BMI and Mortality: Results From a National Longitudinal Study of Canadian Adults

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Although a clear risk of mortality is associated with obesity, the risk of mortality associated with overweight is equivocal. The objective of this study is to estimate the relationship between BMI and all-cause mortality in a nationally representative sample of Canadian adults. A sample of 11,326 respondents aged ≥25 in the 1994/1995 National Population Health Survey (Canada) was studied using Cox proportional hazards models. A significant increased risk of mortality over the 12 years of follow-up was observed for underweight (BMI <18.5; relative risk (RR) = 1.73, $P < 0.001$) and obesity class II+ (BMI >35; RR = 1.36, $P < 0.05$). Overweight (BMI 25 to <30) was associated with a significantly decreased risk of death (RR = 0.83, $P < 0.05$). The RR was close to one for obesity class I (BMI 30–35; RR = 0.95, $P > 0.05$). Our results are similar to those from other recent studies, confirming that underweight and obesity class II+ are clear risk factors for mortality, and showing that when compared to the acceptable BMI category, overweight appears to be protective against mortality. Obesity class I was not associated with an increased risk of mortality.

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The World Health Organization (WHO) classifies ranges of BMI into categories which are meant to represent distinct levels of risk to health (1). Having a BMI in the categories of underweight (BMI <18.5 kg/m^2), overweight (BMI ≥25 kg/m^2), or obese (BMI ≥30 kg/m^2) is considered to be a risk factor for health problems and premature mortality, and Health Canada has adopted the WHO categories as national guidelines for body weight classification (2), while defining overweight as BMI 25 to <30 kg/m^2. We retain this definition throughout the rest of the paper.

Using the WHO definitions, the prevalence of overweight and obesity is rising in Western countries such as the United States, Canada, the United Kingdom, and Australia, and in countries in other world regions such as Brazil, China, and Israel (3). In Canada, the prevalence of obesity based on measured height and weight has almost doubled in the last two decades and now affects 23% of the adult population (4). Overweight and obesity are recognized as important and rapidly growing public health concerns. Obesity has been linked with type 2 diabetes, cardiovascular disease, hypertension, stroke, gallbladder disease, some forms of cancer, osteoarthritis, and psychosocial problems (5). However, although obesity has been clearly identified as a risk for premature mortality (6–11), the relationship between overweight and premature mortality is less clear.

Several recent studies have presented conflicting evidence as to whether overweight is a risk factor for mortality. Recently, Adams *et al.* reported that overweight at age 50 was associated with an increased risk of death among both women and men (7). Because of the study design of retrospective recall of body weight at age 50 among a group of individuals belonging to the American Association of Retired Persons, this study may be subject to effects of sampling bias, recall, and survivor effects. Similarly, analyses by Freedman *et al.* supported overweight as a risk factor for mortality, but only in women aged ≥55 (ref. 12). In this study, the lowest risk for death among older men was observed among those in the overweight category.

In an analysis of the National Health and Nutrition Examination Survey, Flegal *et al.* (6) found that there was no excess risk of death associated with the overweight or obesity class I categories, using measured BMI. Flegal *et al.* (13) confirmed these findings in a more recent analysis of cause-specific deaths. Their findings suggest that the overweight category might even have protective qualities. An analysis of within-category variation of mortality by Gronniger (14) indicated heterogenous risk within BMI categories, and a lowest risk of mortality for men at a BMI of 26 kg/m^2, and for women with BMI from 23 to 24 kg/m^2. Similarly Calle *et al.* (9) found that for subjects who had never smoked and who had no

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history of a chronic disease, the relative mortality risks were not elevated through a range of 22.0–26.4 in men and 20.5–24.9 in women. Finally, Janssen (10) found that within elderly populations, the overweight category may put individuals at an increased risk for illness, but is associated with lower mortality rates overall.

