



PAPER

Knee osteoarthritis and obesity

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OBJECTIVES: To assess the risk of knee osteoarthritis (OA) attributable to obesity, and the interactions between obesity and other established causes of the disorder.

METHODS: We performed a population-based case–control study in three health districts of England (Southampton, Portsmouth and North Staffordshire). A total of 525 men and women aged 45 y and over, consecutively listed for surgical treatment of primary knee OA, were compared with 525 controls matched by age, sex and family practitioner.

RESULTS: Relative to a body mass index (BMI) of 24.0–24.9 kg/m², the risk of knee OA increased progressively from 0.1 (95% CI 0.0–0.5) for a BMI < 20 kg/m² to 13.6 (95% CI 5.1–36.2) for a BMI of 36 kg/m² or higher. If all overweight and obese people reduced their weight by 5 kg or until their BMI was within the recommended normal range, 24% of surgical cases of knee OA (95% CI 19–27%) might be avoided. As a risk factor for knee OA obesity interacted more than additively with each of Heberden's nodes, earlier knee injury and meniscectomy. In comparison with subjects of normal weight, without Heberden's nodes, and with no history of knee injury, people with a combination of obesity, definite Heberden's nodes and previous knee injury had a relative risk of 78 (95% CI 17–354).

CONCLUSIONS: Our findings give strong support to public health initiatives aimed at reducing the burden of knee OA by controlling obesity. People undergoing meniscectomy or with a history of knee injury might be a focus for targeted advice. *International Journal of Obesity* (2001) 25, 622–627

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Introduction

Osteoarthritis of the knee is a common cause of pain and disability, especially in the elderly.¹ In Britain, hospital activity data² suggest that 1.5% of people will undergo surgical treatment for the disorder (usually total knee arthroplasty) at some stage in their lives. Case–control studies have consistently demonstrated a strong association between knee osteoarthritis and obesity,³ and in the Framingham longitudinal study high body mass index (BMI) predicted development of the disease in later life.⁴ Furthermore, analysis of women in the same cohort has shown that incidence is lower in obese women who lose weight than in

those who do not;⁵ these data suggest that controlling obesity can reduce risk.

Other established causes of knee osteoarthritis include constitutional predisposition to osteoarthritis in multiple joints (generalized osteoarthritis) and injury or surgery to the knee.⁶ It is possible that when obesity is present in combination with one or more of these risk factors, risk is increased to the extent that targeted advice on weight control would be appropriate. We have explored this question using data from a case–control study of knee osteoarthritis requiring surgical treatment.

Methods

The cases were residents of North Staffordshire, Portsmouth and Southampton Health Districts who were consecutively placed on a waiting list for knee surgery because of osteoarthritis during a 2 y period. In Portsmouth and North Staffordshire we included private as well as National Health

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Service (NHS) patients but for logistic reasons that was not possible in Southampton. Each patient's case-notes and radiographs were reviewed to confirm the diagnosis of osteoarthritis, and to exclude those with underlying rheumatoid arthritis, ankylosing spondylitis, or injury to the knee within the past 12 months. The radiographic severity of osteoarthritis in the knee requiring surgery was graded according to the Kellgren and Lawrence classification.⁷

Eligible cases who agreed to take part in the study were visited at home by a research nurse who administered a structured questionnaire. Among other things this asked about earlier surgery to the knees and whether they had ever suffered a knee injury bad enough to impair weight bearing for a week or longer. In addition, the nurse examined their hands for the presence of Heberden's nodes (as a marker for osteoarthritis at a different site) and measured their height (using a portable stadiometer) and weight (using electronic scales). A Heberden's node was defined as a palpable, tender or non-tender, bony swelling adjacent to the distal interphalangeal joint of a finger and was assessed using a three-point scale (none, possible or definite). If a clear swelling was palpable and felt to be bony, the node was assigned as definite; if the research nurse was uncertain as to bony texture, it was assigned as possible. Although the research nurse was not the principal member of the research staff responsible for the selection of cases and controls, the inclusion of questions pertaining to knee pain, disability and surgery made it impossible for her to be blinded as to case-control status.

