**Health care costs associated with muscle weakness: a UK population-based estimate**

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**Abstract**

Sarcopenia and muscle weakness are responsible for considerable health care expenditure but little is known about these costs in the UK. To address this, we estimated the excess economic burden for individuals with muscle weakness regarding the provision of health and social care among 442 men and women (aged 71-80 years) who participated in the Hertfordshire Cohort Study (UK). Muscle weakness, characterised by low grip strength, was defined according to the Foundation for the National Institutes of Health (FNIH) criteria (men<26kg, women<16kg). Costs associated with primary care consultations and visits, outpatient and inpatient secondary care, medications, and formal (paid) as well as informal care for each participant were calculated. Mean total costs per person and their corresponding components were compared between groups with and without muscle weakness.Prevalence of muscle weakness in the sample was 11%. Mean total annual costs for participants with muscle weakness were £4,592 (CI £2,962-£6,221), with informal care, inpatient secondary care and primary care accounting for the majority of total costs (38%, 23% and 19% respectively). For participants without muscle weakness, total annual costs were £1,885 (CI £1,542-£2,228) and their three highest cost categories were informal care (26%), primary care (23%) and formal care (20%). Total excess costs associated with muscle weakness were £2,707 per person per year, with informal care costs accounting for 46% of this difference. This results in an estimated annual excess cost in the UK of £2.5 billion.

**Keywords:** sarcopenia; muscle weakness; health care costs; ageing

**Introduction**

Sarcopenia is characterised by the aggressive loss of skeletal muscle mass and strength with age [1]. It is associated with increased risk of functional impairment, poor health-related quality of life, physical frailty, and premature death [2]. Sarcopenia is now regarded as a specific disease according to the International Classification of Diseases [3].

There is currently no consensus algorithm for defining sarcopenia. Low grip strength in older age is a risk factor for disability and mortality and a key component of sarcopenia [4]. For example, the European Working Group on Sarcopenia in Older People (EWGSOP), defines sarcopenia as having weak grip strength or slow gait speed in combination with low lean mass [5] and the Foundation for the National Institutes of Health (FNIH) Sarcopenia Project has defined sarcopenia as having weak grip strength and a low appendicular lean mass, adjusted for BMI [6].

Sarcopenia and muscle weakness are responsible for considerable health care expenditure. Annual direct medical costs attributable to sarcopenia were estimated at around $18.5 billion in the United States in 2000, representing 1.5% of total direct health care costs [7]. A cost-of-illness study in the Czech Republic, comprising 689 participants, aged 70 years and over, suggested that muscle weakness, indicated by low grip strength, was associated with increased yearly health care costs of €564 per person [8].

To our knowledge, no previous studies have estimated the economic costs of sarcopenia or muscle weakness in the UK. To address this gap, we have estimated the excess economic burden (regarding the provision of health and social care) for individuals with muscle weakness (identified by low grip strength according to the FNIH thresholds: men <26kg, women <16kg) using data from community-dwelling men and women (aged 71-80 years) who participated in the Hertfordshire Cohort Study (HCS).

**Methods**

*The Hertfordshire Cohort Study*

The Hertfordshire Cohort Study comprises 1579 men and 1418 women born in Hertfordshire in 1931-1939 and who still lived there in 1998-2004 when they attended a clinic visit and a nurse-administered home interview for a detailed characterisation of their sociodemographic, lifestyle and clinical characteristics. This study has been described in detail previously [9]. Smoking status and level of physical activity (Dallosso questionnaire [10]) were ascertained by a nurse-administered questionnaire. Social class was coded from the 1990 OPCS Standard Occupational Classification (SOC90) unit group for occupation [11].

Of the 2997 baseline participants, 966 participants from East Hertfordshire had a dual-energy X-ray absorptiometry (DXA) scan at baseline. In 2004, 642 of them were recruited to a clinical follow-up study. In 2011, 591 were invited to participate in a further follow-up study; 443 agreed to participate [12]{Dennison, 2014 #1311}. Smoking status (ever/never) and whether participants were suffering from a limiting long-term illness were ascertained through a nurse-administered questionnaire. Questions to ascertain Strawbridge frailty [13] and the Townsend disability scale [14], a score to reflect the difficulty in performing activities of daily living, were also asked. Participants were asked whether a doctor had told them that they had any of the following conditions: high blood pressure, diabetes, lung disease (such as asthma, chronic bronchitis, emphysema or COPD), rheumatoid arthritis, multiple sclerosis, thyroid disease, vitiligo, depression, Parkinson's disease, heart disease (such as a heart attack, angina or heart failure), peripheral arterial disease (such as claudication), stroke, osteoporosis or cancer. The number of comorbidities was used as a marker of comorbidity.

