29.95)	1.00	1.00	1.00	1.00
2 (30.15–34.27)	0.93 (0.89, 0.98)	0.90 (0.85, 0.95)	1.02 (0.97, 1.08)	0.99 (0.94, 1.04)
3 (34.35–38.09)	0.96 (0.91, 1.02)	0.92 (0.87, 0.98)	0.99 (0.93, 1.04)	0.93 (0.88, 0.98)
4 (38.98–46.07)	0.93 (0.88, 0.98)	0.87 (0.81, 0.92)	0.94 (0.89, 0.99)	0.88 (0.84, 0.93)
5 (46.15–550.18)	0.85 (0.81, 0.89)	0.79 (0.73, 0.85)	0.94 (0.90, 0.99)	0.91 (0.86, 0.97)
P linear trend	<0.001	<0.001	<0.001	<0.001
Rate of T&O consultants per 100 000				
1 (1.35–2.05)	1.00	1.00	1.00	1.00
2 (2.06–2.41)	0.98 (0.93, 1.03)	1.02 (0.97, 1.07)	0.98 (0.93, 1.03)	0.94 (0.90, 0.99)
3 (2.41–2.75)	1.01 (0.96, 1.07)	1.08 (1.02, 1.14)	1.00 (0.94, 1.05)	1.04 (0.98, 1.09)
4 (2.76–3.11)	0.96 (0.91, 1.02)	1.01 (0.95, 1.06)	0.99 (0.94, 1.04)	1.00 (0.94, 1.06)
5 (3.11–13.72)	1.00 (0.95, 1.05)	1.06 (1.00, 1.12)	1.03 (0.98, 1.09)	1.05 (0.99, 1.11)
P linear trend	0.96	0.07	0.27	0.023
Rate of anaesthetic consultants per 100 000				
1 (1.05–4.85)	1.00	—	1.00	—
2 (4.87–5.98)	0.97 (0.92, 1.02)	—	0.98 (0.93, 1.04)	—
3 (5.99–6.8)	0.96 (0.91, 1.02)	—	1.02 (0.97, 1.08)	—
4 (6.83–8.3)	0.95 (0.90, 1.00)	—	0.97 (0.92, 1.02)	—
5 (8.37–92.32)	0.90 (0.86, 0.95)	—	0.92 (0.87, 0.96)	—
P linear trend	<0.001		0.001	—
Rate of operating theatres per 100 000				
1 (0.00–3.62)	1.00	1.00	1.00	—
2 (3.63–4.46)	0.99 (0.93, 1.04)	1.04 (0.99, 1.10)	0.97 (0.92, 1.02)	—
3 (4.50–5.03)	0.97 (0.92, 1.03)	1.06 (0.99, 1.12)	0.97 (0.91, 1.02)	—
4 (5.07–5.97)	0.97 (0.91, 1.02)	1.10 (1.03, 1.18)	0.91 (0.87, 0.96)	—
5 (6.08–42.42)	0.92 (0.88, 0.97)	1.11 (1.03, 1.20)	0.96 (0.91, 1.01)	—
P linear trend	0.002	0.005	0.018	—
Rate of dedicated day-case theatres per 100 000				
1 (0.00–0.40)	1.00	—	1.00	1.00
2 (0.41–0.68)	0.97 (0.91, 1.02)	—	0.98 (0.93, 1.04)	1.01 (0.95, 1.07)
3 (0.69–1.04)	0.99 (0.94, 1.04)	—	1.04 (0.99, 1.10)	1.03 (0.97, 1.09)
4 (1.04–1.36)	1.00 (0.95, 1.06)	—	0.97 (0.91, 1.02)	0.98 (0.92, 1.03)
5 (1.36–4.27)	0.93 (0.88, 0.99)	—	1.06 (1.00, 1.12)	1.11 (1.04, 1.18)
P linear trend	0.12		0.09	0.011

Continued

Table 2. *Continued*

	THR		*TKR*	
	Crude RR (95% CI)	*Adjusted RR* (95% CI)*	*Crude RR (95% CI)*	*Adjusted RR* (95% CI)*
Bed occupancy rate (% occupied)				
1 (71.12–79.46)	1.00	—	1.00	1.00
2 (79.59–83.52)	1.02 (0.96, 1.08)	—	1.06 (1.00, 1.12)	1.04 (0.98, 1.10)
3 (83.54–86.28)	0.96 (0.91, 1.02)	—	1.00 (0.94, 1.05)	1.02 (0.96, 1.08)
(86.32–89.06)	0.97 (0.92, 1.02)	—	1.00 (0.95, 1.05)	0.99 (0.94, 1.05)
5 (89.08–97.20)	0.98 (0.93, 1.03)	—	1.01 (0.96, 1.06)	1.06 (1.00, 1.12)
P linear trend	0.12		0.61	0.33

THR, total hip replacement; TKR, total knee replacement; RR, rate ratio; CI, confidence interval.

