Published in final edited form as:

J Phys Act Health. 2014 September ; 11(7): 1265–1275. doi:10.1123/jpah.2012-0268.

Physical Activity Matters: Associations Among Body Mass Index, Physical Activity and Health-Related Quality of Life Trajectories Over 10 Years

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Abstract

Background—The objective of this study was to assess the associations among body mass index (BMI), leisure time physical activity (LTPA) and health-related quality of life (HRQL) trajectories among adults.

Methods—Self-reported data were drawn from the Canadian National Population Health Survey, with respondents being interviewed every two years between 1996/97 and 2006/07. Using growth curve modeling, HRQL trajectories for individuals aged 18 and over were associated with measures of BMI and LTPA. Growth models were constructed separately for males and females.

Results—Findings suggested that, for males, BMI categories had little impact on baseline HRQL, and no impact on the rate of change in HRQL. Among women, higher BMI categories were associated with significantly lower baseline HRQL. However, BMI had no impact on the rate of change of HRQL. Conversely, for both men and women and regardless of BMI category, LTPA had significant impacts on baseline HRQL, as well as the rate of change in HRQL. Individuals who were inactive or sedentary had much steeper declines in HRQL as they aged, as compared to individuals who were active in their leisure time.

Conclusions—The results underscore the importance of LTPA in shaping trajectories of HRQL.

Keywords

body mass index; health-related quality of life; growth curve modeling; longitudinal data; population health

Is obesity or a sedentary lifestyle the greater threat to health-related quality of life (HRQL) among aging adults? Given that prevalences of obesity and inactivity are both rising, improved understanding of their relative roles has important implications for public health (1). Because most developed countries are characterized by aging populations, investigations of these factors among older adults gain added importance.

In a 10-year cohort study, Orpana and colleagues estimated trajectories of HRQL by age for males and females ages 40 and older (2). HRQL starts to decline more rapidly for those in their 70s and the rate of decline accelerates for those in their 80s. Using data from the same cohort, Garner and colleagues examined the association between standard World Health Organization body mass index (BMI) categories and HRQL trajectories for males and females (3). For males, the trajectories for acceptable, overweight, obese class I, and obese classes II/III were very similar, while the underweight trajectory lay well below the others. For females, underweight individuals experienced the most favorable trajectory at ages below 60, but by their late 60s their trajectory becomes the least favorable. For non-underweight females, those of acceptable weight experienced the most favorable trajectory, followed by overweight, obese I, and obese II/III. Clearly, BMI is important to HRQL.

There is also evidence that physical activity (PA) is positively related to health status and HRQL (4–8). In cross-sectional analyses Sawatzky and colleagues, examining those age 65 and older in the Canadian Community Health Survey Cycle 1.1 (2000–2001), showed that PA partially mediates the effects of chronic conditions on HRQL (6). Similarly, in another study based on cross-sectional analyses, Herman and colleagues examined data from the Canadian Community Health Survey Cycle 3.1 (2005); their results showed that although both BMI and PA affect HRQL (measured by self-rated health), PA is the more important factor (8). In a systematic review of studies (1996 – 2005) on the general population ages 15 through 64, Bize and colleagues conclude that cross-sectional data showed a consistent positive association between PA and HRQL (9).

While BMI and physical activity are related to trajectories of HRQL in an aging population, there are complex relationships among these variables. For example, the effects of aging in general, and frailty in particular, may limit one's ability to engage in physical activity. Moreover, BMI may affect one's ability to engage in physical activity, or may also affect HRQL directly. Analogously, physical activity affects BMI, and could affect HRQL directly as well as through its effect on BMI.

The objective of the paper is to assess the associations among BMI, physical activity and HRQL trajectories in aging adults. It is hypothesized that each variable will be important (main effects that are statistically significant and quantitatively important) in explaining trajectory variations. It is further hypothesized that interactions between BMI and physical activity will be important. For instance, being physically active may have a different impact on HRQL for obese class I than it does for someone with acceptable weight. In addition, it is hypothesized that interactions between age and BMI will be important, as has been shown in previous work (3). An interaction between age and physical activity is also hypothesized, that is, engaging in physical activity may ameliorate some of the effects of aging. Data from

Statistics Canada's National Population Health Survey, cycles 2 (1996/97) through 7 (2006/07), will be used to test these hypotheses.

METHODS

Data were drawn from the Canadian National Population Health Survey (NPHS), a longitudinal survey of the health of the Canadian population (10). The NPHS, conducted by Statistics Canada, started in 1994/95 and interviews occurred every two years until the final cycle in 2010/2011. Due to changes in collection methods (primarily in-person in 1994/95, primarily by telephone since 1996/97) which may influence the accuracy of responses, particularly self-reported weight and height (11, 12), the current study uses data starting with NPHS cycle 2 (1996/97). At the time of this study, data were available through cycle 7 (2006/07). The current study was limited to longitudinal respondents who were alive and age 18 or older in 1996/97. Further information on the NPHS is found in (13).

Measures

Health-Related Quality of Life (HRQL)—The outcome measure used in the study is HRQL. Patrick and Erickson (14) (p 22) provide a definition: "Health-related quality of life is the value assigned to duration of life as modified by the impairments, functional states, perceptions, and social opportunities that are influenced by disease, injury, treatment, or policy."