*Ascertainment of anthropometry and grip strength at clinic*

Height was measured to the nearest 0.1 cm using a Harpenden pocket stadiometer (Chasmors Ltd., London, UK) and weight to the nearest 0.1 kg on a SECA floor scale (Chasmors Ltd., London, UK). Body mass index (BMI) was calculated as weight divided by height2 (kg/m2). Grip strength was assessed three times for each hand using a Jamar dynamometer; the highest measurement was used for analysis. Muscle weakness, characterised by low grip strength, was defined according to FNIH criteria (men<26kg, women<16kg). This approach accords with that previously implemented in an analysis of data from the Survey of Health, Ageing and Retirement in Europe (SHARE)[8].

*Ascertainment of health and social care use*

The number of primary care visits in the previous month to and from general practitioners (GPs), nurses and physiotherapists was ascertained from the nurse-administered questionnaire. The number of outpatient secondary care visits in the previous year to and from rheumatologists, orthopaedic surgeons, accident and emergency doctors, physiotherapists and podiatrists was also obtained. Medical procedures performed during the previous year were reported by participants. Participants provided details of all prescriptions as open text, detailing quantity, frequency and duration. Participants were asked whether they had received formal (paid) care or informal care at home in the past year, including questions about the type, frequency and provider. Please see Appendix 1 for further details.

*Derivation of health and social care costs*

Costs were calculated by multiplying quantities of resource use by their respective unit costs. For GP and nurse consultations, the official publication of Unit Costs of Health and Social Care 2015 [15] was used. This was also the source of unit costs for outpatient secondary care consultations with physiotherapists and podiatrists, whilst for rheumatologists, orthopaedic surgeons and A&E doctors/traumatologists, unit costs were obtained from the 2014-15 national reference costs for outpatient attendances [16].

For hospitalisations, operation-specific weighted averages of NHS reference costs were used as unit costs. These were calculated by identifying the set of health care resource groups (HRG), which group health care activities demanding similar levels of resources, that relate to operations reported by participants. Weighted average unit costs were calculated using the activity reported for those HRGs on patients 70 years of age or older in national admitted patient care statistics [17] combined with hospital costs reported in theNHS National Schedule of Reference Costs tariff for 2014-15 [18].

Unit costs for prescriptions were obtained from the national report on the net ingredient cost of all prescriptions dispensed in England [19]. The net ingredient cost per quantity (such as individual tablet or capsule) was used, matching the patient-reported prescription upon which the annual quantity of medication was estimated.

Unit costs for formal care were obtained from the Unit Costs of Health and Social Care 2015 publication [15], accounting for the differences between Social Services and those privately provided. For informal care, following the opportunity cost method [20], we used national average wages as an estimate for the value in monetary terms of the unpaid time dedicated to providing care at home. Where the care was provided by the participant’s children, we assumed they would have been employed and hence applied the average wage, whereas when provided by other friends of the family, we used the minimum wage. Appendix 2 details the unit costs used for primary and secondary care visits and consultations, hospitalisations, as well as formal and informal care. All costs estimated are in 2015 British pounds.

*Statistical methods*

Data were described using summary statistics. Differences in participant characteristics between individuals with and without muscle weakness were examined using t-tests, chi-squared tests, Fisher's exact tests and Wilcoxon rank-sum tests as appropriate; normality was assessed by visual inspection of histograms.

Mean total costs per patient during one year and their corresponding cost components were compared between individuals with and without muscle weakness, the difference between them considered as the excess economic burden associated with muscle weakness. The estimated burden was then combined with the observed prevalence to produce an estimate for the economic burden of the disease in the UK.

Patient-level excess economic burden was modelled adjusting for social class and for variables ascertained in 2011 that differed significantly between the two groups to test their impact on the statistical significance of muscle weakness as a determinant of excess costs. A multivariate generalised linear (GL) model was estimated, with the family distribution identified using the Modified Park Test and the link function based on the Akaike and Bayesian information criteria.

Missing data for variables with a frequency equal to or lower than 1% was addressed by single imputation using regression and mean imputation. In the case of medication, missing quantity, frequency and/or duration was addressed by applying multiple imputation by chained equations methods [21] and 40 datasets were generated.

Sensitivity analyses were conducted using two alternative muscle strength criteria: <30kg and <20kg for men and women, respectively, proposed by Lauretani [22]; and the lowest decile of grip strength within each sex group. To produce an estimate of prevalence, we used the number of individuals classified as having muscle weakness over the total number of subjects reporting grip strength in the study. Statistical difference between excess costs by groups using these alternative criteria was assessed via the GL model described above.

The analysis sample consisted of the 442 participants (221 men and 221 women) with non-missing values for grip strength. Healthy participant effects were assessed by comparing HCS baseline participant characteristics between this analysis sample of 442 participants and the group of 2555 participants who attended the HCS baseline clinic but were not included in the analysis sample. All analyses were conducted in Stata 15 (StataCorp. 2017. Stata Statistical Software: Release 15. College Station, TX: StataCorp LLC).