—, variable excluded from the multivariable model.

*Hierarchical Poisson regression model fitted in MLwiN allowing for clustering across CASwards and Districts, adjusted for socio-demographic, hospital and distance variables.

Perhaps surprisingly, many of the provider characteristics either did not predict rates of provision or were associated with reduced provision. For example, trusts that were training centres did relatively fewer knee procedures. This may be because such units take more time per patient due to training junior doctors or they have more complex cases that result in fewer cases per year. Similarly, the weak association between the numbers of T&O

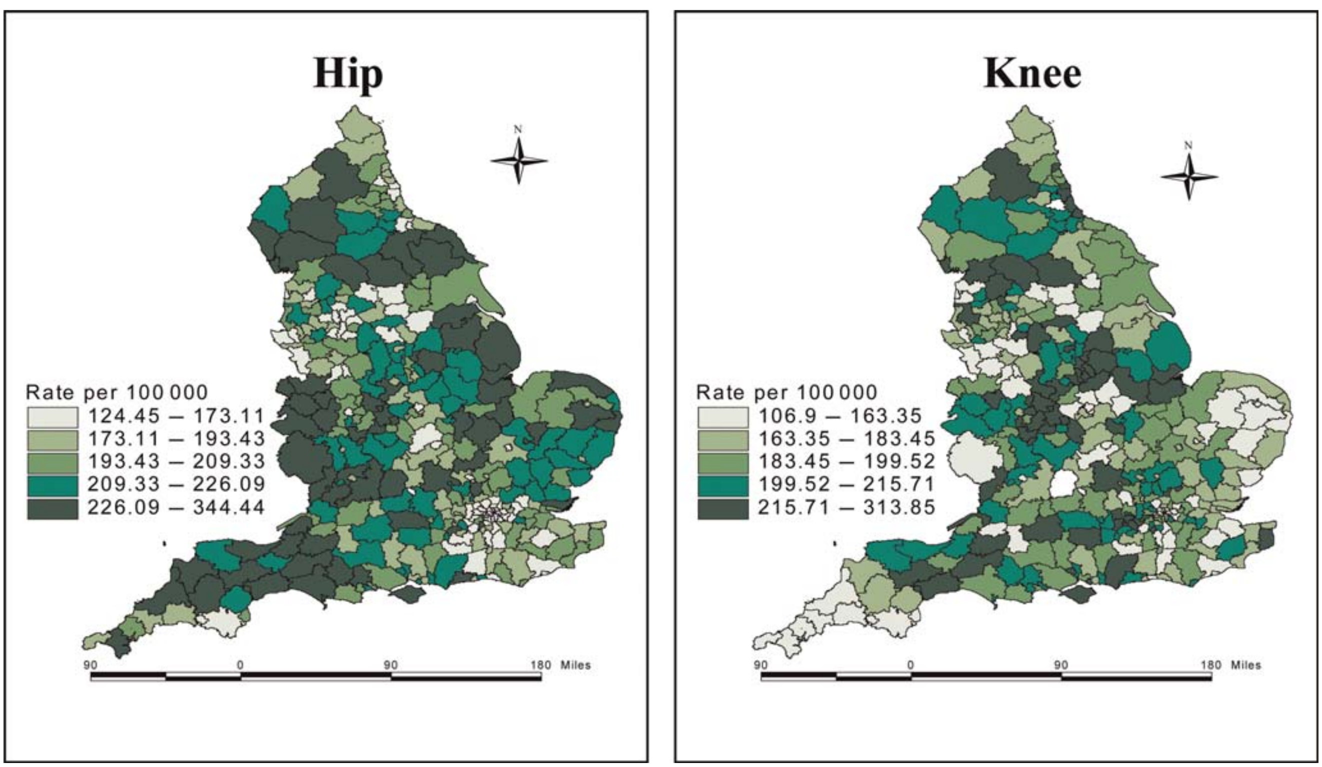

Fig. 1 Rate of provision of primary elective hip and knee replacement per 100 000 population in each district in England, adjusted for socio-demographic, hospital and distance variables, and incorporating estimates of additional unexplained district level variation. This work is based on data provided through EDINA UKBORDERS with the support of the ESRC and JISC and uses boundary material which is copyright of the Crown. ©Crown Copyright/database right 2007. An Ordnance Survey/EDINA supplied service.

