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# A patient-centred approach to estimate total annual Healthcare Costs by Body Mass Index in the UK Counterweight Programme

William W. Tigbe<sup>a,\*</sup>, Andrew H Briggs<sup>b</sup>, Michael E.J. Lean<sup>c</sup>

<sup>a</sup> Public Health, Institute of Health & Wellbeing , 1 Lilybank Gardens, University of Glasgow, G12 8RZ, UK.

<sup>b</sup>Health Economics & Health Technology Assessment, Institute of Health & Wellbeing , 1 Lilybank Gardens, University of Glasgow, G12 8RZ, UK.

<sup>c</sup> School of Medicine, University of Glasgow, 4th Floor, Walton Building, Glasgow Royal Infirmary, 84 Castle Street, Glasgow G4 0SF, UK.

## \*Corresponding author:

Dr. William Tigbe  
Division of Health Science  
Warwick Medical School  
University of Coventry  
Gibbet Hill Road  
Coventry CV4 7AL  
Email: [W.W.Tigbe@warwick.ac.uk](mailto:W.W.Tigbe@warwick.ac.uk)  
Tel: +44 2476150539

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## 21 **Abstract**

### 22 **Background**

23 Previous studies, based on relative risks for certain secondary diseases, have shown greater  
24 healthcare costs in higher body mass index (BMI) categories. The present study quantifies the  
25 relationship between BMI and total healthcare expenditure, with the patient as the unit of analysis.

### 26 **Methods**

27 Analyses of cross-sectional data, collected over 18-months in 2002-2003, from 3,324 randomly-  
28 selected patients, in 65 general practices across UK. Healthcare costs estimated from primary care,  
29 outpatient, accident/emergency and hospitalisation attendances, weighted by unit costs taken from  
30 standard sources.

### 31 **Results**

32 In univariate analyses, significant associations ( $p<0.05$ ) were found between total healthcare  
33 expenditure and all dependent variables (women>men, drinker<non-drinkers, smokers>non-smokers,  
34 and increasing with greater physical activity, age and BMI. In multivariate analysis, age, sex, BMI,  
35 smoking and alcohol consumption remained significantly associated with healthcare cost, and  
36 together explained just 9% of the variance in healthcare expenditure. Adjusted total healthcare cost  
37 was £16 (95% CI £11-£21) higher per unit BMI. All cost categories were significantly ( $p<0.003$ )  
38 higher for those with BMI >40 compared to BMI<20 kg/m<sup>2</sup>: prescription drugs (men: £390 versus  
39 £16; women: £211 versus £73), hospitalisation (men: £72 versus £0; women: £243 versus £107),  
40 primary care (men: £191 versus £69; women: £268 versus £153) and outpatient care (£234 versus  
41 £107 women only).

### 42 **Conclusions**

43 Annual healthcare expenditure rose a mean of £16 per unit greater BMI, doubling between BMI 20-  
44 40kg/m<sup>2</sup>. This gradient may be an underestimate if the lower-BMI patients with heights and weights  
45 recorded had other costly diseases.

46 **Word count - 240**

47

## 48 **Introduction**

49 The obesity epidemic is a major drain on world economies, as obesity becomes the leading cause of  
50 ill-health in the developed world.<sup>1</sup> In Scotland, 66% of adults are overweight (BMI>25), including  
51 26% obese with BMI >30kg/m<sup>2</sup>.<sup>2</sup> Obesity is a known risk factor for a variety of diseases, including  
52 cardiovascular disease, diabetes, colon cancer, arthritis, gallbladder disease and depression.<sup>3</sup> It also  
53 increases “minor illnesses” and drug prescriptions in almost all prescribing categories.<sup>4</sup>

54 In addition to direct healthcare cost, obesity also causes lost productivity, from absence from work  
55 and premature death. Partial costing based on limited health outcomes, for which age/sex/BMI-  
56 stratified data exist, put the direct healthcare cost of obesity in the UK in 2002 at between £991  
57 million to £1.124 billion, plus indirect costs of between £2.4 billion-2.7 billion.<sup>5</sup>