For each case who was interviewed we sought a control of the same sex and matched as closely as possible for date of birth, who was registered with the same general practitioner as the case, and who had not undergone earlier surgery for osteoarthritis. Following an introductory letter, those who agreed to take part were visited at home and interviewed and examined according to the same protocol as the cases. Where possible, controls who could not be contacted or declined to participate were replaced.

Associations of knee osteoarthritis with obesity, alone and in combination with other risk factors, were examined by conditional logistic regression.

Results

We identified a total of 729 cases who were eligible for inclusion in the study, of whom 675 (93%) agreed to be interviewed. The response rate from controls was rather lower, interviews being obtained from 57% of the 1171 men and women whom we attempted to recruit. The incomplete response occurred because the general practitioner did not want the person to be approached (152 controls) or because the control could not be contacted or declined to take part (354). This left 665 matched pairs in which both the case and control had been interviewed; 140 of these were excluded from analysis because the control had previously undergone knee surgery for osteoarthritis (eight pairs) or

information was missing on one or more of weight, height, Heberden's nodes and history of knee injury or surgery (132 pairs). Missing information on these risk factors was more frequent among cases (72%) than among controls (25%) among these 132 pairs (in the remaining 3%, information was missing in both case and control of a given pair). However, the relative proportions of subjects with missing information on each specific risk factor were similar among cases and controls (BMI 31% of cases, 36% of controls; previous injury 44% of cases, 58% of controls; Heberden's nodes no cases, 3% of controls).

Of the 525 cases who were included in the analysis, 205 were men and 320 were women. Their ages ranged from 47 to 93 y with a median of 72 y, and the ages of all but six controls were matched to within 2 y. The largest age difference between a case and matched control was 4.1 y. In all, 78% of cases had a Kellgren and Lawrence grade of 3 or 4 in the knee listed for surgery. Of the remainder, 17% had Kellgren and Lawrence grade 2 osteoarthritis, 4% grade 1, and 1% grade 0.

The median BMI in the cases was 28.1 kg/m² (inter-quartile range (IQR) 25.6–31.3) as compared with 25.3 kg/m² (IQR 23.1–28.0) in the controls. Table 1 shows the distribution of cases and controls according to whether they were underweight (BMI < 20.0 kg/m²), normal weight (BMI 20.0–24.9 kg/m²), overweight (BMI 25.0–29.9 kg/m²) or obese (BMI ≥ 30.0 kg/m²), and the associated risks of knee osteoarthritis. Odds ratios increased progressively across these categories, more than a third of cases being classified as obese.

To assess the relation of obesity to risk of knee osteoarthritis in more detail, BMI was partitioned into 12 categories with roughly equal numbers of subjects in each. Figure 1 shows odds ratios (OR) for each category relative to a BMI of 24.0–24.9. There was a progressive increase in risk throughout the range from 0.1 (95% CI 0.0–0.5) for a BMI less than 20 to 13.6 (95% CI 5.1–36.2) for a BMI of 36 or higher, and within the range of the data the trend was well approximated by an exponential function as illustrated. This took the form: $OR = (BMI/24)^i$, where the point estimate for i was 5.2 with 95% CI 4.2–6.3.

We used this formula to estimate the proportion of surgical cases of knee osteoarthritis in the community that might be avoided by controlling obesity. The complete derivation of this attributable proportion is provided in Appendix 1. We calculated the fraction of cases in the study sample that

Table 1 Prevalence of obesity and association with knee osteoarthritis

BMI (kg/m ²)	Cases		Controls		OR (95% CI)
	n	%	n	%	
< 20.0	5	1.0	42	8.0	0.1 (0.0–0.5)
20.0–24.9	96	18.3	201	38.3	1
25.0–29.9	247	47.1	221	42.1	2.5 (1.8–3.6)
≥ 30.0	177	33.7	61	11.6	6.8 (4.4–10.5)

Odds ratios derived from matched, unadjusted analysis.

