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The lifetime health and economic burden of obesity in five European countries: what is the potential impact of prevention?

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Abstract

Aim: Estimating the burden of obesity in five European countries (Germany, Greece, the Netherlands, Spain and the UK) and the potential health benefits and changes in health care costs associated with a reduction in body mass index (BMI).

Materials and Methods: A Markov model was used to estimate the long-term burden of obesity. Health states were based on the occurrence of diabetes, ischaemic heart disease and stroke. Multiple registries and literature sources were used to derive the demographic, epidemiological and cost input parameters. For the base-case analyses, the model was run for a starting cohort of healthy obese people with a BMI of 30 and 35 kg/m^2 aged 40 years to estimate the lifetime impact of obesity and the impact of a one-unit decrease in BMI. Different scenario and sensitivity analyses were performed.

Results: The base-case analyses showed that total lifetime health care costs (for obese people aged 40 and BMI 35 kg/m^2) ranged from €75 376 in Greece to €343 354 in the Netherlands, with life expectancies ranging from 37.9 years in Germany to 39.7 years in Spain. A one-unit decrease in BMI showed gains in life expectancy ranging from 0.65 to 0.68 year and changes in total health care costs varying from −€1563 to +€4832.

Conclusions: The economic burden of obesity is substantial in the five countries. Decreasing BMI results in health gains, reductions in obesity-related health care costs, but an increase in non-obesity related health care costs, which emphasizes the relevance of including all costs in decision making on implementation of preventive interventions.

KEYWORDS
cardiovascular disease, cost-effectiveness, health economics, obesity therapy, type 2 diabetes, weight control

1 | INTRODUCTION

The prevalence of obesity in Europe is high and increasing over time. In 2014, 51.1% of the adult EU members was overweight defined as a body mass index (BMI) of ≥25 kg/m^2, of which 15.4% could be classified as obese (BMI ≥30 kg/m^2).[1] These values increased to 52.7% and 16.3%, respectively in 2019,[2] and are expected to increase even more because of a continuing increase in intake of energy-dense foods and a decrease in physical activity.[3] Obesity is a major risk factor for diabetes, cardiovascular disease (heart disease and stroke), several types of cancer and musculoskeletal disorders.[3] According to the Global Burden of Disease Study (GBD), a high BMI was associated with 4.7 million deaths and 147.7 million disability-adjusted life-years worldwide in 2017.[4] Consequently, obesity is associated with substantial health care costs for treating obesity-related diseases and complications,[5–7] and other costs (e.g. lost productivity).[8,9]

A review from Tremmel et al.[5] showed that most of the studies investigating the economic burden of obesity included costs associated with treating obesity-related diseases and some included costs related to loss of productivity and premature mortality. However, costs related to informal care, defined as unpaid care provided by people other than health care professionals, were not considered in any of the studies in the review. Two recently published studies on the economic burden of obesity included short-term costs for informal care.[10,11] Consideration of the long-term costs of informal care is relevant because obese people receive more informal care than people with normal weight.[12]

Besides investigating the economic burden of obesity, several studies explored the impact of a reduction in BMI or the reduction in percentage of people with obesity on health and costs, concluding that a reduction in obesity prevalence is associated with cost savings in obesity-related costs.[13,14] Other studies investigating the cost-effectiveness of treatments for obesity concluded that treatments are cost-effective or cost saving based on the change in costs for obesity-related diseases and complications.[15–17] However, because high BMI is associated with an increased mortality risk,[18] a reduction in BMI will result in an increase in life expectancy with a certain risk for getting other non-obesity-related diseases requiring treatment and thus costs in these additional years lived.[19–21] Reducing high BMI might therefore lead to a reduction in costs for obesity-related diseases, but these savings might be (partly) compensated by the additional health care costs for other diseases in life-years gained.[22] All relevant health care costs should therefore be included in an analysis to show the full lifetime impact of an intervention that reduces BMI.

The aim of the current study was to estimate the long-term burden of obesity in five European countries, including Germany, Greece, the Netherlands, Spain and the UK by presenting a wide range of health outcomes and health care costs using a newly developed obesity model. In addition, the study aimed to assess the potential health benefits and changes in health care costs associated with a reduction in high BMI to normal values because of a hypothetical health intervention. Costs included in the model were lifetime medical costs for obesity-related diseases, informal care costs and medical costs for other diseases.

