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NARRATIVE REVIEW

On Determining How Much Obesity is Costing Society.

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Abstract

Objective: The objectives of this narrative review are to examine techniques used in determining the health costs accrued by obese individuals, and to estimate the overall costs of the current obesity epidemic to society **Methods:** Information obtained from Ovid/Medline and Google Scholar through to August 2018 was supplemented by a search of the author's personal files. **Results:** Reasons for undertaking an economic analysis of obesity include the generation of favourable publicity, reviewing the efficacy of current treatment programmes, considering the effects of expanding or compressing therapeutic options, and assessing the need for alternative treatments. Technical difficulties in making such estimates include both differences in the relative impacts of overweight, moderate and gross obesity and the more general issues faced by all health economists: differential rates of inflation, international exchange rates, an appropriate choice of discount rate, and regional differences in medical costs, treatment patterns, job participation rates, and employee benefits. Allowance must also be made for secular shifts in population profile, opportunity costs of obesity and its treatment. losses due to the premature death of workers, and the value of services contributed by volunteers. In most developed countries, an excessive accumulation of body fat accounts for 2-5% of total medical expenditures, and in the U.S. costs are as high as 5-9%, with even larger indirect costs. Problems arise when obese individuals travel by plane or car. Per capita greenhouse gas emissions are also greater for the obese, and they experience a significant loss of potential human capital. **Discussion and conclusions:** The validity of current estimates of the economic costs of obesity remains vulnerable to a substantial interaction and overlap between charges attributable to obesity and those due to physical inactivity. The respective magnitude of these 2 effects remains to be clarified by careful multivariate analyses, using samples with reliable and valid objective measures of habitual physical activity. Such an analysis is important, because it should influence the allocation of resources for both prevention and treatment. **Health & Fitness Journal of Canada 2019;12(1):80-116.**

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Introduction

In recent years, investigators have suggested that a major fraction of all medical costs (both direct and indirect) is now attributable to the ever-growing obesity epidemic. (Colditz, 1992) published one of the earliest analyses of this question. He suggested that in the U.S., a conservative fiscal estimate for the year 1986 was $39.3 B, or 5.5% of the total costs of all forms of illness. A more recent report prepared by the McKinsey Global Economic Institute (Dobbs et al., 2014) calculated that by 2014, the world-wide cost of obesity was US $2 Trillion, or 2.8% of the gross global domestic product; indeed, obesity had become one of the 3 top economic burdens borne by society, matched only by similar expenditures on smoking-related diseases, and on warfare and associated military expenditures (Table 1). Dobbs et al. further suggested that a number of possible interventions to correct current obesity levels would be cost-effective in terms of enhanced productivity and reductions in medical expenditures.

In this narrative review, we will look first at some common reasons why people have tried to estimate the medical costs associated with obesity. We will then make a critical examination of the methods that economists use to estimate health costs, considering the many technical obstacles that still limit the precision of such estimates, and noting some specific issues that arise when accepted technique are applied to the problem of obesity. We will then summarize what we currently know about the direct and indirect costs of obesity, and will focus upon attempts to disentangle the effects of fat accumulation from problems attributable to an inadequate level of habitual physical activity. The impact of obesity upon human transportation and the optimization of human capital will also be considered briefly, and after commenting on the cost-efficacy of solutions we will conclude the article by noting some ethical issues raised by an administrative review of health care costs.

The general principles underlying economic analyses of the consequences of impaired health were developed initially in relation to cardiovascular disease (Klarman, 1965) and inadequate levels of habitual physical inactivity (Russell, 1986; Shephard, 1969, 1986a), but a similar methodology has subsequently been applied to determine the costs associated with many other acute and chronic medical conditions, including obesity (Katzmarzyk et al., 1999; Katzmarzyk, 2011; Katzmarzyk & Janssen, 2004).

Table 1: Selected global economic burdens, based on 2010 disability-adjusted life years and World Bank data for 2012 that include direct health care costs, direct costs of mitigation, and losses of productivity due to disability and death.

Source of burden	Annual cost (US $Trillion)	Percent of global GDP	Secular trend
Smoking	2.1	2.9	Increase
Violence, war and terrorism	2.1	2.8	Increase
Obesity	2.0	2.8	Increase
Alcoholism	1.4	2.0	No change
Illiteracy	1.3	1.7	Decrease
Climate change	1.0	1.3	Increase
Air pollution	0.9	1.3	No change
Drug use	0.7	1.0	Increase
Traffic incidents	0.7	1.0	Increase
Workplace injuries	0.4	0.6	Increase
Household air pollution	0.4	0.5	Increase
Undernutrition	0.3	0.5	Decrease
Unsafe sex	0.3	0.4	No change
Lack of clean water & sanitation	0.1	0.1	Decrease

Reasons for estimating the costs associated with obesity

Health economists will suggest that formal calculation of the economic consequences of obesity are undertaken for such administrative reasons as reviewing the efficacy and cost-effectiveness of current treatment programmes, considering the wisdom of expanding or compressing existing therapeutic options, and assessing the need for alternative treatment initiatives. Such questions are of interest to those concerned with health policy, but probably the most common reason for evaluating the costs associated with various chronic conditions including obesity is to generate publicity that will have a favourable influence on the proportion of available research funding and health services to the condition in question.

Favourable publicity. The quest for research funding and favourable consideration in the utilization of publicly funded health facilities is fiercely competitive. Thus, many charitable groups such as the Heart and Stroke Foundation and the Cancer Foundation devote a considerable fraction of their staff time and resources to appeals for donations, with the supposed costs caused by their favourite illness playing a major part in such appeals. I have spent a substantial amount of time attending committee meetings at the offices of the Ontario Heart Foundation, and I was already keenly aware of this phenomenon in the late 1960s, when I wrote a section on the direct and indirect costs of cardiovascular disease in the final chapter of the monograph “Endurance Fitness" (Shephard, 1969). My hope, like that of many aspiring health economists, was that the publicizing of these substantial costs would spur various levels of government and indeed the entire medical community to recognize the preventive value of increased habitual physical activity, and would encourage greater support of exercise-related initiatives.

Nevertheless, the cost estimates presented by the various health foundations must be viewed with a certain amount of scepticism, since the larger the figures they can calculate, the more likely they are to attract public attention. Indeed, there is much double counting between various health disorders, and if one were to add together all of the costs reported by the various agencies, it seems likely that these would far exceed total health-sector expenditures.

A number of organizations now actively promote the allocation of funds to the prevention and treatment of obesity. Some, such as the World Obesity Federation, the Obesity Action Coalition, the Canadian Obesity Network, Australia's "Measure Up" and Britain's "Fightin Fat, Fighting Fit" have a specific focus on the excessive accumulation of fat. One of three objectives of the Canadian Obesity Network is "changing the ways policy makers and health professionals approach obesity."

Other groups, such as ACTNOW BC have broader concerns, addressing such lifestyle issues as inadequate habitual physical inactivity, low fruit and vegetable consumption, smoking, overweight and alcohol use during pregnancy.

Programme efficacy. In the context of obesity, both government and private health agencies may wish to compare costs for various potential obesity treatment programmes in terms of the behavioural changes and/or the reductions in medical costs that each of these initiatives are likely to achieve (see, for example, the data of the McKinsey Global Institute (Dobbs et al., 2014) and reports from the Brookings Institution). Such an analysis requires an estimate of the unit cost of a given programme, together with information on the likely long-term reduction in obesity or gains in disability-adjusted life years that it can achieve (Table 2). A full cost-benefit analysis will take note of volunteer contributions to operation of the programme, and any changes in the local economy that it may generate, such as a stimulation of private-sector involvement in weight-maintenance and weight-reduction programmes.

One important component of an economic analysis is to compare costs and effectiveness between possible high cost options such as gastric bypass procedures and long-term pharmaceutical treatments relative to much simpler low cost alternatives such as increases of physical activity, restrictions on labelling and the control of portion sizes. Such comparisons may be complicated by considerations of disease stage. For example, physical activity may be effective in preventing obesity and in treating moderate overweight, but many of the morbidly obese do not tolerate effective volumes of physical activity, and at this stage in the disease the only effective form of treatment may be a high-cost surgical initiative such as gastric by-pass.

Expansion or compression of existing therapeutic services. If the data from a programme evaluation suggests the need to expand or compress existing services, health administrators will need to obtain information on what are termed marginal costs.

For example, in terms of a workplace wellness facility, how large an additional expenditure will be required to double its capacity, and how much extra investment in promotion of the facility will be needed to attract and sustain the participation of double the number of obese and/or physically inactive clients? Many of the initial recruits to such an initiative may previously have attended other wellness programmes, simply transferring their allegiance to the worksite classes because of their convenience. But per-capita costs are likely to be substantially greater when recruiting new participants, rather than simply sustaining the interest of the minority who are already committed to an on-going programme.

Moreover, the current clients of many wellness and obesity programmes are drawn largely from the upper socio-economic stratum of "white" society, particularly management in the industrial setting, and it as yet unclear whether the marginal costs and benefits of any new initiatives would be similar for lower socio-economic groups such as blue-collar workers and members of other ethnic and immigrant groups. Further, it remains to be explored how far expanded programmes can become sufficiently attractive that they can operate successfully on a for-profit basis, rather than relying on a continued infusion of governmental or corporate funding.

Alternatively, an economic analysis may look at the economic consequences of compressing a service or treatment option because of its apparent limited efficacy, or pressing budgetary constraints. The question then arises what would be the likely immediate savings in programme costs with the compression of a service or facility, and how many more people would likely become obese because of such a reduction in services? For example, if governmental support for surgical interventions were cut because of the high-cost per disability-adjusted life year (Table 2), would this help the overall health care budget, or would the funds thus released be swallowed up immediately, either by some other health sector or by a need to provide direct

Table 2: Potential initiatives for the control of obesity and their dollar costs per gain in disability-adjusted life years (based on the analysis of (Dobbs, Sawers, and Thompson, 2014)).

Initiative	Unit cost
Media restrictions	50
Public health campaigns	200
Food availability	200
Price promotions	200
Portion control	400
School curriculum	600
Weight management programmes	1400
Sugar & fat taxation	1800
Labeling	2000
Parental education	2000
Reformulation	2600
Workplace wellness	2700
Pharmaceuticals	5600
Surgery	10,000
Healthy meals	14,000
Active transport	31,000

medical treatment for complications arising in a larger population of obese individuals?

In making calculations about the effects of compressing group health and wellness programmes, it should be recognized that the residual participants would likely be the highly motivated core members. Unit costs of programme maintenance would probably be lower and per capita therapeutic benefits greater for this sub-group than for the much larger and less well-motivated population of clients as a whole.