Fewer Canadian studies have been published; however, they also reflect conflicting results surrounding the overweight/mortality relationship. In a study of Canadians examining mortality risk and BMI, Katzmarzyk *et al.* (15) reported an increased but statistically nonsignificant risk of mortality associated with the overweight category. In a study of Canadian women, being in the overweight BMI category significantly increased the relative risk (RR) of death by about 30% as compared to those women with a BMI of 18.5–21.9 kg/m^2 (ref. 16).

In this paper, we use a longitudinal nationally representative population-health survey of Canadian adults to answer the following questions: Do Canadian data demonstrate an increased risk of all-cause mortality among the underweight, overweight, and obese? Is there heterogeneity in the risk of death within the WHO-defined categories?

PARTICIPANTS AND METHODS

We analyzed data from the National Population Health Survey, a longitudinal panel study conducted by Statistics Canada every 2 years from 1994/1995 onward (17). Data are available for follow-up to 2006/2007. The longitudinal panel selected for the first cycle in 1994/1995 consisted of 17,276 members of private households using a multistage stratified sample of dwellings with clusters of dwellings. One participant from each selected household was chosen to participate in the survey. The household response rate was 86%. Participants aged ≥25 in 1994/1995 were included in the present analyses (n = 12,455). In total, 109 women were excluded due to pregnancy in 1994/1995. After excluding participants with missing data on BMI, and a single remaining participant with missing data on smoking status, the final sample size was 11,834 persons. Missing data on physical activity frequency and alcohol consumption were coded as a response category in order to minimize the effect of missing data on sample size. Respondents who were reported as deceased were matched to the Canadian Deaths Database up to 31 December 2005. Subsequent deaths could not be confirmed; however, historically there has been very good concordance between reported deaths and confirmed deaths. Within the studied sample, 1,929 deaths were observed among the 115,225 person-years of follow-up.

Data and analytical techniques

Self-reported height and weight were used to calculate BMI in 1994/1995. Age, sex, self-reported smoking status, physical activity frequency, and alcohol consumption were included as covariates. Cox proportional hazards models were used to estimate RRs of death by BMI categories in SUDAAN (18). All the analyses were weighted using the longitudinal weights constructed to represent the total population of the ten Canadian provinces in 1994. Survey bootstrap weights were used in SUDAAN to generate confidence intervals while taking into account the complex sampling design and initial nonresponse.

Two analyses were conducted. The first analysis examined the RR of mortality based on the initial WHO category of BMI and adjusted for age, sex, smoking status, physical activity frequency, and alcohol consumption. Analyses were also conducted stratified by sex, age group (25–59 vs. 60+), and smoking status (ever vs. never smoker). Additionally, analyses were conducted excluding cases of death within the first 4 years in order to account for possible reverse causation, where pre-existing illness could lead to lower BMI and earlier mortality. The second set of analyses divided BMI into nine categories to explore further its association with mortality, using the most prevalent category as the reference group.

Because of well-documented reporting biases for self-reported height and weight, all analyses were also conducted using a correction factor developed by Statistics Canada based on analysis of self-reported and measured height and weight data (19). For men, BMI was recalculated as −1.08 + (1.08 × BMI). For women, it was recalculated as −0.12 + (1.05 × BMI).

Table 1 RRs of death by WHO BMI-categories, controlling for sociodemographics and selected health-related behaviors

