Published in final edited form as:

Pharmacoeconomics. 2015 July ; 33(7): 723–734. doi:10.1007/s40273-014-0234-y.

Did Statins Reduce the Health and Health Care Costs of Obesity?

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Abstract

Context—Obesity impacts both individual health and, given its high prevalence, total health care spending. However, as medical technology evolves, health outcomes for a number of obesity-related illnesses improve. This article examines whether medical innovation can mitigate the adverse health and spending associated with obesity, using statins as a case study. Due to the relationship between obesity and hypercholesterolemia, statins play an important role in the medical management of obese individuals and the prevention of costly obesity-related sequelae.

Methods—Using well-recognized estimates of the health impact of statins and the Future Elderly Model (FEM) – an established dynamic microsimulation model of health of Americans aged over 50 – we estimate the changes in life expectancy, functional status and health care cost of obesity due to the introduction and widespread use of statins.

Results—Life expectancy gains of statins are estimated to be 5%–6% higher for obese than healthy-weight individuals, but most of this additional gain is associated with some level of disability. Considering both medical spending and the value of quality-adjusted life-years, statins do not significantly alter the costs of class 1 and 2 obesity (BMI larger or equal to 30 and 35 kg/m²), and *increase* the costs of class 3 obesity (BMI larger or equal to 40 kg/m²) by 1.2%.

Conclusions—Although statins are very effective medications for lowering the risk of obesity-associated illnesses, they do not significantly reduce the costs of obesity.

1 Introduction

Between 1960 and 2002, the average height of American adults increased by approximately 1 inch, while average weight increased by over 24 pounds (11 kg).[1] As a result, during these four decades the prevalence of obesity (a body mass index, or BMI, larger or equal to 30 kg/m²) more than doubled and the prevalence of extreme obesity (BMI larger or equal to 40 kg/m²) increased six-fold. As of 2010, 36.1% of American adults were obese and 6.6% were extremely obese. A similar trend is apparent among men and women, most racial subgroups, and the elderly.[1]

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This increase in the prevalence of obesity is a serious concern from both a public health and fiscal perspective. Obesity is associated with an increased risk of type II diabetes, ischemic heart disease, ischemic stroke, hypertension, dyslipidemia, osteoarthritis, and several cancers.[2] Published estimates of the healthcare costs attributable to obesity have consistently increased as the epidemic has grown.[3–6] Finkelstein et al. find— after adjustment for demographic factors, economic factors, and smoking status—that obese individuals incurred 42% more direct medical costs.[5] This translated into roughly 9.1% of all public and private healthcare spending, or about \$147 billion in 2006—with roughly one-quarter paid by Medicare.[5] Given the fact that most obesity-associated diseases do not present themselves until later adulthood, this finding is not surprising. However, it does underscore the importance of tackling the obesity epidemic in the aging population of the United States.

The past decades have also seen numerous medical innovations, several of which have become important components of the management of obesity-associated illnesses. However, little is known about how these innovations affect the health and health care costs of obesity.

In this study we use the introduction of statins as a case study to shed light on this issue. Statins offer an interesting example for several reasons. First, statins are perhaps one of the most important innovations in recent medical history. Not only do they lower the risk of death from obesity-associated illness, they also lower the risk of developing some of these diseases in the first place.[7–12] Second, statin use has rapidly increased since 2000, with more than 40 million adult Americans filling a prescription in 2011.¹ A recent study finds a large social value for this widespread use, and suggests it may have prevented as many as 40,000 deaths and 100,000 hospitalizations for heart attacks and strokes in 2008 alone [13]. Third, statins are well studied, allowing us to model the effects of statins on long term health outcome and health care costs.

We note that other examples of medical innovations, such as bariatric surgery and prescription weight loss drugs, directly reduce the weight of obese people. The former was shown to be quite effective,[14] but has recently plateaued around 120,000 procedures per year.[15] Statin therapy differs from such innovations in that it is so widely used that it may plausibly have had a noticeable impact on the costs of obesity. We also believe that statins are a better case study for medical innovation as a whole, since they prevent diseases associated with obesity rather than obesity itself.

Statins might affect obesity through multiple channels. On the one hand, statin therapy lowers both the chance of contracting cardiovascular diseases and stroke and the health consequences of these diseases.[7–12] Since obesity is an important risk factor for these diseases, statin therapy likely reduces the health consequences of being obese. On the other hand, the effects of statins on health care costs are *a priori* ambiguous because of competing factors. By decreasing morbidity associated with obesity, statins plausibly diminish obesity-

¹Authors' calculations with Medical Expenditure Panel Survey (MEPS) data. A MEPS respondent is defined as a statin user if he or she filled at least one prescription associated with the "HMG-CoA reductase inhibitor" therapeutic subclass during a given year, or a prescription of "Simcor", "Advicor" or "Vytorin" (which combine statins with other active ingredients). Therapeutic classes in MEPS correspond to Multum Lexicon variables from Cerner Multum, inc.

related costs at a given age. However, by increasing the length of life of obese people, statins enable the accumulation of health care costs over more years. To our knowledge, no study has thus far attempted to quantify these effects of statins on obesity.² In this study, we fill this gap in the literature and ask the following question: How did the introduction and widespread use of statins impact the health and health care costs of obesity?

To answer this question, we use the Future Elderly Model (FEM) – an established dynamic microsimulation model of the health of Americans aged over 50.[16] Using the well-recognized estimates of the health impacts of statins, we construct an FEM scenario in which statins have not been discovered. By comparing life trajectories and medical costs of elderly Americans in this scenario and the baseline version of the FEM, we estimate the change in the health and health care cost of obesity due to the introduction and widespread use of statins. We focus our analysis on the long-term impact of statins on life expectancy, disability, and health care costs including total spending and spending by public programs.

2 Methods

2.1 FEM

We conduct simulations using the Future Elderly Model (FEM), a dynamic microsimulation model that follows Americans aged 51 and older and projects their health and medical spending over time. The FEM was initially developed by Goldman et al. (2004) to forecast the implications of different medical technology scenarios on long-term health and health care costs [16]. Its unique feature is to follow the evolution of individual-level health trajectories, rather than the average or aggregate health characteristics of a cohort. It has proved useful for a number of purposes in the recent past, including forecasting the future costs of cancer [17] and obesity [18], assessing the benefits of risk prevention [19], and evaluating the marginal cost of being obese [20] and the value of medical interventions for reducing its prevalence [14].