**Results**

*Participant characteristics*

The characteristics of the 442 participants according to muscle strength are presented in Table 1. Median (lower quartile, upper quartile) age of the sample at the 2011 follow-up was 75.5 (73.5, 77.9) years. Overall, 49 (11.1%) participants (20 [9.0%] men and 29 [13.1%] women) had muscle weakness. On average, participants with muscle weakness were older (p=0.008) and had higher scores for Townsend disability (p<0.001) compared to those without muscle weakness. Having previously smoked, a limiting long-term illness and Strawbridge frailty were each more common among individuals with muscle weakness compared to those without (p<0.01 for all associations). There were no statistically significant associations between muscle strength and gender or BMI.

*Assessing healthy participant effects in analysis sample*

Compared to the 2555 participants who attended the HCS baseline clinic but were not included in the analysis sample, both men and women in the analysis sample had higher baseline self-reported physical activity. Men in the analysis sample were more likely to have never smoked at baseline compared to men who were not included (p=0.04). However, the proportion who were of manual social class (classes IIIM, IV and V) did not differ significantly (p>0.05) between the two groups; this was the case among men and women. Descriptive statistics for these HCS baseline characteristics, according to muscle strength in 2011, are presented in Table 1.

*Health and social care costs for participants with and without muscle weakness*

Estimated annual costs per person for different uses of health and social care according to muscle strength are presented in Table 2 and Fig. 1. For each type of health and social care use, costs were greater for individuals with muscle weakness compared to those without. Mean yearly total costs for participants with muscle weakness was £4,592 (95% confidence interval: £2,962-£6,221), with informal care, inpatient secondary care and primary care being responsible for 38%, 23% and 19% of their total costs, respectively. For participants without muscle weakness, total costs were £1,885 (£1,542-£2,228) and their three highest cost categories were informal care (26%), primary care (23%) and formal care (20%). Details of estimated costs by specific classification such as health care specialist consulted, procedure classification or prescription group within each cost category are summarised in Appendix 3.

The excess annual costs per person for individuals with muscle weakness compared to those without and the proportion of these excess costs, according to types of health and social care use, are presented in Fig. 2. The total excess cost observed for individuals with muscle weakness was £2,707 per person per year, with informal care accounting for 46% of total excess costs. After controlling for potential confounders included in Table 1 (age, ever smoking, limiting long-term illness, social class, frailty and disability scores), highly statistically significant differences (p<0.001) in total cost were still observed between individuals with and without muscles weakness based on a GL model using a Poisson family distribution and identity link function.

*Estimate of the economic burden associated with muscle weakness in the UK*

A calculation of the excess economic burden associated with muscle weakness in the UK is illustrated in Table 3. In mid-2016, the UK population aged 70 years and older was estimated at 8.2 million [23]. Under the assumption that the prevalence of muscle weakness among this group is the same as in HCS (11.1%), a per person per year excess cost of £2,707 for muscle weakness results in an annual excess cost associated with muscle weakness of approximately £2.5 billion for the use of health and social care; corresponding costs for health care alone (excluding formal and informal care) were around £1.3 billion.

*Sensitivity analyses*

Using grip strength cut-points proposed by Lauretani (<30kg for men, <20kg for women), 118 (26.7%) participants had low grip strength and the annual per person excess costs were £1,256; the corresponding figures for the lowest sex-specific decile approach were 46 (10.4%) participants and £2,670. Highly statistically significant differences in total costs were obtained regardless of the grip strength criterion used (p<0.001).

**Discussion**

Among HCS participants, the excess economic burden associated with muscle weakness, using FNIH thresholds (<26kg for men, <16kg for women), was estimated at £2,707 per person per year; this results in an estimated total annual excess cost in the UK of £2.5 billion. Informal care was the largest contributor to these excess costs, followed by inpatient secondary care.

These findings have several important implications. They demonstrate that costs associated with muscle weakness represent an important proportion of the health and social care budgets in the UK which are projected to increase in the future due to the ageing population. Furthermore, these results demonstrate that a large proportion of these costs fall on family and friends in the form of informal care, resulting in even higher costs for the state if family and friends were not able to assist with care.

Our results are similar to the findings of a cost-of-illness study in the Czech Republic [8] which reported higher annual direct and indirect health care costs of €564 per person for individuals with weak grip strength (<26kg among men, <16kg among women) compared to those without. A study among community-dwelling older people in the Netherlands reported significantly higher costs among participants with EWGSOP sarcopenia (€4325 per person per three months, 95% CI: €3198–€5471) compared to those without (€1533, 95% CI: €1153–€1912) with residential care being a main driver of costs; however, differences in costs between sarcopenics and age and sex matched non-sarcopenics were not significant [24]. Annual direct medical costs attributable to sarcopenia were estimated in the United States at around $18.5 billion in 2000, reflecting annual per person excess costs associated with sarcopenia of $860 among men and $933 among women [7]. This was calculated by estimating the health care cost of disability from national surveys and then estimating the proportion of this cost which was due to sarcopenia by examining the extent to which sarcopenia increases the risk of physical disability. Although the costs per person differ between these studies, probably due to the different methods and unit costs used and depending on whether the condition was muscle weakness or sarcopenia, the wider literature supports the substantial economic burden associated with muscle weakness and sarcopenia in Western populations.