Health Utilities Index Mark 3—In the study, the concept of HRQL was operationalized using the Health Utilities Index Mark 3 (HUI3), a measure of health status and HRQL that describes individuals' functional status in vision, hearing, speech, ambulation, dexterity, emotion, cognition and pain and discomfort. There are five or six levels for each attribute, ranging from no disability to severe disability. Overall HUI3 scores are derived from a multiplicative multi-attribute utility function based on preference scores obtained from a random sample of the Canadian population (15), yielding a scale in which dead=0.00 and perfect health=1.00: scores below zero represent health states considered worse than dead. A change of 0.03 or more in HUI3 is considered to be clinically meaningful (16–17). There is extensive evidence of the construct validity of the HUI3 in population health applications (2, 18–25).

In the NPHS, HUI3 items were self-reported at every cycle. Individuals in the sample who died during follow-up were assigned a value of zero for the first cycle following their death, and were not assigned an HUI3 value for subsequent cycles.

Body Mass Index (BMI)—BMI is defined as an individual's weight in kilograms divided by their height in meters squared. In the NPHS, height and weight are self-reported. Women pregnant at the time of interview were not assigned a BMI score.

Using standards set by the World Health Organization (26) (p 9) and Health Canada (27) (p 3), continuous BMI scores were categorized into 5 groups: underweight (BMI<18.5); acceptable weight (18.5, < 25); overweight (25, <30); obese class I (30, <35); and obese classes II and III (> 35). BMI Classes II and III were combined because of their low

prevalence. In all analyses, individuals of acceptable weight formed the reference group. For individuals who died during follow-up, BMI at their final observation was set to be equal to their BMI at their last interview.

In the process of data cleaning, the following criteria were used to set certain BMI values, deemed as implausible, to missing: (i) all BMI values based on self-reported weights less than 28 kg (n=9 observations, only 1 observation per individual); (ii) all BMI values based on self-reported weights greater than 135 kg, and where this weight was the only one above this threshold in the respondent's series of observations (n=53).

Leisure time physical activity (LTPA)—Respondents reported whether and how often they engaged in a variety of non-work-related physical activities. The energy expenditure of participants in their leisure activities, measured in kilocalories per kilogram of body weight per day (kcal/kg/day), was estimated by calculating the frequency and time per session of physical activity as well as its metabolic energy demand (MET value) based on standards published by the Canadian Fitness and Lifestyle Research Institute (28). Because the NPHS did not ask respondents to specify the intensity level of their activities, the MET values adopted correspond to the low intensity value of each activity, an approach adopted from the Canadian Fitness and Lifestyle Research Institute.

Based on their average daily energy expenditure in LTPAs, individuals were classified as: (i) active (3 or more kcal/kg/day), (ii) moderately active (1.5 to less than 3 kcal/kg/day), (iii) inactive (less than 1.5 kcal/kg/day), or (iv) sedentary (0 kcal/kg/day). These four categories were used in a number of previous studies that employed data on LTPA collected by Statistics Canada (5–7). For individuals who died during follow-up, LTPA at their final observation was set to be equal to their LTPA at their last interview.

Age—Age at interview was centered at 48, the grand mean of retained observations (mean=48.33, standard error=0.12). For individuals who died, their age at their final observation point was set to their age at death. If date of death was not available, age at death was set to two years greater than their age at last interview.

Statistical analysis

Measures of BMI and LTPA were used to model trajectories of HUI3 scores. To account for non-independence of repeated measures, multilevel growth curve modeling was utilized. This technique allowed for the examination of both intra- and inter-individual differences in change in HUI3 over age. In these analyses, BMI and LTPA categories were used as time-varying covariates.

Previous work has shown that normative HUI3 trajectories differ for men and women (2), therefore models were run separately by gender. A two-level model was structured with time (level 1) being nested within individuals (level 2). HUI3 was modeled over age (centered at 48), and linear, quadratic and cubic rates of change in HUI3 were examined for statistical significance and improvement to model fit (as measured by change in $-2 \log$ likelihood). In models for both men and women, a cubic pattern was found to fit the data best (data not shown).

In addition to the effects of age, seven blocks of predictors were examined in the growth curve models: (i) BMI categories (overweight, obesity class I, obesity class II/III; acceptable weight is reference group); (ii) LTPA categories (moderately active, inactive, sedentary; active is reference group); (iii) BMI by LTPA interactions; (iv) BMI by linear age interactions; (v) BMI by quadratic age interactions; (vi) BMI by cubic age interactions; and (vii) LTPA by linear age interactions. The decision to include a block of parameters in the final model was based on change in model fit and the statistical significance of parameters within a block. If inclusion of the block of parameters did not significantly improve model fit, or if none of the estimates within the block was statistically significant, the entire block was removed. The exception was that, if a block of parameters was included in one of the final sex-specific models, it was retained for the other sex as well.

Intercept and linear age terms were allowed to vary randomly in both sex-specific models; all other terms were fixed. Models were weighted using the sampling weights applied to the upper level of the model. Due to software limitations (MIWin version 2.1), variance estimates were not adjusted for the complex sampling design of the survey.

Due to the highly skewed nature of the distribution of HUI3 scores, adjustment and transformation of the outcome measure was necessary to achieve normally distributed residuals. Following the work of Bernier, Feng and Asakawa, HUI3 was first linearly transformed so that the adjusted HUI3 scores were bounded by -1 and $+1$ and then transformed using the arcsine function (29).

Preliminary model building for trajectories of HRQL and subsequent sample selection—In preliminary models, inclusion of observations in the underweight BMI category was found to result in poor predictive ability. In both models, particularly the female model, the difference between predicted and observed HUI3 values for the underweight category was especially large at older ages. None of the interaction terms resolved this discrepancy. It was decided, therefore, to exclude all underweight observations ($n=1,155$, 1.78% of observations) from the model.