The FEM simulates the lives of people from the age of 51 onward using the Health and Retirement Survey (HRS), a biennial survey of the American population aged 51 and over that has been ongoing since 1992. The HRS data is used to compute the health transition models at the core of the FEM and the input population that goes into the simulations. It is supplemented by the Medical Expenditure Panel Survey (MEPS), a set of large-scale surveys of the non-institutionalized population of the United States, and the Medicare Current Beneficiary Survey (MCBS), a nationally representative survey of Medicare beneficiaries, to project health care spending and assess quality-of-life during the simulations. For each individual, the FEM takes into account initial demographic characteristics and health conditions to project medical spending, health conditions and behaviors, disability status, and quality of life. We describe the model and methods briefly here; a complete technical appendix containing details on the modeling is provided in the Electronic Supplementary Material.

The FEM's core module calculates transition probabilities across various health states, including mortality, functional status, and BMI based on the individual's current characteristics. These transition probabilities are modeled using first-order Markov

processes that depend on a battery of predictors: age, sex, education, race, ethnicity, BMI, smoking behavior, marital status, employment, functional status and health conditions. We also control for baseline factors using a series of initial health variables.

Health conditions are derived from HRS survey questions and include diabetes, high blood pressure, heart disease, cancer (except skin cancer), stroke or transient ischemic attack, and lung disease (either or both chronic bronchitis and emphysema). Transitions into illness and death are synthesized in Figure 1, which is analyzed in further detail in Appendix B. The concept of chronic conditions used in the simulations corresponds to having *ever* been diagnosed with a condition. We thus treat them as absorbing: once individuals receive a diagnosis, they are henceforth considered to have that condition.³ The BMI variable is based on the self-reported height and weight of HRS respondents and its evolution is projected with the estimates of a log-linear model. We adopt a log-linear specification to account for the ‘thick’ right tail of the BMI distribution in HRS. We adjust for height and weight self-reporting biases using the average BMI underreporting by age group and sex in the National Health and Nutrition Examination Survey (NHANES) data.[21] Functional status is measured by limitations in instrumental activities of daily living (IADLs), activities of daily living (ADLs), and residence in a nursing home. The IADL indicator is based on questions about difficulty using the phone, managing money, and taking medications. The ADL indicator is based on respondents’ assessment of their ability to conduct basic tasks such as dressing, eating, and bathing. For the purpose of this study, we consider an individual as free of disability if he reported no IADL or ADL limitation and did not live in a nursing home; as disabled if he reported at least one IADL or ADL limitation but did not live in a nursing home; and we consider nursing home living as indicating the most severe functional status impairment. Unlike health conditions, we allow for transitions into and out of functional states.

To evaluate quality-of-life, we predict quality-adjusted life years (QALYs) using the EQ-5D, a commonly used quality-of-life index based on five health-related variables addressing mobility, daily activities, self-care, anxiety, depression and pain. Using the MEPS data, we use an ordinary least squares regression to fit derived EQ-5D quality adjustment scores as a function of the chronic conditions and functional states included in the FEM simulations. This model is then used to predict the quality of each person’s life-years in our simulations.

Based on two complementary medical spending data sources, a second FEM module predicts an individual’s health spending with regards to health status (chronic conditions and functional status), demographics (age, sex, race, ethnicity and education), nursing home status, and mortality. Our definition of medical costs includes medical provider visits, hospital events, inpatient stays, outpatient visits, emergency room visits, dental care, home health care, optometry, other medical equipment and services, prescribed medicines, and nursing home stay. Our estimates are based on spending data from the 2002–2004 MEPS for individuals under 65 years-old and the 2002–2004 MCBS for individuals aged 65 and over. We separately predict total medical costs and medical costs paid for by the Medicare and

³This interpretation is consistent with the HRS questionnaire, which asks respondents if they were ever diagnosed with a condition.

Medicaid programs. The estimates are based on pooled least squares regressions of each type of spending on risk factors, self-reported conditions, and functional status, with spending inflated to current dollars using the medical component of the consumer price index.

2.2 Simulations

We simulate the health trajectories of elderly Americans characterized by a range of different BMIs and predict their health care costs with and without the possibility to use statins. These simulations focus on a representative cohort of Americans aged 51 to 52 in 2010. For each period, the spending module predicts medical expenditure on the person's current state vector. Then, the health module predicts survival, health transitions, BMI, functional status and QALY for the next period,⁴ using the FEM's transition probabilities. The same process is repeated at each time step until everyone in the cohort has died.

2.2.1 Scenarios—The baseline FEM provides projections consistent with the current medical technology, and thus implicitly includes the health effects and costs of statins. In the remainder of this article, we refer to the baseline FEM as the “With Statins” scenario. Our simulation strategy consists of comparing the predictions of the “With Statins” scenario to a scenario in which statins were never invented. We implement this “Without Statins” scenario in two steps. First, we augment the FEM to identify individuals who currently use statins. Second, we remove the well-recognized health impact of statins from individuals identified as statin users. The differences in outcomes between the scenarios reveal the impact of statins.

Since there is no HRS question about statin use, we turn to MEPS Prescribed Medicine File data, which contains detailed information about prescription drugs and associated costs. Since statin use is a dichotomous variable, we use a probit model to estimate the probability that an individual is using a statin within the FEM simulations. We define a MEPS respondent as a statin user if he or she filled at least one prescription associated with the “HMG-CoA reductase inhibitor” therapeutic subclass⁵ during a given year, or a prescription of “Simcor”, “Advicor” or “Vytorin” (which combine statins with other active ingredients).