Previous literature has also demonstrated the substantial impact of sarcopenia and muscle weakness on direct hospitalisation costs. Among a study of hospitalised patients in Portugal, EWGSOP sarcopenia increased hospitalisation costs by €1240 (95% CI: €596–€1887) for patients < 65 years and €721 (95% CI: €13–€1429) for patients aged ≥ 65 years [25]. In another study of hospitalised patients in Portugal, increased risks of high hospitalisation costs were observed for people with EWGSOP sarcopenia (OR = 5.70, 95% CI: 1.57–20.71) and low grip strength (OR = 2.40, 95% CI: 1.12–5.15) compared to those without these conditions [26]. Among a study of patients who underwent radical gastrectomy for gastric cancer in China, the hospital costs, duration of stay and number of complications increased with increasing severity of EWGSOP sarcopenia (pre-sarcopenia, sarcopenia, and severe sarcopenia) [27].

This study has some limitations. Firstly, a healthy responder bias has been observed in HCS and attrition across the various waves of follow-up could have resulted in additional selection effects. However, baseline participants remained broadly comparable with participants in the nationally representative Health Survey for England [9] and examining participant characteristics according to inclusion status across the study revealed no major differences. Secondly, health care costs were estimated based on the conservative assumption that, when the frequency of visits and consultations reported by study participants within the last month was once a week or higher, the frequency would have built up to that level and not have been constant at the reported frequency during the whole year. Regarding prescription costs, net ingredient costs by quantity were used as it is the main component of the cost of drugs to the NHS. However, our analysis does not account for the discount percentage received by pharmacists or the container allowance which both influence the total cost to the NHS. Despite this, these two costs may nearly offset each other, meaning ours should be a reliable estimate of prescription costs. Thirdly, direct assessment of muscle mass was not available for the analysis sample, preventing a derivation of sarcopenia status; instead we characterised muscle weakness using the FNIH criteria on grip strength. A final limitation is that this study is observational and hence estimates were based on the costs estimated for study participants with and without muscle weakness. Therefore, interventions to improve muscle strength among participants with muscle weakness, to the point where they do not have muscle weakness according to the definition used in our study, may not significantly reduce costs as these participants are likely to have poorer health compared to those without muscle weakness. Nevertheless, there is evidence of gains in function and independence in intervention studies that have promoted muscle strength [28], which are likely to have little effect on health care costs but potentially sizeable implications by reducing dependence of people with sarcopenia or muscle weakness on informal care, hence lowering broader societal costs. Further research is therefore required on whether lifestyle interventions reduce sarcopenia or muscle weakness among older people and result in reductions in health and social care use.

**Conclusion**

This is the first study to show that muscle weakness in older people is associated with significant excess annual costs for health and social care in the UK of around £2.5 billion. These costs are projected to increase in the future due to the ageing population. Lifecourse interventions to reduce the prevalence of muscle weakness among older people are likely to have a substantial beneficial impact on the cost of health and social care in the UK.

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**Compliance with Ethical Standards**

**Conflict of interest:** CC reports personal fees (outside the submitted work) from Alliance for Better Bone Health, Amgen, Eli Lilly, GSK, Medtronic, Merck, Novartis, Pfizer, Roche, Servier, Takeda and UCB. EMD reports personal fees (outside the submitted work) from Pfizer Healthcare and from the UCB Discussion panel. RPV, LDW, HES, MTSS and SMR declare that they have no conflict of interest.

**Ethical Approval:** The baseline Hertfordshire Cohort Study had ethical approval from the Hertfordshire and Bedfordshire Local Research Ethics Committee and the follow-up had ethical approval from the East and North Hertfordshire Ethical Committees.

**Human and Animal Rights:** All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

**Informed Consent:** All participants gave signed consent to participate in the study and for their health records to be accessed in the future.

**Contributors:** CC (guarantor) designed the study. RPV conducted the main analyses and prepared the first draft of the manuscript. LDW prepared the first draft of the manuscript and conducted some descriptive analyses. HES and MTSS provided guidance regarding the statistical analyses. EMD and SMR were investigators of the Hertfordshire Cohort Study. All authors made substantial contributions to the manuscript and approved the final version.