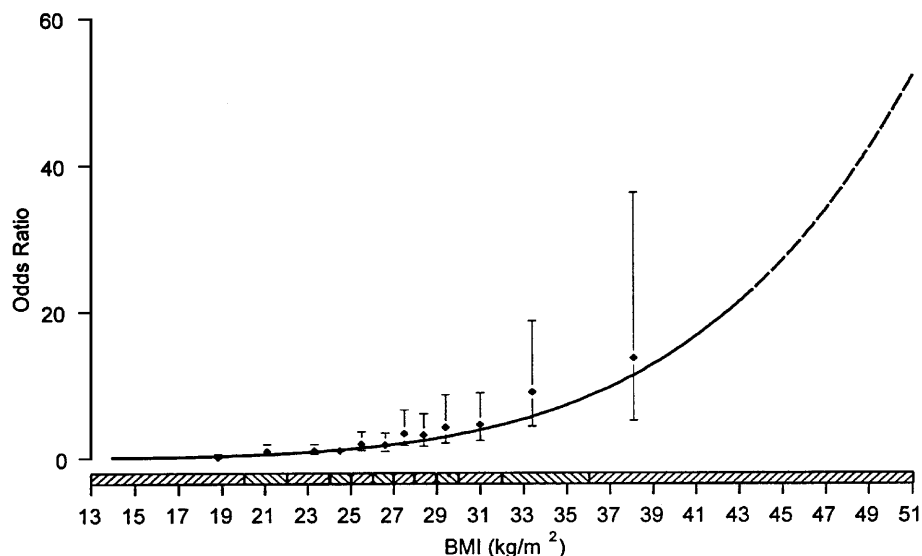


Figure 1 Odds ratios and 95% confidence intervals for 12 categories of BMI. The boundaries of these categories are indicated by the shading on the horizontal axis, and the odds ratios are depicted at points corresponding to the median BMI in each category. Also shown is the fitted curve, odds ratio = $(\text{BMI}/24)^{5.2}$.

would have been eliminated if the risk among people who were overweight or obese were reduced to that of people with lower BMIs, assuming three different degrees of weight loss (Table 2). Lowering their risk to the level associated with a BMI in the normal range would have prevented more than half of all cases, and even a more modest reduction (equivalent to reducing weight by no more than 5 kg) would have eliminated about a quarter of cases.

Table 3 shows the associations of knee osteoarthritis with Heberden’s nodes, earlier knee injury and meniscectomy when each of these variables was examined independently. For the purposes of this analysis, we only counted injuries and meniscectomies in a case and his or her matched control where they occurred on the side for which the case’s surgical treatment of osteoarthritis was planned and clearly preceded the onset of the case’s osteoarthritic symptoms on that side.

Table 2 Proportions of knee osteoarthritis cases that might be avoided by reducing obesity

Reduction in obesity	Proportion of cases (95% CI) that might be eliminated
All overweight and obese reduce weight by 2 kg or until their BMI is in the recommended normal range, whichever is less weight loss	10.9% (8.8–12.8%)
All overweight and obese reduce weight by 5 kg or until their BMI is in the recommended normal range, whichever is less weight loss	23.6% (19.4–27.4%)
All overweight and obese reduce weight until their BMI is in the recommended normal range	57.1% (46.7–64.2%)

As expected, each risk factor was significantly associated with knee osteoarthritis.

Table 4 shows associations with the same risk factors when subjects were classified according to their BMI. BMI interacted with the other risk factors more than additively so that, for example, the OR for obesity when combined with a history of knee injury was 21.6 as compared with 8.2 in the absence of knee injury and 6.1 for knee injury in subjects of normal weight. A combination of obesity, definite Heberden’s nodes and earlier knee injury carried an even higher risk (OR 78, 95% CI 17–354 in comparison with normal weight, no Heberden’s nodes and no knee injury). All of the above analyses were repeated separately in men and women. The patterns of interaction between risk factors were similar in the two sexes, but the risks associated with obesity tended to be rather higher in women than in men. The table also

Table 3 Association of knee osteoarthritis with Heberden’s nodes, earlier knee injury and meniscectomy

Risk factor	No of cases	No of controls	OR (95% CI)
Heberden’s nodes			
None	73	125	1
Possible	71	81	1.6 (1.0–2.6)
Definite	381	319	2.4 (1.6–3.5)
Previous knee injury^a			
No	365	474	1
Yes	160	51	4.3 (2.9–6.3)
Previous meniscectomy^a			
No	492	517	1
Yes	33	8	5.2 (2.2–12.4)

Odds ratios derived from matched, unadjusted analyses. Each risk factor was analysed in a separate regression model. ^aFor definition see text.