	n	%	RR (95% confidence interval)
Sex			
Female[a]	6,461	51	1.00
Male	5,373	49	1.54 (1.35–1.75)
Age			
25–34[a]	2,799	25	1.00
35–44	2,681	26	2.20 (1.27–3.81)
45–54	2,072	19	6.71 (3.97–11.35)
55–64	1,621	13	18.72 (11.47–30.55)
65–74	1,556	11	44.35 (27.53–71.43)
75+	1,105	7	119.10 (72.57–195.46)
BMI level			
<18.5	286	2	1.73 (1.25–2.39)
18.5 to <25[a]	5,619	48	1.00
25 to <30	4,184	36	0.83 (0.72–0.96)
30 to <35	1,329	11	0.95 (0.77–1.18)
≥35	416	3	1.36 (1.00–1.85)
Smoking			
Daily	3,183	26	2.27 (1.85–2.78)
Occasional	495	4	1.61 (1.12–2.32)
Former	3,939	33	1.40 (1.22–1.62)
Never[a]	4,216	37	1.00
Physical activity			
Active	5,936	50	1.00
Moderately active	2,379	21	1.10 (0.92–1.31)
Inactive	3,056	25	1.43 (1.24–1.64)
Missing	463	5	1.63 (1.24–2.14)
Daily alcohol consumption			
Never	1,039	8	1.36 (1.08–1.70)
Former	1,786	13	1.28 (1.04–1.57)
<1 Portion daily	6,074	53	0.96 (0.81–1.15)
1–2 portions daily[a]	2,464	22	1.00
≥3 portions daily	419	4	1.31 (0.93–1.86)
Missing	52	<1	0.57 (0.16–2.01)

RR, relative risk; WHO, World Health Organization.
[a]Reference group.

Table 2 RRs of death by WHO BMI-categories, corrected BMI and stratified analyses, controlling for sociodemographic factors and health behaviors

	RR (95 % confidence interval)						
Category	Corrected BMI (*n* = 11,829)	Age 25–59 (*n* = 8,371)	Age 60+ (*n* = 3,458)	Males (*n* = 5,373)	Females (*n* = 6,456)	Ever smoked (*n* = 7,616)	Nonsmokers (*n* = 4,213)
<18.5	1.51 (0.99–2.30)	0.87 (0.20–3.85)	1.88 (1.32–2.68)	2.54 (1.47–4.37)	1.50 (1.01–2.22)	1.69 (1.10–2.60)	2.05 (1.32–3.18)
18.5 to <25[a]	1.00	1.00	1.00	1.00	1.00	1.00	1.00
25 to <30	0.75 (0.65–0.86)	0.91 (0.66–1.25)	0.81 (0.68–0.97)	0.86 (0.71–1.03)	0.77 (0.63–0.95)	0.82 (0.69–0.96)	0.76 (0.58–0.99)
30 to <35	0.84 (0.67–1.05)	0.89 (0.49–1.60)	0.96 (0.76–1.21)	1.10 (0.81–1.49)	0.81 (0.62–1.08)	0.94 (0.73–1.21)	0.83 (0.55–1.26)
≥35	1.09 (0.86–1.39)	1.53 (0.91–2.58)	1.25 (0.83–1.90)	1.72 (1.13–2.63)	1.09 (0.69–1.74)	1.21 (0.85–1.74)	1.68 (0.93–3.05)

RR, relative risk; WHO, World Health Organization.
[a]Reference group.

RESULTS

Due to the nature of the sample design, the participants of our study reflect the composition of the Canadian household population living in the 10 provinces. There were approximately equal numbers of men and women. More than half the sample was under the age of 45. Almost half of the sample fell within the acceptable BMI range, while half had excess weight. Close to 40% of the sample had never smoked, and half of the sample engaged in physical activity often enough to be considered active. Just over half of the sample reported drinking less than one portion of alcohol daily, while almost a quarter reported moderate consumption at one to two portions a day.

The first model (**Table 1**) showed a significantly increased risk of death for underweight RR = 1.73, 95% confidence interval (CI) 1.25–2.39) and for obesity class II+ (BMI ≥35, RR = 1.36, 95% CI 1.00–1.85). The RR was very close to one for obesity class I (BMI from 30 to <35, RR = 0.95, 95% CI 0.72–1.18), and was not significant. As compared to those in the normal weight category, overweight individuals had a lower risk of mortality (BMI from 25 to <30, RR = 0.83, 95% CI 0.72–0.96). The proportional hazards assumption was met.