The MEPS data reveals the dramatic increase in statin use over the recent years. In 2000, about 16 million Americans had filled at least one statin prescription in the previous year. By 2006, that number doubled. Then, by the end of the decade, the number of Americans purchasing statins reached 40 million (Figure A1, in the Electronic Supplementary Material). Remarkably, over half of the obese elderly population now uses statins (Figure A2, in the Electronic Supplementary Material).⁶ To take these factors into account, we restrict our analysis to 2009 to 2011 MEPS data. This ensures that our statins use imputation is consistent with 2010, the first year of our simulations. More detail about this task and the results of our estimations are presented in the Electronic Supplementary Material.

⁴Since the HRS is biennial, we simulate health and costs over two-year periods.

⁵Therapeutic classes in MEPS correspond to Multum Lexicon variables from Cerner Multum, inc.

⁶Authors' calculations with Medical Expenditure Panel Survey (MEPS) data.

The benefits of statin therapy in primary and secondary prevention of cardiovascular disease have been widely studied and well reported by many researchers. Table 1 (available in the Electronic Supplementary Material) summarizes the most important findings from recent literature.

As mentioned above, the “Without Statins” scenario alters the FEM’s health transition module to realistically remove the health benefits of statins from individuals who are identified as statin users by the simulations. For these individuals, we increase the probabilities of contracting diseases and mortality, using the inverse of the health effects of statins documented in Table 1:

1. **Heart disease:** We increase the probability of contracting a heart disease by factors with a mean of 1.30. The distribution used corresponds to the inverse of the risk ratios of contracting a non-fatal ⁷ cardio-vascular disease among the primary prevention population reported by the Cochrane collaboration [12].
2. **Stroke:** We increase the probability of contracting a stroke by factors with a mean of 1.45, based on the Cochrane collaboration’s non-fatal stroke primary prevention result.
3. **Mortality:** The literature indicates that statins have differential mortality effects depending on sex and whether they are used for primary prevention or secondary prevention. We thus make the following adjustments:
 - a. For individuals who have never been diagnosed with a stroke or a heart disease, we increase the mortality probability by factors with a mean of 1.16, based on the primary prevention risk ratios reported by the Cochrane collaboration.
 - b. For men and women who have been diagnosed with a heart disease, we increase the mortality probability by factors with means of 1.27 and 1.09, based on Gutierrez et al. [10].

To account for uncertainty in statin effectiveness, we sampled new estimates of the clinical effect of statins from the confidence intervals for relative risks reported by the literature. Assuming parameters to be independent from each other, we drew 200 sets of risk ratio estimates from a log-normal distribution and computed the factors described above. To obtain robust simulation results for each set of estimates, we ran 100 repetitions of the cohort simulations for each draw. We then computed and sorted the 200 means (one per draw) over these repetitions for all our variables of interest. In the remainder of the article, the point estimates of our results correspond to the mean of each variable of interest across the 200 draws and their 100 repetitions. The bounds of the 95% confidence intervals correspond to the 5th lowest and highest results for each variable of interest. These intervals can be interpreted as simulated 95% confidence intervals with regards to the clinical uncertainty of the effectiveness of statins.

⁷This is consistent with the FEM health transition models, which are estimated only for live individuals.

2.2.2 Isolating the impact of obesity—The key objective of this article is to isolate the difference in the impact of statins between otherwise identical healthy-weight and obese individuals. A challenge in obtaining this differential impact arises because of the obesity gradient in the distribution of chronic conditions. For instance, the prevalence of diabetes and heart disease at age 51 is significantly higher among the obese population than among the population with a healthy BMI.

To address this issue, we start by assigning a healthy BMI of 24.9 to each individual with a BMI greater or equal to 25 in our 2010 cohort while keeping other states unchanged. We conduct simulations of our “With Statins” and “Without Statins” scenarios for this healthy-weight cohort. We find the impact of statins on lifetime medical costs, length of life, and quality of life associated with this BMI. We then repeat this process for BMIs of 30 to 40 by units of 5. The difference in the effect of statins obtained with one of these higher BMIs and the healthy weight reflects the marginal effect of statins for individuals of that BMI, since the distribution of health and economic statuses is identical otherwise. This strategy is outlined in Figure 2 and the effects of obesity and statin use on health are expanded upon in greater detail in Appendix B, in the Electronic Supplementary Material. Overall, we expect obese individuals to benefit more from the existence of statins in the “With Statins” scenario and see their health deteriorate faster in the “Without Statins” scenario.

3 Results

3.1 Effects of Statins on Life Expectancy and Functional Status

Our simulations show the impact of the widespread use of statins on life expectancy. According to our results, a 51-year-old American with a healthy BMI gains on average 1.2 year of life because of the existence of statins. This value corresponds to the difference in life expectancy between the “With Statins” (33.2 years) and the “Without Statins” scenario (32.0 years) when imposing a BMI below 25 to the FEM’s 2010 cohort.

As could be expected, life expectancy gains from statins are greater for obese individuals. Figure 3 shows a measure of the health cost of obesity, the difference in life expectancy between otherwise identical obese individuals and their healthy-weight counterparts. Each bar can be interpreted as the estimated loss of life expectancy that can be expected if an average individual traded a healthy weight for an obese weight. For a given BMI, the difference between the “With Statins” and the “Without Statins” bars correspond to the differential gain in life expectancy of statins for obese people (the difference-in-difference illustrated in Figure 2). When compared to healthy-weight Americans, life expectancy gains are estimated to be 5%–6% (0.06 to 0.07 years) higher for people with obese BMIs. While these differences are modest, they are statistically significant⁸ and support the notion that statins lower the health consequences of obesity. We emphasize that these results do not mean that statins are not effective for obese people, but mean that statins are *almost as effective* for people with a healthy BMI as they are for obese people.

⁸As detailed in section 2.2.1, statistical significance refers to the 95% confidence intervals with regards to the clinical uncertainty of the effectiveness of statins.

As discussed in the Electronic Supplementary Material's Appendix 2, as health evolves with the simulations, obese individuals are more likely to be ill and benefit from the secondary mortality prevention effect of statins (i.e. after the onset of heart disease). In contrast, healthy-weight individuals are more likely to have never had a stroke or a heart disease, and thus likely benefit more from the primary prevention effects of statins. It therefore matters whether the life expectancy gains of Figure 3 are in good health or disabled.