Table 4 Associations of knee osteoarthritis with Heberden's nodes, earlier injury and meniscectomy according to body mass index

Risk factors	BMI (kg/m ²)							
	< 20		20–24		25–29		≥ 30	
	Number of cases	OR (95% CI)	Number of cases	OR (95% CI)	Number of cases	OR (95% CI)	Number of cases	OR (95% CI)
Heberden's nodes								
None	0	0 (0–0.6)	16	1	28	1.6 (0.7–3.4)	29	8.2 (3.0–22.6)
Possible	0	0 (0–4.4)	9	1.0 (0.4–2.7)	36	3.7 (1.6–8.7)	26	12.2 (4.4–33.7)
Definite	5	0.3 (0.1–1.7)	71	2.0 (1.0–4.1)	183	5.5 (2.7–11.0)	122	12.1 (5.7–25.6)
Previous knee injury								
No	3	0.1 (0.0–0.6)	60	1	172	3.0 (2.0–4.6)	130	8.2 (4.9–13.8)
Yes	2	0.7 (0.1–6.4)	36	6.1 (2.9–12.7)	75	13.1 (6.8–25.4)	47	21.6 (8.7–53.7)
Previous meniscectomy								
No	5	0.1 (0.0–0.5)	89	1	230	2.5 (1.8–3.6)	168	6.6 (4.3–10.3)
Yes	0	—	7	6.8 (1.3–36.4)	17	8.2 (2.8–24.5)	9	∞ (13.3–∞)

A separate regression model was used to explore the interaction of BMI with each of Heberden's nodes, previous knee injury and previous meniscectomy.

illustrates that the risk of knee osteoarthritis associated with nodes, injury and meniscectomy does in fact vary by category of BMI.

With the assumptions that the overall lifetime risk of surgery for knee osteoarthritis is 1.5% and that the distribution of risk factors in the general population is similar to that in our control group, Table 5 gives estimates of the lifetime risk of surgically treated knee osteoarthritis according to BMI and the presence or absence of other risk factors. In people with no Heberden's nodes and no history of knee injury the excess lifetime risk associated with obesity was estimated as 2.0%, but this rose to an excess of 9.5% for people who have both definite Heberden's nodes and a past history of knee injury.

Discussion

Our findings suggest that a large proportion of severe knee osteoarthritis is attributable to obesity, and that risk is particularly high among obese people who also have other risk factors for the disease. The risk estimates are broadly in accord with other population-based studies of osteoarthritis.^{6,8–11} In particular, the first National Health and Nutrition Examination survey conducted throughout the United States

in 1971–1975 showed that women with a BMI between 30 and 35 kg/m² had almost four times the risk of knee osteoarthritis of women with a BMI under 25.⁸ Our study explored the relation of obesity to knee osteoarthritis and its interaction with other risk factors in greater detail than previous investigations.

The cases we studied came from geographically defined populations in two regions of England (the South and the Midlands), and although we were not able to recruit all privately treated patients, only a small minority of those eligible for entry to the study are likely to have been missed. Thus, our study sample should be fairly representative of cases that occur nationally.

The response rate from potential controls was lower than for cases, but this is not surprising in a community-based study of elderly people. In general, we would expect those too frail or ill to participate to be underweight more often than overweight, which if anything would cause the risks associated with obesity to be under-estimated rather than over-estimated.