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| **Table 1 Characteristics of the 442 Hertfordshire Cohort Study participants according to muscle strength at the 2011 follow-up** |
|
| **N(%)** | **Without muscle weakness (n=393)** | **Muscle weakness (n=49)** | **P-value** |
|  |  |  |  |
| **Characteristics at HCS baseline (1998-2004)** |  |  |  |
| Age (years)\*\* | 64.5 (62.5, 67.0) | 65.9 (63.9, 68.0) | **0.004** |
| BMI (kg/m2)\* | 26.7 (4.1) | 27.5 (3.6) | 0.131 |
| Ever smoked | 181 (46.1%) | 30 (61.2%) | **0.045** |
| Physical activity (Dallosso)\* | 63.7 (13.5) | 61.5 (15.8) | 0.301 |
| Social class (manual) | 208 (54.5%) | 34 (69.4%) | **0.047** |
|  |  |  |  |
|  |  |  |  |
| **Characteristics at follow-up (2011)** |  |  |  |
| Age (years)\*\* | 75.2 (73.3, 77.7) | 76.6 (74.3, 78.7) | **0.008** |
| Gender (women) | 192 (48.9%) | 29 (59.2%) | 0.173 |
| BMI (kg/m2)\* | 28.1 (4.6) | 28.5 (4.3) | 0.508 |
| Ever smoked | 182 (46.3%)  | 33 (67.3%) | **0.005** |
| Limiting long-term illness  | 94 (23.9%)  | 21 (42.9%) | **0.004** |
| Strawbridge overall frailty | 52 (13.3%)  | 14 (28.6%) | **0.005** |
| Townsend disability score\*\* | 2.0 (0.0, 4.0) | 5.0 (2.0, 8.0) | **<0.001** |
| Number of comorbidities+: 0 | 91 (23.2%) | 6 (12.2%) | 0.303 |
|  1 | 122 (31.0%) | 19 (38.8%) |
|  2 | 102 (26.0%) | 11 (22.4%) |
|  3 | 40 (10.2%) | 6 (12.2%) |
|  4 or more | 38 (9.7%) | 7 (14.3%) |
|  |  |  |  |
| \*Mean (SD); p-values derived using t-tests |  |  |
| \*\*Median (lower quartile, upper quartile); p-values derived using the Wilcoxon rank-sum test |
| +P-value derived using Fisher's exact test |
| For other characteristics, p-values were derived using chi-squared tests |  |
| Muscle weakness was defined using low grip strength (<26kg for men, <16kg for women)P-values are in bold where p<0.05 |  |

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| **Table 2 Estimated annual cost per person by cost component according to muscle strength** |
|  |  |  |  |
|  | **Without muscle weakness a** | **With muscle weakness a** |  |
| **Cost component** | **Mean** | **Std. Err.** | **95% confidence interval b** | **Mean** | **Std. Err.** | **95% confidence interval b** | **P-value c** |
| Primary care | £ 434 | £ 31 | £ 372 - £ 495 | £ 879 | £ 204 | £ 469 - £ 1,288 | <0.001 |
| Outpatient secondary care | £ 100 | £ 10 | £ 80 - £ 120 | £ 137 | £ 43 | £ 50 - £ 223 | <0.001 |
| Inpatient secondary care | £ 256 | £ 56 | £ 145 - £ 367 | £ 1,033 | £ 375 | £ 278 - £ 1,789 | <0.001 |
| Formal care | £ 385 | £ 90 | £ 208 - £ 562 | £ 421 | £ 142 | £ 135 - £ 708 | <0.001 |
| Informal care | £ 492 | £ 95 | £ 306 - £ 679 | £ 1,734 | £ 388 | £ 953 - £ 2,515 | <0.001 |
| Prescriptions | £ 218 | £ 29 | £ 161 - £ 276 | £ 388 | £ 187 | £ 10 - £ 766 | <0.001 |
| **Total** | **£ 1,885** | **£ 175** | **£ 1,542 - £ 2,228** | **£ 4,592** | **£ 810** | **£ 2,962 - £ 6,221** | <0.001 |
|  |
| a Muscle weakness was defined using low grip strength (<26kg for men, <16kg for women)b Based on observed data and 40 imputed datasets via multiple imputation by chained equationsc Obtained from corresponding univariate generalised linear models using a Poisson family distribution and identity link function with each cost component as the outcome variable and muscle weakness classification as the explanatory variable. |

|  |
| --- |
| **Table 3 Calculation of the excess economic burden associated with muscle weakness in the UK** |
|  |  |
| UK population |  65,648,100  |
| UK population aged 70 years and older |  8,177,500  |
| UK population aged 70 years and older with muscle weakness\* |  8,177,500 x 11.1% = 907,703 |
|  |  |
| Excess economic burden for health care in the UK | 907,703 x £1,429 = £1.30 billion |
| Excess economic burden for health and social care in the UK | 907,703 x £2,707 = £2.46 billion |
|  |  |
| \*11.1% of the Hertfordshire Cohort Study participants had muscle weakness using the FNIH criteria (<26kg for men and <16kg for women). It is assumed that this prevalence is similar in the UK |
|
| Population estimates according to the Office for National Statistics |
|  |
| Muscle weakness was defined using low grip strength (<26kg for men, <16kg for women) |

**Fig. 1 Annual costs per person for different uses of health and social care according to muscle strength**

Muscle weakness was defined using low grip strength (<26kg for men, <16kg for women)

**Fig. 2 Excess annual costs per person for individuals with muscle weakness compared to those without and proportion of costs according to types of health and social care**

Muscle weakness was defined using low grip strength (<26kg for men, <16kg for women)

**Appendix 1**

*Ascertainment of health and social care use*

Questionnaire items asking participants about the number of visits made, and home visits by a general practitioner (GP) and nurse during the previous month were used to estimate resource use for primary care consultations. Yearly estimates were produced based on response options for the previous month as follows: “never” = 0; “once per month” = 12; “twice per month” = 24; “once a week” = 30 (assuming four monthly for first three months, and twice a month thereafter); “three times per week” = 54 (assuming 12 for the first three months, and twice a month thereafter); and “daily” = 72 (assuming 30 for first month, three times weekly for the following two months, and twice a month thereafter).