Practical difficulties in estimating the economic costs of obesity

Many practical difficulties beset those who try to estimate the economic costs associated with a chronic condition such as obesity. One immediately questionable assumption is that the health costs incurred by a person with diabetes mellitus are similar for someone who is grossly obese and for a person of relatively normal body mass. We may note also the general issues faced by health economists: differences in rates of inflation, international exchange rates, and choices of discount rate. Further, there are substantial international differences in medical costs, accepted patterns of treatment, job participation rates, and the extent of payments made to employees during periods of payments sickness and retirement. Finally, allowance must be made for secular shifts in population profile, the opportunity costs imposed by various illnesses, changing economic losses due to the premature death of workers, and the economic value of the services contributed by caregivers.

Effects of disease stage. The types of treatment applicable to a person who is overweight (with a body mass index, BMI, in the range 25-30 kg/m2) or with stage I obesity (BMI 30-35 kg/m2) are very different from those applicable to a person with type III disease (morbid obesity, BMI >40 kg/m2). Many people with gross obesity find it impossible to undertake an effective volume of habitual physical activity. Thus, the cost estimates of treatment must be related to the disease stage.

Moreover, the likelihood of a need to treat various complications and co-morbidities is much greater in those who are grossly obese than in those who are simply overweight. T One of the more common co-morbidities of obesity is type 2 diabetes mellitus. Colditz et al. (Colditz, Willett, & Rotnirzky, 1995) carried out a 14-year follow-up on a large sample of 114,281 nurses. The risk of developing maturity-onset diabetes was strongly related to the individual's initial body mass index, and this risk increased in exponential rather than linear fashion in those with a greater BMI (Table 3).

Table 3: Relationship between the individual's initial BMI (based on self-reported height and body mass) and the relative risk of developing type 2 diabetes mellitus over a 14-year follow-up. Based on the age-adjusted data of Colditz et al. (Colditz et al., 1995) for 114,281 female nurses initially aged 30-55 years.

BMI (kg/m^2)	<22	22.0-22.9	23.0-23.9	24.0-24.9	25.0-26.9	27.0-28.9	29.0-310,9	31.0-32.9	33.0-34.9	>35.0
Relative risk of diabetes	1.0	2.9	4.3	5.0	8.1	15.8	27.6	40.3	54.0	93.2

Li et al. (Li, Blume, & Huang, 2015) underlined the impact of disease severity upon the costs associated with the complications of diabetes. Health expenditures were classified by blood glucose level. In those who were normo-glycaemic, the incremental costs of fat accumulation ranged from $336/year in those who were overweight to $1850/year for those with class III obesity. In contrast, among those who were hyper-glycaemic, the corresponding values were $1139 and $4649/year.

Inflation and exchange rates. Much of the available data on health costs was collected some years ago, and if an attempt is made to compare such findings with more recent research, an appropriate allowance must be made for the effects of intervening inflation. The inflationary process reflects a decrease in the purchasing power of a given currency with time. Economists commonly adjust for inflation by applying corrections based upon changes in a consumer price index (the costs of a fixed basket of goods and services in a given year, expressed as a ratio to their costs in a criterion year, for example 1960 = 1.00). In Canada, the Federal Bank now attempts to keep the overall inflation rate at about 2% per annum through a manipulation of interest rates; they have determined that such a rate is optimal in terms of economic expansion. However, the choice of contents for the fixed basket of goods and services is necessarily a value judgment, and indeed it has been thought necessary to change the items included in the standard basket over the years in order to reflect current household expectations in terms of methods of communication (ownership of a telephone or mobile phone, television and internet connection) and transportation (ownership of a car).

Moreover, the general consumer price index adopted by government economists does not work well when adjusting for changes in the cost of medical services. In part because of population aging, but also of because of the introduction of ever more sophisticated methods of diagnosis, new medications and complicated forms of surgical treatment, the overall medical inflation rate is several times greater than the annual increase in consumer prices, and it differs from one disease to another (Table 4). Further, the gap between overall and medical inflation rates has widened sharply since about 1985. To add to the difficulties of the economist, general and medical inflation rates each differ from one country to another, and even from one region to another, depending on the state of the local economy and the level of medical expectations. Given the large fraction of health costs that are associated with chronic medication, rates can be sharply increased by the introduction of a very expensive medication for a particular disorder, and the ability of individual governments to negotiate favourable deals with pharmaceutical companies. When looking at a specific medical condition, the inflation rate may also increase with a change in treatment patterns; for example, in the case of obesity, there has been a growing recourse to bariatric surgery; the average cost of such a procedure has recently been estimated at US $14,389 (Doble, Wordsworth, & Rogers, 2017).

In order to make international comparisons of health costs, it is necessary to express the figures reported by different nations in terms of a common currency, such as Canadian or U.S. dollars. However, in many cases international exchange rates fluctuate substantially over the course of a few months or years. Thus, the Canadian dollar was valued at more than one U.S. dollar in 2013, but during 2018 its value sometimes dropped as low as 74 cents U.S.. Moreover, official exchange rates do not always provide an accurate reflection of the purchasing power across international borders. For example, a Swiss franc is currently valued at about $1.32 Cdn, but the net post-tax incomes salaries and the costs of goods and services are substantially higher in Switzerland than in Canada, at official exchange rates.

Table 4. Overall inflation rate for Canada and USA and U.S. medical inflation rate.

Year	Overall inflation (Canada)	Overall inflation (USA)	Medical inflation (USA)
1960	1.000	1.000	1.000
1965	1.084	1.064	1.132
1970	1.310	1.311	1.526
1975	1.871	1.818	2.133
1980	2.839	2.784	3.365
1985	4.085	3.635	5.101
1990	5.058	4.416	7.316
1995	5.652	5.149	9.907
2000	6.155	5.818	11.717
2005	6.903	6.598	14.524
2010	7.516	7.367	17.455
2015	8.168	8.007	20.075
2018	8.555	8.500	21.721

Choice of discount rate. The discount rate is an expression of the willingness of society and/or governments to invest capital now in anticipation of a financial return at some future date. It is an important element in calculations of medical economics, since much of the expenditures incurred currently in preventing or treating a condition such as obesity have as their objective the avoiding of costs from an associated co-morbidity that would otherwise develop 10-20 years hence. There is much discussion of an appropriate discount rate, but economists commonly assume a figure equivalent to the yield on government bonds or premium industrial investments.

A typical long-term average figure is around 3%, and in the U.S. it stands at this level in 2018; however, it rose as high as 15% in the early 1980s.

Differences in medical costs and expected patterns of treatment between countries. Calculation of the economic costs of a condition such as obesity usually assumes that once a person has been diagnosed, a standard pattern of treatment will be given to the individual concerned at a standard cost. However, in practice both accepted patterns of treatment and the costs of their implementation differ widely from one country to another; for those who wish bariatric surgery, for example, costs can be greatly reduced by seeking treatment in a third-world country such as Turkey or Mexico. Moreover, there are often considerable regional discrepancies in patterns of treatment and the costs of various initiatives, even with a given country.

This issue of differing treatment patterns is illustrated by the findings from a panel of experts in obesity management drawn from 23 European countries (Uerlich et al., 2016). This conference determined that substantial individual support to live healthily was provided in only 7 of the 23 countries, although it was available to a more limited extent in a further 3 of the 23 countries. Anti-obesity drugs were readily available in only 9 of the 23 countries, but such medication was rarely available or used in 8 of the countries represented. At the time of the survey, one drug only was licensed for prescription in Europe. Surgery was available to the morbidly obese in 19 countries, and in 16 of these countries counselling was available post-surgery. Plainly, these differences have a substantial influence upon both costs and the likelihood of successful treatment.

In Canada and the United States, gastric bypass surgery in 2017 typically cost from $20,000 to $30,000 per patient, with averages of $24,000 in Canada and $25,000 in the U.S. However, within the United States, costs ranged from $15,000 to $35,000 in different parts of the country. Moreover, a similar operation could be performed in Mexico at an average cost of only $6915. Figures for other countries were Australia $20,000, India $15,000, Costa Rica $13,000, and Thailand $11,000.

Global differences in drug prices are also widely recognized, an issue documented most fully for drugs used in the treatment of cancer. The mean costs of monthly treatment with 23 drugs, 15 available generically, are summarized for 6 countries in Table 5; notice that there is an almost 6-fold difference in costs between the U.S. and India.

Table 5: Monthly costs for cancer treatment, averaged across 23 patented drugs, 15 generic, expressed in U.S. dollars (based on data of (Goldstein et al., 2017)

Country	Patent drug cost	Generic drug cost
U.S.	8,694	654
Australia	2,741	226
China	3,173	532
India	1,515	159
South Africa	1,708	120
U.K.	2,587	458

Job participation rate. One substantial element in assessing the indirect costs of any illness, chronic disorder or premature death is the resulting loss of industrial output. Several of the complications of obesity can cause absence from work, and the productivity while at work may also be lower for those who are obese. However, one cannot assume that everyone who is affected by morbid obesity or its clinical complications is actively seeking work. A proportion of the affected individuals will already have reached the age of retirement, and others for various reasons may not be seeking work outside of the home. The loss of industrial output from any form of illness depends on the physical demands of the individual's normal employment, the immediate demand for healthy individuals in the labour force (the employment rate), and the proportion of working age individuals who actively seek full-time employment (the participation rate).

With a few exceptions, the physical demands of employment are now low in developed countries, but in developing societies many jobs still make heavy physical demands upon the worker that may be difficult to meet if a person is obese and/or is suffering from one of the complications of obesity. Further, unemployment has generally been declining around the world over the past several decades (Table 6), and in some countries such as Canada, the U.S., Germany, the U.K. and Japan there is currently a relatively full employment rate (~95%), leading to a substantial economic loss for every person who is prevented from working by ill-health. But in other nations there remain large numbers of unemployed (25-50%), many of whom are healthy young adults with the potential to replace any workers who are sick after a modicum of training. Other factors leading to secular change in the loss of productivity from illness are a progressive trend to an increase in the average retirement age around the world, and a growing replacement of workers by robots. Labour force participation rates have trended to an increase in recent years, as an increasing fraction of women have sought work outside of the home. However, this has been offset in part by a greater participation in higher education and a greater length of many university programmes. The ILO estimates that labour force participation rates for individuals over the age of 15 years are currently around 50-66%, being lowest in those countries where a high percentage of older citizens have already moved into retirement.