Another potential source of bias was differences in recall between cases and controls. In particular, cases may have remembered earlier injuries more completely than controls. This possibility cannot be excluded, but by restricting our definition to more severe injuries that interfered with weight

Table 5 Estimated lifetime risk (%) of surgery for knee osteoarthritis according to body mass index and the presence or absence of other risk factors

Risk factors	Lifetime risk (%)			Excess lifetime risk (%) associated with BMI ≥ 30 kg/m ²
	All BMI	BMI < 30 kg/m ²	BMI ≥ 30 kg/m ²	
No knee injury and no Heberden's nodes	0.5	0.3	2.3	2.0
Knee injury but no Heberden's nodes	3.8	3.9	3.6	–0.3
No knee injury but definite Heberden's nodes	1.3	1.0	3.6	2.6
Knee injury and definite Heberden's nodes	6.1	5.0	14.5	9.5

The calculations assume that the overall lifetime risk of surgery for knee osteoarthritis is 1.5% and that the prevalence of risk factors in the general population is similar to that in the control group.

bearing for at least a week, we should have reduced the chance of such errors. We also evaluated the extent to which information on the key risk factors might have been differentially missed between cases and controls. Although missing information was more frequent among cases than among controls, there were similar proportions of those in whom data on BMI, Heberden's nodes and knee injury were unobtainable.

A more important limitation was our ability to measure obesity only after the cases' osteoarthritis had reached an advanced stage. This meant that the association of obesity with knee osteoarthritis could have been exaggerated if some patients had put on weight as a consequence of immobility caused by their disease. Against a major contribution of this type, however, is the fact that similar associations have been found with the incidence, progression and later prevalence of knee osteoarthritis in prospective studies where height and weight were measured at the start of follow-up.^{5,9,12-15} Furthermore, in one such study, subjects who lost weight during follow-up had a lower risk than those who did not.⁵ When set alongside these findings and those of other retrospective investigations, our observations indicate that control of obesity could have a major impact on the occurrence of severe knee osteoarthritis.

Of course, knee osteoarthritis is only one of many adverse consequences of obesity, but persuading people to reduce weight and then maintain the loss is difficult.¹⁶ One factor which may influence their motivation is the perceived personal gain in relation to the sacrifices that must be made. Table 4 indicates that the risks associated with obesity are particularly high in people who have other risk factors for knee osteoarthritis, and Table 5 attempts to translate the observed associations into estimates of the potential gain to individuals from controlling weight, with risks quantified by an absolute rather than a relative measure. These calculations involve several assumptions and simplifications. The lifetime risk of surgery for knee osteoarthritis is taken as 1.5%, and it is assumed that the distribution of risk factors in the general population is similar to that in our control group. Furthermore, no account is taken of the age at which people first develop Heberden's nodes or suffer knee injuries. Nevertheless, the findings suggest that the reduction in risk from controlling weight could be substantial in obese people with definite Heberden's nodes and a past history of significant knee injury. This information might provide an added incentive to weight loss in such individuals.

Another potential target for advice about weight control is patients undergoing meniscectomy. Most of the cases in our study who reported meniscectomy would have been treated by open surgery, and we do not yet know whether similar risks of osteoarthritis are associated with arthroscopic meniscectomy. However, it would be prudent to advise patients who have a meniscectomy about the need to avoid obesity in order to minimize their risk of further knee trouble.

Ultimately, confirmation of the benefits of weight control in reducing the occurrence and severity of knee osteoarthritis would best come from prospective intervention studies. Meanwhile, our findings give encouragement to public health initiatives aimed at reducing obesity, and identify certain groups of people who might be a focus for targeted advice. They also highlight a further adverse effect that can be expected if the prevalence of obesity in the general population continues to rise.¹⁷ Projections of the impact of this trend on future demands for health care should take into account the likely increase in requirements for knee replacement surgery.