58 There are, methodologically, two approaches to calculating the healthcare cost of obesity. Most have  
59 linked the relative risk of selected diseases associated with obesity, to the population prevalence of  
60 obesity and applied standard unit costs.<sup>6-8</sup> This population-attributable-risk method provides an  
61 estimate of only part of the economic burden of obesity because few secondary diseases have sound  
62 epidemiological data broken down by age, sex and BMI. A second approach is direct linkage of  
63 obesity or BMI data to healthcare expenditure at the individual level.<sup>9-12</sup>

64 A recent systemic review by Mueller-Riemenschneider et al.<sup>13</sup> reported obesity-related healthcare  
65 burdens, based only on diabetes, CHD, colon cancer costs, of up to 10.4 billion Euros across Western  
66 European countries. The figure varies widely from 0.09 % to 0.61 % of the gross domestic product  
67 of each country. Obese individuals are more likely to be hospitalised.<sup>14</sup> In Sweden, excess annual  
68 healthcare cost for the overweight (BMI = 25 to  $\leq 30\text{kg/m}^2$ ) and the obese (BMI $\geq 30\text{kg/m}^2$ ) was  
69 estimated at 2.3 % (US\$ 269 million) of the country’s total hospital care.<sup>15</sup> In Brazil, the estimated  
70 total cost of overweight and obesity is put at 3.0 % of total inpatient cost for men and 5.8 % for  
71 women, aged 20-60 years.<sup>16</sup> Among the claims made on 61 US employers’ health plans, obesity-

72 related medical expenses (not including drugs) accounted for 2.8% of all medical costs between  
73 2000-2004.<sup>17</sup>

74 Above BMI 30 kg/m<sup>2</sup>, healthcare costs increase further.<sup>8,9,11,12,18-25</sup> In 15,355 US adults, the adjusted  
75 average number of all-cause hospitalisations over 13 years was 1,316, 1,543 and 2,025 per 1,000 for  
76 adults with BMI <25, 25-30 and >30kg/m<sup>2</sup>.<sup>14</sup>.

77 In a cross-sectional study involving 34,932 US participants, Wang et al.<sup>25</sup> reported greater healthcare  
78 cost with each BMI unit between 25-45kg/m<sup>2</sup>, of US\$ 119.7 (4%) per unit BMI for medical cost, and  
79 US\$82.6 (7%) per unit BMI for pharmaceutical cost. A Canadian study of adults in 1994 reported  
80 \$8.90 per capita greater cost of physicians' services per unit BMI above 20kg/m<sup>2</sup>.<sup>10</sup> Using a  
81 hypothetical cohort Markov-type model of obese individuals, Rappange et al.<sup>26</sup> proposed higher  
82 lifetime drug expenditures for obese people, and savings from obesity prevention.

83 Similarly, a patient-centred approach to increased actual drug prescription costs associated with  
84 greater BMI has been published.<sup>4</sup> The total healthcare cost associated with a unit increase in BMI in  
85 the UK population is not known. The present study aimed to quantify the relationship between BMI  
86 and total healthcare cost, calculated from recorded resource use, with the individual patient as the  
87 unit of analysis.

## 88 **Methods**

89 Secondary analyses were conducted on cross-sectional data collected as part of the Counterweight  
90 audit.<sup>27</sup> Ethical approval was received from the West Midlands Multi-Centre Research Ethics  
91 Committee (MREC) and subsequently from various local ethics committees. The sample was 3,450  
92 (1,385 men and 2,065 women) randomly selected adult patient records collected over an 18-month  
93 period in 2002-2003, from 65 UK Primary Care practices selected to represent urban and rural  
94 regions across the UK, with a wide range of socio-economic catchments. They were three random  
95 samples of those patients who for some reason (undefined) had their height and weight recorded,

1150 from each BMI stratum <25, 25-30 and >30. The data also included geographic area, smoking, alcohol consumption and physical activity participation. Healthcare data included appointments with the general practitioner, practice nurse, health visitor, dietitian and outpatient specialist appointments. They also included accident and emergency (A&E) attendance and hospital admissions, healthcare consumption at the primary care, outpatient and inpatient costs were calculated based on these indices, adding drug prescription costs, which have already been published<sup>4</sup>.

