The association between musculoskeletal disorders and obesity

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Abstract

The aim of this study was to examine the association between musculoskeletal disorders and the level of obesity (as defined by the body mass index) for a sample of the Australian population aged 20-64. A logistic regression model was used to estimate the association between musculoskeletal disorders and obesity, controlling for a range of socio-demographic characteristics. Individual-level data on obesity, musculoskeletal disorders, and various socio-demographic characteristics were extracted from the Australian Bureau of Statistics (ABS) 1995 National Health Survey (NHS). Individuals with musculoskeletal disorders were identified using ICD-9 codes 710-739 from a sample of 28,376 individuals from the non-institutionalised population. Estimates from the logistic regression equation indicate that there is a statistically significant positive relationship between the probability of having a musculoskeletal disorder and the level of obesity. Socio-demographic variables such as age, sex, origin, income level, employment status and geographic location also had a statistically significant relationship. This information can be used by public health practitioners and educators to identify those at risk and to design health strategies that target at-risk patients.

Significance of musculoskeletal disorders

In the developed world, musculoskeletal disorders (MSDs) such as arthritis and rheumatism represent a substantial burden to patients and the health care system. Individuals with MSDs experience pain, restricted physical movement, and an overall reduction in quality of life (Coyte et al., 1998).

The costs associated with MSDs are substantial. In the US, the economic costs associated with MSDs totalled $US149.4 billion in 1992 or approximately 2.5 per cent of Gross National Product (Yelin & Callahan, 1995). For Canada, the total cost of MSDs was estimated at $CDN25.6 billion or 3.4 per cent of Gross Domestic Product (Coyte et al., 1998). In Sweden, MSDs were identified as the most expensive disease category in 1991 (Lindgren, 1998), while in Australia it was estimated that the cost of MSDs totalled $A3 billion in 1993/94 (Mathers & Penm, 1999).

There is evidence to suggest that MSDs are associated with a number of risk factors including age, body mass index (BMI), education attainment, income level, and race (Callahan et al., 1996; Yelin, 1997). In this study, the relationship between MSDs and the level of obesity (BMI) is of particular interest. This is because a number of studies have reported that obesity is related to a variety of musculoskeletal disorders ranging from osteoarthritis (in both the knee and hip) to joint pain (Bray, 1985; Colditz, 1992; Jung, 1997; Pi-Sunyer, 1993). For example, the greater prevalence of osteoarthritis with increasing body weight has been reported in several cross-sectional studies (Goldin et al., 1976; Leach et al., 1973). It has been reported that a 6-10 kg weight loss in morbidly obese subjects is associated with a relief from pain in the lower back, ankles, and feet (McGoey et al., 1990).

The purpose of this article is to further explore the relationship between obesity and MSDs from a statistical viewpoint by developing and estimating a logistic regression model that examines the impact of obesity and a range of socio-demographic characteristics on the prevalence of MSDs. From a public health perspective, this type of quantitative information can be used to identify patients at risk of suffering from MSDs, to suggest strategies that will lower the risk, and to guide the allocation of health care resources towards relevant population groups. For example, this information could be used to design and promote alternative weight reduction strategies such as education campaigns, weight-reducing drugs, subsidised foodstuffs, and exercise programs.

Method

A logistic regression model was defined according to whether an individual either has a MSD (Y = 1) or does not (Y = 0). It was postulated that a set of factors - including age, sex, education, origin, income, employment, location, insurance cover, and obesity (BMI) - might be predictive of having a MSD. The relationship between MSDs and a set of explanatory variables can be expressed as follows:

$$L_i = [\ln(P_i / 1 - P_i)] = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \ldots + \beta_{k-1} X_{i,\, k-1} \qquad (1)$$

where L_i is the log of the odds ratio of having a MSD (Gujarati, 1995). The β_0 term is the intercept and β_1 to β_{k-1} are the coefficients associated with the corresponding X_i variables. Equation (1) is estimated using the maximum likelihood procedure (Gujarati, 1995; Aldrich & Nelson, 1984; Griffiths et al., 1993). A distinct advantage of the procedure is that each of the estimated coefficients can be interpreted as odds ratios. For example, the effect of a unit increase in the value of a continuous variable on the odds ratio for MSDs equals the anti-logarithm (ie, *e* to the power) of the corresponding estimated coefficient (Hamilton, 1992; Hosmer & Lemeshow, 1989).