2 | METHODS

2.1 | Model structure

To model the impact of obesity on health and lifetime costs, a health economic model was developed as part of the COMPAR-EU project, a project that aimed to estimate the (cost-)effectiveness of self-management interventions for obesity and included partners from five different countries (Germany, Greece, the Netherlands, Spain and the UK).[23] The developed Markov model included obesity-related diseases as health states and had a cycle length of 1 year. Figure 1 shows the model structure. Besides the death state, the following health states were included: diabetes, ischaemic heart disease (IHD) and stroke. These obesity states were included in the model, as, compared with other obesity-related diseases, prevalence and costs of these diseases were the highest.[24,25] The first state included obese people without any of the three diseases, but who are at risk to develop diabetes, IHD or stroke depending on their BMI. When patients have developed one of the three diseases, they have a higher risk for one of the other diseases. Therefore, all possible combinations of diseases were modelled; patients could have one disease, combinations of two diseases or all three diseases combined. The impact of other obesity-related diseases than diabetes, IHD and stroke was not explicitly modelled but had been included through the impact on mortality.

Transition rates between health states reflected the incidence of disease(s), while mortality rates for the population without disease(s) and for patients with disease(s) reflected the transition probabilities from the health states to death. Occurrence of diseases and mortality were dependent on BMI, which was modelled continuously.

The model starts with an obese population specified by sex, age and mean BMI. The model then simulates the changes in this cohort over time because of occurrence of diabetes, IHD and stroke, and death. The time horizon of the model was lifetime, which means that subjects were followed up to the age of 100, after which they are assumed to die in the next cycle. Transition rates were not fixed, as both incidences of diseases and mortality were dependent on sex, age and BMI and being in a certain health state (e.g. incidence of IHD is higher for patients in the diabetes state than patients in the no diabetes/IHD/stroke state). Mortality in the diabetes state was a combination of mortality attributable to diabetes plus mortality because of other causes. For IHD, including myocardial infarction and for stroke, which are events with a high risk for mortality at the time of occurrence, mortality has been separated in case-fatality, mortality attributable to either IHD or stroke and mortality because of other causes. The case-fatality rate was applied to the new incident cases, which implies that from the new incident cases of IHD or stroke, a certain proportion was assumed to die immediately. Mortality attributable to either IHD or stroke was applied to patients in the 'stable' state, that is, these mortality rates were applied only to people who did not die from IHD or stroke immediately.

Each health state was associated with a certain value for quality of life (QOL) and costs. QOL values were specified by sex, age and disease status. Costs included in the model were all health