To examine the composition of these gains, we decompose the additional life expectancy gains for obese individuals by functional status in Figure 4. The bars correspond to the difference-in-difference in life expectancy with a functional status due to both the existence of statins and to having an obese BMI. We find that the estimated additional gain in longevity for obese people is predominantly composed of time living with a disability. Difference-in-difference estimates of healthy life-years are either not significant (for obesity classes 1 and 2), or significantly negative (for obesity class 3).

Taken together, these estimates indicate that statins somewhat reduce the health cost of being obese as measured by life expectancy, but this gain mainly amounts to time in bad health.

3.2 Effects of Statins on Health Care Costs

Of course, by delaying the onset of chronic conditions and mortality, statins also impact medical costs. To quantify this impact, we computed the present value of the expected lifetime medical costs of our cohorts at age 51, discounted with a 3% interest rate. The detailed results are shown in Table 2.

Since medical costs in MEPS and MCBS include prescription drugs, the direct cost of statin therapy is included in both the "With Statins" and "Without Statins" projections. In 2010, according to MEPS data, the average annual costs of statins prescriptions for statin users aged over 51 was of \$532. Of this amount, \$125 and \$26 were paid for by Medicare and Medicaid, respectively. For the "With Statins" scenario, we subtracted these values from the FEM's cost projections for all individuals identified as statin users in the simulations and reassigned them to the "Statins" row. For the "Without Statins" scenario, we removed these costs altogether from the FEM's cost projections.⁹

Our estimates indicate that statins have a modest impact of about \$25,000–\$30,000 on lifetime health care costs for individuals of all BMIs. Of this amount, 25% stems from the direct costs of statins prescriptions, mainly paid for privately. The remainder corresponds to medical costs linked to the health benefits of statins. These notably arise because of the secondary prevention effect of statins, which enables individuals to live and require care longer after the onset of cardiovascular diseases. Thus, 60% of the additional costs are incurred when individuals are disabled or living in a nursing home. Nursing home living is

⁹By doing so, we assume that the direct costs of statin therapy for the elderly will be stable at their 2010 levels in the future. This is consistent with the remainder of the FEM's cost projections, which surmise that costs of treatments remain proportional over time. The 2010 values however constitute a higher bound for the future cost of statin prescriptions, given atorvastatin's patent expiration in 2011 and rosuvastatin's forthcoming patent expiration in 2016. The 2010 prescription costs are converted in 2009 dollars, the base year for the FEM's costs projections, using the U.S. City Average CPI from the Bureau of Labor Statistics.

the highest contributor to the costs of statins and is largely paid for by the Medicaid program. Overall, Medicare and Medicaid spending account for over half of the added costs.

While our estimates reveal a BMI gradient in the additional costs of statins, it is quite small: \$2,800 for class 1 obesity, \$3,500 for class 2 obesity, and \$4,000 for class 3 obesity. This gradient is consistent with the life expectancy gains described in Section 3.1, and indicate that statins increase the health care costs of being obese, albeit mildly.

3.3 Cost-Effectiveness of Statins

In Table 3, we compare the additional health care costs of statins with their health benefits. We consider total life expectancy gains (including time disabled or in a nursing home), disability-free life-years and quality-adjusted life-years. Again, our results show a BMI gradient, especially with regards to disability and quality of life. For instance, since individuals with class 3 obesity gain less healthy life-years and incur more costs, the estimated cost of statins per non-disabled life-year is \$10,900 higher for them than for healthy-weight individuals. Despite this higher unit cost, we find that, for any reasonable value of life, statins are estimated to be quite cost-effective for all health effectiveness measures and all BMIs. The expiration of atorvastatin's patent in 2011 has likely increased the use of generics and further improved the cost-effectiveness of statins. We expect that rosuvastatin's patent expiration in 2016 will continue this trend.

According to MEPS data, 56.7 million Americans were aged 50 to 64 in 2010. Of these, 34% were obese and 26% filled a statin prescription during the previous year. Based on our estimates, this cohort will have collectively lived 67.6 million life-years more than it would have if statins did not exist. Of these, 33.2 million years will be lived free of disability. These additional life-years gained by obese people will be associated with \$1.5 trillion additional lifetime health care costs, for an average of \$22,200 per life-year gained. Earlier, we saw that our estimates of life expectancy gains and costs of statins are modestly higher for obese individuals. When aggregated to the level of 2010's cohort aged 50 to 64, this gradient sums up to 1.3 million additional life-years and \$61 billion additional lifetime medical costs.

3.4 Effect of Statins on the Cost of Obesity

In the previous sections, we saw that the existence and widespread use of statins have large longevity and health impacts for both healthy-weight and obese individuals, contributing about one year to life expectancy at age 51. However, we noticed only a modest gradient of life expectancy (and lower QALY gains) with BMI, so it is unclear at this stage whether statins have a noticeable impact on the total costs of obesity. In other words, how do the additional longevity gains and medical costs of statins for obese people compare to the health and medical care costs of obesity?

In Table 4, we present estimates of the total costs of obesity in both scenarios, accounting for both medical care and health costs. The medical care cost of being obese corresponds to the additional lifetime medical costs at age 51 that can be expected when an individual moves from a healthy BMI to an obese BMI.¹⁰ In Panel A., our health cost concept refers to the loss in QALY that can be expected when an individual moves from a healthy BMI to an

obese BMI. We assign a value in \$2009 to this health cost by assuming a value of \$150,000 per QALY [22]. In Panel B, we conduct the same calculations with raw life expectancy losses, assuming a value of \$100,000 per year.

In a world without statins, we estimate that 51-year-olds with obesity class 1, 2, and 3 would respectively incur \$14,000, \$21,000, and \$25,800 higher lifetime healthcare costs than average healthy-weight individuals, and could expect to live 1.9, 3.1, and 4.1 less QALYs. With our assumption of the value of QALYs, the total costs of obesity class 1, 2, and 3 if statins did not exist would be \$303,500, \$488,200, and \$636,400.

In the “With Statins” scenario, the medical costs of obesity increases somewhat over the “Without Statins” scenario, while the difference in QALYs between BMIs remain mostly unchanged. This implies estimates of total costs of obesity class 1, 2, and 3 of \$303,700, \$492,000, and \$643,900, respectively.