Furthermore, when observations with missing BMI or LTPA were included in the model (through the use of dummy variables), many of the parameter blocks entered into the model were retained only due to significant parameters for the missing categories. Because observations with missing values, particularly on the BMI measure, were deemed to be heterogeneous, and therefore not easily interpreted, it was decided to exclude all incomplete observations ($n=3,254$ missing BMI, 4.17% of observations; $n=3,207$ missing LTPA, 4.61% of observations) from the models. After these exclusions, the final sample ($n=59,817$) consisted of those observations that had: (i) a valid HUI3 score, (ii) a non-missing value for age, (iii) a non-missing value for the measure of LTPA, and (iv) a non-missing, non-underweight value for the measure of BMI. A comparison of retained and omitted observations is given in the Web Appendix, which is available online.

The study was approved by the Institutional Review Board of Kaiser Permanente Northwest Region.

RESULTS

Of the 13,198 individuals aged 18 and older in the longitudinal cohort, approximately half (49.2%) were male. During follow-up, 1.6% of respondents were institutionalized and 8.9% of respondents died (Table 1). Women were significantly more likely than men to be institutionalized (2.2% versus 1.0%), significantly less likely to die during follow-up (7.8% versus 10.1%) and, for those who died, significantly older at death (76.1 years versus 72.0 years). On average there were five cycles per respondent (mean 4.92, sd = 1.48); 54.7% had six cycles; 16.0% had five; 10.1% had four; 8.7% had three; 7.0% had two; and 3.6% had only one cycle.

Men were significantly more likely to be classified as overweight at baseline, whereas women were significantly more likely to be classified as acceptable weight (Table 2). Furthermore, men were significantly more likely than women to be classified as active (19.9% versus 15.2%) whereas women were significantly more likely than men to be classified as inactive (47.4% versus 42.0%); the proportion of respondents classified as moderately active or sedentary were similar for men and women (Table 2).

Table 3 shows the distribution of BMI and LTPA categories across age groups for men and women. Among men, half (51.4%) of observations in the youngest age group (18 to 29) were in the acceptable weight category: this percentage dropped to 26.1% of observations among men in their fifties. Thereafter, the proportion of men in the acceptable weight category increased with age, until men were in their eighties when more than half of the observations (54.7%) were again in the acceptable weight category. Concomitantly, the proportion classified as overweight increased into men's late forties, with the proportion of observations in the overweight category remaining stable at approximately half thereafter until men were in their eighties. The proportion of observations classified as obese class I was stable among men from their thirties through their sixties. Finally, the proportion classified as obese class II/III increased for men starting in their thirties, becoming stable in their forties through sixties.

Among women, 73% of observations in the youngest age group (18 to 29) were of acceptable weight: this proportion decreased with age, to its lowest among women in their sixties (38.2%). Thereafter, the proportion of acceptable weight observations increased with age, until women were in their eighties when 55% were again in the acceptable weight category. Conversely, the proportion classified as overweight increased steadily into women's fifties (36.3%), and remained stable until women's late seventies, and then started to drop for women as they entered their eighties. Unlike men, the proportion of women's observations that were classified as obese class I increased with age, until its high point for women in their sixties and seventies.

Leisure time physical activity categories seemed more stable across age than BMI categories. The proportion of observations in the moderately active category remained stable for men up until their eighties, when the proportion dropped slightly: this drop occurred a decade earlier for women (Table 3). The proportion of observations in the sedentary category slowly increased with age among both men and women, with 6.9% and 6.0%

(respectively) of observations among 18 to 29-year-olds being classified as sedentary, to a high of 27.5% and 31.9% (respectively) of observations among those aged 80 and up falling into this category.

Growth curve results

Coefficients from the final models of HRQL are given in Table 4. However, due to the adjustment and transformation of the outcome measure, coefficients cannot be interpreted directly as changes in HUI3. Therefore, predicted values from the final models were back-transformed and graphed: these are shown in Figures 1 (males) and 2 (females).

Among men, BMI had little impact on baseline HRQL: only men in obese classes II/III differed from men of acceptable weight at age 48 (Table 4). Baseline HRQL was similar for men who were active and moderately active: men who were inactive or sedentary had significantly lower baseline HRQL than men who were active in their leisure time. The impact of physical activity on baseline HRQL also did not differ dramatically by BMI category: the only LTPA by BMI interaction term that was statistically significant was between sedentary LTPA and obese class I.

The association between HRQL and age (linear) differed across LTPA groups for men. Relative to those in the active group, those who were moderately active, inactive or sedentary saw greater decreases in HRQL as they aged. There was no interaction between BMI category and age in the final model.

Among women, BMI had a significant impact on baseline HRQL. Compared to women of acceptable weight, women who were overweight or obese had significantly lower HRQL at age 48 (Table 4). Baseline HRQL was similar for active and moderately active women, whereas baseline HRQL was significantly lower for women who were inactive or sedentary in their leisure time. The impact of LTPA on baseline HRQL did not differ by BMI category.

The association between HRQL and age (linear) differed across LTPA groups for women. Active and moderately active women shared similar decrements in their HRQL as they aged. However, relative to physically active women, women who were inactive or sedentary saw a more rapid decrease in HRQL as they aged.