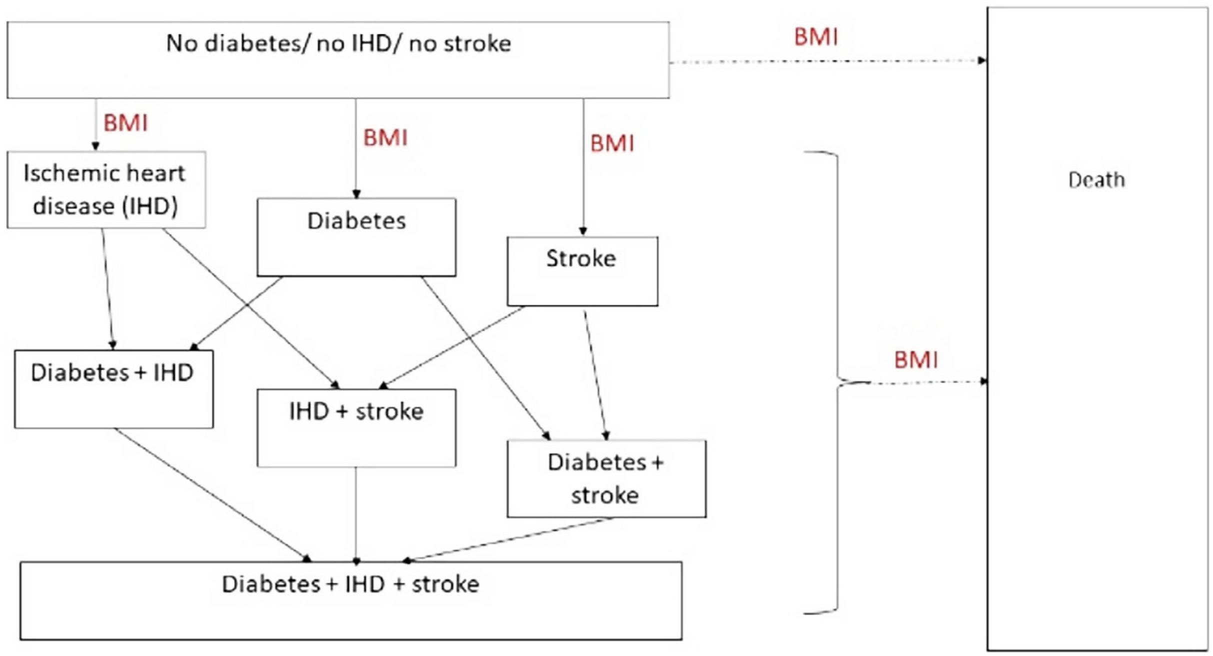

FIGURE 1 Structure of the Markov model for obesity. BMI, body mass index; IHD, ischaemic heart disease.

care-related costs (in 2020 euros), including medical costs for diabetes, IHD and stroke, informal care costs and medical costs for other diseases. (The Consumer Price Index was used to calculate prices of goods and services in a country over time and the Purchasing Power Parity was used as currency conversion rate to convert prices/expenditures expressed in national currency to other currencies.)

The model was implemented in R using RStudio (version Ri386 3.6.1/Rx64 3.6.1).

2.2 | Model inputs

Multiple sources from registries and literature were used to derive the demographic, epidemiological and cost input parameters. All details on the input parameters are presented in Appendix S1. The mean BMI by sex and age for the different countries was obtained from the GBD.[26] Relative risks (RRs) for the association between BMI and all-cause mortality, specified by sex, were obtained from a meta-analysis of 230 cohort studies,[18] while RRs for the association between BMI and diabetes, IHD and stroke, specified by age, were obtained from the GBD.[26] In addition, RRs for the co-occurrence of 'diabetes and stroke', 'diabetes and IHD' and 'IHD and stroke' were included to take into account that the three diseases tend to cluster.[27–29] The prevalence and incidence for diabetes, IHD and stroke, specified by sex and age for the five European countries, were obtained from the DYNAMO-HIA study.[27,28] Mortality data were based on the DYNAMO-HIA study,[27,28] two studies by Vaartjes et al.,[30,31] one study by Hoogenveen et al.[32] and OECD data.[33] QOL data were based on general population sex- and age-specific utilities derived from the EQ-5D, which is a generic health-related QOL measure,[34] and adjusted for the occurrence of diabetes, IHD and stroke using prevalence data and previously published utility decrements for the different diseases.[35] Medical costs for treating diabetes, IHD and stroke were obtained from different country-specific literature sources.[36–47] Medical costs for other diseases in the Netherlands and the UK, were obtained from the Dutch PAID tool version 3 and UK PAID tool version 1, respectively.[48,49] For the other three countries these costs were calculated by subtracting the obesity-related costs per capita for diabetes, IHD and stroke from the annual health care spending per capita by sex and age.[50–52] See the study of Mokri et al.[53] for the complete description of this cost calculation.

2.3 | Model analyses

For the base-case analyses, the model was run for a cohort aged 40 years at the start of the simulation (50% women) with either a BMI of 30 kg/m^2 or a BMI of 35 kg/m^2 to show the impact of different levels of BMI on health outcomes and costs. In addition, the impact of a one-unit decrease in BMI was explored by comparing lifetime results for a cohort with starting BMI of 30 kg/m^2 with the results of a cohort with a BMI of 29 kg/m^2. Furthermore, results for a cohort with BMI 35 kg/m^2 were compared with a cohort with BMI 34 kg/m^2 to show the impact of the starting level of BMI on changes in health outcomes and costs. Outcomes predicted by the model were: life expectancy, years with diabetes, incident cases of obesity-related diseases, quality-adjusted life years (QALYs) and different types of costs from an extended health care perspective. Costs and effects were not discounted in the base-case analyses to increase comparability between countries (Appendix S3 shows the discounted results).