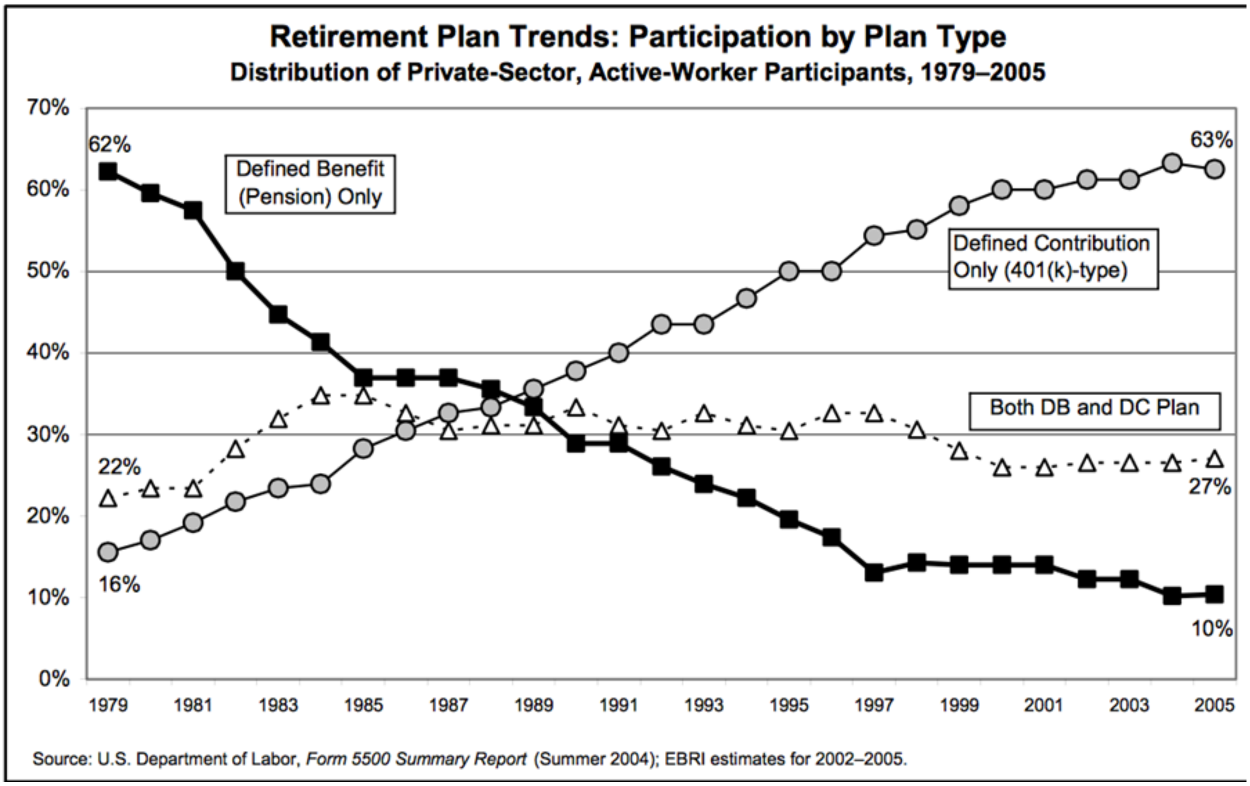
Table 6: Estimated unemployment rates and employment participation rates for selected countries, based on ILO data for the years 1991 and 2017.

Country	Unemployment		Participation
	1991	2017	2017
Albania	22.3	13.9	56
Australia	9.6	5.7	65
Bulgaria	21.2	6.3	53
Canada	10.3	6.4	65
France	9.1	9.7	55
Germany	5.3	3.7	60
Greece	7.7	21.4	53
Italy	10.1	11.3	49
Japan	2.1	2.8	60
Lesotho	36.4	27.2	66
Macedonia	36.0	22.9	55
New Zealand	10.6	4.9	69
Spain	15.9	17.4	58
United Kingdom	8.6	4.3	62
U.S.A.	6.8	4.4	62

Financial provision for extended sickness and premature retirement.
A related issue is the period for which a disabled individual may be eligible for sickness benefits and/or early retirement payments. Until recently, many employers offered their workers generous, fixed and pre-defined benefit packages. But in North America there was an unfortunate trend between 1975 and 2005 to replace this form of benefits by fixed payments based on the defined contributions of an employee to a sickness/retirement fund (Figure 1). In some instances, sickness and retirement benefits have been eliminated entirely, whether by an alteration in the terms of employment for new recruits, a shifting to the use of part-time personnel, or by the bankruptcy of a company that has supposedly been holding accumulated disability and pension payments in trust. Such changes plainly have substantial economic consequences for both employers and workers if obesity-related illnesses lead to extended disability or premature retirement of the worker.

Changing age distribution and ethnic composition of the population. The age distribution of the population is changing progressively in many countries (Shephard, 1997), with the most common trend a growing fraction of old and very old individuals. Population pyramids show a dramatic difference of age distributions between a developing country such as the Congo (where a large proportion of the

Figure 1: Trend to replacement of defined benefits by defined contribution pensions in the United States, 1975-2005. Based on data of U.S. Department of Labour.



population are children) and mature countries such as Canada, where a large and growing segment of the population are elderly (Figure 2). Data from Statistics Canada show that the number of Canadians 85 years of age and older grew by 19.4% over the brief period from 2011 to 2016, and there was a 41.3% increase in those aged >100 years over the same quinquennium.

The ethnic composition of the population in countries such as Canada has also shown a marked secular change in recent years, contributing factors being a substantial immigration rate and differing birth rates between indigenous and other populations. According to Statistics Canada, the proportion of Canadians born abroad increased from around 15% in 1971, to a current level of around 22%, with this percentage being much greater in Ontario and British Columbia than in Newfoundland and Labrador (Figure 3). Aboriginal groups (First nations, Metis and Inuit) comprised 2.8% of the Canadian population in 1996, but by 2016 this figure had risen to 4.6%.

Inevitably, these rapid demographic changes are changing required patterns of health care and are increasing the total demand for medical services. In the case of obesity, a larger fraction of the Canadian population has now reached an age when the adverse effects of fat accumulation are becoming fully manifest in associated co-morbidities. At the same time, a decreasing proportion of the population are of school age, potentially allowing some reallocation of government funding from education to the provision of medical services for the elderly. The prevalence of obesity also shows apparent ethnic differences (Gatineau & Mathrani, 2011;

Figure 2: A comparison of population pyramids for Congo (left) and Canada (right).

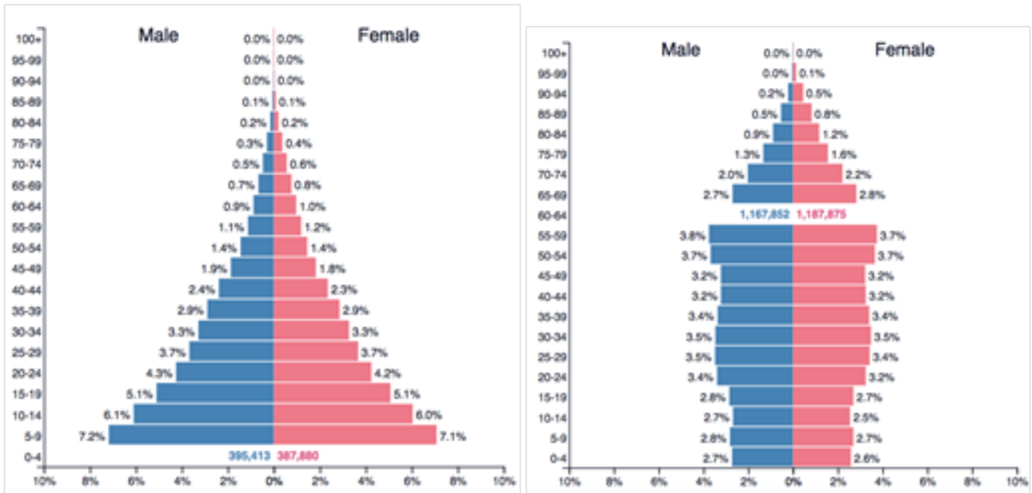
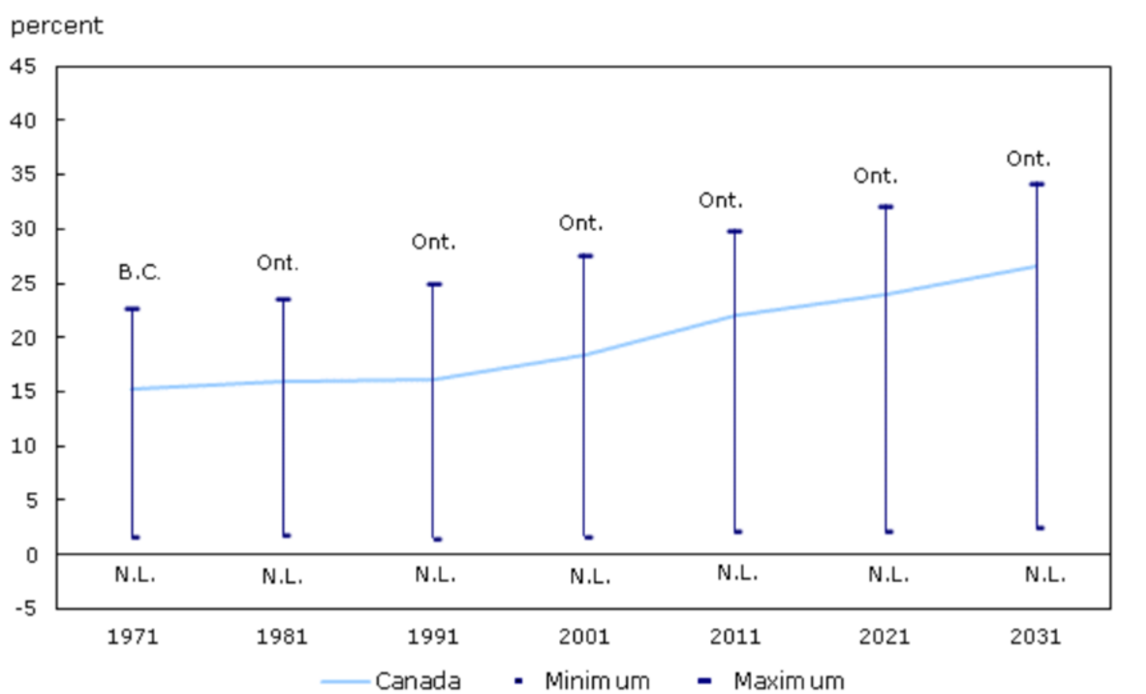


Figure 3: Percentage of the Canadian population who were born abroad in different Statistics Canada population surveys.



Sources: Statistics Canada, Censuses of Canada, 1971, 1981, 1991, 2001 and 2011; Projections of the Diversity of the Canadian Population, reference scenario.

Valera, Sohani, & Rana, 2015). In the United States, the Kaiser Family Foundation reported in 2016 that 64.1% of "whites". 72.0% of "blacks" and 69.9% of "Hispanics" were overweight or obese, and in Canada, also, large ethnic differences have been observed (Table 7).