Examining the Figures helps to clarify what is happening in the growth curve models. Among men, all groups cluster together at younger ages. Within LTPA categories, there is little to no difference across BMI categories, although obese class II/III men always have lower HRQL than men of acceptable weight (Figure 1). Starting in their late forties or early fifties, men who follow a path of sedentary activity see a much steeper decline in HRQL as compared to men in other LTPA categories (Figure 1). Even if they are of acceptable weight, if men continue to be sedentary rather than active in their leisure time, by the time they are 52, their HUI3 score is 0.03 points lower than men of similar BMI who are physically active, a clinically meaningful drop in HRQL (Web Figure 1). This gap continues to grow for men who continue to be sedentary into older age.

The story is similar among women, with most groups clustering together at younger ages. The exceptions are obese class II/III women who are sedentary in their leisure time. These women, even at age 18, have HUI3 scores that are 0.03 points lower than women who are active and of acceptable weight (Web Figure 2). Starting in their late fifties or early sixties, women who are sedentary in their leisure time start to see a much steeper decline in HRQL as compared to women in the other LTPA categories (Figure 2).

DISCUSSION

As previous research has shown (3, 30), the association between BMI and HRQL trajectories differs for males and females. Recalling that underweight observations were excluded from the dataset, the results indicate that, for males, HRQL trajectories do not differ greatly by BMI categories. In contrast, for females, BMI categories above acceptable weight exert significant HRQL penalties. Conversely, there were similarities between men and women with respect to some of the associations between HRQL and LTPA. For both males and females, HRQL trajectories are significantly more favorable for the active and moderately active.

Moreover, our results underscore the importance of physical activity in shaping HRQL trajectories. For both males and females, the interaction terms between age and being inactive or sedentary are significant: for males, the interaction term between age and being moderately active is also significant. These results indicate that being active “delays” the effects of aging on HRQL and that being inactive or sedentary accelerates the rate of decline. That the curves for being sedentary cross the curves for the other categories of activity illustrates these results. Those who are sedentary decline more rapidly for all BMI categories. The noteworthy age-sedentary interaction may also reflect frailty.

This study is one of the few that examines the associations among trajectories of HRQL, PA, and BMI in a nationally representative sample of a community-dwelling population. In cross-sectional analyses based on data from the US National Physical Activity and Weight Loss Study, Kruger and colleagues reported results similar to those reported in this paper, namely that levels of PA were significantly associated with HRQL (assessed by self-rated health) regardless of BMI status (4). In a cohort study based on the Whitehall II project, Sabia and colleagues (31) showed that baseline PA, controlling for a wide range of covariates, is predictive of survival and successful aging (absence of major chronic diseases and disability, good mental health, and maintenance of function).

Results from a number of clinical studies also highlight the important association between PA and HRQL. Using data from a large cohort of survivors of colorectal cancer in the Netherlands, Buffart and colleagues (32) reported results from cross-sectional analyses showing that moderate-to-vigorous physical activity was positively associated with physical HRQL as assessed by the Short-Form 36 (SF-36). Similarly, Paxton and colleagues showed that women who met current US guidelines for PA had higher physical HRQL and vitality (assessed by the SF-36) in a large and diverse cohort study of breast cancer survivors (33). Studies showing a positive association between PA and HRQL are not confined to cancer. In

cross-sectional analyses of data collected from German patients with type-2 diabetes, Eckert reports that physically active patients had higher HRQL as assessed by SF-36 (34).

Viewed in a life course perspective, these findings on trajectories of HRQL have substantial public health relevance. Health behaviors, particularly engaging in physical activity, are acquired early in life (35–38), although there are notable exceptions to this generalization. Some change their lifestyle in response to health events, for instance, taking up exercise after experiencing a myocardial infarction (39, 40). However, the association between the onset of chronic conditions and an increase in LTPA is at best weak (41). In some cases, recently retired persons initiate routine exercise programs. Nonetheless, the foundations for health behaviors in general, and exercise behavior in particular, are in place by early adulthood. There are several implications. One is the importance of the built environment, pedestrian and cycling friendly environments, and public transit to provide opportunities for engaging in physical activity both for recreation and commuting (42–45). Another is the inclusion of physical education in kindergarten through high school programs, perhaps with an emphasis on physical education programs that teach activities and skills promoting life-long participation and activity, rather than achieving competitive excellence. Further, perhaps there needs to be an emphasis on community recreation programs and helping families to promote physically active lifestyles (38, 44).

There are also implications for clinical practice. At the risk of over-burdening primary-care clinicians, it may be important for them to ask how physically active their patients are and to provide counseling to equip patients with the tools needed to engage in a sustained program of regular physical activity. Further, counseling by physical activity counselors can enhance the effectiveness of strategies to promote behavior change (46). For both men and women, it seems more important that individuals remain active in their leisure time as they age, and less important that they lose weight.

An important issue is the possibility of reverse causality or, more generally, the issue of bi-directionality in the relationship between LTPA and HRQL. Those who experience a decline in health status associated with aging or the onset or worsening of one or more chronic conditions may as a consequence reduce their LTPA. This possibility is particularly salient for those who develop problems with mobility, chronic pain, or fatigue.

Results from a cross-sectional analysis of data for respondents 50 years of age or older from the 2009 Behavioral Risk Factor Surveillance System provides some insight into this issue. Thompson and colleagues (47) found a stronger relationship between LTPA and HRQL for those who reported functional limitations than for those who did not report functional limitations. Surrogate measures were used as an indicator of HRQL: the number of days in the past 30 days during which physical health (or mental health) was not good. The analyses controlled for an array of potential confounders. The stronger relationship for those with functional limitations could be evidence that declines in health status lead to reductions in LTPA. Nonetheless, even for those who reported no functional limitations, there was a quantitatively important and statistically significant relationship between LTPA and HRQL.