Data were obtained from the Australian Bureau of Statistics 1995 National Health Survey (NHS) (ABS, 1996). This survey was designed to collect a range of health-related information on a sample of the Australian population. Individuals between the ages of 20-64 were selected, resulting in a sample of 28,376 people from the non-institutionalised population. Individuals with MSDs were identified using the International Classification of Diseases (version 9) codes 710-739. A total of 6,595 people (23.2 per cent) were classified as having at least one musculoskeletal condition. The study sample consisted of 51 per cent female and 49 per cent male.

Besides BMI, other variables that might be expected to influence susceptibility to MSDs and that are identifiable in the NHS include age, sex, education, origin, income, employment status, location, and insurance status. Hence the particular specification of (1) used here is given by equation (2) using simplified notation for convenience:

$$L_i = \ln[(P_i/(1 - P_i)] = \beta_0 + \beta_1 AGE + \beta_2 SEX + \beta_3 EDUCATION + \beta_4 ORIGIN + \beta_5 INCOME + \beta_6 EMPLOYMENT + \beta_7 LOCATION + \beta_8 INSURANCE + \beta_9 BMI \qquad (2)$$

where P_i is the probability that person *i* has one or more MSDs. Explanatory variable BMI in (2) is continuous, and defined as the subject's weight in kilograms divided by height in meters squared, which was calculated from self-reported weight and height data in the 1995 NHS. Obesity was defined according to World Health Organization (WHO) guidelines as a BMI value greater than 30 (Seidell & Flegal, 1997). It was expected that the estimated coefficient β_9 would be positive (an increase in the BMI is associated with an increasing probability of suffering a MSD), given the available evidence.

All other explanatory variables in (2), that are described below (and with details given in Table 1), are discrete, either by definition, or because of the way in which these data were collected in the 1995 NHS. This means that a set of dummy variables, equal in number to one less than the number of categories into which a particular explanatory variable is classified, is needed to measure a single explanatory variable, and one category (the 'reference category') is excluded. The estimated coefficients on any of the dummy variables then measures the impact on the dependent variable of a subject being in one category rather than being in the reference category.

Table 1. Descriptive statistics for the sample (n = 28,376)

Name	Mean	Std Dev	Label
MSD	0.23	0.42	Musculoskeletal Disorder
AGE1	0.11	0.32	20-24 years
AGE2	0.13	0.33	25-29 years
AGE3	0.14	0.35	30-34 years
AGE4	0.14	0.35	35-39 years
AGE5	0.13	0.34	40-44 years
AGE6	0.12	0.33	45-49 years
AGE7	0.09	0.29	50-54 years
AGE8	0.08	0.26	55-59 years
AGE9	0.06	0.24	60-64 years
SEX	0.51	0.50	1 if female; 0 if male
EDUC1	0.25	0.43	No higher qualifications
EDUC2	0.46	0.50	NA, inadequately described
EDUC3	0.01	0.10	Higher degree
EDUC4	0.02	0.12	Postgraduate diploma
EDUC5	0.05	0.22	Bachelor degree
EDUC6	0.02	0.15	Undergraduate diploma
EDUC7	0.03	0.16	Associate diploma
EDUC8	0.13	0.33	Skilled/basic vocational
ORIGIN1	0.74	0.44	Australia and New Zealand
ORIGIN2	0.09	0.29	British Isles and Ireland
ORIGIN3	0.08	0.28	Europe
ORIGIN4	0.01	0.09	Middle East
ORIGIN5	0.05	0.22	Asia
ORIGIN6	0.03	0.17	Other
INC1	0.08	0.27	$30000-34999
INC2	0.13	0.34	NA, Don't know / Not Stated
INC3	0.01	0.11	Negative
INC4	0.07	0.25	$1-4999
INC5	0.14	0.35	$5000-9999
INC6	0.08	0.27	$10000-14999
INC7	0.08	0.27	$15000-19999
INC8	0.11	0.31	$20000-24999
INC9	0.10	0.30	$25000-29999
INC10	0.06	0.23	$35000-39999
INC11	0.04	0.20	$40000-44999
INC12	0.03	0.16	$45000-49999
INC13	0.02	0.15	$50000-54999
INC14	0.01	0.11	$55000-59999
INC15	0.01	0.10	$60000-64999
INC16	0.01	0.08	$65000-69999
INC17	0.01	0.08	$70000-74999
INC18	0.03	0.16	$75000 or more
EMP1	0.75	0.43	Wage and salary
EMP2	0.05	0.21	In own business
EMP3	0.21	0.40	Other/NA
LOC1	0.59	0.49	Capital City
LOC2	0.11	0.31	Large/small rural centres
LOC3	0.14	0.34	Other rural area/remote
LOC4	0.16	0.37	Australian Capital Territory/Northern Territory
INSUR1	0.28	0.45	Does not have private insurance cover
INSUR2	0.49	0.50	N/A
INSUR3	0.23	0.42	Has private insurance cover
BMI	25.30	4.19	Body Mass Index