Table 7: Ethnic differences in the prevalence of overweight and obesity in Canada (based on data of (Valera et al., 2015)).

Ethnic Group	Overweight	Obese
"White"	52%	17%
Southeast Asian	22	3
South Asian	40	8
"Black"	48	13
Latin American	53	13
West Asian/Arab	45	11
Off-reserve aboriginal	63	28

However, a part of these inter-racial differences probably reflect associated differences in socio-economic status and dietary preferences.

Costs of dying prematurely. The economic loss associated with premature death is commonly calculated as the gross earnings that would have accrued if the individual had continued working to the normal age of retirement (Rice, 1967); thi is itself a moving target, as noted above. However, a substantial part of any putative income would have been consumed by the continuing needs of the person in question if they had survived for a longer period. Some economists thus prefer to estimate the net value that a person would have added to the national economy by continued employment (perhaps no more than 25% of the cumulative gross earnings to the normal age of retirement) (Weisbrod, 1961). An alternative option is to equate each year of a person's survival with the corresponding average per capita contribution to the gross domestic product (Roberts, 1982).

The costs of lost opportunity. Many programmes for the treatment of obesity, such as physical activity classes and formal weight-reduction programmes, require the attendance of patients at a clinic or rehabilitation centre several times per week. In addition to the direct expenses involved in travelling to and from such a programme, repeated visits to the facility demand a substantial time commitment from those who are involved. Thus, opportunity is lost to spend a corresponding amount of time in other ways that might be more profitable to the person or to society. Economists commonly assess such opportunity costs at the average industrial wage, currently about $25/hour in Canada.

Volunteer care-giving. Volunteer care-givers, particularly spouses, provide many of the personal services that are needed by those who develop the co-morbidities associated with obesity. Often, such care extends over much of a 24-hour day. It is difficult to set an economic worth upon such efforts. If charged at the overtime salary of a personal nurse, the sums involved would be very large, but often calculations are based on the smaller emoluments paid to a full-time servant, and some economists have even assumed that volunteer labour is of unlimited supply, at zero cost (Freeman, 1997).

A study from Toronto underlined the important contribution of volunteers in the hospital sector. Services valued at $6.84 were contributed for every dollar that was invested in such initiatives (Handy & Srinivasa, 2004). When the volunteers were asked what they would consider a reasonable financial recompense for their contribution, those were also had full-time employment suggested $10.53/hour (although their average wage was $16.42/hour), while those who were not currently part of the paid labour force set their contribution at $12.58/hour.

Other limitations to data on health care costs. There are many other important limitations to estimates of health care costs, some specific to obesity and others having a broader reach. Populations, the ranges of treatment available, methods of paying for medical services, currencies and rates of inflation all differ from one country to another, and these issues complicate year-to-year comparisons not only internationally, but also within a given country. Such problems have been compounded by inter-investigator differences in methodology, which have also led to substantial differences of cost estimates between analysts (Dee, Kearns, & O'Neill, 2014). Future advances will depend heavily on reaching a consensus concerning the most appropriate methodologies to use in cost-benefit studies of health care expenditures.

Many health economists have underline that if the prevalence of costly chronic diseases is to be reduced by tackling the issues of obesity and associated habitual inactivity, substantial expenditures will be required to treat what seem to be relatively intractable problems. Moreover, it cannot be assumed that if the prevalence of obesity is reduced, that this will automatically result in overall savings to governmental health care budgets. Even assuming there is a widespread and successful response to treatment, there would be large continuing costs for the programmes needed to maintain habitual physical activity and prevent the return of excessive body fat. Moreover, the likely scenario is that the same overall fraction of a nation's GDP would be assigned to the provision of medical services, even if physical activity were to be increased and obesity corrected. If less money were needed to treat the complications of obesity and inadequate physical activity, that particular fraction of an unaltered total health care budget would likely be reassigned to meet other pressing medical concerns.

When attempting to assess the specific costs associated with obesity, differing criteria have been adopted for diagnosis of the condition, and this has resulted in differing estimates of prevalence and differing lists of potential adverse health consequences. Moreover, although the statistical association between obesity and many chronic co-morbidities is well documented, evidence of a causal relationship is generally lacking. Many of the health problems that are commonly regarded as sequelae of obesity could in fact have arisen through a lack of adequate habitual physical activity or a poor overall lifestyle, rather than as a consequence of obesity. In other instances, obesity could have impaired physical activity, and this in turn could have led to the patient's illness. Unfortunately, few of the published analyses have attempted to disentangle the respective contributions of obesity, an inadequate level of habitual physical inactivity and a poor overall lifestyle to the observed costs of an excessive accumulation of body fat.

Nevertheless, a large proportion of the costs imputed to obesity have arisen not from the treatment of obesity itself, but rather because of the need to treat co-morbid sequelae such as diabetes mellitus. Individual economic analyses have included the costs arising from differing numbers of such co-morbidities, and since many of these conditions have multiple predisposing causes, it has been difficult to determine what fraction of the resulting costs should be blamed upon either an excessive accumulation of body fat or an inadequate level of habitual physical activity.

Direct medical costs associated with obesity

Having due regard to the various technical difficulties discussed above, we turn now to available estimates of the direct medical costs associated with obesity. But before presenting the actual numbers for various countries, we will outline briefly the main components of these costs, the methods used in their calculation, issues that arise when relying upon BMI as the criterion of obesity, the choice between presenting data for the effects of obesity alone or of overweight plus obesity, possible interactions between obesity and pre-existing disease, the several co-morbidities of obesity (with a ranking of their respective contributions to health costs), the distribution of total added costs among various types of medical service, and specific variables modifying each of these items.

Components of direct medical costs. The direct medical costs associated with obesity include not only the immediate charges for personal medical services (hospital visits, the services of physicians, nurses and health professionals, and expenditures on prescription and non-prescription drugs), but also non-personal items (the costs of health promotional initiatives, research, the training of health professionals, the construction and maintenance of medical and health-care facilities, and the administration of health insurance schemes). Few of the available analyses have included figures for all of these items, and some have considered only the costs of personal medical services.

Most authors have chosen to present the costs of obesity as joint figures for men and women. However, this may not be appropriate, given large sex differences in both total costs and their distribution. Thus, the analysis of Krueger et al. (2014) found that although the prevalence of overweight and obesity was much lower for Canadian women than for their male peers, the per capita cost for those women who were obese obesity was substantially greater than that for obese men (Table 8).

Likewise, Cawley et al. (2007) reported that each additional unit of BMI above the population mean increased annual medical costs (in-patient and out-patient services, prescription drugs, vision, dental, home health, and medical equipment) by $82 in men, but by $178 for women, with expenditures on the first 3 of these items accounting for almost all of sex differences. The total additional medical costs (2005 US dollars) averaged $1171 for an obese man and $3696 for an obese woman.

Methods of calculating costs. Analysts have chosen either a top-down approach

Table 8: Sex differences in estimated costs associated with overweight and obesity. Based on data of Krueger et al. (2014).

	Males			Females		
	Overweight	**Obese**	**Total**	**Overweight**	**Obese**	**Total**
Direct cost	$945M	$1567M	$2513M	S1020M	$1901M	$2921M
Indirect cost	$2827M	$3838M	S6665M	$2730M	$4209M	$6939
Total cost	$3772M	S5405M	$9178	$3750M	S6110M	$9857

(looking at population attributable fractions of the various diseases associated with overweight and obesity and summing their likely costs), or a bottom-up approach (where cross-sectional or longitudinal analyses have related individual health experience to body mass indices). The total costs associated with individual illnesses have been taken from such data sets as the U.S. medical expenditures surveys (Cawley & Meyerhoefer, 2012; Dee et al., 2014), and in Canada, analyses from the Institute of Health Information (Canadian Institute of Health, 2011).

The population attributable fraction (PAF) of the total direct cost of a given condition due to obesity is generally calculated as:

PAF = P/RR - 1)/[P (RR - 1) + 1]

where P is the probability of a person being obese in a given population and RR is the sex-specific relative risk of developing that condition in those who are obese. The PAF is then multiplied by the average per capita direct cost attributable to the co-morbidity in question (Table 9), with this figure being based ideally on the need for hospital care, the services of physicians and other health professionals, other components of health care, prescribed drugs and related research activity. Notice the implicit assumption in this calculation that the medical costs associated with a given clinical condition are similar for those who are obese and those who are overweight or have a normal body mass. But in fact, the costs of any given disorder are likely to be greater for the obese than those who do not carry an excessive burden of body fat, with particularly high costs occurring amongst those who are morbidly obese.

Where precise numbers for the costs associated with an individual medical condition remain unknown, estimates have sometimes been made by an arbitrary splitting of the overall costs established for larger illness categories.

Issues arising from use of BMI as the criterion of overweight and obesity. Most investigations of the costs associated with an excessive accumulation of fat have adopted the individual's BMI as the criterion when deciding upon the presence and/or extent of overweight or obesity. One immediate difficulty is that some early studies (for example, Birmingham, Muller, and Palepu, 1999; Lévy, Lévy, and Le Pen, 1995) set the threshold of obesity at a non-standard level (a BMI of 27 kg/m^2, rather than 30 kg/m^2). Further, the BMI has typically been calculated from reported heights and weights rather than objective measurements, and since heights are usually over-reported and weights under-reported (Lu et al., 2016; Rowland, 1990; Zhou et al., 2010), this has led to substantial under-estimates of the population prevalence of obesity in the samples concerned. One analysis opted to adjust the prevalence of obesity upwards by the substantial factor of 1.46, to allow for likely errors in self-perceptions of height and body mass (Katzmarzyk, 2011). Moreover, whatever threshold of BMI has been chosen, there remains a problem from a U-shaped non-linearity in the data linking BMI and health care costs (Allison et al., 1997; Flegal et al., 2005; Flegal et al., 2013). A number of conditions, particularly cancer, cigarette smoking and the muscular wasting of old age, are associated with a low BMI, yet lead to a substantial increase in medical costs.

The classification of obesity in terms of waist circumference measurements rather than BMI would circumvent some of these issues, but to date there is insufficient information to allow an attribution of health costs on the basis of circumference data.

Should we look at the costs of obesity alone, or those of overweight plus obesity? Many analyses have estimated increases in medical costs only for those who are obese. However, costs are also augmented, albeit to a lesser extent, for those who are overweight. Moreover, such individuals have a substantial impact upon total national costs, since the prevalence of overweight is much greater than that of obesity. The analysis of Anis et al. (2010) estimated that in Canada 34% of the total $6 billion costs attributed to fat accumulation for the year 2006 was due to overweight rather than obesity, and in the Netherlands, overweight was responsible for the major fraction of imputed additional costs (Seidell, 1995).