Hoogeboom and colleagues (48) in a longitudinal study of patients with knee osteoarthritis provide additional relevant evidence. In the Osteoarthritis Initiative study data on health status and HRQL were collected at baseline and at annual follow up interviews for each of four years. The cohort included those who reported and did not report joint pain comorbidity (JPC). The frequency of JPC, including never, was systematically associated with HRQL as assessed using a condition-specific measure. However, in longitudinal analyses JPC was not associated with the level of physical activity.

Results from the longitudinal NPHS reported in this paper undoubtedly reflect both lower LTPA leading to deterioration in HRQL and declines in health status leading to reductions in LTPA. Sorting out the relative importance of each of these mechanisms is an important topic for the research agenda.

There are several limitations to the study. First, the underweight were excluded. Therefore the results do not generalize to the underweight. Given the low prevalence of the underweight, this exclusion is not a major limitation in population studies. However, this omission could limit generalization to clinical investigations focused on patient groups with relatively high prevalence of underweight persons. Second, height, weight, and physical activity were self-reported. However, self-reported and measured weight and height are highly correlated (49, 50). Further, even if LTPA is over-reported, weight is under-reported, and height is over-reported, as long as the degree of misreporting is roughly constant over time, the estimated trajectories should be valid. Third, model fitting required deletion of some observations. Fourth, only leisure-time physical activity was considered, therefore overall physical activity levels may be underestimated for those with physically demanding work activities. Fifth, health determinants other than BMI, physical activity, and age were omitted from the already complex models. Sixth, participants were, of course, not followed individually from age 18 through age 88. Rather, growth curve models were used in a “cohort-sequential” or “accelerated design” analysis (51). This approach takes advantage of variation in participants’ ages at baseline to provide a picture of change across the lifespan. Seventh, as noted, these complicated models did not include lagged predictors. Finally, no adjustments were made for the complex survey design, which may have led to underestimated standard errors.

These limitations notwithstanding and even though the results are based on self-reported data, this study is one of the few nationally-representative projects to follow individuals through much of adult life. Participant retention rates and data completeness were both substantial. The dependent variable is a well-studied and widely used indicator of health-related quality of life. Building on these strengths, the study emphasizes the importance of physical activity.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

The authors acknowledge the contributions of Jillian Oderkirk and Kathy Easter to the research reported here. An earlier version of the paper was presented at a seminar in the Department of Economics of Indiana University Purdue University Indianapolis on April 25, 2012; the authors acknowledge helpful comments provided by members of the audience. The authors also acknowledge the constructive comments provided by two anonymous reviewers.

Funding

This work was supported by National Institutes of Health grants AG027129 from the National Institute on Aging and DK080277 from the National Institute of Diabetes and Digestive and Kidney Diseases.

Reference List

1. Shields M, Tremblay MS. Sedentary behaviour and obesity. *Health Rep.* 2008; 19:19–30. [PubMed: 18642516]
2. Orpana HM, Ross N, Feeny D, et al. The natural history of health-related quality of life: A 10-year cohort study. *Health Rep.* 2009; 20:1–7.
3. Garner RE, Feeny DH, Thompson A, et al. Bodyweight, gender, and quality of life: a population-based longitudinal study. *Qual Life Res.* 2012; 21:813–825.10.1007/s11136-011-9989-1 [PubMed: 21842378]
4. Kruger J, Bowles HR, Jones DA, et al. Health-related quality of life, BMI and physical activity among US adults (18 years): National Physical Activity and Weight Loss Survey, 2002. *Int J Obes (Lond).* 2007; 31:321–7. [PubMed: 16703001]
5. Probert AW, Tremblay MS, Gorber SC. Desk potatoes: the importance of occupational physical activity on health. *Can J Public Health.* 2008; 99:311–8. [PubMed: 18767278]
6. Sawatzky R, Liu-Ambrose T, Miller WC, et al. Physical activity as a mediator of the impact of chronic conditions on quality of life in older adults. *Health Qual Life Outcomes.* 2007; 5:68.10.1186/1477-7525-5-68 [PubMed: 18093310]
7. Zhang X, Geiss LS, Caspersen CJ, et al. Physical activity levels and differences in the prevalence of diabetes between the United States and Canada. *Prev Med.* 2010; 50:241–5. [PubMed: 20211199]
8. Herman KM, Hopman WM, Vandenkerkhof EG, Rosenberg MW. Physical activity, Body Mass Index, and health-related quality of life in Canadian adults. *Med Sci Sports Exerc.* 2012; 44:625–636. [PubMed: 21971297]
9. Bize R, Johnson JA, Plotnikoff RC. Physical activity level and health-related quality of life in the general adult population: A systematic review. *Prev Med.* 2007; 45:401–415. [PubMed: 17707498]
10. Tambay JL, Catlin G. Sample design of the National Population Health Survey. *Health Rep.* 1995; 7:29–42. [PubMed: 7578995]
11. Ezzati M, Martin H, Skjold S, et al. Trends in national and state-level obesity in the USA after correction for self-report bias: Analysis of health surveys. *J R Soc Med.* 2006; 99:250–7. [PubMed: 16672759]
12. St-Pierre, M.; Béland, Y. Mode effects in the Canadian Community Health Survey: A comparison of CAPI and CATI. Presented at American Statistical Association Meeting, Survey Research Methods Section; Toronto, Canada. August 2004;
13. Statistic Canada. National Population Health Survey: Household Component Cycles 1 to 9 (1994/1995 to 2010/2011) Longitudinal Documentation. Ottawa: Statistics Canada; 2012.
14. Patrick, DL.; Erickson, P. Health Status and Health Policy: Quality of Life in Health Care Evaluation and Resource Allocation. New York: Oxford University Press; 1993.
15. Feeny DH, Furlong W, Torrance GW, et al. Multi-attribute and single-attribute utility functions for the health utilities index mark 3 system. *Med Care.* 2002; 40:113–28. [PubMed: 11802084]
16. Drummond M. Introducing economic and quality of life measurements into clinical studies. *Ann Med.* 2001; 33:344–9. [PubMed: 11491193]

