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The effect of physical activity on adult obesity: Evidence from the Canadian NPHS panel

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ABSTRACT

Although physical activity has been considered as an important modifiable risk factor for obesity, the empirical evidence on the relationship between physical activity and obesity is mixed. Observational studies in the public health literature fail to account for time-invariant unobserved heterogeneity and dynamics of weight, leading to biased estimation of the effect of physical activity on obesity. To overcome this limitation, we propose dynamic fixed-effects models to account for unobserved heterogeneity bias and the dynamics of obesity. We use nationally representative longitudinal data on the cohort of adults aged 18–50 years in 1994/95 from Canada's National Population Health Survey and followed them over 16 years. Obesity is measured by BMI (body mass index). After controlling for a wide range of socio-economic factors, the impact of four alternative measures of leisure-time physical activity (LTPA) and work-related physical activity (WRPA) are analyzed. The results show that each measure of LTPA exerts a negative effect on BMI and the effects are larger for females. Our key results show that participation in LTPA exceeding 1.5 kcal/kg per day (i.e., at least 30 min of walking) reduces BMI by about 0.11–0.14 points in males and 0.20 points in females relative to physically inactive counterparts. Compared to those who are inactive at workplace, being able to stand or walk at work is associated with a reduction in BMI in the range of 0.16–0.19 points in males and 0.24–0.28 points in females. Lifting loads at workplace is associated with a reduction in BMI by 0.2–0.3 points in males and 0.3–0.4 points in females relative to those who are reported sedentary. Policies aimed at promotion of LTPA combined with WRPA like walking or climbing stairs daily would help reduce adult obesity risks.

1. Introduction

Obesity has been recognized as a major public health challenge not only in Canada but also throughout the developed world (WHO, 2013) as it is an important risk factor for morbidity, including incidence of various chronic

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diseases (CDC, 2007; Luo et al., 2007; PHAC and CIHI, 2011; Waxman and Assembly, 2004). For adults, obesity is generally defined as having a body mass index (BMI) of 30 or above, where BMI equals weight in kilograms divided by height in metres squared. In Canada, the prevalence of adult obesity increased from 10% to 25% between 1970 and 2008 (PHAC and CIHI, 2011). Obesity places a significant financial burden on the health care system worldwide; the 2008 estimates suggest that it costs Canadian society somewhere between $4.6 billion per annum (if 8 chronic diseases are attributed to obesity) to $7.1 billion per annum (if 18 chronic diseases are attributed to obesity) (PHAC and CIHI, 2011). Thus, understanding the modifiable risk factors for obesity such as physical activity is of considerable importance. Even if decline in physical activity is not the primary cause of the dramatic rise in obesity, policies aimed at promoting physical activity in the workplace and community can be a part of a broader solution to obesity prevention strategy. This paper contributes to this debate by focusing on the effects of leisure time physical activity (LTPA) and work-related physical activity (WRPA) on BMI using population-based longitudinal data on adults from Canada for the first time.

From an economics perspective, an individual's allocation of time to various activities depends on the opportunity costs of time (Grossman, 2000). In Grossman's model, individuals produce health capital by investing time and goods through health production functions. Rational individuals maximize their lifetime utility by optimizing their stock of health subject to time and budget constraints. In his model, health is viewed both as a consumption good (good health or healthy days yield utility) and an investment good (healthy days increase labour income and hence consumption). Time spent on physical activity may decrease the level of immediate utility (due to financial costs and the opportunity costs of time), but it may increase the discounted lifetime utility by increasing the availability of healthy days in future periods (Grossman, 2000). On the other hand, those who enjoy physical activity as such may not experience a decrease in immediate utility and the opportunity cost of their time is considerably low (Hagberg and Lindholm, 2010; Hatziandreu et al., 1988). So motivations like enjoyment, time preference and labour market position will have considerable influence on the allocation of time for physical activity.[1] Although the role of time costs is acknowledged in the literature, it has not been accounted for in the relationship between physical activity and obesity in the empirical literature. This is because the opportunity cost of time, the utility or disutility of physical activity and the utility gains from physical activity induced improvements in health at the individual-level essentially remain unobservable to the researcher. Thus, without availability of longitudinal data these types of unobservable confounders cannot be easily accounted for.

In the public health literature, physical activity has been considered as an important modifiable risk factor for obesity, but the empirical relationship between changes in physical activity and changes in weight outcomes is mixed at best. A negative association between LTPA and obesity is documented in previous Canadian cross-sectional studies (Chen and Mao, 2006; Craig et al., 2005; Godley and McLaren, 2010; Ross et al., 2007; Tjepkema, 2006). A number of studies find a negative association between measures of physical activity and obesity over time. For instance, Gordon-Larsen et al. (2009) found that 0.5 h of walking a day is associated with reductions in weight gain and that this effect was greater for women than men. Similarly, some studies found that maintaining higher levels of physical activity over time is associated with lower weight gain (Hankinson et al., 2010; Littman et al., 2005; Williams, 2007) or reduced risk of future obesity (Ekelund et al., 2011; Pietiläinen et al., 2008).

By contrast, a number of studies found no relationship between measures of physical activity and the odds of obesity risk (Bak et al., 2003; Brien et al., 2007; He and Baker, 2004; Petersen et al., 2003). For instance, He and Baker (2004) found no statistically significant relationship between light or vigorous physical activity at workplace and weight gain among adults aged 51–61 years in the United States. Some studies found no association between physical activity and weight gain but found that those individuals who became less active over time gained weight (May et al., 2010). Systematic reviews conducted on this subject conclude that a negative association between measures of physical activity and obesity is reported in the majority of cross-sectional studies, but changes in physical activity are typically unrelated to changes in obesity (Fogelholm and Kukkonen-Harjula, 2000; Summerbell et al., 2009; Wareham et al., 2005).