BMI was computed from recorded mean weight and height during audit period (for those with multiple weight records) (n=418), single records during audit (n=1,578), or last recorded data before the audit (n = 1,453). There were 896 current smokers, 649 ex-smokers and 1,552 non-smokers, (status not recorded for 353 (10%)), and 2,009 participants drank alcohol while 801 did not, (data unavailable for 640 participants (19%)). Physical activity categories included 262 inactive, 515 light, 471 moderate and 65 heavy physical activity, (data unavailable for 2011 participants (60%)).

Five categories of cost – primary care, A&E department, outpatient department, and in-patient stay - were identified. The previously calculated total cost of drugs prescribed for each patient over the 18-month period was added,<sup>27</sup> to provide the total healthcare cost of each patient for the 18-month period. Assuming that costs were spread evenly the annual (12-month) healthcare cost was calculated for each patient [as 12/18 x 18-month cost]. Healthcare unit costs were taken from standard figures.<sup>28</sup>

Prescription costs were not available for one general practice (50 participants). The number of GP appointments for one participant was not known and 75 participants had no record of either weight or height and hence no BMI. These 126 participants were excluded from all further analyses. Therefore, 3324 participants (1971 women and 1353 men) with data complete for healthcare cost and BMI were included for analysis.

## 120 **Statistical Analyses**

121 Analyses were undertaken using SPSS version 19.0. Summary statistics of personal, lifestyle  
122 variables (smoking, alcohol intake and physical activity level) and healthcare costs were produced.  
123 Dummy variables were created for missing data and these were considered as a group (unknown)  
124 under each variable. ANOVA was used to explore differences in healthcare costs across each  
125 lifestyle factor. The mean unadjusted healthcare cost associated with each unit BMI was calculated.  
126 The small numbers with BMI below  $20\text{kg/m}^2$  (2.3%) and above  $40\text{kg/m}^2$  (3.2%), were collapsed.

127 In multivariate analyses, the best-fit model was constructed checking for assumptions of linearity,  
128 constancy of variance and normality. Annual healthcare costs at quintiles of BMI (<25, 25-30, 30-35,  
129 35-40,  $>40\text{kg/m}^2$ ) were compared to assess associations with BMI. Furthermore,  $\text{BMI}^2$  was  
130 incorporated to test if a quadratic association was more appropriate. Multiple linear regression  
131 modelled change in annual healthcare cost per unit change in BMI. Annual healthcare cost ( $\pm 95\%$   
132 confidence interval) associated each unit of BMI, adjusting for age, sex and lifestyle (the marginal  
133 effect) was obtained. A two-part model, to calculate the association on condition that cost has been  
134 incurred, was also tested.

## 135 **Results**

136 Data are presented on UK adults (aged 17-76y) randomly selected from a list of patients who, for  
137 some reason (undefined) had had their height and weight recorded in primary care records. During  
138 the 18-month audit period, there were 18,301 GP appointments for 2,827 patients, 6,384 Practice  
139 Nurse appointments for 1,754 patients, and 57 dietitian appointments for 41 patients, and 62% (n=  
140 2230) of the study participants received at least one prescription drug. There were 5,673 visits to  
141 various outpatient departments by 2,983 of the participants, and 384 admissions for a total of 1,545  
142 bed days. Hospitalisation duration ranged from 1-54 days, median two days. There were 336 visits to  
143 the A&E department by 254 patients.