Use of outpatient secondary care consultations was obtained from an item in the questionnaire asking participants to report on the number of times they had seen, either at the hospital or at home and during the previous year, a rheumatologist, orthopaedic surgeon, A&E doctor/traumatologist, physiotherapist, and a podiatrist. Hospitalisations were reported by participants in an open-question item where dates were reported in some but not all cases. As it was not possible to ascertain whether all reported hospitalisation occurred during the prior year, we conducted the base case analysis including those operations with dates falling within the previous year, and a sensitivity analysis excluding those which, based on their reported dates, were performed more than one year prior. Sensitivity analysis results showed proportionally similar higher costs for both groups with no significant difference in the hospitalisations excess cost associated with muscle weakness (£39 or 5% lower in the sensitivity analysis). Baseline values were used for the full analysis.

Medications were reported by participants including dosage, frequency (daily, weekly, or “as needed”, which was assumed in a first instance to be every two weeks), and how long each medication had been taken. Three different response levels were available for duration, assumed to correspond to the following number of days within the previous year: “less than one month” = 15 days; “one month until one year” = 182 days; “over one year” = 365 days. When participants reported taking the medication “as needed”, a conservative assumption was made that the medication would be taken once a fortnight. Based on the reported frequency and duration that the medication was taken, a total yearly quantity was produced for each product reported by each participant in the corresponding unit (i.e. tablet, capsule, ml, gr, etc.). Where the unit reported did not match the unit in which unit prices were available, conversions were made to match the former to the latter (e.g. 5 ml in 1 teaspoon, 15 ml in 1 tablespoon, 20 ml in 1 drop). When annual estimated cost per medication exceeded £5,000, the case was reviewed by a consultant physician to confirm whether general assumptions were appropriate, and if not, to apply new ones according to the specific drug and patient profile.

Information on both formal and informal care was collected from questionnaire items where participants were asked whether they received formal or informal care at home in the last year, and how often care was received. When asked about formal care, the questionnaire also requested an indication of whether it was provided by Social Services or privately. Response options were once a month; twice a month; once per week; three times per week (assumed to be equivalent to 104 days of help, obtained from the first six months of help at three times per week, and the following six months at once per week); and daily (assumed to be equivalent to 252 days of help, from six months of daily help, and six months at three times per week). In the case of informal help, respondents were also asked who provided the help: wife or husband, son/daughter, other relatives, neighbours, or friends.

**Appendix 2**

|  |  |  |
| --- | --- | --- |
|  | **NHS cost** | **Note** |
| **GP visit**  | £65 | Per patient contact lasting 17.2 minutes |
| **GP home** | £89 | Per patient contact lasting 11.7 minutes plus an average of 12 minutes’ travel time  |
| **Nurse visit** | £27 | Cost per hour (£43) x 37.5 working hours per week divided by average of 60 patient consultations per week |
| **Nurse home** | £38 | Mean cost for a face-to-face contact in district nursing services |

Source: Curtis, L. and A. Burns (2015). Unit Costs of Health and Social Care 2015, Personal Social Services Research Unit, University of Kent, Canterbury.

|  |  |  |
| --- | --- | --- |
|  | **NHS cost** | **Note** |
| **Rheumatologist** | £143 | Hospital Associate specialist: per hour |
| **Orthopaedic surgeon** | £113 | Hospital Associate specialist: per hour |
| **A&E doctor** | £141 | Hospital Associate specialist: per hour |
| **Physiotherapist hospital** | £34 | Mean cost for a non-consultant-led (non-admitted) follow-up physiotherapy attendance |
| **Physiotherapist home** | £41 | As hospital attendance plus an average of 12 minutes travel time per visit |
| **Podiatrist hospital** | £34 | Same as physiotherapist |
| **Podiatrist home** | £41 | Same as physiotherapist |

Sources: Reference Cost Collection: National Schedule of Reference Costs - Year 2014-15; and Curtis, L. and A. Burns (2015). Unit Costs of Health and Social Care 2015, Personal Social Services Research Unit, University of Kent, Canterbury.

|  |  |  |
| --- | --- | --- |
|  | **Cost** | **Note** |
| **Social services** | £45 | Local authority day care for older people: £45 per client session lasting 3.5 hours |
| **Private** | £69 | Social care support for older people: Home care: Average weekly costs: £178 (9 hours per week). Prorated to 3.5 hours |

Source: Curtis, L. and A. Burns (2015). Unit Costs of Health and Social Care 2015, Personal Social Services Research Unit, University of Kent, Canterbury.

|  |  |  |
| --- | --- | --- |
|  | **Cost** | **Note** |
| **Help provided by son or daughter** | £42 | Average weekly earnings during 2015 was £483. Assuming full time of 40 hours and 3.5 hours informal help per day session (same as formal care) |
| **Help provided by any other than son or daughter** | £23 | For 2015, National Minimum Wage was £6.70 per hour. Assuming 3.5 hours’ informal help per day session (same as formal care) |

Sources: Office of National Statistics. Time series: LMSB SA AWE total pay WE. Available from: https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/earningsandworkinghours/timeseries/kab9/emp; and Gov UK. National Minimum Wage and National Living Wage rates. Available from: https://www.gov.uk/national-minimum-wage-rates.