Table 3 Overall rate of provision of hip and knee replacement, adjusted for socio-demographic, hospital trust and distance variables

Ten lowest		*Ten highest*	
District	*Adjusted rate per 100 000 (95% CI)*	*District*	*Adjusted rate per 100 000 (95% CI)*
Hip replacement			
Tower Hamlets (00BG)	124.45 (101.08, 152.62)	Huntingdonshire (12UE)	268.79 (230.19, 312.29)
Barnet (00AC)	125.58 (106.69, 146.34)	Copeland (16UE)	270.14 (223.17, 325.36)
Hackney (00AM)	125.70 (102.20, 154.00)	Oswestry (39UD)	270.95 (217.88, 336.61)
Leicester (00FN)	131.49 (110.49, 155.08)	Mendip (40UB)	272.85 (232.04, 320.51)
Stoke-on-Trent (00GL)	131.49 (111.16, 155.39)	North Warwickshire (44UB)	273.94 (224.51, 330.61)
Maidstone (29UH)	133.74 (109.61, 162.38)	West Oxfordshire (38UF)	278.08 (211.65, 368.31)
Camden (00AG)	134.55 (110.60, 163.19)	Tewkesbury (23UG)	282.29 (233.91, 338.64)
Northampton (34UF)	135.90 (112.50, 163.52)	Harrogate (36UD)	287.13 (248.87, 329.29)
Greenwich (00AL)	137.13 (114.31, 164.01)	Mid Devon (18UD)	289.72 (242.24, 345.82)
Croydon (00AH)	138.09 (118.50, 160.76)	South Somerset (40UD)	344.44 (302.15, 393.05)
Knee replacement			
Stoke-on-Trent (00GL)	106.90 (89.03, 127.99)	South Holland (32UF)	272.31 (228.13, 324.06)
Kensington and Chelsea (00AW)	110.05 (88.05, 136.99)	Hounslow (00AT)	275.32 (235.55, 319.55)
Torbay (00HH)	127.99 (105.42, 155.39)	Hartlepool (00EB)	277.53 (231.58, 331.27)
Newcastle-under-Lyme (41UE)	127.99 (103.85, 156.32)	Harlow (22UJ)	277.81 (225.41, 339.99)
Penwith (15UF)	128.89 (100.68, 163.68)	Mansfield (37UF)	280.88 (235.32, 333.93)
Northampton (34UF)	129.53 (106.80, 156.64)	South Somerset (40UD)	285.41 (248.87, 326.34)
Rutland (00FP)	131.75 (98.59, 173.98)	North Warwickshire (44UB)	285.70 (232.97, 346.86)
South Norfolk (33UH)	132.94 (107.98, 162.38)	Solihull (00CT)	299.74 (261.37, 342.72)
Fylde (30UF)	133.48 (106.26, 165.82)	Slough (00MD)	302.76 (251.87, 362.83)
Carrick (15UC)	134.01 (108.63, 164.67)	Isle of Wight (00MW)	313.85 (275.59, 356.71)

Top 10 highest and lowest rates. CI, confidence interval.

consultants and rates of provision suggests that hospitals calibrate demand in relation to their respective catchment populations, whereby larger hospitals with a bigger population have more staff but by no more than expected given their size. An ecological study in Ontario found that the availability of orthopaedic surgeons was not associated with knee utilization rates.[38]

Limitations of this study

A limitation of using HES data is that private operations are not included. If more affluent people use the private sector for joint surgery, it is likely that the observed deprivation effect is under-estimated and inequalities may be worse in more deprived areas. Another limitation is the lack of individual data. Information on social class or obesity is unavailable in HES and ethnicity incompletely recorded. To overcome this, we used ecological variables of deprivation, rurality and ethnicity; hence, ecological bias may be present. Concerns have been raised over the completeness and accuracy of data collected for administrative rather than research purposes, and importantly, it may contain incomplete or inaccurate diagnostic and operation coding.[26,32]

What this study adds

Local healthcare planners need to monitor inequalities in the provision of surgery, and the results of this study provide them with exactly the information required. It may be argued that the models used are complex; however, they need only be used once in order to obtain local estimates for the whole of England. Such a modelling exercise could be undertaken by governmental statisticians at either a national or regional level or by academic units. The resource can then be shared across all local-based healthcare units or released to commissioners and the general public. By using routinely available data, analyses can be repeated over time to provide an updated picture of the pattern of inequalities and to monitor the effect actions of health planners have on reducing inequalities in access to hip and knee replacement.