2.4 | Scenario analyses

In addition, two scenario analyses were performed to show the effects and costs attributable to obesity and the potential impact of prevention. The first scenario was performed by comparing the results of an obese cohort (BMI 35 kg/m^2) aged 40 years at the start of the simulation (50% women) with the results of a cohort with BMI 25 kg/m^2 (i.e. lowest BMI in the overweight range) aged 40 years at the start of the simulation (50% women). The second scenario was performed on a population level using the obese population aged 25-65 years in the five countries as a starting point for the simulation. For this scenario, we first estimated the total numbers of obesity cases in the specific countries; the general population by sex and age in a specific country, was combined with sex- and age-specific percentages of obesity.[1,2] Next, the total numbers of obese cases (with information about BMI, sex and age) were used to calculate the mean BMI, the percentage of women and mean age of the obese population, which were used as inputs for the model. Lifetime results for the obese population in the different countries were then compared with results for a population comparable in sex and age, but with a BMI of 25 kg/m^2 to show the potential of prevention on a population level.

2.5 | Sensitivity analyses

To translate uncertainty around the input parameters into uncertainty around the outcomes of the model, probabilistic sensitivity analyses (PSA) were performed for the scenario analyses. Uncertainty around the RRs for the association of BMI with all-cause mortality and the RRs for BMI and obesity-related diseases was included as well as uncertainty around costs. The other parameters were kept fixed. Appendix S2 shows additional information on the probabilistic SA.

In addition, several one-way sensitivity analyses (SA) were performed for all countries to estimate the impact of key model parameters or assumptions on the outcomes. The first SA used a time horizon of 20 years instead of lifetime. In the second SA, RRs for the association between BMI and obesity-related diseases were obtained from DYNAMO-HIA[27,28] instead of the GBD. The third SA explored the impact of using RRs for the association between BMI and all-cause mortality based on DYNAMO-HIA[27,28] instead of the meta-analysis of Aune et al.[18] In the fourth SA, no increased risk for the co-occurrence of diabetes and stroke and diabetes and IHD was assumed to be conservative. In the fifth SA, productivity costs were added calculated using the SHARE data.[54] Productivity costs are costs because of missing work or productivity because of illness or health conditions related to obesity, specified by BMI. The last SA added productivity- and age-specific non-medical costs, resulting in an analysis from an extended societal perspective. Non-medical costs were estimated from national household consumption/expenditure surveys in each country considering the household size.[55–59] These costs were included as living longer results in more opportunity to consume other goods and services, such as electricity, gas, housing and water.[20,53] More details about the productivity- and non-medical costs can be found in Appendix S1.

2.6 | Model validation

The model was validated by running a cohort of men/women with a starting age of 40 years and a mean BMI of the general population as was observed in each country.[26] The resulting life expectancy was compared with the life expectancy for men and women for the different countries reported by EUROSTAT.[60] In a second analysis, the model results were compared with outcomes of other obesity models in the literature[61,62] by comparing the predicted difference in life expectancy between a healthy and obese 40-year-old person.

3 | RESULTS

Table 1 shows the lifetime results for cohorts with a starting age of 40 years and a mean BMI level of 30 or 35 kg/m^2. For both cohorts, Spain had the highest life expectancy. Total lifetime health care costs in a cohort with BMI level of 35 kg/m^2, ranged from €75 376 (Greece) to €343 354 (the Netherlands). In general, total costs were higher in the cohort of people with a BMI of 35 kg/m^2 compared with a BMI of 30 kg/m^2. In most countries, medical costs for other diseases had the largest contribution to the total costs.