17. Grootendorst P, Feeny D, Furlong W. Health Utilities Index Mark 3: evidence of construct validity for stroke and arthritis in a population health survey. *Med Care*. 2000; 38:290–9. [PubMed: 10718354]
18. Horsman J, Furlong W, Feeny D, et al. The Health Utilities Index (HUI®): concepts, measurement properties and applications. *Health Qual Life Outcomes*. 2003; 1(1):54.10.1186/1477-7525-1-54 [PubMed: 14613568]
19. Asakawa K, Rolfson D, Senthilselvan A, et al. Health Utilities Index Mark 3 showed valid in Alzheimer Disease, arthritis, and cataracts. *J Clin Epidemiol*. 2008; 61:733–9. [PubMed: 18359192]
20. Asakawa K, Feeny D, Senthilselvan A, et al. Do the determinants of health differ between people living in the community and in institutions? *Soc Sci Med*. 2009; 69(3):345–53. [PubMed: 19527920]
21. Feeny D, Huguette N, McFarland BH, et al. The construct validity of the Health Utilities Index Mark 3 in assessing mental health in population health surveys. *Qual Life Res*. 2009; 18:519–26. [PubMed: 19277898]
22. Garster NC, Palta M, Sweitzer NK, et al. Measuring health-related quality of life in population-based studies of coronary heart disease: comparing six generic indexes and a disease-specific proxy score. *Qual Life Res*. 2009; 18:1239–47. [PubMed: 19760103]
23. Kaplan MS, Berthelot JM, Feeny DH, et al. The predictive validity of two measures of health-related quality of life: Mortality in a longitudinal population-based study. *Qual Life Res*. 2007; 16:1539–46. [PubMed: 17899447]
24. Maddigan SL, Feeny DH, Majumdar SR, et al. Health Utilities Index mark 3 demonstrated construct validity in a population-based sample with type 2 diabetes. *J Clin Epidemiol*. 2006; 59:472–7. [PubMed: 16632135]
25. Maddigan SL, Feeny DH, Majumdar SR, et al. Understanding the determinants of health for people with type 2 diabetes. *Am J Public Health*. 2006; 96:1649–55. [PubMed: 16873750]
26. World Health Organization. Obesity: Preventing and Managing the Global Epidemic WHO Technical Report Series 894. Geneva: World Health Organization; 2000. http://libdoc.who.int/trs/WHO_TRS_894.pdf; accessed December 13, 2012
27. Health Canada. Canadian Guidelines for Body Weight Classification in Adults. Ottawa: Health Canada; 2003. <http://www.hc-sc.gc.ca/fn-an/nutrition/weights-poids/guide-ld-adult/index-eng.php>; accessed December 13, 2012
28. Canadian Fitness and Lifestyle Research Institute. <http://www.cflri.ca/> accessed December 13, 2012
29. Bernier J, Feng Y, Asakawa K. Strategies for handling normality assumptions in multilevel modeling: A case study estimating trajectories of Health Utilities Index Mark 3 scores. *Health Rep*. 2011; 22:1–7.
30. Hopman WM, Berger C, Joseph L, et al. The association between body mass index and health-related quality of life: data from CaMos, a stratified population study. *Qual Life Res*. 2007; 16:1595–603. [PubMed: 17957495]
31. Sabia S, Singh-Manoux A, Hagger-Johnson G, Cambois E, Brunner EJ, Kivimaki M. Influence of individual and combined healthy behaviours on successful aging. *CMAJ*. 2012; 184:1985–1991. [PubMed: 23091184]
32. Buffart LM, Thong MSY, Schep G, Chinapaw MJM, Brug J, van de Poll-Franse LV. Self-reported physical activity: Its correlates and relationship with health-related quality of life in a large cohort of colorectal cancer survivors. *PLoS One*. 7:e36164. [PubMed: 22567135]
33. Paxton RJ, Phillips KL, Jones LA, Chang S, Taylor WC, Courneya KS, Pierce JP. Associations among physical activity, Body Mass Index, and health-related quality of life by race/ethnicity in a diverse sample of breast cancer survivors. *Cancer*. 118:4024–4031. [PubMed: 22252966]
34. Eckert K. Impact of physical activity and bodyweight on health-related quality of life in people with type 2 diabetes. *Diabetes Metab Syndr Obes*. 5:303–311. [PubMed: 22952412]
35. Fortier MD, Katzmarzyk PT, Malina RM, et al. Seven-year stability of physical activity and musculoskeletal fitness in the Canadian population. *Med Sci Sports Exerc*. 2001; 33:1905–11. [PubMed: 11689742]