144 Mean (SD) age was 47(15)y and 48(14)y for women and men respectively. BMI ranged from 16.2-  
145 64.3kg/m<sup>2</sup> for women and 18.4-53.9kg/m<sup>2</sup> for men; mean (SD) of 28.1(6.0)kg/m<sup>2</sup> and 27.9(5.2)kg/m<sup>2</sup>  
146 respectively. Mean healthcare costs for each category of care are displayed in Table 1. Most of the  
147 patients included had some health resource use: 3.6% of the women and 12.5% of the men had zero  
148 healthcare cost during the study period.

149 Annual healthcare cost was significantly ( $p<0.001$ ) associated with BMI and with age, in men  
150 (Pearson's  $r=0.10$ ,  $r=0.29$  respectively) and also in women ( $r=0.13$ ,  $r=0.22$  respectively). This  
151 significant association of cost with age and BMI was also observed at the different levels of  
152 healthcare (supplementary table 1). Mean healthcare cost was therefore, generally higher at higher  
153 BMI though the relationship is not totally clear with unadjusted figures (supplementary table 2).

154 There were 744 current smokers with reported mean (SD) number of cigarettes smoked per day of  
155 17(11). Alcohol consumption was more common ( $n=1796$ ) and reported mean (SD) consumption  
156 was 13(11) units per week. The number of cigarettes smoked currently per day (Pearson  $r=0.03$ ,  
157  $p=0.10$ ) and the number of units of alcohol drank per week ( $r=-0.04$ ,  $p=0.06$ ) showed poor  
158 correlation with annual healthcare cost. In grouped (categorical) analyses, ex-smoker, non-drinkers  
159 and the inactive had significantly higher healthcare cost than other categories (Figure 1).

160 Annual healthcare cost at quintiles of BMI suggested a linear relationship, and linear association  
161 explained 9% of the variance in healthcare cost. Using a quadratic function (BMI<sup>2</sup>) in the model was  
162 not significant ( $p=0.07$ ). Higher annual healthcare cost was significantly associated with increasing  
163 age, increasing BMI, being female and smoking (Table 2). No demonstrable effect was observed  
164 with physical activity, while alcohol consumption was associated with a lower cost. After adjusting  
165 for sex, age, smoking, alcohol consumption and physical activity, each higher unit BMI was  
166 associated with £16 (95% CI £11 to £21) higher annual healthcare cost. BMI accounted for 1.3% of  
167 the variance in healthcare cost. The two-part model produced similar results. As demonstrated in  
168 Figure 2, annual healthcare cost more than doubles at BMI 40kg/m<sup>2</sup> compared to 20kg/m<sup>2</sup>.



169 All categories of cost were higher for those with BMI above 40kg/m<sup>2</sup> compared to BMI below  
170 20kg/m<sup>2</sup>, significantly so for prescription drugs (£390 versus £16 for men, £211 versus £73 for  
171 women, p<0.001), hospitalisation (£72 versus £0 for men, £243 versus £107 for women, p=0.002),  
172 primary care (£191 versus £69 for men, £268 versus £153 for women, p<0.001) and outpatient care  
173 (£234 versus £107 women only, p<0.003) [Figure 2 and much clearer in the coloured supplementary  
174 figure].

## 175 **Discussion**

176 The present study used individual-level healthcare cost data to quantify the change in healthcare cost  
177 associated with greater body mass index. The data indicated that a unit difference in BMI of a UK  
178 adult relates to a £16 difference in annual healthcare cost, across the BMI range 20-40kg/m<sup>2</sup>, with  
179 very similar figures for men and women. The data were collected from a large number (65) of  
180 randomly selected general practices across the UK, reflecting both rural and urban populations, and  
181 across a wide range of socio-economic catchments, as indicated by post codes. The sample size was  
182 large (n=3324) and the ability to control for lifestyle factors was important, to confirm the significant  
183 association between BMI, lifestyle factors and healthcare cost.