Table 2 shows that a reduction of one unit in BMI for a cohort of 35 kg/m^2 resulted in a higher gain in life expectancy and reduction in disease cases compared with a cohort of 30 kg/m^2 in most countries. The savings in medical costs for diabetes, IHD and stroke were lowest in Greece and highest in Germany. In the Netherlands, an increase in total costs was observed, mainly because of the change in medical costs for other diseases. When the results of Tables 1 and 2 were discounted (see Appendix S3), medical costs for other diseases still appeared to have the largest contribution to the total costs, but to a lesser extent.

Table 3 shows the results of the scenario analyses. On a population level, the reduction of the BMI to healthy levels will result in cost savings in all countries in medical costs for obesity-related diseases, ranging from €8532 in Greece to €22 042 per person in Germany. Moreover, there was a gain in life expectancy and QALY in all countries, but this gain was lower than in the cohort analyses. Because of this increase in life expectancy, the risk for getting other non-obesity-related diseases (including costs) increased as well. The increase in costs for non-obesity-related diseases was larger in the cohort analyses because the gain in life-expectancy was higher. Total health care costs decreased in all countries, except for the Netherlands.

Table 4 shows the results of the SAs in the UK cohort. Health outcomes appeared to be most sensitive to the time horizon used (0.625 and 0.545 less gain in life expectancy and QALYs, respectively

TABLE 1 Lifetime results (per person) for the base-case analysis for a healthy cohort (starting age of 40 years) and different BMI levels in the absence of any weight loss intervention, costs in 2020 euros (undiscounted)

BMI	Outcome	Germany	Greece	Netherlands	Spain	UK
30 kg/m^2	Life expectancy (years)	40.7	41.3	40.9	42.5	41.3
	Years with diabetes	5.0	4.3	6.3	7.1	3.3
	Cum. incident cases IHD/1000	331	194	375	204	338
	Cum. incident cases stroke/1000	280	557	294	288	317
	QALY	35.4	34.2	35.3	36.1	33.1
	Medical costs diabetes, IHD, stroke	€59 027	€22 895	€35 464	€29 894	€42 917
	Medical costs for other diseases	€204 807	€17 016	€312 588	€88 557	€109 361
	Informal care costs	€17 480	€29 737	€17 977	€48 193	€31 839
	Total costs	€281 314	€69 648	€366 031	€166 633	€184 117
35 kg/m^2	Life expectancy (years)	37.9	38.6	38.1	39.7	38.6
	Years with diabetes	10.5	8.3	12.1	13.4	6.9
	Cum. incident cases IHD/1000	418	246	463	275	406
	Cum. incident cases stroke/1000	354	604	382	365	382
	QALY	32.6	31.7	32.5	33.3	30.6
	Medical costs diabetes, IHD, stroke	€87 535	€33 121	€56 487	€47 853	€60 846
	Medical costs for other diseases	€184 443	€16 644	€271 619	€83 995	€98 976
	Informal care costs	€14 837	€25 612	€15 248	€41 344	€27 178
	Total costs	€286 814	€75 376	€343 354	€173 183	€187 000

Abbreviations: BMI, body mass index; cum., cumulative; IHD, ischaemic heart disease; QALY, quality-adjusted life year.

TABLE 2 Lifetime results (per person) for the base-case analysis of one unit decrease in BMI for a cohort age 40 years, costs in 2020 euros (undiscounted)

BMI	Outcome	Germany	Greece	Netherlands	Spain	UK
30 kg/m^2	Gain in life expectancy (years)	0.363	0.360	0.371	0.379	0.347
	Decrease in years with diabetes	0.737	0.567	0.839	0.941	0.470
	Decrease in cum. incident cases IHD/1000	15	9	16	12	13
	Decrease in cum. incident cases stroke/1000	12	11	15	13	12
	Gain in QALY	0.376	0.348	0.390	0.396	0.322
	Change in medical costs diabetes, IHD, stroke	€ −4327	€ −1608	€ −3174	€ −2704	€ −2863
	Change in medical costs for other diseases	€2879	€49	€6209	€637	€1377
	Change in informal care costs	€378	€597	€406	€990	€656
	Change in total costs	€ −1072	€ −961	€3441	€ −1076	€ −829
35 kg/m^2	Gain in life expectancy (years)	0.675	0.645	0.658	0.677	0.657
	Decrease in years with diabetes	1.338	0.960	1.370	1.487	0.874
	Decrease in cum. incident cases IHD/1000	19	11	18	16	14
	Decrease in cum. incident cases stroke/1000	17	8	20	17	14
	Gain in QALY	0.692	0.611	0.681	0.696	0.598
	Change in medical costs diabetes, IHD, stroke	€ −6744	€ −2369	€ −4914	€ −4207	€ −4147
	Change in medical costs for other diseases	€4735	€91	€9129	€1073	€2520
	Change in informal care costs	€610	€946	€617	€1573	€1086
	Change in total costs	€ −1398	€ −1332	€4832	€ −1563	€ −539