Analyses stratified by sex, age, and smoking status yielded a similar pattern of results (**Table 2**), as did analyses excluding deaths in the first 4 years of follow-up and deaths due to external causes. The main deviation from the observed patterns of results was the effect of underweight by age. For the younger participants (aged 25–59), underweight was not associated with an increased risk of mortality. However, for older participants (aged 60+), being underweight was associated with a significantly increased risk of mortality (RR = 1.88 (1.32–2.68)). Underweight was a significant risk factor among men (RR = 2.54 (1.47–4.37)) and women (RR = 1.50 (1.01–2.22)). Obesity class II+ was a significant risk factor among men, but not among women, while overweight was significantly protective for women, but not men. Among both smokers and nonsmokers, underweight was associated with a significantly increased risk of mortality, while overweight was significantly protective. However, nonsignificant results should be interpreted cautiously because the reduced sample sizes may have decreased the power to detect effects. Analyses conducted using BMI adjusted by the correction factor yielded the same pattern of results, indicating that the results reported here appear to be robust. We also ran analyses controlling for income as an indicator of socioeconomic status and the results were not substantively different.

Table 3 presents the results with BMI divided into nine groups. The most prevalent BMI group (BMI from 22.5 to <25) accounted for 24% of the Canadian adult population and was used as the reference group. Overall, the results support the well-documented U-shaped association between BMI and mortality and show heterogeneity within the WHO-defined acceptable range category. The lowest risks were associated with individuals in the 27.5 to <30 and BMI 32.5 to <35 categories. However, these groups were not significantly different from the reference group, which is not surprising given the small numbers of individuals in each of these categories. The RR for the BMI category ranging from 32.5 to <35 was lower than anticipated but nonsignificant at 0.92 (95% CI 0.67–1.26). This result may be due to the small sample size for this group, which represented 3% of Canadians living in households aged ≥25.

DISCUSSION

We found that although the Canadian data demonstrated a significantly increased risk of mortality over 12 years of follow-up among individuals in the underweight and obesity class II+ categories, being overweight was associated with a significant protective effect as compared to those in the acceptable weight category. Obesity class I was not associated with a significantly increased risk of mortality. Further analyses demonstrated a U-shaped relationship between BMI and mortality when smaller increments of BMI were studied. As compared to the reference group of BMI from 22.5 to <25, several BMI categories in the range of ≥25 had lower (although not statistically significantly) RRs of 12-year mortality, indicating heterogeneity of risk within the acceptable and overweight categories.

Our findings are consistent with those of Flegal *et al.* who demonstrate in multiple studies that overweight does not appear to be a risk factor for mortality (6,13). Both the results of our study and those by Flegal *et al.* have good generalizability due to nationally representative samples. Even though there are differences in the methodology of the surveys, there is a tendency to obtain lower excess risk than had been found

Table 3 RRs of death by nine BMI categories adjusted for sociodemographics and selected health-related behaviors

	n	%	Adjusted RR (95 % confidence interval)
<18.5	286	2	1.89 (1.36–2.64)
18.5 to <20	627	6	1.23 (0.86–1.76)
20 to <22.5	2,142	18	1.18 (0.98–1.44)
22.5 to <25[a]	2,850	24	1.00
25 to <27.5	2,566	22	0.93 (0.77–1.12)
27.5 to <30	1,618	14	0.87 (0.69–1.10)
30 to <32.5	905	7	1.08 (0.80–1.45)
32.5 to <35	424	3	0.92 (0.67–1.26)
≥35	416	3	1.48 (1.06–2.06)

RR, relative risk.
[a]Reference group.

using clinical or cohort studies (6), and results from cohort studies with select populations such as nurses or members of a voluntary association may not be generalizable to the general population. Because of the limited number of control variables included in the present analyses, caution should be taken with respect to inferring causality. Further research documenting the mechanisms through which weight affects mortality would be useful. In fact, our inclusion of physical activity as a covariate may have attenuated effects, as physical inactivity not only contributes to excess weight, but is also associated with age and poor health, both risk factors for mortality. However, the coefficients related to BMI were only marginally different between models excluding and including physical activity. In order to address the potential for reverse causation, we conducted analyses excluding deaths occurring in the first 4 years of the study. The results were not significantly affected.