184 At the univariate level of analyses, healthcare cost was significantly associated with age, sex, BMI  
185 and lifestyle factors. Women had greater healthcare cost than men, and cost increased with  
186 increasing age. Physical activity appeared to be protective while smoking increases healthcare cost.  
187 After adjustments, inactivity was no longer significantly associated with healthcare cost, perhaps  
188 because the effects of physical activity on healthcare cost are mediated through changes in BMI and  
189 after controlling for BMI, and smoking and drinking (which also influence BMI), the independent  
190 effect of physical activity was no longer significant.

191 Paradoxically, alcohol consumers had lower healthcare cost compared to non-drinkers. The  
192 relationship between health and alcohol consumption is a “J-shaped” curve<sup>29</sup>, such that low-to-

193 moderate drinking is protective against ill-health, so might reduce healthcare cost. However, it could  
194 be that drinkers did not take up healthcare appointments or stopped seeking healthcare, thus reducing  
195 their healthcare cost. Alternatively, sick individuals might have stopped drinking or simply  
196 misreported no consumption, thus leading to misclassification. Social desirability response bias is a  
197 major limitation to all self-report data<sup>30</sup>. Many confounders and mediators affect the relationship  
198 between healthcare cost and BMI. Biologically, men and women have different health needs. BMI  
199 increases with age, and health commonly deteriorates. Physical activity is useful in weight control,  
200 and has other health benefits. Smokers tend to have lower weights but poorer health, while alcohol  
201 consumption may be associated with excess weight and also poor health, and non-drinkers include  
202 sick former drinkers.

203 After adjusting for age, sex and lifestyle, increasing BMI remained significantly associated with  
204 higher healthcare cost. If this association were causal, BMI might not simply be in the causal  
205 pathway between biology/lifestyle and healthcare cost, but may have its own marginal effect on  
206 healthcare cost. Across the BMI range 20-40kg/m<sup>2</sup>, adjusted annual healthcare cost was £16 greater  
207 for each higher unit BMI. This figure might be of value in planning obesity prevention and weight  
208 management services. However, the gradient of healthcare costs, between BMI 20 and 40kg/m<sup>2</sup> seen  
209 in this study is likely to underestimate the true gradients, because the study relied on data from  
210 patients whose height and weight had been recorded. The reasons for recording height and weight in  
211 primary care vary. Firstly, only patients attending for a consultation of some kind are included.  
212 Secondly, while those with BMI >30kg/m<sup>2</sup> may have had height and weight recorded purely because  
213 of their evident obesity, these measurements are rarely made for normal-weight patients (BMI  
214 <25kg/m<sup>2</sup>) – and usually only if there is a disease which threatens weight-loss. Thus the normal-  
215 weight patients in the present study are likely to be those with relatively high disease burdens.

216 In figure 2, it appears healthcare costs plateaus at BMI 35 kg/m<sup>2</sup>. This may be a statistical  
217 uncertainty due to the relatively small numbers in the highest BMI categories. Above BMI 35 kg/m<sup>2</sup>,  
218 the number of subjects at each BMI point dropped to <60 compared to >200 subjects for BMI 22-28

219 kg/m<sup>2</sup>, and >100 subject for BMI 29-34 kg/m<sup>2</sup>. The study was not stratified to achieve equal numbers  
220 for each BMI point. However, these numbers may reflect current population distribution of BMI.  
221 There is in fact a small increase in adjusted healthcare cost at each higher BMI point above 35 kg/m<sup>2</sup>.  
222 Viewed as a whole, there is a steady increase in healthcare costs with higher BMI.

223 A limitation of the project was variation in how and when weight and height were measured. In more  
224 recent times, due to the rising awareness of obesity, patients usually have weight and height recorded  
225 at registration with a GP. In this study, height was generally by self-report. There were multiple  
226 entries for weights of some people, for whom the average weight recorded during the data collection  
227 period was used. For some participants, there were no recorded weights during the study period and  
228 the last recorded weight, which could have changed, was used. However, if weight is not being  
229 recorded, it is less likely that there is weight change in the particular individual.