**Appendix 3**

**Primary care consultations**

|  |  |  |
| --- | --- | --- |
|  | **Estimated number of yearly consultationsper person** | **Estimated annual costper person** |
|  | **Mean** | **SD** | **Mean** | **SD** |
| **Without muscle weakness** |  |  |  |  |
| GP |  |  | £329.8 | £538.6 |
| *GP practice visit* | 5.0 | 8.2 |  |  |
| *GP home visit* | 0.1 | 0.9 |  |  |
| Nurse |  |  | £103.9 | £228.4 |
| *GP practice visit* | 3.6 | 7.6 |  |  |
| *Nurse home visit* | 0.2 | 2.8 |  |  |
| **Total** |  |  | **£433.7** |  |
| **Total post-imputation\*** |  | **£433.5** | **£615.5** |
|  |  |  |  |  |
| **With muscle weakness** |  |  |  |  |
| GP |  |  | £592.6 | £837.7 |
| *GP practice visit* | 7.1 | 10.3 |  |  |
| *GP home visit* | 1.5 | 5.3 |  |  |
| Nurse |  |  | £286.0 | £742.5 |
| *GP practice visit* | 4.4 | 9.9 |  |  |
| *Nurse home visit* | 1.1 | 5.4 |  |  |
| **Total** |  |  | **£878.6** | **£1,424.6** |
| \* One individual reported missing number of consultations and their costs were imputed using a generalised linear model |
|  |
| Muscle weakness was defined using low grip strength (<26kg for men, <16kg for women) |

**Secondary care consultations**

|  |  |  |
| --- | --- | --- |
|  | **Number of yearlyconsultationsper person** | **Annual costper person** |
|  | **Mean** | **SD** | **Mean** | **SD** |
| **Without muscle weakness** |  |  |  |  |
| Rheumatologists | 0.04 | 0.4 | £6.3 | £57.3 |
| Orthopaedic surgeons | 0.21 | 0.75 | £23.5 | £84.6 |
| Trauma doctors | 0.15 | 0.43 | £21.1 | £60.4 |
| Physiotherapist  |  |  | £17.0 | £77.3 |
| *Hospital visit* | 0.47 | 2.2 |  |  |
| *Home visit* | 0.03 | 0.4 |  |  |
| Podiatrist  |  |  | £31.5 | £90.8 |
| *Hospital visit* | 0.29 | 1.4 |  |  |
| *Home visit* | 0.53 | 2.0 |  |  |
| **Total** |  |  | **£99.4** |  |
| **Total post-imputation\*** |  | **£99.7** | **£201.4** |
|  |  |  |  |  |
| **With muscle weakness** |  |  |  |  |
| Rheumatologists | 0.14 | 0.5 | £20.4 | £71.4 |
| Orthopaedic surgeons | 0.18 | 0.7 | £20.7 | £78.5 |
| Trauma doctors | 0.14 | 0.4 | £20.1 | £57.4 |
| Physiotherapist  |  |  | £17.5 | £70.2 |
| *Hospital visit* | 0.49 | 2.1 |  |  |
| *Home visit* | 0.02 | 0.1 |  |  |
| Podiatrist  |  |  | £57.9 | £258.1 |
| *Hospital visit* | 1.41 | 7.4 |  |  |
| *Home visit* | 0.24 | 1.4 |  |  |
| **Total** |  |  | **£136.6** | **£299.5** |
| \* Nine people reported missing number of consultations and their costs were imputed using the arithmetic mean of non-missing responses for the missing components after regression imputation models failed to converge |
|  |
| Muscle weakness was defined using low grip strength (<26kg for men, <16kg for women) |