Further, most of the added costs associated with fat accumulation lie on a BMI-related continuum. This creates statistical problems if one calculates separate costs attributable to overweight and obesity and then sums the two figures (Krueger, Williams, & Ready, 2013).

Interactions between obesity and pre-existing chronic disorders. The development of obesity may limit both the individual's ability to access medical care and the extent of his or her habitual physical activity, thus increasing the risk associated with many pre-existing disorders, and predisposing to a wide range of chronic health problems. Cost estimates are further complicated in that a given fat accumulation has a much larger adverse impact upon costs in those who are already in poor health from other causes.

Thus Li et al. (2015) examined interactions between obesity and diabetes mellitus. Health costs were classified by the individual's blood glucose level. In those who were normo-glycaemic, the *incremental* costs of an above optimal BMI ranged from $336/year in those who were overweight to $1850/year for those with class III obesity. In those who were hyper-glycaemic, the corresponding increments were $1139 and $4649/year on much larger average costs (Table 9).

The costs associated with individual co-morbidities of overweight and obesity. Different analysts have divided data between 4 to 11 major co-morbidities when calculating the health costs arising from a combination of overweight or obesity and other chronic health conditions. The respective impact of individual co-morbidities upon total costs can be seen from the data of Birmingham

Table 9: Interactions between obesity and glycaemic status. Total annual health care costs associated with fat accumulation, expressed as ratio to values for those with an optimal BMI (18.5-25.0 kg/m²) at the corresponding glycaemic stage. Based on data of Li et al. (2015)

Blood glucose	Body Mass Index (kg/m²) and annual health care costs					
	All BMIs	18.5-25	25-30	30-35	35-40	>40
Normo-glycaemic	$4467	1.00	1.09	1.25	1.30	1.51
Pre-diabetic	$9342	1.00	1.09	1.09	$1.04	1.28
Diabetic	$11,983	1.00	1.11	1.17	1.29	1.46

Table10: Estimates of the annual medical costs of obesity attributable to associated co-morbidities. Based on the data reported by Birmingham et al. (1999) for direct costs in the Canadian population of 1999, and by Katzmarzyk (2011) for direct and indirect costs in the Ontario population of 2009. All data are expressed in millions of 1997 and 2009 Canadian dollars, respectively.

Co-morbid condition	Direct cost ($M) (B, K)	Indirect cost ($M) (K)	Total (direct + indirect) costs ($M)
Coronary artery disease	346, 392	1016	1408
Stroke	106, 128	111	239
Hypertension	657, 486	487	954
Colon cancer	20,*19	92	112
Post-menopausal breast cancer	20,25	120	145
Type 2 diabetes mellitus	423, 221	162	383
Gall bladder disease	137, 174	113	287
Endometrial cancer	137, NE+		
Hyperlipidaemia	61, NE+		
Pulmonary embolism	38, NE+		
Osteoarthritis	NE+ 152	787	939
Total, all conditions	1596	2870	4466

*colorectal cancer; +NE Not estimated B = Birmingham, K = Katzmarzyk

et al. (1999) (for all of Canada, setting the diagnostic criterion of obesity at a BMI of only 27 kg/m^2)) and of Katzmarzyk (2011) for the Province of Ontario, population, using the more conventional BMI cut-off of 30 kg/m^2 (Table 10). The overall distribution of costs between the various co-morbidities seem relatively comparable for the 2 analyses. But because the Canadian population grew substantially between 1997 and 2009, obesity cut-offs differed between the 2 studies, direct annual medical expenditures escalated over the intervening 12 years, and a substantial allowance for errors in subjective estimates of height and body mass was included in the figures of Katzmarzyk, absolute estimates of costs for the Province of Ontario are quite similar to the earlier figures calculated by Birmingham for Canada as a whole, even though Ontario comprises only about 37.5% of the total Canadian population. The biggest source of expenditure in both analyses appears to be the co-morbidities included in some of the earliest published analyses (hypertension, coronary heart disease and diabetes mellitus).

Lai et al. (2012) included figures for renal cancer in their analysis of co-morbidities for a New Zealand population. The risk ratio for renal cancer in those who were obese was 1.84 relative to those with a normal body mass, but because of a low prevalence of this condition, the addition of renal cancer to the list of co-morbidities added an expenditure of only NZ$ 1.3M into total costs of NZ$ 624 M for the overweight and obese.

Distribution of the added health costs amongst various medical services. A study of 1286 patients aged 35-64 years who were enrolled in the Kaiser Permanente Insurance plan provides an example of the distribution of the added direct costs of overweight and obesity among expenses for primary medical care, specialist consultations, hospital treatment and medications in a middle-class U.S. sample (Thompson, Brown, & Nichols, 2001). The patients were divided on the basis of their initial BMI (20-24.9, 25.0-25.9 and >30 kg/m^2). Those who were overweight showed 10% greater medical costs, and for those who were obese the increase was 36%. Moreover, the largest increments (37% and 105% in the overweight and obese categories respectively) were for increased expenditures upon the purchase of prescription drugs.

Prescription drugs make up a large fraction of the total added expense associated with overweight and obesity in many countries. In a British survey from 2002, for example, the purchase of drugs accounted for £600 M out of a total of £945-1075 M costs attributed to obesity-related conditions (House of Commons, 2004), and in Portugal, pharmaceuticals (particularly antihypertensive medications) accounted for 43% of the total additional expenditures incurred by those who were obese (Pereira, Mateus, & Amaral, 2000).

Copley at al. (2017) looked at the impact of a high BMI on another element of health care not often considered in economic analyses, namely the provision of social services (particularly the provision of help with the activities of daily living in the elderly segment of the population). After adjusting data for long-term illness and socio-demographic factors, a cross-sectional study of 6462 English adults aged > 65 years set the annual cost of such services at £599 (US $773) for those with a normal body mass (about 21% of the sample, with an average measured BMI of 23 kg/m^2), but annual costs of the same services increased progressively to £1086 (US $1401) in those with morbid obesity (1.7 % of the sample, BMI > 40 kg/m^2). More than 50% of the morbidly obese required help in undertaking the activities of daily living.

Factors potentially modifying the health-care costs associated with obesity. Looking at sub-groups in an American sample of 9852 men and 13,837 women aged 20-64 years, Cawley & Meyerhoefer (2012) found that the impact of obesity was similar for those of white and black ethnic backgrounds, but that costs were larger in those without medical insurance than in insured members of their sample.

Calculations have commonly been based on the assumption that (in contrast with the obese) those who are overweight do not have an increased mortality (Flegal et al., 2005; Mehta & Chang, 2009). This, data from the three NHANES surveys showed an excess of deaths in those with a BMI <18.5 kg/m^2, and also in those with a BMI >30 kg/m^2, but there were no excess deaths in those with a BMI in the range 25-30 kg/m^2 (Flegal et al., 2005). These findings raise the possibility that at least a small part of the immediate health costs associated with obesity could be offset by an earlier age of death among obese seniors (Allison, Zannoli, & Narayan, 1999). However, it is also arguable that if those of normal weight remain well and contribute productively to society until shortly before their death (that is, they followed a "square" age/illness profile, [Shephard, 1997]), the reverse might also be the case. Plainly, there is need to compare the shape of mortality curves between the obese and those of normal weight.

Estimates of the added costs from being overweight or obese have increased greatly in recent years, in part due to the inclusion of additional associated co-morbidities, and in part to substantial overall escalations in medical costs (Anis et al., 2010).

Estimates of direct health costs of overweight and obesity

The direct health costs associated with overweight and obesity have been estimated for many developed and a few developing countries. Although the absolute figures differ between analyses, the percentage of total health-care expenditures attributed to obesity are substantial and they seem to be relatively consistent across investigators (2-5% of total direct health care expenditures). One important exception is the U.S., where (with a much higher prevalence of obesity than in most other countries) estimates of the direct medical costs associated with overweight and obesity have commonly been in the range 5-9% and sometimes have been as high as 20% of total expenditures (Cawley & Meyerhoefer, 2012). There remains a need for more data from some developing countries, where both the prevalence of obesity and the availability of medical treatments still show steep socio-economic gradients.

An alternative method of expressing data is in terms of the increase of costs induced by fat accumulation. In almost all such analyses, the reference point has been the costs for individuals with a BMI < 25 mg/kg^2 (and unfortunately usually not excluding those with a BMI <18.5 kg/m^2). As might be expected from Table 11, medical expenditures were substantially greater in the overweight and obese than in the non-obese, but much of this per-capita increase was attributable to those who were morbidly obese. For example, in the studies of Andreyava et al. (2004) and of Arterburn et al. (2005), direct costs for those with BMIs > 40 kg/m^2 were, respectively, 100% and 81% greater than the reference values.

Indirect costs associated with obesity

Factors contributing to the indirect costs of a condition such as obesity are much more nebulous and difficult to assess than the direct health care costs, and for this reason many investigators have omitted some or all of the indirect costs from their calculations. Available estimates are usually based on the Human Capital approach, which assumes that a sick person's services to the community are lost if they die prior to the normal age of retirement. However, as noted above, if there is elasticity in the labour force due to a high rate of unemployment, a smaller figure can be estimated, based on the assumption that a dead or sick person will eventually be replaced by someone who is currently seeking work; the only economic loss to society is then the cost of training the new recruit.

The indirect costs of obesity are undoubtedly large (Table 12**,** Oster, Edelsberg, & O'Sullivan, 2000), and in most studies exceed direct costs. Contributing factors include the loss of production from periods of ill health, poor productivity, and absenteeism, and financial allowances for a poor quality of life, premature mortality, the provision of invalid care by close family members, and the grief of relatives due to a premature death.

In a British survey (House of Commons, 2004), indirect costs attributable to illness (£1.30-1.45 B) were slightly larger than those due to premature mortality (£1.05-1.15 B). Obesity may impair productivity not only

Table 11: Estimates of additional direct health care costs associated with being overweight or obese in various countries, expressed as absolute dollar values and percentages of total health-care budget.