Although it is useful to be aware of inequalities in the provision of healthcare, this does not necessarily imply that there are inequities. It is important to establish whether provision matches need across socio-demographic groups to determine whether it is equitable. It is unlikely that socio-demographic differences in disease morbidity will vary so dramatically across districts. This suggests that some of the geographical findings reflect local variations in patient expectation, clinician management and/or available resources rather than true differences in need. Future research from this project will address this issue, by developing small-area estimates of the need for joint replacement, then combining data on need and provision to explore equity in access to care.

Supplementary data

Supplementary data are available at the *Journal of Public Health* online.

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References

1 Chair: Sir Donald Acheson. Independent Inquiry into Inequalities in Health. London: TSO, 1998.

2 Department of Health. Saving Lives: Our Healthier Nation. London: HMSO, 1999.

3 Department of Health. The NHS Plan. 2000. London: HMSO. 1 June 2005.

4 Department of Health. Tackling Health Inequalities: 2002 Cross-Cutting Review. 2002.

5 Department of Health. Tackling Health Inequalities: 2004–06 data and policy update for the 2010 National Target. 14 December 2007.

6 Liang MH, Cullen KE, Larson MG *et al*. Cost-effectiveness of total joint arthroplasty in osteoarthritis. *Arthritis Rheum* 1986;**29(8)**:937–43.

7 Chang RW, Pellisier JM, Hazen GB. A cost-effectiveness analysis of total hip arthroplasty for osteoarthritis of the hip. *JAMA* 1996;**275(11)**:858–65.

8 Rand JA, Ilstrup DM. Survivorship analysis of total knee arthroplasty. Cumulative rates of survival of 9200 total knee arthroplasties. *J Bone Joint Surg Am* 1991;**73(3)**:397–409.

9 Scuderi GR, Insall JN, Windsor RE *et al*. Survivorship of cemented knee replacements. *J Bone Joint Surg Br* 1989;**71-B(5)**: 798–803.

10 Kirwan JR, Currey HL, Freeman MA *et al*. Overall long-term impact of total hip and knee joint replacement surgery on patients with osteoarthritis and rheumatoid arthritis. *Br J Rheumatol* 1994;**33(4)**:357–60.

11 Hawker G, Wright J, Coyte P *et al*. Health-related quality of life after knee replacement. *J Bone Joint Surg Am* 1998;**80(2)**:163–73.

12 Callahan CM, Drake BG, Heck DA *et al*. Patient outcomes following unicompartmental or bicompartmental knee arthroplasty. A meta-analysis. *J Arthroplasty* 1995;**10(2)**:141–50.

13 Callahan CM, Drake BG, Heck DA *et al*. Patient outcomes following tricompartmental total knee replacement. A meta-analysis. *JAMA* 1994;**271(17)**:1349–57.

14 Williams MH, Frankel SJ, Nanchahl K *et al*. Total hip replacement. In: Stevens A, Raftery J (eds). *Health Care Needs Assessment: The Epidemiological Based Needs Assessment Review*, **Vol 1**. Oxford: Radcliffe Medical Press, 1994.

15 NHS Centre for Reviews and Dissemination. Total Hip Replacement. York: NHS Centre for Reviews and Dissemination, 1996. Effective Health Care Bulletin.

16 Walker DJ, Heslop PS, Chandler C *et al*. Measured ambulation and self-reported health status following total joint replacement for the osteoarthritic knee. *Rheumatology* 2002;**41(7)**:755–8.

17 McMurray A, Grant S, Griffiths S *et al*. Health-related quality of life and health service use following total hip replacement surgery. *J Adv Nurs* 2002;**40(6)**:663–72.

18 Dixon T, Shaw M, Ebrahim S *et al*. Trends in hip and knee joint replacement: socioeconomic inequalities and projections of need. *Ann Rheum Dis* 2004;**63(7)**:825–30.

19 Melzer D, Guralnik JM, Brock D. Prevalence and distribution of hip and knee joint replacements and hip implants in older Americans by the end of life. *Aging Clin Exp Res* 2003;**15(1)**:60–6.

20 Millar WJ. Hip and knee replacement. *Health Rep* 2002;**14(1)**:37–50.

21 Katz BP, Freund DA, Heck DA *et al*. Demographic variation in the rate of knee replacement: a multi-year analysis. *Health Serv Res* 1996;**31(2)**:125–40.

22 Hoaglund FT, Oishi CS, Gialamas GG. Extreme variations in racial rates of total hip arthroplasty for primary coxarthrosis: a population-based study in San Francisco. *Ann Rheum Dis* 1995;**54(2)**:107–10.