Abbreviations: BMI, body mass index; cum., cumulative; IHD, ischaemic heart disease; QALY, quality-adjusted life year.

when SA1 was compared with the base case). Including productivity costs (SA5) did not change the total costs much (€52 difference when SA5 was compared with base case), whereas adding non-medical costs as well (SA6) considerably changed the total costs (€7316 difference). The results of SAs in other countries showed comparable impact and are presented in Appendix S4.

TABLE 3 Lifetime results scenario analyses (per person) (95% uncertainty interval), costs in 2020 euros (undiscounted).

Outcome	Germany	Greece	Netherlands	Spain	UK
Cohort (40 years, BMI 35 kg/m^2), decrease BMI to 25 kg/m^2					
Gain in life expectancy (years)	3.88 (3.66; 4.11)	3.82 (3.60; 4.05)	3.92 (3.71; 4.13)	4.00 (3.80; 4.22)	3.73 (3.51; 3.97)
Gain in QALY	4.04 (3.86; 4.23)	3.70 (3.54; 3.87)	4.14 (3.97; 4.32)	4.22 (4.06; 4.39)	3.48 (3.31; 3.65)
Change in medical costs diabetes, IHD, stroke	€ −45 994 (−56 012; −37 968)	€ −16 756 (−21 102; −13 367)	€ −33 584 (−42 156; −26 182)	€ −28 747 (−36 136; −22 995)	€ −30 022 (−36 632; −24 632)
Change in medical costs for other diseases	€29 137 (18 797; 42 895)	€522 (181; 994)	€61 063 (40 371; 87 660)	€6538 (3840; 10 394)	€14 511 (9586; 20 883)
Change in informal care costs	€3821 (2434; 5481)	€6041 (3, 851; 8626)	€4062 (2586; 5819)	€10 020 (6372; 14 319)	€6673 (4261; 9581)
Change in total costs	€ −13 036 (−28 306; 3781)	€ −10 192 (−14 679; −6097)	€31 541 (8394; 59 697)	€ −12 189 (−20 433; −4081)	€ −8838 (−17 683; −150)
Obese population, 25-65 years, decrease BMI to 25 kg/m^2					
Gain in life expectancy (years)	1.70 (1.48; 1.92)	1.76 (1.54; 1.97)	1.77 (1.57; 1.97)	1.82 (1.62; 2.03)	1.71 (1.48; 1.94)
Gain in QALY	1.74 (1.56; 1.92)	1.71 (1.55; 1.87)	1.85 (1.69; 2.01)	1.89 (1.73; 2.05)	1.62 (1.46; 1.78)
Change in medical costs diabetes, IHD, stroke	€ −22 042 (−26 764; −17 975)	€ −8532 (−10 500; −6942)	€ −15 405 (−19 108; −12 397)	€ −13 391 (−16 668; −10 720)	€ −16 663 (−20 363; −13 549)
Change in medical costs for other diseases	€13 563 (8614; 20 093)	€225 (83; 417)	€31 100 (20 388; 45 319)	€3029 (1766; 4748)	€6797 (4376; 9752)
Change in informal care costs	€1813 (1170; 2637)	€3050 (1975; 4460)	€2069 (1344; 3002)	€4851 (3142; 7075)	€3393 (2189; 4940)
Change in total costs	€ −6666 (−13 705; 1595)	€ −5256 (−7479; −3085)	€17 764 (5456; 32 730)	€ −5511 (−9447; −1484)	€ −6473 (−11 017; −1472)

Abbreviations: BMI, body mass index; IHD, ischaemic heart disease; QALY, quality-adjusted life year.