Author	Sample	Items included	Annual cost	Comments
Anis et al. (2010)	Canada, cross-section nationally representative sample	Hospital and out-patient care, physician & health professional services, drugs, research	Overweight (>25 kg/m²) Cdn $2.04 B (2006), 1.4%) Obesity (>30 kg/m²), $4.0 B, 2.7%)	18 co-morbidities included, estimates based on directly measured height and weight
Bahia et al. (2012)	54,339 Brazilian adults > 18 yr	In-patient & out-patient hospital costs	Overweight + obesity, U.S. $2.1 B (2010), 33% of total hospital costs	10% due to overweight & obesity, 90% to co-morbidities
Birmingham et al. (1999)	Canada, cross-sectional study, nationally representative sample	Hospital care, doctor & health professional visits, drugs, research	Cdn $1.8 B (1997); 2.4%	Comparison of BMI <27 vs. >27 kg/m²; 10 co-morbidities
Borg et al. (2005)	23,365 Swedes aged 26-61 yr, followed for 15 yr	Hospital treatments only	US $269 M (2005); 2.3%	BMI >27 kg/m² vs. <25 kg /m²
Cawley & Meyerhoefer (2012)	9852 M, 13.837 F US adults aged 20-64 yr	Medical treatment	US $22.9 B (2005), 16.6%,	Obese compared with normal weight and overweight, estimates based on comparisons within families
Colditz (1999)	Literature search, U.S. adults	Hospital & nursing home care, physician & nursing services, drugs	US $70 B (1995) if BMI >30 kg/m² (cost of physical inactivity $ 24 B)	Costs claimed independent of habitual physical activity, but PA measures weak
De Oliveira et al. (2015)	188,461 Brazilians accessing public health system	In-patient & out-patient treatment, drugs, orthotics	US $ 270 M (2011), 1.86%	Morbid obesity accounts for 23% of total excess costs of obesity
Detournay et al. (2000)	14,670 French >18 yr (National Health Survey)	Self-reported use of medical services	Fr 6.5 B (1992); US $ 1.26 B; 1.1%	
Doherty et al. (2012)	10,184 adults > 18 yr, Republic of Ireland	In-patient, out-patient and G.P. services	BMI >25 kg/m² E 41 M (US 53 M) (2011)	Values low-conservative estimate?
Effertz et al. (2016)	146,000 German insured population	Medical & nursing costs, rehabilitation, drugs	E 29.4 B (US $38.2 B) (2015), 9.3%	Higher than earlier estimates, e.g. Konnopka et al. (Konnopka, Bödemann, & König, 2011)
Finkelstein et al. (2009)	21,887 U.S. adults aged > 18 yr, self-reported height & weight	In-patient, out-patient services and drugs	$147 B in 2008, 9.1% in obese >30 kg/m²	About half of costs financed by Medicare and Medicaid; Private payers get more in-patient treatment .
House of Commons (2004)	Cost estimates for English population	GP consultations, out-patients & day attendances, hospital admissions, drugs	£945-1057 M (2002), £600 M of total attributable to drug costs), 1.5% in 1998	Lower back pain, and lipid lowering drugs not included
Katzmarzyk (2011)	Representative sample of Ontario population (39.3% of Canadian costs)	Hospital care, physician & other professional services, drugs, research, public health programs, research	Obesity $Cdn 1.60 B (2009), 3.8% Physical inactivity $Cdn 1.02 B	Data corrected for self-estimates of height and weight, based on 8 co-morbidities
Katzmarzyk & Janssen (2004)	Representative sample of Canadian population	Hospital care, physician & other professional services, drugs, research, public health programs, research	Obesity $Cdn 1.6 B (2001), 1.7%; Physical inactivity $Cdn1.6 B	

Author	Sample	Items included	Annual cost	Comments
Kang et al. (2011)	1,190,194 Korean adults aged > 20yr	In-patient & out-patient treatment & drugs	$1.08 B (2010), 2.2%	
Konnopka et al. (2011)	Estimates for German population >18 yr	Hospital and out-patient treatment, rehabilitation & non-medical costs	E 4.85 B (2002), 2.1%	German obesity prevalence data, but U.S. data on relative risk used
Krueger et al. (2014)	Representative sample, Canadian population > 12 yr	Hospital treatment, medical & health professional care, drugs, research	Overweight Cdn Cdn $0.95 B (M), Cdn $1.02 B (F); 1.97 B (Total costs, 2012), 1.3% Obesity Cdn$1.57B (M), Cdn $1.90 B (F) 3.47 B (Total costs, 2012), 2.3%	Attempt to disaggregate effects of obesity and physical activity
Lal et al. (2012)	Large cohort of New Zealand population	Hospital and residential care, out-patient, primary practitioner & health professional services, lab tests	NZ $624 M (2006), 4.4% of total national health expenditures)	Increased prevalence of obesity, more co-morbidities included than in Swinburn study of NZ population
Lette et al. (2016)	German, Dutch & Czech populations > 20 yr	All health care providers & drugs	Germany E 5.1 B, 3.7%* Holland E 0.59 B, 2.3% Czech 0.11 B, 2.1%	
Lévy et al. (1995)	Prevalence study of French population	Hospital care, physician services & drugs	11.9 B French Francs 1992 (2% of medical costs in France)	Obese = those with BMI >27 kg/m²
Oster et al. (2000)	>5000 U.S. adults	Medical costs paid by health care plan	Additional $346/person (2000) if BMI >25 kg/m²	
Pitayatienanan et al. (2014)	Adult population of Thailand	In-patient & out-patient costs	US $0.344 B, 1.8%	
Riveladze et al. (2014)	Adult population of Mexico	All health care and disease- related costs	US $ 0.806 B (2010), 4.2%	
Schmid et al. (2005)	Swiss adults > 15 yr	Hospital, physician & health professional care, drugs	SF 2.5B (US$4.1 B) in 2001 if BMI > 25 kg/m², 2.3-3.5%	
Swinburn et al. (1997)	Prevalence in nationally representative NZ population	Hospital & physician care, drugs & ambulances	NZ $ 135 M (US $89 M) if > 30kg/m², 2.5% of national health expenditures ($24/head)	
Vellinga et al. (2008)	All hospital discharges with diagnosis of obesity in Ireland	Hospital costs	E 2.4M (no diagnostic BMI specified)	
Wolf & Colditz (1996)	Representative sample of U.S. adults 18-84 yr	Costs of medical care	$22.6 B (1993), BMI >29 kg/m² vs <23 kg/m2	
Zhao et al. (2008)	Prevalence study in 39,834 Chinese adults	Hospital & physician services, professional care, drugs	US $ 2.74 B for overweight (BMI >24 kg/m²) + obesity (BMI >28 kg/m²)	Based on only 4 diseases (hypertension, stroke, diabetes and CHD

*shown as 37% in text, presumably a typographical error

Table 12: Indirect costs associated with overweight and obesity, expressed as total dollars and percentage of costs of ill-health.

Author	Sample	Items considered	Estimated costs	Comments
Anis et al. (2010)	Canada, cross-section nationally representative sample	Short and long-term disability, but not premature mortality	Can $5B (2006) (54%)	Overweight + obesity
Borg et al. (2005)	23,365 subjects followed for >15 yr	Indirect costs due to death before retirement	Overweight + obese accrue 2.9B SwKr extra costs = US $363 M (57.4%)	>27 kg/m² vs. <25 kg /m²
Effertz et al. (2016)	146,000 German insured population	Sickness absence, early retirement, premature mortality, widows & orphans pensions	$33.7B (2015), 53.4%	
Finkelstein et al. (2009)	21,887 U.S. adults aged > 18 yr, self-reported height & weight	Absenteeism and presenteeism	US $30B (59%)	
House of Commons (2004)	British population, 2002	Premature mortality and sickness	£ 2.48B (70.3%)	
Kang et al. (2011)	1,190,194 Korean adults aged > 20yr	Sickness absence, premature mortality	$0.71B (2010), 39.5%	
Katzmarzyk & Janssen (2004)	Representative sample of Canadians ages 20-64 yr	Absenteeism, disability, premature mortality	Physical inactivity Cdn $3.7B (69.8%), Obesity Cdn $2.7B (2.8%) (2001)	
Katzmarzyk (2011)	Representative sample of Ontario population (39.3% of Canadian costs)	Short & long-term disability, premature death	Physical inactivity Cdn $2.37B (68.8%), Obesity Cdn $2.87B (63.8%)(2009)	
Konnopka et al. (2011)	Prevalence study in German population	Sickness absence, early retirement and mortality	E 5.02 B (51%)	
Krueger et al. (2014)	Canadian population	Premature mortality, short & long-term disability	Overweight $2.83B (74.9%) (M), $2.73B (72.8%) (F); Obesity $3.87B (71.0%) (M), $4.21B (68.9%) F	Attempt to disaggregate effects of obesity and physical activity
Lal et al. (2012)	New Zealand, 2006	Lost productivity only	NZ $225 M (26.5%); Friction Cost approach NZ $98 M (11.5%)	
Lehnert et al. (2013)	Entire German adult population	Absenteeism, early retirement, premature mortality	E 6.19 B (50.7%)	
Pitayatienanan et al. (2014)	Adult population of Thailand	Absenteeism, premature mortality	US $0.39 B, (54.0%)	
Schmid et al. (2005)	Swiss adults > 15 yr	Absenteeism, early retirement, premature mortality	About $0.45 B (50% of total costs)	
Wolf & Colditz (1996)	Representative sample of US adults	Absenteeism, disability, premature mortality	$65.1B (74.2% total costs)	Obesity = BMI > 29 kg/m²

because of absenteeism due to associated health problems, but also because of "presenteeism" (a poorer productivity and more frequent minor absenteeism than slimmer individuals when a fat person is nominally at work) (Frone, 2007). Serxner et al. (2001) found that obese individuals had a 23% greater than average likelihood of being placed in the high-absenteeism segment of the labour force. The Shell Oil Company also noted that each year obese employees accumulated 3.7 more days of undocumented absence than their peers, at a direct cost to the company of $11.2 M/year (Tsai et al., 2008). On a nation-wide basis, such minor absenteeism would imply an annual cost in the range $3.4-6.4 B (Trogdon et al., 2008). The likelihood of claiming disability insurance was also 6% above average in those who were obese (Burkhauser & Cawley, 2004).

The Shell Oil survey suggested that the loss of productive time while at work was greater in the obese than in those workers who were of normal body mass, creating an annual estimated nation-wide cost of $7.8 B (Ricci & Chee, 2005), with additional adverse effects from poor inter-personal relationships (Pronk et al., 1999).

In most situations, there are also losses to the economy if a person dies before reaching the normal age of retirement. A 20-year old male with a BMI >45 kg/m^2 has a 22% reduction in life expectancy (a loss of 11 working life-years. Konnopka et al. (2011) estimated that 67% of the indirect costs of obesity in Germany were due to premature mortality. But against these undoubted costs one must set a reduced consumption of goods and services and fewer pension payments if a person dies prematurely because of obesity; this may counter the costs attributed to lost productive years by as much as 25% (Wang et al., 2003).

Disentangling the respective effects of obesity and inadequate physical activity upon health care costs

Added direct and indirect medical costs are associated with both obesity and a low level of habitual physical activity, but few investigators have as yet tackled the difficult issue of disentangling these two factors. Plainly, this is an issue that should not be ignored, and indeed it has an important bearing upon future resource allocations (Table 13).