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References

- Cooper C. Epidemiology of Osteoarthritis. In: Klippel JH, Dieppe PA (eds). *Rheumatology* (2nd edn). Mosby: London; 1998. pp 8.2.1-8.2.8.
- Williams M, Frankel S, Nanchahal K, Coast J, Donovan J. *Epidemiologically based needs assessment: total knee replacement*. Health Care Evaluation Unit, University of Bristol: Bristol; 1992.
- Spector TD. The fat on the joint: osteoarthritis and obesity. *J Rheumatol* 1990; **17**: 283-284.
- Felson DT, Anderson JJ, Naimark A, Walker AM, Meenan RF. Obesity and knee osteoarthritis. The Framingham Study. *Ann Intern Med* 1988; **109**: 18-24.
- Felson DT, Zhang Y, Anthony JM, Naimark A, Anderson JJ. Weight loss reduces the risk for symptomatic knee OA in women: the Framingham Study. *Ann Intern Med* 1992; **116**: 535-539.
- Cooper C, McAlindon T, Snow S, Vines K, Young P, Kirwan J, Dieppe P. Mechanical and constitutional risk factors for symptomatic knee osteoarthritis: differences between medial tibiofemoral and patellofemoral disease. *J Rheumatol* 1994; **21**: 307-313.
- Kellgren JH, Lawrence JS. *Atlas of Standard Radiographs: The Epidemiology of Chronic Rheumatism*, Vol 2. Oxford: Blackwell; 1963.
- Anderson JJ, Felson DT. Factors associated with osteoarthritis of the knee in the first national health and nutrition survey (HANES 1): evidence for an association with overweight, race and physical demands of work. *Am J Epidemiol* 1988; **128**: 179-189.
- Schouten JSAG, Van den Ouweland FA, Valkenburg HA. A twelve year follow-up study in the general population on prognostic factors of cartilage loss in osteoarthritis of the knee. *Ann Rheum Dis* 1992; **51**: 932-937.
- Davis MA, Ettinger WH, Neuhaus JM, Hauck WW. Sex differences in osteoarthritis of the knee; the role of obesity. *Am J Epidemiol* 1988; **127**: 1019-1030.
- Hart DJ, Spector TD. The relationship of obesity, fat distribution and osteoarthritis in women in the general population: the Chingford study. *J Rheumatol* 1993; **20**: 331-335.
- Spector TD, Hart DJ, Doyle DV. Incidence and progression of osteoarthritis in women with unilateral knee disease in the general population: the effect of obesity. *Ann Rheum Dis* 1994; **53**: 565-568.

- 13 Felson DT, Zhang Y, Hannan MT, Naimark A, Weissman B, Aliabadi P, Levy D. Risk factors for incident radiographic knee osteoarthritis in the elderly: the Framingham Study. *Arthritis Rheum* 1997; **40**: 728–733.
- 14 Oliveria SA, Felson DT, Cirillo PA, Reed JI, Walker AM. Body weight, body mass index and incident symptomatic osteoarthritis of the hand, hip and knee. *Epidemiology* 1999; **10**: 161–166.
- 15 Hart DJ, Doyle DV, Spector TD. Incidence and risk factors for radiographic knee osteoarthritis in middle aged women: the Chingford Study. *Arthritis Rheum* 1999; **42**: 17–24.

- 16 Summerbell CD, Watts C, Higgins JPT, Garrow JS. Randomised controlled trial of novel simple and well supervised weight reducing diets in outpatients. *Br Med J* 1998; **317**: 1487–1489.
- 17 Bost L, Primatesta P, Dong W. Anthropometric measures and children's iron status. In: Prescott-Clarke P, Primatesta P (eds). *Health survey for England' 96*, Vol 1. The Stationery Office: London; 1998. pp 282–304.

Appendix 1

The attributable proportion of cases due to an exposure is calculated as

$$\frac{(RR_e - 1) C_e}{RR_e * C_T}$$

where RR_e is the relative risk of the exposed to the unexposed group (estimated by an odds ratio, OR_e), C_e is the number of cases exposed and C_t is the total number of cases.

By using the function $OR = (BMI/24)^i$ where $i = 5.2$ (4.2–6.3), we can calculate the individual OR for every subject for their actual weight vs their hypothetical reduced weight as:

$$OR_k = \left(\frac{BMI_{ak}}{BMI_{rk}} \right)^i$$

where BMI_{ak} is the actual BMI for subject k and BMI_{rk} is the reduced BMI for subject k made by reducing their weight. Then the attributable proportion of cases that might be eliminated by weight loss, using the above two equations is

$$\sum_{k=1}^{C_e} \frac{OR_k - 1}{OR_k}$$

That is the summation over all exposed (overweight or obese) cases.