TABLE 4 Results of SA for scenario of one-unit change in a cohort aged 40 years old with BMI 35 kg/m^2 (UK), costs in 2020 euros (undiscounted)

Outcome	Base case	SA1: 20 years time horizon	SA2: RR BMI-diseases DYNAMO-HIA	SA3: RR BMI-all-cause mortality DYNAMO	SA4: no co-occurrence of diseases	SA5: including productivity costs	SA6: including productivity and non-medical costs
Assumptions that were changed	-	20 years instead of lifetime	RRs from the DYNAMO-HIA[27,28] instead of GBD[26]	RRs from the DYNAMO-HIA[27,28] instead of Aune et al.[18]	No clustering of diseases assumed	Adding productivity costs	Adding productivity costs and non-medical costs
Gain in life expectancy (years)	0.657	0.032	0.614	0.567	0.533	0.657	0.657
Gain in QALY	0.598	0.053	0.553	0.534	0.489	0.598	0.598
Change in medical costs diabetes, IHD, stroke	€ −4147	€ −1024	€ −3558	€ −4254	€ −3064	€ −4147	€ −4147
Change in medical costs for other diseases	€2520	€42	€2351	€2151	€2060	€2520	€2520
Change in non-medical costs	-	-	-	-	-	-	€7368
Change in informal care costs	€1086	€ −16	€1022	€840	€906	€1086	€1086
Change in productivity costs	-	-	-	-	-	€ −52	€ −52
Change in total costs	€ −539	€ −997	€ −185	€ −1264	€ −97	€ −591	€6777

Abbreviations: BMI, body mass index; IHD, ischaemic heart disease; QALY, quality-adjusted life year; RR, relative risk; SA, sensitivity analysis.

The model validation exercises showed that in general, the current model resulted in slightly lower estimates of the life expectancy for both men and women compared with EUROSTAT data (i.e. 0.4-0.9 years lower compared with EUROSTAT data). See Appendix S5 for figures related to this validation check.

Comparison of the difference in life expectancy between a healthy and obese 40-year-old person with the current model and other published studies showed that results were comparable with the results presented by van Baal et al.[62] but lower than the results of Peeters et al.[61] The current model predicted a difference in life expectancy ranging from 3.7 years for the UK to 4.0 years for Spain comparable with the 4.2 years reported by van Baal et al. Peeters et al. reported a difference in life expectancy ranging from 5.82 to 6.85 years for men and from 6.18 to 7.21 years for women.

4 | DISCUSSION

This study investigated the lifetime health and health care burden of obesity, by including a wide range of health care costs, in five European countries. We found that total lifetime costs and health outcomes varied between European countries; total costs were lowest in Greece and highest in the Netherlands. Annual treatment cost per case for obesity-related diseases obtained from the literature (Appendix S1: Table A3) showed substantial variation between countries, being the highest in Germany and the lowest in Greece. Medical costs for other diseases showed an even larger variation. The latter costs were relatively low in Greece compared with other countries, because in Greece there is large out-of-pocket spending (i.e. private spending), which is not included in health care expenditure databases.[53] Moreover, differences in medical costs for other diseases were calculated using best available data,[53] using inpatient hospital care costs for Greece and multiple cost components for the Netherlands. In line with a previous study,[14] health outcomes were better in a cohort with a BMI of 30 kg/m^2 compared with 35 kg/m^2, as higher BMI results in higher risks for obesity-related diseases.

In addition, we showed the potential of preventing obesity, by reducing high BMI with one unit and by assuming a reduction in BMI to a healthy BMI of 25 kg/m^2, resulting in gains in life expectancy and QALY. Moreover, the total health care costs will be reduced when obesity is prevented, which is comparable with other studies.[10,63] However, in the Netherlands the total costs did not decrease because of a large increase in medical costs for other diseases. It must be noted that discount rates had not been applied in base-case analyses; when discount rates were applied in the Netherlands, this resulted in cost savings for the Netherlands as well as the increase in medical costs for other diseases will happen in the future.