The intertwined relationship is illustrated by data from the 2000/2001 Canadian Community Health Survey; this found a 16% greater risk of inactive leisure in the obese than in those individuals with a normal body mass (Statistics Canada, 2002). Similarly, in the U.S., the prevalence of obesity in those taking exercise >5 times/week was 50% less than in those who were physically inactive (King, Fitzhugh, & Bassett, 2001). Thus, for many people, greater health care costs could be attributed to either their obesity or their physical inactivity. On the other hand, a multivariate analysis from the U.K. (Tigbe et al., 2013) found highly significant partial correlations of health care costs with BMI, but no statistically significant relationships between such costs and a weak, self-reported 4-category classification of habitual physical activity. This highlights the problem of those trying to distinguish the two sources of added cost. Obesity can be characterized with reasonable accuracy using the individual's BMI, but population data rarely offer an accurate quantification of habitual physical activity levels.

In 1995, Colditz (1999) set the direct costs of physical inactivity in the U.S. at $24 B per year (2.4% of total U.S. health costs), but the direct costs of obesity were estimated at the much higher figure of $70

B per year. Colditz asserted that the two costs were independent of each other, but this seems unlikely, and the evidence supporting his claim seems limited to 2 studies where the effects of physical inactivity upon the risk of colon cancer were independent of BMI.

In order to estimate the respective contributions of physical inactivity and of obesity to overall health care costs, it is necessary to calculate multiple regression analyses, so that appropriate fractions of the various associated co-morbidities can be attributed to each of the two variables. Unfortunately, there is relatively little data that can be used for this purpose. Estimates of the chronic conditions associated with inadequate physical inactivity have not always included some measure of obesity as a co-variate, and many of the analyses of relationships between obesity and co-morbidities have either used very weak subjective measures of physical activity. or have failed to co-vary at all for levels of habitual physical activity (Katzmarzyk & Janssen, 2004). Where investigators have attempted to assess physical activity, categorization has usually lacked precision. In Canada, for example, individuals who are supposed to have been inactive have usually been identified simply on the basis of a questionnaire-reported active energy expenditure of less than 1.5 kcal/kg per day, although some reports have set the threshold for an active person at a higher self-reported expenditure of 3 kcal/kg per day. Issues with the accuracy of such reports are discussed in a critical review of the Canada Fitness Surveys (Shephard, 1986b).

In an analysis of data for 7 U.S. States, Chenowith and Leutzinger (2006) attributed direct annual health care costs of US $93B to individuals with an inadequate level of physical activity and a similar cost of US $94B to those with an excessive body mass. In their analysis of Canadian data for 2001, Katzmarzyk & Janssen, (2004) also estimated rather similar total annual health care costs for physical inactivity ($1.6 B for direct, and $3.7B for indirect costs) and obesity (excluding people who were overweight) ($1.56B for direct, $2.7B for indirect costs). The direct costs of physical inactivity found in this analysis were somewhat smaller than the $2.1B total that had estimated in 1999, when a different definition of habitual inactivity had been used (Katzmarzyk, Gledhill, & Shephard, 2000). The health direct costs attributed to obesity were similar to the $1.8 B that Birmingham et al. (1999) had calculated for the Canadian health care system; however, the 2 data sets are not really comparable, since the latter study had included in their estimates all individuals with a BMI > 27 kg/m2, had ignored one of the major health costs of obesity (problems of osteoarthritis), and had included other items that were not considered in the Katzmarzyk analysis.

A further Canadian study by Krueger et al. (2014) attempted to split the total additional health care costs associated with various life-style risks between smoking, an excessive body weight and inadequate physical activity. Krueger et al. (2013) proposed estimating aggregate costs for the various co-morbidities, both direct and indirect, across the 3 risk factors, and subsequently attempting to disaggregate the risk, calculating the effect of the three individual risk factors as ratios of the total cost. Although their approach recognized the difficulty of overlap between putative sources of medical expenditure, it is less clear whether costs were appropriately allocated between obesity and physical inactivity, since the two variables are not independent of each other, and calculations were sex-specific for obesity but not for physical activity. They assigned $19 B to a combination of excess weight and obesity, and $10 B to physical inactivity.

The World Cancer Research Fund had previously attempted the even more ambitious task of splitting health impact (measured in disability-adjusted life-years) through a sequential analysis among 67 potential conditions. On a world-wide basis, an excessive weight was ranked sixth as a source of decreased disability-adjusted life years, and a low level of physical activity was tenth; however, in the North America data, these rankings rose to third and fourth respectively (Lim et al., 2012).

Kuriyama et al. (2004) sought to disentangle the relative effects of physical inactivity and obesity at an individual level. They looked at a 7-year analysis of Japanese health insurance data for 26,110 subjects, estimating that a BMI > 25 kg/m^2 alone increased costs by 7.1%, that inadequate walking alone (leisure, occupational and household activity totaling less than 1 h/day) increased costs by 8.0%, and that a combination of overweight and inadequate physical activity increased costs by 16.4%.

A multivariate logistic analysis of 18 months of data for 5977 subjects served by a Minnesota health care provider (Pronk et al., 1999) also attempted to differentiate the respective effects of physical inactivity and obesity, although the method of presentation limited comparison of the 2 statistics in terms of relative magnitude. A 1-unit increase of self-reported BMI over the study period increased medical charges by 1.9%, and an additional day of self-reported physical activity per week reduced charges by 4.7%.

Brown et al. (2008) examined the health care costs associated with 3 levels of physical activity (<40, 240-600 and >600 MET.min/week) in Australian women who had been classified by BMI (<25, <30 and >30 kg/m^2). Both a low level of habitual physical activity and a high BMI had an impact on medical expenditures. Cost increases due to obesity (BMI >30 vs < 25 kg/m^2) over 3 the categories of habitual physical activity were 9.9%, 15.9%, and 20.5 %, respectively, whereas the effect of limited physical activity (<40 vs. > 640 MET.min/wk) over 3 categories of BMI was greater, at 30.3%, 25.4% and 18.8%, respectively; the largest relative benefit of physical activity was seen in those individuals having a normal BMI.

In summary, much of the available data on medical costs has not analyzed the potential problem of overlap between effects due to obesity and those due to physical inactivity. There is good evidence that obese people are less active than those of normal weight, but possibly because of weak measures of habitual physical activity and/or a limited variance of physical activity patterns in many populations, some reports have attributed a rather small proportion of the joint cost estimates to inadequate habitual physical activity. On the other hand, recent reports suggest that physical inactivity may account for as much as three quarters of the added health care expenditures associated with a combination of obesity and inactivity.

Table 13: Attempts to disentangle the respective contributions of obesity and inadequate physical activity to health care costs.

Author	Costs due to obesity	Costs due to inadequate physical activity	Methodology	Comments
Brown et al. (2008)	Medical costs if obese +9.9, 15.9, 20.5% across 3 activity levels	Medical costs of inactivity over 3 BMI categories +30.3, 25.4, 18.8%		Note: Physical activity has MORE benefit if normal body weight than in obese
Chenowith & Lutzinger (2006)	Direct costs US $94B	Direct costs US $93B	Data abstracted from health plans in 7 US states	
Colditz (1999)	Direct costs in US $70B	Direct costs in US $24B	Review	Claimed that effects of obesity & physical activity independent of each other
Katzmarzyk & Janssen (2004)	Direct Cdn $1.56B Indirect Cdn $2.7B	Direct Cdn $1,6B Indirect Cdn $3.7B	Prevalence of obesity and physical inactivity taken from published national surveys	
Krueger et al. (2014)	Direct Cdn $3B Indirect Cdn $7B	Direct Cdn $5.4B Indirect Cdn $13.6B	Calculations sex specific for obesity but not for activity	Costs split between overweight plus obesity, physical inactivity and smoking
Kuriyama et al. (2004)	BMI >25 kg/m2 increased direct costs by 7.1%, if also inactive by 16.4%	Leisure, occupational and household activity < 1 h/day increased direct costs by 8.9%	Analysis of Japanese health Insurance data	
Lim et al, (2012).	Ranking- world wide 6, N. America 3	Ranking world wide 10 N. America 4	Ranking of 67 health issues as impact on disabilty adjusted life years	
Pronk et al. (1999)	1 unit increase of self-reported BMI increased medical costs 1.9%	Additional day per week of self-reported activity decreased costs 4.7%	Data from Minnesota health care provider	
Tigbe et al. (2013)	Significant partial correlation of costs with BMI	No partial correlation with physical activity	Partial correlation analysis	Self-reported 4-category measure of physical activity

Impact of obesity upon passenger transportation and greenhouse gas emissions

The added costs associated with obesity extend widely across many areas of life and society. One largely neglected area is passenger transportation and associated greenhouse gas emissions. If a traveler is overweight, he or she may need a larger seat or a larger vehicle to accommodate the added girth, and extra fuel will also be expended during their transportation over a given distance (Figure 4). Further, several safety concerns are raised by passengers with an excessive body mass.

Figure 4: Obesity has many adverse consequences for passengers engaged in air and car travel.

Aircraft passengers. The Federal Aviation Administration requires that all aircraft passengers be able to fasten their seat belts and lower their seat arms, which are separated by a distance of separated by a distance of 17-19 inches in economy compartments. However, there is no statutory requirement for the carrier to provide an upgrade to premium accommodation or to offer a second seat to those individuals who are obese and have difficulty in using standard seating. The policies of South-West Airlines (with a 17 inch gap between economy seat arm-rests) are fairly typical of carriers in the U.S. Charges are levied for a prearranged additional reserved seat or an upgrade, but passengers can discuss at the airport gate whether there is a vacant seat that can be exploited on a given flight. If not, then obese passengers may be bumped from the flight. A number of airlines offer extensions to standard seat belts on request.

Some international airlines also apply an additional charge if a second seat is required (typically, the full cost of the additional seat, less taxes and surcharges). One of every three passengers polled by Ryanair believed that such a charge is a viable approach to reducing airfares. And at least one Pacific airline (Samoa Air), recognizing the prevalence of obesity in Samoa, now charges passengers in proportion to their weight (for example, $4.16/kg on the short flight from Samoa to American Samoa). They have also introduced a special XL category that offers wider width seating for passengers weighing more than 260 pounds. Attendants on some smaller aircraft may predetermine the distribution of seating for heavy passengers, in order to balance the loading of an aircraft.

The Canadian government, working from the premise that obesity is a medical condition, requires national airlines to assign a second seat on an aircraft, at no additional charge, if this is made necessary because of a client's obesity. The inevitable consequence is that the airline faces a financial penalty if a plane is flying at capacity. However, obtaining the second seat is no easy matter; passengers requesting a free second seat on Air Canada or West Jet must have a 5-page form completed by their doctors, giving (among other information) detailed measurements of their posteriors.