The last rows show the difference in total costs due to the existence of statins. These values correspond to the difference-in-difference in health and medical care cost when considering both the existence of statins and obesity. Our estimates indicate that the availability of statins has no significant impact on the healthcare costs of obesity class 1 and 2, and *increase* the costs of obesity class 3 by \$7,500 (1.2% of the cost of obesity if statins did not exist). This occurs because statins are about as beneficial to the expected QALYs of all BMIs, and have a higher impact on the lifetime medical costs of obese individuals. The added costs stem from the additional time disabled gained by obese individuals, as illustrated by Figure 4.

In Panel B, we replicate the calculations of Panel A without accounting for quality-of-life. In this panel, all length-of-life lost due to obesity are valued equally at \$100,000 per year. With this health cost concept, we find significantly positive effects of statins on the cost of obesity classes 1 and 2. These different findings reflect the reality that much of the difference in life expectancy gains for obese individuals is spent with some level of disability. For both health concepts, we find that the effect of statins is quite small relative to the cost of obesity.

3.5 Sensitivity Analyses

To further our understanding of the factors at play behind these results, we consider two sensitivity analyses for the effect of statins on the costs of obesity.

First, a plausible explanation for the small impact of statins on the cost of being obese is our very concept of the cost of obesity. In this paper, we reassigned the BMI of the FEM’s nationally representative 2010 cohort to specific values and conducted separate simulations with these synthetic cohorts (as described in Section 2.2.2). We thus interpreted the costs of obesity as the health consequences and medical costs of trading a healthy BMI for an obese BMI at age 51, when other variables (including health) remain unchanged. An alternative interpretation would be that the costs of obesity should include comorbidities associated

¹⁰These are computed with the present values presented in Table 2. For instance, the medical care cost of class 2 obesity in the “With Statins” scenario (\$24.5) corresponds to the difference between the total medical costs with BMI = 35 and BMI < 25 in the “With Statins” column (485.5 and 460.9, respectively).

with obesity at the beginning of the simulations (higher prevalence of diabetes, hypertension, heart disease, etc.). Hypothetically, statins could have a larger impact under this interpretation. In Appendix C1, we adopted this concept and conducted simulations without reassigning BMIs. While we found larger effects of statins on the life expectancy of obese individuals, these effects remain small relative to the costs of obesity.

Second, another factor that could be preventing statins from lowering the costs of obesity is their *effectiveness* for the primary prevention of diseases and mortality. Since healthy-weight individuals are more likely than obese individuals to avoid heart disease and stroke, they may benefit from primary prevention effects of statins over more years, while obese individuals benefit more from secondary prevention. To test this hypothesis, we conducted a second sensitivity analysis, in which we only removed the secondary prevention effects of statins in the “Without Statins” scenario. This analysis is presented in the Electronic Supplementary Material’s Appendix C2. Our results do show an increase in the differential effectiveness of statins with higher BMIs, which supports the notion that medical innovations aimed at preventing disease may be more beneficial to non-obese people. To significantly reduce the costs of obesity, innovations would thus need to treat, rather than prevent, disease. However, the differential effects of statins on life expectancy and quality-of-life for obese people remain small in comparison with the costs of obesity, and are associated with higher medical costs. When taking both medical costs and health consequences into account, we do not find a significant net reduction in the total costs of obesity.

Overall, both analyses confirm the robustness of the small effect of statins on the costs of obesity.

4 Discussion

Obesity, given its high prevalence, impacts both individual health and the American fiscal outlook. As medical technology evolves over time, health outcomes for a number of obesity-related illnesses improve, changing the life outlook for obese people. In this article, we asked if such innovation could effectively alleviate the health and health care costs of obesity. We used statins, one of the most effective medical innovations of the recent decades, as a case study.

In many ways, statins constitute a best case scenario of medical innovations capable of lowering the burden of obesity. Statin therapy is inexpensive and has shown to be quite effective at both preventing the onset of diseases for which obesity is a risk factor and decreasing their health impact.

Our main findings are fivefold. First, the current use of statins significantly extends life, with estimated gains in life expectancy at age 51 of over one year for all BMIs. Second, life expectancy gains are modestly higher for obese individuals than healthy-weight individuals. Third, most of the additional gain in life expectancy of obese people is lived in poor health, with at least some level of disability. Fourth, this additional time lived disabled is associated with higher health care costs. Finally, when taking both quality of life and medical costs into account, our simulations indicate that statins have little or no effect on the costs of obesity.

Our study has several limitations. Notably, we do not take into account the potential moral hazard effect of statins in our “Without Statins” scenario: by lowering the probability of contracting chronic diseases and reducing mortality, statins may reduce the incentive for preventive behavior. In concept, the emergence of statins may explain some of the trend towards higher obesity rates, by lowering the health cost of being obese. A recent study revealed that caloric and fat intake of statins users have indeed grown from 1999 to 2010. However, the study could not determine if the changes stemmed from an expanded use of statins among people who eat more or from a change in the eating habits of statin users in response to the medical efficiency of statins [25]. In another recent study, Kaestner and colleagues find that statin use is associated with conflicting behavioral responses.[26] On the one hand, they find an increase in BMI and the probability of being obese among both men and women, as well as an increase in moderate or greater alcohol consumption. On the other hand, statin use leads to increased exercise rates among men. Overall, their results appear to support a net substitution between the medical effectiveness of statins and healthy behaviors. If such responses were introduced in our model, they would *reduce* the health effectiveness of statins. Thus, our results can be viewed as an upper bound of the impact of statins on the costs of obesity.

Also, this study is based on the premise that the health effects of statins reported by the randomized clinical trials literature can be generalized to all statin users, regardless of the number of filled prescriptions during the year or their characteristics. In practice, real world effects of statins are bound to differ from those obtained in a clinical trial setting. However, observational research has shown that the effectiveness of statins in community practice is comparable to what has been observed in clinical trials [27]. Moreover, since the FEM does not include biomarker data, cholesterol levels do not directly contribute to the probability of mortality and contracting diseases in the simulation. Thus, even if the adjustments used in the “Without Statins” scenario are correct, we may underestimate the probability of contracting diseases and mortality for individuals identified as statin users. Since this is true for both scenarios and other key risk factors, such as diabetes and BMI, are included in the transition models, the bias in the difference between scenarios is likely to be small.