Applying a shorter time horizon is important for the final outcomes (SA1). In the analysis with a time horizon of 20 years, which is below the average life expectancy of a 40-year-old person with a BMI of 35 kg/m^2 (see Table 1; 38.6 years), the gain in life expectancy was very low (0.032 years), resulting in only a small increase in medical costs for other diseases. The incremental informal care costs were negative, which could be explained by the fact that these costs mainly occur in the last year(s) of life.[64] The results of SA6 did show a large impact of non-medical costs on the total lifetime costs and it could therefore be argued that these costs should not be neglected. There is still discussion in the literature whether to include these costs, but there is an increase in favour of the arguments as practical issues can be overcome.[20,48,53,65]

One way to compare the burden of obesity in terms of reduced life expectancy with the additional health spending that might result in successful obesity prevention is to attach a monetary value to reduced life expectancy.[66] Such monetary values are used in decision making based on cost-effectiveness results. Monetary values that have been used in that context are defined, for example, by the National Institute for Health and Care Excellence (NICE) to be 20 000 pounds (22 676 euros) per 1 additional QALY.[67] The scenario analyses on a population level showed a gain in QALY of 1.62 for preventing obesity, corresponding to a cost of €36 735 for reduced quality-adjusted life expectancy, which is much higher than the increase in health care costs (i.e. change in total costs) associated with obesity (about €6500 for the UK). Economic evaluations can help to assess whether specific interventions reducing BMI are good value for money by comparing the change in total lifetime costs with the acquired health benefits. It is important that new initiatives to prevent obesity keep being developed, such as the use of systems science for strategic planning of obesity, or by targeting a sustainable change in behaviour by introducing personalised nutrition.[68,69] Future studies can use this newly developed obesity model to evaluate the cost-effectiveness of obesity-related interventions.

The current study included a wide range of health care costs. Another strength of the study was that the newly developed Markov model is representative for five different countries, which allows comparison between countries on costs and health outcomes. In contrast to most previously published obesity models that include classes (e.g. normal weight, overweight and obese),[70] BMI was modelled continuously. Modelling BMI as a continuous parameter gives the model more flexibility in simulating the impact of, for example, prevention on BMI reductions. However, the model also had some limitations. First, only three main obesity-related diseases were modelled directly. Thus, the effect of BMI reduction on occurrence and costs of other obesity-related diseases could not be explicitly shown. A reduction in BMI has been shown to be beneficial for other diseases as well, such as osteoarthritis, sleep apnoea, many types of cancers and mental illness.[71–73] The impact of these other diseases on life expectancy was considered, however, by including RRs for BMI on all-cause mortality. Costs for the other (obesity-related) diseases were included in the medical costs related to other diseases. Second, the model used BMI as a parameter to estimate the lifetime cost and effects of a certain cohort. However, other parameters, such as body fat or waist circumference, might yield more accurate estimates of the long-term costs and effects.[3] The association between body fat and other factors such as life expectancy, QOL and costs, however, was not yet well established in the literature. From the model validation, it could be found that results were slightly comparable or even somewhat conservative in comparison with other models. Finally, we did not consider any differences in BMI between ethnicities. However, it is shown that an equivalent risk of type 2 diabetes, was at substantially lower BMI values in black Caribbean, south Asian, Chinese and Arab populations (in populations living in England) than the current BMI cut-offs for obesity.[74] Future research could look at the impact of these ethnic differences on the total costs and effects.

In conclusion, our findings show that the total impact of obesity on health care costs is substantial in the five different countries that were investigated. In addition, results show that the life expectancy of people with obesity is on average about 4 years lower compared with people with a normal weight. Reductions in BMI resulted in a reduction of obesity-related diseases and a gain in life-expectancy, which emphasizes the importance of reducing BMI and the development of interventions that support this reduction. However, the wide range of health care costs that was included showed that an increase in life expectancy, because of a BMI reduction, has implications for non-obesity-related health care costs, which is relevant to support decision making on implementation of preventive interventions.

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CONFLICTS OF INTERESTS

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DATA AVAILABILITY STATEMENT

Data are available upon reasonable request.

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