36. Kuh DJ, Cooper C. Physical activity at 36 years: patterns and childhood predictors in a longitudinal study. *J Epidemiol Community Health*. 1992; 46:114–9. [PubMed: 1583424]
37. Telama R. Tracking of physical activity from childhood to adulthood: a review. *Obes Facts*. 2009; 2:187–95. [PubMed: 20054224]
38. Gustafson S, Rhodes R. Parental correlates of physical activity in children and early adolescents. *Sports Med*. 2006; 36:79–97. [PubMed: 16445312]
39. Hillers TK, Guyatt GH, Oldridge N, et al. Quality of life after myocardial infarction. *J Clin Epidemiol*. 1994; 47:1287–96. [PubMed: 7722565]
40. Oldridge N, Guyatt G, Jones N, et al. Effects on quality of life with comprehensive rehabilitation after acute myocardial infarction. *Am J Cardiol*. 1991; 67:1084–9. [PubMed: 2024598]
41. Ramage-Morin PL, Bernier J, Newsom JT, Huguet N, McFarland BH, Kaplan MS. Adopting leisure-time physical activity after diagnosis of a vascular condition. *Health Rep*. 2012; 23:17–29. [PubMed: 22590802]
42. Ross NA, Tremblay S, Graham K. Neighbourhood influences on health in Montreal, Canada. *Soc Sci Med*. 2004; 59:1485–94. [PubMed: 15246176]
43. Ross NA, Tremblay S, Khan S, et al. Body mass index in Urban Canada: Neighbourhood and metropolitan area effects. *Am J Public Health*. 2007; 97:500–8. [PubMed: 17267734]
44. Sallis J, Prochaska J, Taylor W. A review of correlates of physical activity of children and adolescents. *Med Sci Sports Exerc*. 2000; 32:963–75. [PubMed: 10795788]
45. Sallis J, Bowles H, Bauman A, et al. Neighborhood environments and physical activity among adults in 11 countries. *Am J Prev Med*. 2009; 36:484–90. [PubMed: 19460656]
46. Fortier M, Tulloch H, Hogg W. A good fit: Integrating physical activity counselors into family practice. *Can Fam Physician*. 2006; 52:942–4. 947–9. [PubMed: 17273491]
47. Thompson WW, Zack MM, Krahn GL, Andresen EM, Barlie JP. Health-Related Quality of Life Among Older Adults With and Without Functional Limitations. *Am J Public Health*. 2012; 102:496–502. [PubMed: 22390514]
48. Hoogeboom TJ, den Broeder AA, de Bei RA, van den Ende CHM. Longitudinal impact of joint point comorbidity on quality of life and activity levels in knee osteoarthritis: data from the Osteoarthritis Initiative. *Rheumatol*. 2013; 52:543–546.
49. Spencer EA, Appleby PN, Davey GK, Key TJ. Validity of self-reported height and weight in 4808 EPIC-Oxford participants. *Public Health Nutr*. 2002; 5:561–555. [PubMed: 12186665]
50. Stevens J, Keil JE, Wald LR, Gazes PC. Accuracy of current, 4-year, and 28-year self-reported body weight in an elderly population. *Am J Epidemiol*. 1990; 132:1156–1163. [PubMed: 2260547]
51. Duncan, TL.; Duncan, SC.; Stryker, LA. An Introduction to Latent Variable Growth Curve Modeling. 2. Mahwah, New Jersey: Lawrence Erlbaum Associates; 2006.

Figure 1.

Health-related quality of life trajectories by Body Mass Index and Leisure Time Physical Activity categories for males, Canada, 1996–2007

Figure 2.

Health-related quality of life trajectories by Body Mass Index and Leisure Time Physical Activity categories for females, Canada, 1996–2007

Table 1

Description of Retained and Omitted Body Mass Index (BMI) and Leisure Time Physical Activity (LTPA) Observations, by Sex, Canada, 1996–2007

	BMI observations			LTPA Observations		
	Retained	Omitted		Retained	Omitted (Missing)	
		Underweight	Missing		Retained	Omitted (Missing)
Males						
Observations, n	28,567	229	573	27,813	1,556	
Age, mean	47.83	58.30 *	65.75 *	47.48	61.66 *	
HUI, mean	0.88	0.64 *	0.38 *	0.89	0.55 *	
LTPA category						
Active, %	22.09	12.92 *	2.68 *			
Moderately active, %	25.22	12.79 *	6.40 *			
Inactive, %	39.08	42.23	13.83 *			
Sedentary, %	9.52	21.19 *	10.76			
Missing, %	4.09	10.87 *	66.33 *			
BMI category						
Underweight, %				0.84	1.90 *	
Acceptable weight, %				34.27	33.55	
Overweight, %				46.80	32.84 *	
Obese class I, %				14.04	8.93 *	
Obese class II/III, %				3.50	2.66	
Missing, %				0.55	20.11 *	
Females						
Observations, n	33,024	926	2,681	34,980	1,651	
Age, mean	49.70	48.96	51.91 *	48.89	71.32 *	
HUI, mean	0.86	0.80 *	0.69 *	0.87	0.42 *	
LTPA category						
Active, %	18.02	15.59	8.94 *			

	BMI observations			LTPA Observations		
	Retained	Omitted		Retained	Omitted (Missing)	
		Underweight	Missing			
Moderately active, %	24.78	17.75*	15.73*			
Inactive, %	44.00	43.20	33.00*			
Sedentary, %	11.00	18.37*	11.62			
Missing, %	2.19	5.10*	30.70*			
BMI category						
Underweight, %				2.57	3.20	
Acceptable weight, %				48.63	25.66*	
Overweight, %				28.20	14.18*	
Obese class I, %				11.13	5.85*	
Obese class II/III, %				4.71	2.22*	
Missing, %				4.77	48.90*	

BMI, body mass index; LTPA, leisure time physical activity; HUI, Health Utilities Index

* Estimate among omitted observations is significantly different ($P<0.05$, two sided) from estimate among retained observations