In addition to demonstrating that overweight was not associated with an increased risk of death, our study also suggests that there might have been a reduction in the impact of excess weight on mortality in Canada over recent years. RRs calculated by Katzmarzyk *et al.* through a 13-year mortality follow-up of the 1981 Canada Fitness Survey were: 1.6 for underweight, 1.2 for overweight, 1.3 for obesity class I (BMI of 30–35 kg/m^2), and 3.0 for obesity class II+ (BMI >35 kg/m^2) (ref. 15). The risk associated with underweight was lower than we found in our study, but the risks for overweight and obesity classes I and II were considerably higher than the risks observed in our study. This may be a result of differences in the age range studied. Our study includes individuals aged ≥25, while the study by Katzmarzyk *et al.* focused on Canadians age 20–69. Nevertheless, it would appear that the pattern observed by Flegal *et al.* in the United States of a reduction of the excess risk of mortality associated with obesity may also be occurring in Canada. The documented reduction in the United States of cardiovascular risk factors for all categories of BMI may explain part of this, although these findings would need to be replicated in Canada (20).

The analysis of the shape of the association between BMI and mortality raises an important question about which reference group to use for the calculation of excess deaths associated with excess weight. Using the acceptable BMI category as defined by the WHO will include individuals with higher risk of death than those in the overweight category. This may have a significant impact on the RR used in the calculation of excess deaths attributable to excess body weight. For example, the RR for obesity class II+ is estimated to be 1.36 when acceptable BMI is used as the reference category vs. 1.64 when the overweight BMI category (25 to <30) is used.

This study contributes new evidence from Canada to the debate surrounding the association between body weight and mortality risk. Strengths of this study include the representative sample of Canadians from a wide age range. A limitation of our study is that height and weight were self-reported for the 1994/1995 National Population Health Survey. It is well documented that respondents have a tendency to underestimate their weight and/or overestimate their height (4). However, self-reported height and weight are considered valid for identifying relationships in epidemiological studies (20), with self-reported values being strongly correlated with measured values (21,22). Our analyses using a correction factor developed by Statistics Canada showed the same pattern of results, thus we believe that our results are robust (19). As well, this study has a relatively short follow-up, at 12 years. It is possible that the pattern of results could change given a longer period of follow-up. There is also evidence that the distribution of fat matters; it is possible that the underlying relationships between weight and the risk of mortality cannot be identified adequately when relying on BMI alone (23,24). This study examined BMI at an initial point in time and related it to mortality over the subsequent 12 years, whereas others studies have shown that mid life BMI category is important for subsequent mortality in older cohorts (7).

Care should be taken before extrapolating results on mortality to morbidity. Overweight and obesity have been clearly associated with morbid conditions like heart disease, hypertension, and type 2 diabetes (5,10). The threshold for morbidity may differ from the threshold for mortality, indicating the need for the use of summary measures of population health that incorporate both mortality and morbidity consequences of excess weight. This is an important public health message, because while overweight may not be a risk factor for mortality, becoming overweight is a necessary step between being of acceptable weight and becoming obese. Other analyses using the National Population Health Survey data demonstrated that almost a quarter of Canadians who had been overweight in 1994/1995 had become obese by 2002/2003 (ref. 25) and Canadian adults within all BMI categories continue to gain weight (26). Because using acceptable weight as the reference category for estimating excess deaths due to excess weight is being questioned, more research is required to understand the association among BMI, morbidity, mortality, and the evolution of BMI over time. This goal can be accomplished by further in-depth analyses of existing longitudinal population-based data sets.

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DISCLOSURE

The authors declared no conflict of interest.

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