Consider, for example, the AGE variable. Although this is continuously measurable in principle, in the 1995 NHS subjects interviewed were assigned into one of a number of age categories. Excluding the young and the old, in this study the AGE variable was classified into nine categories covering five-year intervals over the age range 20 to 64. These categories ran from 20-24 (category 1) to 60-64 (category 9). Individuals in the age group 20-24 were selected as the excluded reference group and all other age groups were treated as dummy variables, assigned a value 1 if the relevant subject was in the particular age group, and 0 otherwise. Hence the age of a person in age group 3 (30-34 years) would be described in terms of a value of 0 for variables AGE1, AGE2 and AGE4-AGE9, and a value of 1 for AGE3. The value of the estimated coefficient on the variable AGE3 is interpreted as the impact on the dependent variable of being in this age group as compared with being in the reference age group (20-24). Interpretations of other explanatory variables are similar.

SEX is a dichotomous variable that takes the value 1 if female, and 0 if male. EDUCATION was classified into seven categories according to the highest-level qualification obtained, rather than years of schooling, with 'no higher qualifications' (ie, no post-school education) as the excluded reference group. As with INCOME, a separate category was included for 'unknown' or 'unstated', both to avoid excluding observations and to allow for the possibility that this category was associated with other (unmeasured) characteristics that might have an impact on the dependent variable. An individual's ORIGIN was used as a proxy for racial and cultural background. This variable is categorical, and five categories are used in this study, with people born in Australasia selected as the reference group. Gross personal INCOME is continuously measurable in principle, but (as for AGE) income information was collected by ranges in the 1995 NHS. Seventeen income brackets are utilised in this study, with people in the income bracket $30,000-34,999 per annum being selected as the reference group.

A person's EMPLOYMENT status was captured by three discrete variables, with those individuals who were wage and salary earners selected as the reference group. A person's geographic LOCATION was captured by three discrete variables, with people residing in capital cities being chosen as the excluded reference group. Health INSURANCE status was indicated simply by whether a person did or did not have private insurance cover for health, with those not covered chosen as the reference group.

Results

The estimated impact of BMI and the various socio-demographic control variables on the susceptibility to MSDs is presented in Table 2. Included in Table 2 are the estimated logistic regression coefficients and constant (the β values), standard errors (SE), the odds ratios (OR) and corresponding 95 per cent confidence intervals (CI) for all the socio-demographic (control) and obesity (BMI) variables. Values listed in the OR column for the control variables - all discrete - are the estimated impact of being in that group rather than in the excluded reference group. For the (continuous) BMI variable, the OR figure is the impact of a unit increase in the BMI on the odds in favour of having MSDs.

Joint hypothesis tests were conducted to assess whether each set of control variables had a statistically significant influence on the dependent variable. Characteristics that were statistically significant are age ($p < 0.01$), origin ($p < 0.01$), income ($p < 0.01$), employment status ($p < 0.01$), and geographic location ($p < 0.05$).

Among patient characteristics, seven of the discrete age variables (AGE2-AGE8) show a statistically significant positive association with the dependent variable (all p values < 0.01). This association is particularly striking for older age groups. For example, compared to individuals in the age group 20-24, individuals age 60-64 (AGE8) were more likely to have a musculoskeletal disorder. The SEX variable enters with a statistically significant negative sign, indicating that females are less likely to have a MSD compared to men (OR = 0.91; CI = 0.85-0.97). This result is contrary to other studies, which indicate that MSDs are more prevalent in females (Callahan et al., 1996; Yelin, 1997).