Table 2

Characteristics of Sample Respondents with Baseline and Follow-up Information, Canada, 1996–2007

	Overall (n=13,198)	Males (n=6,030)	Females (n=7,168)
During follow-up (1996–2007)			
Institutionalized, %	1.62	1.01	2.21*
Died, %	8.93	10.07	7.83*
Age at death, mean ^a	73.80	72.01	76.05*
Body mass index category (1996)			
Acceptable weight, %	46.50	39.57	53.22*
Overweight, %	34.42	43.31	25.81*
Obese class I, %	9.73	10.31	9.17
Obese class II & III, %	2.67	2.04	3.29*
Leisure time physical activity category (1996)			
Active, %	17.51	19.88	15.20*
Moderately active, %	21.84	22.07	21.62
Inactive, %	44.77	42.04	47.43*
Sedentary, %	11.65	11.01	12.28

* Estimate among females is significantly different ($P<0.05$, two-sided) from estimate among males

^a Calculated only among those who died during follow-up

Proportion of Observations by Body Mass Index and Leisure Time Physical Activity Categories Across Age Groups, Separately for Males and Females, Canada, 1996–2007

Table 3

Age group	n	Body mass index categories					Leisure time physical activity categories				
		Acceptable	Overweight	Obese Class I	Obese Class II/III	Active	Moderately active	Inactive	Sedentary		
Males	27,426	9,055	13,305	4,051	1,015	6,078	7,001	11,334	3,013		
18–29	3,411	51.41	38.16	9.24	1.19	31.20	27.40	34.52	6.88		
30–39	5,719	37.64*	45.56*	14.02*	2.78*	23.02*	25.74	42.11*	9.14*		
40–49	6,225	29.66*	50.28*	15.41	4.65*	21.80	26.67	43.73	7.80		
50–59	5,056	26.10*	51.81	16.83	5.27	20.73	25.51	42.83	10.93*		
60–69	3,491	29.72*	49.67	16.71	3.90	24.37*	27.57	37.55*	10.51		
70–79	2,493	35.26*	49.68	12.42*	2.65*	20.20*	26.27	39.34	14.20*		
80 and over	1,031	54.72*	37.78*	6.93*	0.57*	12.28*	21.92*	38.33	27.47*		
Females	32,391	16,186	10,178	4,165	1,862	5,832	8,118	14,574	3,867		
18–29	3,595	72.64	17.17	7.33	2.86	24.12	27.14	42.70	6.04		
30–39	6,525	60.15*	24.61*	9.95*	5.29*	19.25*	25.62	47.24*	7.89*		
40–49	6,682	54.96*	28.11*	11.60*	5.34	19.78	25.69	46.52	8.00		
50–59	5,336	42.56*	36.33*	13.81*	7.30*	18.57	26.92	43.12*	11.39*		
60–69	4,390	38.17*	39.61	16.54*	5.68	17.76	26.35	43.13	12.76		
70–79	3,751	42.60*	39.22	14.69	3.49*	12.20*	22.49*	45.32	20.00*		
80 and over	2,112	54.79*	33.88*	9.30*	2.03*	7.84*	14.72*	45.58	31.86*		

* Estimate of proportion in body mass index category/leisure time physical activity category in a particular age group (row) is significantly different ($P < 0.05$, two-sided) from proportion in previous age group.

^a Observations missing either body mass index or leisure time physical activity measures have been omitted from this table.

Table 4

Coefficients from Final Models Predicting Health-Related Quality of Life, Separately for Males and Females, Canada, 1996–2007

	Males	Females
Baseline HRQL (age 48)		
Intercept	1.19 [*]	1.20 [*]
BMI, acceptable weight (reference)	0.00	0.00
BMI, overweight	0.021	−0.052 [*]
BMI, obese class I	0.009	−0.093 [*]
BMI, obese class II/III	−0.086 [*]	−0.097 [*]
LTPA, active (reference)	0.00	0.00
LTPA, moderately active	−0.011	−0.010
LTPA, inactive	−0.045 [*]	−0.055 [*]
LTPA, sedentary	−0.087 [*]	−0.128 [*]
Active × Overweight (reference)	0.00	0.00
Moderately active × Overweight	0.006	0.015
Inactive × Overweight	0.012	0.014
Sedentary × Overweight	0.010	0.030
Active × Obese class I (reference)	0.00	0.00
Moderately active × Obese class I	−0.014	0.027
Inactive × Obese class I	−0.002	0.026
Sedentary × Obese class I	−0.074 [*]	0.014
Active × Obese class II/III (reference)	0.00	0.00
Moderately active × Obese class II/III	0.038	0.020
Inactive × Obese class II/III	0.039	−0.018
Sedentary × Obese class II/III	0.045	−0.056
Rate of change in HRQL		
Age	−0.0067 [*]	−0.0047 [*]
Age square	−0.0002 [*]	−0.00012 [*]
Age cubed	−0.000004 [*]	−0.000004 [*]
LTPA, active × Age (reference)	0.00	0.00
LTPA, moderately active × Age	−0.0012 [*]	−0.0004
LTPA, inactive × Age	−0.0009 [*]	−0.0016 [*]
LTPA, sedentary × Age	−0.0045 [*]	−0.0039 [*]
N observations	27,426	32,391

BMI, body mass index; LTPA, leisure time physical activity

^{*} Estimate is significantly different ($P < 0.05$, two-sided) from zero

Note: For males the interactions between age and BMI category were insignificant. For females, interactions between age and BMI categories are described in the text.