Finally, while we accounted for the clinical uncertainty of the effectiveness of statins, other sources of uncertainty are more difficult to correctly account for and were ignored. For example, there could also be changes over time in the mortality benefits of statin use, as other treatments for clogged arteries and heart disease continue to improve; the medical care costs associated with various conditions and states will change over time; and transition probabilities between health states will also change over time with changes in medical technology. These are all reasons for caution when predicting the changes in lifetime costs associated with a given treatment. Thus, our results are indicative of the effect of the innovation of statins on lifetime outcomes when assuming that medical technology remains constant over time, which is of course unrealistic.

The results presented here refute the notion that people do not need to watch their weight as much as in the past because of the availability of statins and other medical innovations. This is particularly true when taking factors such as quality of life and disability into account. Given these results, policymakers and practitioners should direct greater attention towards

obesity prevention, as opposed to treatment of the consequences of obesity. This research should also serve as an example to researchers studying the economics of obesity of the difficulty of predicting the net effects on the costs of obesity from treatments that may, at first glance, seem to have obviously significant effects.

5 Conclusions

While our estimates indicate that the innovation of statins increased life expectancy at age 51 by roughly 1.2 years, life expectancy gains have been only slightly greater for the obese compared to individuals with a healthy BMI. The small marginal gain in life expectancy for the obese compared to the non-obese (0.06 – 0.07 years) was mostly associated with some level of disability. A similar story emerged with respect to lifetime healthcare costs. Statins increased healthcare costs about roughly \$25,000 – \$30,000, but the marginal increase estimates for the obese compared to the non-obese was relatively small (\$2,800 – \$4,000). Therefore, after valuing the quantity and quality of differences in life expectancy, we find that the innovation of statins has had little impact on simulated the cost of obesity (the sum of both health and healthcare costs). Statins significantly reduce the risk of heart disease, stroke, and mortality, but because they do so for both the obese and non-obese, they have not significantly reduced the cost of obesity.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

The authors did not receive financial support for conducting this study. Étienne Gaudette has no conflicts of interest to declare. Dana Goldman is a Partner at Precision Health Economics, a life sciences consulting company. Neeraj Sood has consulting relationships with Precision Health Economics and Bates White. Both firms have clients from the pharmaceutical industry. Andrew Messali is employed as a part time consultant for Allergan, Inc. Allergan, Inc. played no role in funding or conducting this research.

Étienne Gaudette is the guarantor for the overall content in this article. He designed the simulation specifications and performed the analyses. Andrew Messali performed the literature review. Gaudette and Messali wrote the article. Neeraj Sood and Dana Goldman gave advice in the design of the study, the analyses performed and the interpretation of the results. All authors reviewed draft versions of the article and gave permission for the final version to be published.

The authors are grateful to Bryan Tysinger, Jeff Sullivan, and Duncan Ermini Leaf and for their expert technical help, and to the National Institute on Aging for its support through the Roybal Center for Health Policy Simulation (P30AG024968).

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Key Points for Decision Makers

- Over 40 million Americans currently use statins, including 55% of the elderly obese population.
- The current use of statins is estimated to increase the life expectancy of 51-year old Americans by about 1 year. Life expectancy gains are estimated to be 5% – 6% higher for obese individuals. However, most of the additional gains are associated with some level of disability.
- By extending longevity, statins increase the expected lifetime medical costs of 51-year old Americans by about \$25,000. The increase in medical costs is estimated to be \$2,800 – \$4,000 greater for obese individuals.
- Considering both medical spending and the value of quality-adjusted life-years, statins do not significantly alter the costs of class 1 and 2 obesity (BMI larger or equal to 30 and 35 kg/m²), and *increase* the costs of class 3 obesity (BMI larger or equal to 40 kg/m²) by 1.2%.
- Although statins are inexpensive and very effective medications for lowering the risk of obesity-associated illnesses, they do not significantly reduce the costs of obesity. This highlights the importance of preventing obesity, rather than treating its consequences.

Figure 1.
Chronic Conditions Transitions in the FEM

Figure 2.**Empirical Strategy**

Both the “With Statins” and the “Without Statins” scenarios are run four times: first, with all individuals given a healthy BMI; then, with all individuals given an obese BMI (30, 35, or 40 in separate simulations). For each scenario, the differences in outcomes between obese and healthy-weight simulations reveal the cost of obesity. The difference in these differences (the difference-in-difference) reveals the impact of statins on the cost of obesity.

Figure 3.

Life Expectancy Cost of Obesity in Both Scenarios after Age 50

BMI refers to “body mass index”, defined as the ratio between mass of individuals, expressed in kilograms, and the square of height, expressed in meters. The “life expectancy cost of obesity” is the simulated difference in life expectancy of otherwise identical 51-year-olds with obese BMIs (we consider values of 30, 35 and 40) compared to individuals with a healthy BMI. 95% confidence intervals with regards to the uncertainty of the effectiveness of statins are shown for each bar.

Figure 4.

Difference-in-difference in Life Expectancy Gains after Age 50, by Functional Status

BMI refers to “body mass index”, defined as the ratio between mass of individuals, expressed in kilograms, and the square of height, expressed in meters. A “disabled” functional status refers to reporting at least one instrumental activity of daily living (IADL) or activity of daily living (ADL) limitation. The “free of disability” status refers to reporting no IADL or ADL limitation and not living in a nursing home. “In a nursing home” indicates the most severe functional status impairment. 95% confidence intervals with regards to the uncertainty of the effectiveness of statins are shown for each bar.