**Prescriptions**

|  |  |  |
| --- | --- | --- |
| **British National Formulary classification** | **Annual costper personwithout muscle weakness** | **Annual costper personwith muscle weakness** |
|  | **Mean** | **Std. Err.** | **Mean** | **Std. Err.** |
| Gastro-Intestinal | £5.0 | £5.9 | £11.7 | £6.4 |
| Cardiovascular | £47.0 | £5.2 | £51.7 | £15.6 |
| Respiratory | £29.1 | £7.3 | £30.0 | £20.8 |
| Central Nervous System | £16.7 | £4.5 | £21.6 | £9.6 |
| Infections | £0.8 | £0.3 | £11.7 | £30.2 |
| Endocrine System | £49.8 | £21.1 | £30.5 | £82.1 |
| OB/GY/UT disorders | £6.0 | £2.7 | £1.8 | £1.4 |
| Malignant disease | £5.6 | £3.5 | £161.2 | £161.2 |
| Nutrition & blood | £26.1 | £7.9 | £14.3 | £4.7 |
| Musculoskeletal | £6.3 | £1.8 | £40.5 | £28.2 |
| Eye | £9.4 | £5.6 | £0.4 | £0.6 |
| Ear, Nose and Throat | £2.6 | £1.3 | £1.7 | £1.4 |
| Skin | £1.9 | £1.3 | £2.0 | £1.8 |
| Other | £0.3 | £0.3 | - | - |
| Appliances | £0.6 | £0.3 | £6.0 | £6.0 |
| Incontinence\* | £10.9 |  | £2.7 | £2.7 |
| **Total** | **£218.1** |  | **£387.8** |  |
| Note: Estimates produced after applying multiple imputation by chained equations methods. In groups where no prescriptions were reported, no values are shown and £0 was added to their overall annual costs. \* Standard errors could not be calculated due to inconsistency amongst multiple imputation datasets for the prescription group amongst study participants without muscle weakness. The mean value was estimated by subtracting all other groups means from the total cost for prescriptions. |
|  |
| Muscle weakness was defined using low grip strength (<26kg for men, <16kg for women) |

**Inpatient secondary care**

|  |  |  |
| --- | --- | --- |
| **Procedure classification** | **Annual costper personwithout muscle weakness** | **Annual costper personwith muscle weakness** |
|  | **Mean** | **SD** | **Mean** | **SD** |
| Endocrine  | - | - | £44.0 | £307.9 |
| Rheumatological  | £7.7 | £152.5 | - | - |
| Orthopaedic  | £96.3 | £662.2 | £131.2 | £707.2 |
| Genitourinary  | £16.5 | £133.3 | £61.8 | £265.3 |
| Haematological  | £1.3 | £25.0 | - | - |
| Neurological  | - | - | - | - |
| Cardiovascular  | £29.3 | £460.5 | £260.3 | £1,304.6 |
| Gastrointestinal  | £9.8 | £137.5 | £281.5 | £1,213.7 |
| Ophthalmology  | £14.1 | £98.4 | £14.5 | £101.6 |
| ENT  | £18.6 | £230.5 | - | - |
| Respiratory  | £7.6 | £151.0 | - | - |
| Dermatology  | £14.9 | £185.3 | £120.8 | £599.6 |
| General Surgical  | £39.7 | £467.0 | £119.3 | £834.9 |
| Other  | £0.5 | £10.3 | - | - |
| **Total** | **£256.3** |  | **£1,033.4** |  |
| Note: In operation classification groups where no procedures were reported, no values are shown and £0 was added to their overall annual costs. |
|  |
| Muscle weakness was defined using low grip strength (<26kg for men, <16kg for women) |

**Formal care**

|  |  |  |
| --- | --- | --- |
|  | **Without muscle weakness** | **With muscle weakness** |
|  | **n** | **(%)** | **n** | **(%)** |
| **Received formal care at home?**  |  |  |  |
| No  | 349 | (88.8) | 40 | (81.6) |
| Yes  | 44 | (11.2) | 9 | (18.4) |
| **If so, who provided it?** |  |  |  |
| Social services | 4 | (9.1) | 1 | (11.1) |
| Private | 40 | (90.9) | 8 | (88.9) |
| **If so, how frequent?** |  |  |  |
| Daily | 4 | (9.1) | 0 | (0) |
| Once week | 19 | (43.2) | 4 | (44.4) |
| Twice month | 7 | (15.9) | 4 | (44.4) |
| Once month | 8 | (18.2) | 1 | (11.1) |
| *Missing* | *6* | *(13.6)* | *0* | *(0)* |
|  |  |  |  |  |
| Muscle weakness was defined using low grip strength (<26kg for men, <16kg for women) |

**Informal care**

|  |  |  |
| --- | --- | --- |
|  | **Without muscle weakness** | **With muscle weakness** |
|  | **n** | **(%)** | **n** | **(%)** |
| **Received informal help at home?**  |  |  |  |
| No  | 356 | (91.0) | 31 | (63.3) |
| Yes  | 35 | (9.0) | 18 | (36.7) |
| *Missing* | *2* | *(0.5)* | *0* | *(0)* |
| **If so, who provided it?** |  |  |  |
| Spouse | 11 | (31.4) | 13 | (72.2) |
| Child | 22 | (62.9) | 4 | (22.2) |
| Other relative | 1 | (2.9) | 0 | (0) |
| Friend | 1 | (2.9) | 0 | (0) |
| Neighbour | 0 | (0) | 1 | (5.6) |
|  |  |  |  |  |
| Muscle weakness was defined using low grip strength (<26kg for men, <16kg for women) |