23 Overgaard S, Knudsen HM, Hansen LN *et al*. Hip arthroplasty in Jutland, Denmark. Age and sex-specific incidences of primary operations. *Acta Orthop Scand* 1992;**63(5)**:536–8.

24 Rajaratnam G, Black NA, Dalziel M. Total hip replacements in the National Health Service: is need being met? *J Public Health Med* 1990;**12(1)**:56–9.

25 Ingvarsson T. Prevalence and inheritance of hip osteoarthritis in Iceland. *Acta Orthop Scand Suppl* 2000;**298**:1–46.

26 Willis CE, Kee F, Beverland D *et al*. Urban-rural differences in total hip replacements: the next stage. *J Public Health Med* 2000;**22(3)**:435–8.

27 Baron JA, Barrett J, Katz JN *et al*. Total hip arthroplasty: use and select complications in the US Medicare population. *Am J Public Health* 1996;**86(1)**:70–2.

28 Seagroatt V, Tan HS, Goldacre M *et al*. Elective total hip replacement: incidence, emergency readmission rate, and postoperative mortality. *BMJ* 1991;**303(6815)**:1431–5.

29 Cookson R, Dusheiko M, Hardman G. Socioeconomic inequality in small area use of elective total hip replacement in the English National Health Service in 1991 and 2001. *J Health Serv Res Policy* 2007;**12(Suppl. 7)**:S1-10-7.

30 Williams MH, Newton JN, Frankel SJ *et al*. Prevalence of total hip replacement: how much demand has been met? *J Epidemiol Community Health* 1994;**48(2)**:188–91.

31 Sharkness CM, Hamburger S, Moore RM Jr *et al*. Prevalence of artificial hip implants and use of health services by recipients. *Public Health Rep* 1993;**108(1)**:70–5.

32 Majeed A, Eliahoo J, Bardsley M *et al*. Variation in coronary artery bypass grafting, angioplasty, cataract surgery, and hip replacement rates among primary care groups in London: association with population and practice characteristics. *J Public Health Med* 2002;**24(1)**:21–6.

33 Agabiti N, Picciotto S, Cesaroni G *et al*. The influence of socioeconomic status on utilization and outcomes of elective total hip replacement: a multicity population-based longitudinal study. *Int J Qual Health Care* 2007;**19(1)**:37–44.

34 Dunsmuir RA, Allan DB, Davidson LA. Increased incidence of primary total hip replacement in rural communities. *BMJ* 1996;**313(7069)**:1370.

35 Oishi CS, Hoaglund FT, Gordon L *et al*. Total hip replacement rates are higher among Caucasians than Asians in Hawaii. *Clin Orthop Relat Res* 1998;**353**:166–74.

36 Skinner J, Weinstein JN, Sporer SM *et al*. Racial, ethnic, and geographic disparities in rates of knee arthroplasty among Medicare patients. *N Engl J Med* 2003;**349(14)**:1350–9.

37 Merx H, Dreinhofer K, Schrader P *et al*. International variation in hip replacement rates. *Ann Rheum Dis* 2003;**62(3)**:222–6.

38 Coyte PC, Hawker G, Wright JG. Variations in knee replacement utilization rates and the supply of health professionals in Ontario, Canada. *J Rheumatol* 1996;**23(7)**:1214–20.

39 Dixon T, Shaw ME, Dieppe PA. Analysis of regional variation in hip and knee joint replacement rates in England using Hospital Episodes Statistics. *Public Health* 2006;**120(1)**:83–90.

40 Roderick P, Clements S, Stone N *et al*. What determines geographical variation in rates of acceptance onto renal replacement therapy in England? *J Health Serv Res Policy* 1999;**4(3)**:139–46.

41 Williams B, Whatmough P, McGill J *et al*. Private funding of elective hospital treatment in England and Wales, 1997–98: national survey. *BMJ* 2000;**320(7239)**:904–5.

42 Noble M, Wright G, Dibben C *et al*. Indices of Deprivation 2004. Report to the Office of the Deputy Prime Minister. London: Neighbourhood Renewal Unit, 2004.

43 Boots BN. *Voronoi (Thiessen) Polygons (Concepts and Techniques in Modern Geography)*. Norwich: Geo Books, 1986.

44 White P. Doncaster Health Authority—Determining Travel Times for Medical Student Community Based Teaching Placements. The University of Sheffield. Public Health GIS Unit, 2000.

45 Rasbash J, Steele F, Browne W *et al*. A User's Guide to *MLwiN*. Centre for Multilevel Modelling. Institute of Education. University of London, 2004.