Table 1

Health Impact of Statins

Source	Population	Effects of statin therapy compared to placebo
Cochrane Collaboration 2013[12]	Primary prevention of cardiovascular disease	Reduced all-cause mortality (OR 0.86, 95% CI 0.79–0.94) Reduced fatal (RR 0.83, 95% CI 0.72–0.96) and non-fatal (RR 0.77, 95% CI 0.62–0.96) CVD Reduced fatal (RR 0.82, 95% CI 0.7–0.96) and non-fatal (RR 0.67, 95% CI 0.59–0.76) CHD Reduced non-fatal stroke (RR 0.69, 95% CI 0.58–0.83) Reduced incidence of MACCE (RR 0.79, 95% CI 0.66–0.95) Reduced the risk of stroke (RR 0.71, 95% CI 0.54–0.94) No significant effect on all-cause mortality (RR 0.79, 95% CI 0.58–1.08).
Chen 2012[7]	Primary prevention of cardiovascular disease among diabetics	Reduced risk of major vascular events (RR 0.79, 95% CI 0.77–0.81, per 1.0 mmol/L reduction in LDL) Reduced risk of vascular mortality (RR 0.85, 95% CI 0.77–0.95, per 1.0 mmol/L reduction in LDL) Reduced all-cause mortality (RR 0.91, 95% CI 0.85–0.97 per 1.0 mmol/L reduction in LDL).
Cholesterol Treatment Trialists 2012[8]	Primary prevention of cardiovascular disease	Reduced major cardiovascular or cerebrovascular events (RR 0.75, 95% CI 0.67–0.85) Reduced fatal/non-fatal stroke (RR 0.69, 95% CI 0.51–0.92) Reduced fatal/non-fatal MI (RR 0.70, 95% CI 0.54–0.90)
de Vries 2012[9]	Primary prevention of cardiovascular disease among diabetics	No significant effect on all-cause mortality (RR 0.84, 95% CI 0.65–1.09) Reduced all-cause mortality (RR 0.90, 95% CI 0.86–0.94) Reduced CVD mortality (RR 0.80, 95% CI 0.74–0.87)
Mills 2011[11]	Primary and secondary prevention of cardiovascular disease	Reduced fatal (RR 0.82, 95% CI 0.75–0.91) and non-fatal (RR 0.74, 95% CI 0.67–0.81) MI Reduced revascularization (RR 0.76, 95% CI 0.70–0.81) Reduced fatal/non-fatal strokes (RR 0.86, 95% CI 0.78–0.95)
Gutierrez 2012[10]	Secondary prevention of cardiovascular disease	Reduced CVD events in women (RR 0.81, 95% CI 0.74–0.89) and men (RR 0.82, 95% CI 0.78–0.85) Reduced all-cause mortality (RR 0.79, 95% CI 0.72–0.87) in men Reduced stroke (RR 0.81, 95% CI 0.72–0.92) in men No significant effect on all-cause mortality (RR 0.92, 95% CI 0.76–1.13) in women No significant effect on stroke (RR 0.92, 95% CI 0.76–1.10) in women
Wei 2005[27]	Secondary prevention of cardiovascular disease	Significant reduction in all-cause mortality among overall community population (RR 0.69, 95% CI 0.59–0.80), women (RR 0.63, 95% CI 0.49–0.80), and age 65 (RR 0.72, 95% CI 0.61–0.84) Significant reduction in fatal/non-fatal MI among overall community population (RR 0.82, 95% CI 0.71–0.95), women (RR 0.69, 95% CI 0.54–0.88), and age 65 (RR 0.84, 95% CI 0.71–0.99)

RR: Relative risk; OR: Odds ratio; CVD: Cardiovascular disease; CHD: Coronary heart disease; MACCE: Major cardiovascular and cerebrovascular events

Table 2

Impact of Statins on Lifetime Medical Costs after Age 50, \$2009 thousands

	With Statins	Without Statins	Difference	Private (%)	Medicare (%)	Medicaid (%)
Healthy weight (BMI < 25)						
Total Medical Costs	460.9	435.5	25.4	40	35	25
Excluding Statins	456.1	435.5	20.6	32	38	30
Free of disability	288.9	283.6	5.2	48	48	4
Disabled	96.9	91.7	5.1	38	56	6
In a nursing home	70.4	60.2	10.2	21	24	55
Statins	4.8	0	4.8	72	24	5
Obese class 1 (BMI = 30)						
Total Medical Costs	477.7	449.5	28.2	39	36	24
Excluding Statins	472.2	449.5	22.6	32	39	29
Free of disability	284.4	279.0	5.4	47	49	4
Disabled	116.5	110.2	6.3	38	57	6
In a nursing home	71.3	60.3	11.0	20	25	55
Statins	5.6	0	5.6	72	24	5
Obese class 2 (BMI = 35)						
Total Medical Costs	485.5	456.6	28.9	39	37	24
Excluding Statins	479.9	456.6	23.4	31	40	29
Free of disability	277.9	272.5	5.4	46	50	4
Disabled	131.2	124.3	6.9	38	57	6
In a nursing home	70.8	59.8	11.0	20	25	55
Statins	5.5	0	5.5	72	24	5
Obese class 3 (BMI = 40)						
Total Medical Costs	490.7	461.3	29.4	39	38	24
Excluding Statins	485.3	461.3	24.0	31	41	28
Free of disability	268.1	262.8	5.3	46	50	4
Disabled	147.3	139.6	7.7	37	57	6
In a nursing home	69.8	58.9	11.0	19	26	55
Statins	5.4	0	5.4	72	24	5

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All amounts are in present value at age 51, computed with a 3% interest rate. BMI refers to “body mass index”, defined as the ratio between mass of individuals, expressed in kilograms, and the square of height, expressed in meters. The first two columns present lifetime medical costs at age 51 in the “With Statins” and “Without Statins” scenarios. The third column presents the difference between the scenarios, and corresponds to the additional medical costs due to the existence of statins. The last three columns decompose the additional costs due to statins by spending source. In the rows, we decompose medical costs by type (total medical costs excluding statins prescriptions and statin prescriptions) and by functional status. A “disabled” functional status refers to reporting at least one instrumental activity of daily living (IADL) or activity of daily living (ADL) limitation. The “free of disability” status refers to reporting no IADL or ADL limitation and not living in a nursing home. “In a nursing home” indicates the most severe functional status impairment. Confidence intervals for this table are presented in Table A2.