People born in Europe (ORIGIN2; OR = 0.77; CI = 0.69-0.85) and Asia (ORIGIN4; OR = 0.45; CI = 0.38-0.54) were significantly less likely to have a musculoskeletal condition than individuals born in Australasia, which is an interesting result meriting further research. The association between INCOME and MSD is not clear, although it appears that individuals with higher income levels (INC11, INC13, INC14, INC15, and INC17) are less likely to have a MSD condition compared to the reference group (ie, people with a gross income of between $30,000-34,999 per annum). These results probably disguise a real impact of other factors that are correlated

with income, such as the nature of employment and leisure activities, and the likelihood that people in higher income brackets spend more on health care and health-related activities. Of the other control variables, the only significant impact of location is that people living in rural centres (rather than remote rural) have a higher likelihood of a MSD (OR = 1.14; CI = 1.04-1.26), with the influence of other locations (LOC2 and LOC3) being only moderately significant ($p < 0.1$). Neither education nor insurance cover had a statistically significant influence on the dependent variable.

Table 2. Logistic regression estimates (β), standard errors (SE), odds ratios (OR) and 95% confidence intervals (CI) (n = 28,376); dependent variable = Musculoskeletal Disorder

Variable	β	SE	OR	CI lower	CI upper	Label
Control variables						
AGE2	0.02	0.07	1.02	0.88	1.18	25-29 years
AGE3	0.27***	0.07	1.31	1.14	1.50	30-34 years
AGE4	0.49***	0.07	1.63	1.43	1.86	35-39 years
AGE5	0.62***	0.07	1.86	1.63	2.13	40-44 years
AGE6	0.92***	0.07	2.52	2.21	2.88	45-49 years
AGE7	1.16***	0.07	3.18	2.77	3.65	50-54 years
AGE8	1.41***	0.07	4.08	3.54	4.70	55-59 years
AGE9	1.62***	0.08	5.07	4.37	5.88	60-64 years
SEX	-0.10***	0.03	0.91	0.85	0.97	Female
EDUC2	0.45*	0.26	1.57	0.93	2.63	NA, inadequately described
EDUC3	-0.12	0.17	0.89	0.64	1.23	Higher degree
EDUC4	-0.10	0.13	0.91	0.70	1.18	Postgraduate diploma
EDUC5	0.01	0.08	1.01	0.87	1.18	Bachelor degree
EDUC6	-0.09	0.10	0.92	0.75	1.13	Undergraduate diploma
EDUC7	-0.05	0.10	0.96	0.79	1.16	Associate diploma
EDUC8	0.10*	0.05	1.10	1.00	1.22	Skilled/basic vocational
ORIGIN2	-0.03	0.05	0.97	0.88	1.07	British Isles and Ireland
ORIGIN3	-0.27***	0.05	0.77	0.69	0.85	Europe
ORIGIN4	-0.26	0.18	0.77	0.54	1.10	Middle East
ORIGIN5	-0.80***	0.09	0.45	0.38	0.54	Asia
ORIGIN6	-0.07	0.09	0.94	0.78	1.12	Other
INC2	-0.12*	0.07	0.89	0.77	1.02	NA, Don't know/Not Stated
INC3	0.18	0.14	1.20	0.92	1.57	Negative
INC4	-0.20**	0.09	0.82	0.69	0.97	$1-4999
INC5	0.29***	0.07	1.33	1.15	1.54	$5000-9999
INC6	0.08	0.08	1.08	0.93	1.26	$10000-14999
INC7	-0.05	0.08	0.95	0.81	1.11	$15000-19999
INC8	0.04	0.07	1.04	0.90	1.20	$20000-24999
INC9	-0.13*	0.07	0.88	0.76	1.02	$25000-29999
INC10	0.01	0.08	1.01	0.86	1.19	$35000-39999
INC11	-0.12	0.09	0.89	0.74	1.06	$40000-44999
INC12	-0.35***	0.12	0.71	0.56	0.88	$45000-49999
INC13	-0.21*	0.11	0.81	0.65	1.02	$50000-54999
INC14	-0.56***	0.17	0.57	0.41	0.79	$55000-59999
INC15	-0.46***	0.17	0.63	0.46	0.88	$60000-64999
INC16	-0.48**	0.21	0.62	0.41	0.94	$65000-69999
INC17	-0.16	0.20	0.86	0.58	1.27	$70000-74999
INC18	-0.23**	0.11	0.79	0.64	0.98	$75000 or more

Table 2. cont.