230 Alcohol, smoking and physical activity were self-reported, so the reliability of these measurements is  
231 weak. However, using categorical data for these variables improved their validity. There were  
232 missing data for these measurements, requiring creation of dummy variables. Also, the data in  
233 medical records did not include information on education, occupation or socioeconomic status,  
234 which are important determinants of health and healthcare use.

235 These cross-sectional data may be used for planning healthcare and weight management  
236 programmes, though with caution; they are based on patients who had height and weight recorded in  
237 primary care and not a representative sample of the general population.

## 238 **Conclusion**

239 Each unit increase in BMI is associated with £16 higher annual healthcare cost, after adjusting for  
240 sex, age, smoking, alcohol consumption and physical activity level. BMI accounts for more than one  
241 per cent of the variance in healthcare cost among individuals, but the healthcare cost more than

242 doubles for an individual with BMI 40kg/m<sup>2</sup> compared to BMI 20kg/m<sup>2</sup>. This gradient may be an  
243 underestimate if the lower-BMI patients with heights and weights recorded had other costly diseases.

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246 advice during the analyses.

## 247 **Conflicts of interest**

248 None declared by any co-author

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320 responses. *Hum Nutr App Nutr* 1984; **38**: 29-35.

321 Table 1: Mean and 95% CI of annual cost at each category of healthcare in UK Counterweight Project 2002-  
322 2003. The means are for the number (N) of individuals who benefitted from the care category.

323

Cost category	Women			Men		
	N	Mean (£)	95% CI (£)	N	Mean (£)	95% CI (£)
Primary Care	1774	176	168 - 184	1112	131	123 - 139
Out Patient	946	291	273 - 310	527	293	269 - 316
Accident & Emergency	151	81	73 - 88	100	84	73 - 96
Hospitalisation	172	1162	949 - 1376	100	1307	1056 - 1557
GP Prescription	1645	144	131 - 156	975	180	160 - 201
Any Healthcare	1860	557	519 - 595	1184	519	471 - 568

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326  
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Table 2: Multiple linear regression model for annual healthcare cost in the UK Counterweight Project 2002-2003, showing significant associations and their individual contribution to variance in healthcare (R<sup>2</sup> change). Adjusted annual healthcare cost increased with age, BMI and smoking, and appear to decrease with drinking.

	Unstandardized Coefficients $\beta$	95% CI	Sig.	R <sup>2</sup> Change
Sex (male)	-78	-133 to -23	0.006	0.003
Age (y)	13	11 to 15	<0.001	0.06
<b>BMI (kg/m<sup>2</sup>)</b>	<b>16</b>	<b>11 to 21</b>	<b>&lt;0.001</b>	<b>0.013</b>
Alcohol				
no	reference category			
Yes	-121	-187 to -54	<0.001	0.001
Unknown	-107	-200 to -14	0.024	0.003
Smoking				
Never smoked	reference category			
Ex-smoker	100	26 to 174	0.008	0.001
Current smoker	72	5 to 138	0.034	0.002
Unknown	-67	-174 to 40	0.222	-
Physical activity				
Heavy	reference category			
Inactive	178	-37 to 392	0.105	-
Light	134	-70 to 337	0.199	-
Moderate	40	-164 to 244	0.702	-
Unknown	147	-48 to 342	0.14	-

328



329 **Figure Legends**

330 Figure 1: Associations of annual healthcare cost, with smoking, alcohol consumption and physical  
331 activity in the UK Counterweight Project 2002-2003. On the vertical axes are mean and 95%  
332 confidence interval of the annual healthcare cost associated with each category.

333 Figure 2: Mean annual healthcare cost by care category at each BMI unit, adjusted for sex, age,  
334 smoking, alcohol consumption and physical activity.