Table 3**Cost per Health Gain of Statins**

	Healthy weight (BMI = 24.9)	Obese class 1 (BMI = 30)	Obese class 2 (BMI = 35)	Obese class 3 (BMI = 40)
Costs (\$2009 thousands)	25.4 [12.1 – 38.0]	28.2 [13.3 – 41.9]	28.9 [13.5 – 42.9]	29.4 [13.2 – 44.0]
1. Life expectancy gain				
Years	1.17 [0.6 – 1.6]	1.24 [0.7 – 1.7]	1.24 [0.7 – 1.7]	1.23 [0.7 – 1.7]
Cost/year	21.4 [15.9 – 24.9]	22.5 [16.1 – 26.3]	22.9 [16.3 – 26.9]	23.5 [16.8 – 27.5]
2. Disability-free life expectancy gain				
Years	0.59 [0.4 – 0.8]	0.59 [0.4 – 0.8]	0.57 [0.4 – 0.7]	0.54 [0.3 – 0.7]
Cost/year	42.7 [24.9 – 57.2]	47.2 [26.0 – 63.4]	49.9 [27.2 – 68.3]	53.6 [29.6 – 74.1]
3. Expected quality-adjusted life-years (QALY) gain				
Years	0.88 [0.5 – 1.2]	0.90 [0.5 – 1.2]	0.88 [0.5 – 1.2]	0.86 [0.5 – 1.2]
Cost/year	28.5 [19.3 – 34.9]	31.0 [20.0 – 38.5]	32.4 [20.3 – 40.3]	33.8 [21.4 – 42.1]

Values in the table correspond to the difference in medical costs and life expectancy between the “With Statins” and the “Without Statins” scenarios. Costs are in present value at age 51, computed with a 3% interest rate. BMI refers to “body mass index”, defined as the ratio between mass of individuals, expressed in kilograms, and the square of height, expressed in meters. Disability-free life expectancy refers to reporting instrumental activity of daily living (IADL) or activity of daily living (ADL) limitations and not living in a nursing home. Quality-adjusted life-years (QALYs) adjust length of life for quality based on a person’s chronic conditions and functional status. 95% confidence intervals with regards to the uncertainty of the effectiveness of statins are presented in brackets.

Table 4

Health and Healthcare Costs of Obesity in Both Scenarios, \$2009 thousands

	A. Health costs measured by difference in expected QALYs			B. Health costs measured by difference in unadjusted life expectancy			
	Obese class 1 (BMI = 30)	Obese class 2 (BMI = 35)	Obese class 3 (BMI = 40)	Obese class 1 (BMI = 30)	Obese class 2 (BMI = 35)	Obese class 3 (BMI = 40)	
Without Statins	Medical care cost (\$)	14.0 [12.3 – 15.8]	21.0 [18.6 – 23.5]	25.8 [22.8 – 28.7]	14.0 [12.3 – 15.8]	21.0 [18.6 – 23.5]	25.8 [22.8 – 28.7]
	Health cost						
	Years/QALYs lost	1.90 [1.9 – 2.0]	3.10 [3.1 – 3.2]	4.10 [4.0 – 4.1]	1.20 [1.1 – 1.2]	2.00 [2.0 – 2.1]	2.90 [2.8 – 2.9]
	Value of years/QALYs lost (\$)	289.5 [285.3 – 293.0]	467.2 [461.6 – 472.5]	610.6 [604.4 – 617.0]	116.3 [112.7 – 119.9]	201.1 [195.6 – 205.9]	287.8 [280.8 – 293.9]
	Total cost of obesity (\$)	303.5 [298.8 – 307.7]	488.2 [481.8 – 494.3]	636.4 [629.3 – 644.3]	130.3 [127.0 – 133.5]	222.2 [217.7 – 226.4]	313.6 [308.5 – 318.3]
With statins	Medical care cost (\$)	16.8 [15.9 – 17.6]	24.5 [23.5 – 25.6]	29.8 [28.3 – 30.9]	16.8 [15.9 – 17.6]	24.5 [23.5 – 25.6]	29.8 [28.3 – 30.9]
	Health cost						
	Years/QALYs lost	1.90 [1.9 – 1.9]	3.10 [3.1 – 3.1]	4.10 [4.1 – 4.1]	1.10 [1.1 – 1.1]	1.90 [1.9 – 2.0]	2.80 [2.8 – 2.9]
	Value of years/QALYs lost (\$)	286.9 [283.3 – 289.8]	467.5 [462.2 – 471.4]	614.1 [608.2 – 619.1]	109.7 [106.6 – 112.1]	194.1 [189.3 – 198.0]	281.7 [276.5 – 286.4]
	Total cost of obesity (\$)	303.7 [300.5 – 306.4]	492.0 [487.5 – 495.7]	643.9 [638.2 – 648.4]	126.5 [123.8 – 128.6]	218.7 [214.9 – 221.4]	311.4 [307.0 – 315.3]
Difference due to statins	Total cost of obesity (\$)	−0.2 [−3.7 – 3.7]	−3.8 [−8.4 – 2.3]	−7.5 [−13.9 – −1.2]	3.8 [1.1 – 6.8]	3.5 [0.4 – 6.8]	2.2 [−1.2 – 5.4]
	Percent (%)	−0.1 [−1.2 – 1.2]	−0.8 [−1.7 – 0.5]	−1.2 [−2.2 – −0.2]	2.9 [0.8 – 5.2]	1.6 [0.2 – 3.0]	0.7 [−0.4 – 1.7]

The medical care cost of obesity is the difference in the sum of expected medical costs at age 51 between identical individuals of the obese category and the healthy-weight category (BMI<25) presented in Table 2. BMI refers to “body mass index”, defined as the ratio between mass of individuals, expressed in kilograms, and the square of height, expressed in meters. The total cost of obesity is defined as the sum of the medical cost of obesity and the value of the health cost of obesity, expressed in dollars. Medical costs are in present value, computed with a 3% interest rate. The value of health costs of obesity is obtained by attributing a nominal value of \$150,000 per Quality-adjusted life-year (QALY) lost due to obesity in panel A., and of \$100,000 per life-year lost in panel B. Quality-adjusted life-years (QALYs) adjust length of life for quality based on a person’s chronic conditions and functional status. 95% confidence intervals with regards to the uncertainty of the effectiveness of statins are presented in brackets.