Variable	β	SE	OR	CI lower	CI upper	Label
EMP2	-0.02	0.08	0.98	0.84	1.15	In own business
EMP3	0.32***	0.05	1.37	1.26	1.50	Other/NA
LOC2	0.13***	0.05	1.14	1.04	1.26	Large/small rural centres
LOC3	0.08*	0.04	1.09	1.00	1.18	Other rural area/remote
LOC4	0.07*	0.04	1.08	0.99	1.17	ACT/Northern Territory
INSUR2	-0.32	0.26	0.72	0.43	1.21	N/A
INSUR3	0.06	0.04	1.06	0.97	1.16	Has private insurance cover
Obesity variable						
BMI	0.05***	0.00	1.05	1.04	1.05	Continuous measure
Constant	-3.10***	0.12				

* $p < 0.1$. ** $p < 0.05$. *** $p < 0.01$.

The following control variables, as a group, were statistically significant: age ($p < 0.01$), origin ($p < 0.01$), income ($p < 0.01$), employment status ($p < 0.01$), and geographic location ($p < 0.05$).

Overall, there is a statistically significant positive association between the level of obesity (BMI) and the likelihood that an individual has a MSD. The coefficient for the continuous BMI variable was estimated to be 0.05 ($p < 0.01$). This indicates that for a one-unit increase in BMI, the log of the odds ratio for having a musculoskeletal condition increases by about 0.0452. Taking the antilog of 0.05 results in an increased odds ratio of 1.05. That is, a unit increase in BMI raises the odds of developing a MSD by 5 per cent.

There are several ways to calculate the goodness of fit for the logistic regression model, as an indicator of the 'success' of the overall model in explaining the probability of having a MSD. One approach is to calculate the predicted success table for the regression analysis. Table 3 presents actual values of the dependent variable versus those that the logistic regression model has predicted.

Table 3: Predicted success table for MSDs

	Predicted		
Actual MSD	Yes	No	Total
Yes	840	5755	6595
No	547	21234	21781

Sensitivity = 840/6595 = 12.7%
Specificity = 21234/21781 = 97.5%
Proportion correctly assigned =77.8%

The sensitivity of the model is the probability of predicting a MSD given the number of patients who actually have a MSD. In this model, 12.7 per cent of individuals were allocated into the right category. Specificity of the model is the probability of predicting no event given that no such event has occurred. The model has a success rate of 97.5 per cent in identifying those who did not have a MSD. Overall, the model correctly predicts 78 per cent of actual observations.

Discussion

The aim of this study was to examine the association between MSDs and BMI, controlling for personal characteristics, for a sample of the non-institutionalised Australian population age 20-64. Variables were selected from the 1995 National Health Survey.

An advantage of this type of study is that a set of personal and obesity characteristics can be used to identify those patients who are at risk of developing a musculoskeletal disorder. From a public health perspective, the identification of high-risk individuals using multiple characteristics could be used as a disease management tool for the monitoring and medical intervention of at-risk patients. These results suggest that health policies should be targeted at promoting and maintaining a healthy body weight.

A number of limitations associated with this research need to be noted. First, these data are self-reported, and their reliability is at least questionable. For example, there might be a tendency for survey respondents to over-report their height and under-report their weight. Similar concerns apply to other variables and are a limitation associated with use of any self-reported data.

Secondly, there are limitations associated with using cross sectional data to draw inferences about a long-term dynamic process. A longitudinal dataset would be better suited to examine (over time) the relationship between musculoskeletal disorders and the level of BMI.

Thirdly, another limitation of this exercise, indeed of any exercise of this type, is that there is always the possibility of omitted variable bias, which could potentially exaggerate the effect of BMI on MSDs. To give an example, suppose daily calorie intake (not included in the model) were directly associated with susceptibility to MSDs, and also positively correlated with BMI. Then the measured impact of BMI on the probability of having a MSD confounds the separate impacts of BMI and calorie intake. This would mean that a reduction in BMI that is not associated with a reduction in calorie intake would not decrease the probability by as much as the model indicates, because calorie intake is maintained and has a separate impact on the probability. Omitted variable bias of this type is always a possibility, and the only way of burying the possibility is to include all feasible omitted variables in the model and see if they have a separate impact. Data limitations always preclude this perfectionist approach.

The logistic regression model was shown to be a powerful approach to estimating susceptibility to MSDs, and in particular the impact of obesity on this risk. By extension, the same approach can be applied to other obesity-related medical conditions. The quality of estimates derived from this approach is limited by the quality of these data, and the 1995 NHS data are far from perfect. Nevertheless, the model performs reasonably well by standard statistical criteria, and produces the type of quantitative data that can potentially be useful in targeting health care interventions and healthy living campaigns.

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