Any adverse effect from a reduction of aircraft seating capacity is compounded by the effects of the added weight of those who are obese or overweight. Each gallon of aviation fuel enables an average aircraft to carry 7.3 tons of passengers over 1 cargo mile. Thus, the increased prevalence of obesity of the U.S. population between 1990 and 2000 immediately increased the annual fuel costs of American airlines by 2.4%, an expense of around $275 M over this same period (Dannenberg, Burton, & Jackson, 2004).

There are also issues of safety arising from the over-loading of aircraft. In 1995, the U.S. Federal Aviation Agency recommended calculating the loading from individual passengers at 180 lbs in summer and 185 lbs in winter, but as a result of the crash of a commuter plane in 2003, it was recommended that this estimate be increased by 10 lbs per passenger. It remains unclear how far this recommendation has been implemented. In 2011, Transport Canada increased the assumed weights for male and female passengers to values of 200 and 165 lbs in summer months, and 206 and 171 lbs in the winter.

A further safety consideration is the integrity of a passenger seat in the event of a crash. Seats are currently designed to withstand a force of 14 g when carrying a weight of 170 pounds, but will offer proportionately less protection to a person with gross obesity.

Motor vehicle occupants. Economists have pointed to substantial increases of fuel consumption when obese people travel in passenger cars. One analysis from the U.S. suggested that a 2.5% reduction in fuel efficiency between 1999 and 2005 was associated with a 10% increase in the prevalence of overweight and obesity, and another more conservative analysis put the effect for a 10% increase of overweight and obesity at a 1.4% decrease in miles per gallon in new cars (Li, Liu, & Zhang, 2011). According to the U.S. Environmental Protection Agency, the efficiency of a typical car decreases by 2% for each additional 100 pounds that is carried, so that there is an adverse total effect of perhaps $2.7 B/year for overweight due to obese motorists in the U.S. (Jacobson & McLay, 2006), with 39 million gallons of fuel being consumed annually for each added pound of average passenger weight. The actual increase of fuel consumption is amplified by the greater tendency of inactive and/or obese individuals to drive rather than to walk, particularly over short distances (Jacobson, King, & Yuam, 2011).

On the other hand, obese individuals have a lower risk of pelvic fractures if they are involved in major motor vehicle collisions; in one study, the odds ratio of such fractures for those who were overweight or obese was 0.56 relative to those with a normal BMI (Bansal, Conroy, & Lee, 2009). Moreover, this difference persisted after controlling for such co-variates as age, sex, side air-bag deployment, vehicle weight and seat belt use. In contrast, seat belts are less effective for obese rear-seat occupants, and during head-on crashes they are thrown forward more, and seem at greater risk of injury than passengers with a normal BMI (Reed, Ebert, & Hallman, 2013; Wang, Bai, & Caio, 2015). Probably because obese tissue acts as a buffer for alcohol, reducing blood levels for a given volume ingested, one report commented that alcohol-related vehicle incidents were less frequent in obese individuals than in their leaner peers (Dunn & Tefft, 2011).

Environmental consequences of obesity. A further very undesirable social consequence of population obesity is that the eating of more food, a greater gasoline consumption, and a greater generation of organic waste together translate into a greater per capita rate of greenhouse gas emissions (Michaelowa & Dransfield, 2006). One study estimated that if U.S. obesity levels could be reduced to levels seen in the year 2000, greenhouse gas emissions would be reduced by 2 % (Squalli, 2014; 2017).

Impact of obesity upon human capital

Obesity is associated with a lower self-esteem and a lower level of educational attainment (Geier, Foster, & Womble, 2007; Gortmaker, Must, & Perrin, 1993; Kaestner, Grossman, & Yarnoff, 2009; Sabia, 2007), with a resulting loss of human capital. In part because of adverse societal attitudes, those who are severely overweight are unlikely to realize their full potential contribution to society. Relative to their peers of normal weight, women who were obese at baseline were found to complete 0.3 fewer years of schooling; they were also less likely to be married, had lower household incomes, and were more likely to be living below the poverty line. Likewise, obese men had poorer school attendance records, more commonly dropped out of school, and were less likely to marry than their peers of normal weight.

Ethical issues concerning obesity

Choices regarding the allocation of public funds arise when addressing the health consequences of obesity, and some difficult ethical decisions become necessary (Muir-Gray, 1979). One immediate question is the basis for on which such decisions should be made. Can choices be based on some absolute scale of values, such as the Judaeo-Christian ethic, the Kantian moral imperative, or the golden rule, principles that underlie many world philosophies? Representative, democratic governments might be thought best qualified to make the necessary choices, but too often their decisions are short-term in nature, whereas obesity is a long-term issue. The actions of governments are biased by small pressure groups in marginal constituencies, and are also heavily influenced by upcoming electoral debates. Health professionals undoubtedly have the most appropriate expertise to make wise decisions, but too often they also succumb to vested interests in promoting particular solutions, to the benefit of their particular sub-specialty. Finally, there are the wishes expressed by the lay public, a group who are often ill-informed, and are extremely vulnerable to pressures from commercial advertising, well-organized lobbies and Twitter feeds.

Unlike other socially purchased commodities, communities have an interest in maintaining and/or restoring the health of their citizenry in the hope that this will increase the productivity of their labour force. Moreover, most people feel uncomfortable if they see people suffering from any form of ill-health (Drummond & Mooney, 1982). But on the other hand, how far should this empathy be tempered by a recognition of the personal responsibility of the person who has become obese? If someone has developed a painful arthritic knee joint in part because he or she has chosen to remain overweight rather than seek effective treatment, how much priority should a national health service give to finding the necessary funds and operating rooms associated with knee-joint replacement, when those same resources could be used to provide health care for other needy members of the community? Should the decision regarding access to sophisticated knee surgery be influenced by the patient's willingness to reduce his or her body mass, or is this a case of "blaming the victim?" And if funding for an operation is withheld because of continued obesity, is the further reduction of habitual physical activity that might be associated with a lack of joint replacement condemning the person concerned to a permanent and growing excess of body mass, with its attendant complications?

In addressing the many co-morbidities of obesity, what proportion of health care expenditures should be directed to aggressive attempts at the prevention of fat accumulation, and what proportion should be assigned to treatment after the inevitable complications of obesity have occurred? And can this question be decided simply on the basis of cost-benefit analyses?

In a more general sense, should the allocation of government resources be focused on maximizing productivity and thus the gross national product, or should the emphasis be placed upon maximizing the happiness of the individual citizen? If an economic analysis is attempted, what importance should be attached to a person's survival during the retirement years? Some consider a continuation of life and good health into the "golden years" as a priceless asset that cannot be measured simply in terms of fiscal return (Waaler & Hjort, 1982). Do we agree with Pope John Paul II on *"the principle of the priority of labour over capital... labour is always a primary efficient cause, while capital, the whole collection of the means of production, remains a mere instrument or instrumental cause"* (Pope John, 1981).

The fiscal demands of most national health services are consuming an ever larger fraction of gross national products. Is there a practical ceiling to the fraction of national wealth that can and should be spent on the treatment of chronic medical ailments? Can the just fulfilment of the individual citizen's hopes and ambitions indeed be achieved if government finances are not optimized by some prudent restriction of expenditures on medical services? And in assessing financial disbursements, is there not clear evidence that more money does not necessarily equate with better health? This point is well illustrated by the experience of a country such as Cuba, where a longer life expectancy than that of the United States has been achieved, despite respective 2015 per capita health care expenditures of $817 and $9403.

Discussion and conclusions

Individuals who have accumulated an excess of body fat impose upon society substantial additional direct and indirect medical costs relative to people with a normal body mass. Moreover, many components of this national economic burden increase exponentially from those individuals who are overweight to those with morbid obesity. However, the treatment of overweight, obesity and morbid obesity as a single entity has weakened most economic analyses.

Given the current prevalence of the various grades of obesity, the added expense due to an excessive accumulation of body fat accounts for 2-5% of total medical expenditures in most developed countries. Economic losses from indirect costs are difficult to estimate but are probably even larger. And in the U.S. (where obesity is more prevalent than elsewhere), 5-9% of direct medical costs are now attributable to obesity. The validity of current estimates is nevertheless weakened by the various technical issues discussed above and is further vulnerable to a substantial overlap with effects due to inadequate physical activity. Current research suggests that the 2 effects are of a similar order of magnitude, but this needs to be clarified by careful multivariate analyses, using precise and objective measures of habitual physical activity. Determination of the relative impact of obesity and inactivity is important, not least because it should influence the allocation of resources for both prevention and treatment.

In weighing their practical significance, it is helpful to relate the direct medical expenses of an obese person to those incurred by a person of an acceptable body mass. In the U.S., per capital medical costs are 9% (Tsai, Williamson, & Glick, 2011) greater for those who are overweight, and 30% (Withrow & Alter, 2010) or 43% (Tsai et al., 2011) greater for those who are obese. Further, the added costs escalate sharply as the degree of obesity increases. Arterburn estimated the increase in per capita costs at 10% for those who were overweight, and 23%, 45 % and 81% for those with classes I, II and III obesity (Arterburn et al., 2005).

In many countries the costs that are associated with obesity represent 2-5% of total medical expenditures. Although by no means a negligible fraction of health care budgets such figures must be viewed in the perspective that total costs in many countries are rising by 3-6% per year. In other words, even if one could eliminate all of the excess health care costs associated with obesity, this would do no more than cover the likely one-year escalation in overall medical expenditures. Further, although health economists would like to see more spent on prevention and less on the treatment of established obesity, the principal argument for concentrating upon prevention is not the likely economic gains, but rather the improved quality of life that would result for those who would otherwise be overweight and obese.

Table 14: Cost-effectiveness of various preventive interventions in terms of disability-adjusted life years saved, based on the analysis of Dobbs et al. (2014)

Location of intervention	Total DALY saved (thousands)	Costs per DALY saved (thousand dollars)
Schools	2.14	4.0
Government	1.88	2.6
Manufacturers	1.62	0.4
Health care	1.62	4.9
Restaurants	1.51	0.8
Retailers	1.04	0.5
Employers	1.03	3.1

Finally, the question arises as to the most effective use of available funds. The encouragement of an active lifestyle is an effective basis for prevention, but once obesity is well-established, it seems that the main focus must be upon addressing obesity through dieting and/or surgery, with an increase of physical activity serving mainly to prevent a recurrence of the problem. Dobbs et al. (2014) made one assessment of preventive options for the U.K., looking at the lifetime savings achieved through various intervention sites, and their unit costs in terms of disability-adjusted years of life saved (Table 14). In terms of population impact, school programmes appeared to have the greatest impact, but in terms of cost per year of life saved the most effective approach seemed to be the introduction of changes by manufacturers, restaurants and retailers designed to reduce over-eating.

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