Although the negative association between measures of physical activity and obesity found in the cross-sectional studies is quite interesting, there are several plausible reasons why this association may not be casual. First, most observational studies are unable to account for unobserved heterogeneity bias: a type of confounding in which individual-specific idiosyncratic factors that are unobservable to the researcher may influence both physical activity and weight outcome simultaneously. Factors such as motivations, enjoyment of physical activity, time preference and the opportunity cost of time as well as genetic predisposition, risk aversion and other personal traits may cause this type of bias (Komlos et al., 2004; Norton and Han, 2008; Smith et al., 2005). Second, a number of studies rely on a global self-reported physical activity measure, which may be a good proxy for healthy lifestyle (Wareham et al., 2005), but it does not capture the intensity, frequency and duration of physical activity. Understanding the relationship between physical activity and obesity from both extensive margin (participation) and intensive margin (frequency and duration) is important. Third, most studies do not account for WRPA while

[1] A considerable body of evidence suggests that the opportunity cost of time does play an important role in physical activity (Brown and Roberts, 2011; Humphreys and Ruseski, 2011; Maruyama and Yin, 2012).

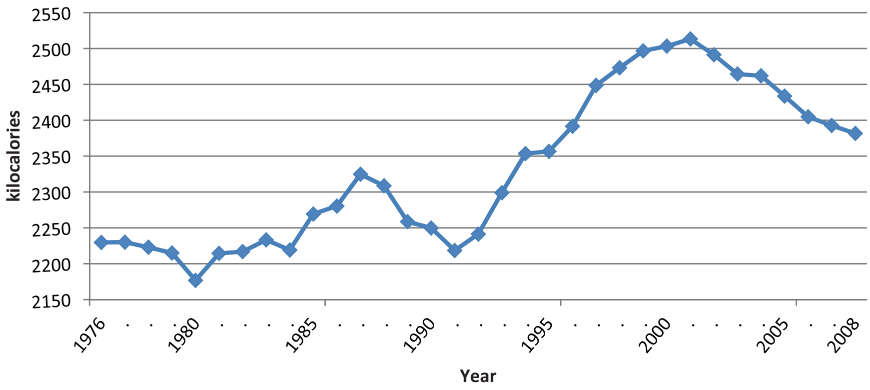

Fig. 1. Energy intake from food consumption in Canada, per person/per day (1976–2008).
Source: CANSIM Table: v31240213 Canada; Energy (Kilocalories); Nutrients available adjusted for losses for all commodities. Statistics Canada, Ottawa, ON.

examining the effect of LTPA and vice versa, primarily due to lack of data availability (Fogelholm and Kukkonen-Harjula, 2000; Summerbell et al., 2009; Wareham et al., 2005). Finally, there may be dynamic adjustments to obesity: past obesity status may be an important predictor of current obesity. This paper attempts to address these critical issues in our understanding of the relationship between physical activity and adult obesity using nationally representative longitudinal data from the Canadian National Population Health Survey (NPHS) spanning 1994/95 to 2008/09.

The objective of this study is to investigate the relationship between physical activity and BMI among Canadian adults empirically to provide answers to three related research questions. Is there a negative relationship between LTPA and BMI in Canada? Is there a negative relationship between WRPA and BMI in Canada? Do these relationships persist once unobserved individual heterogeneity and dynamics of obesity are accounted for?

The remainder of the paper proceeds as follows. Section 2 develops the empirical framework for analyzing the effect of physical activity on obesity. Section 3 presents the data source and variables for the empirical investigation. The results are presented in Section 4. Finally, Section 5 provides policy implications of this study.

2. Materials and methods

Obesity is generally conceptualized as a function of an individual's energy balance over time (Chou et al., 2004). If caloric intake and energy expenditure offset each other in each time period, with a given metabolic regulation, the individual would not be expected to gain weight. An individual's predisposition towards obesity can also be influenced by a vector of observable individual and household characteristics and unobservable individual idiosyncratic characteristics.

In order to formulate empirical models, ideally data on caloric intake and energy expenditure are needed. Although consistent data on energy expenditure are available in Canada, individual-level data on caloric intake are not available. However, based on food supply data, the energy intake trend in Canada over the past three decades shows that there has been a small increase in the overall energy intake – an increase of about 200 kilocalories per person per day during 1990s and declining since 2001 (see Fig. 1). A Canadian study undertaken in 1997/98 based on 24-h recall nutrition consumption data showed that there had actually been a reduction in dietary energy and fat intake since the previous national dietary survey, conducted a generation earlier (1970) (Gray-Donald et al., 2000). Another study also suggests that dietary energy intake among Canadian adults declined in recent decades (Garriguet, 2004).

At the individual level, we assume that caloric intake depends on socio-economic and cultural factors. Also, to some extent, the contribution of excessive caloric intake to obesity can be captured through individual-specific unobservable factors. Given this assumption, we begin with a simplified linear regression model as:

$$BMI_{it} = \alpha + \lambda(LTPA)_{it} + \delta(WRPA)_{it} + \gamma\tau + \beta' X_{it} + u_i + \varepsilon_{it}. \quad (1)$$

where i is indexed for individual and t is indexed for time such that $t = 1, 2, ..., T_i$; BMI_{it} represents the body mass index of individual i at time t, $LTPA_{it}$ represents the leisure time physical activity undertaken by individual i at time t, $WRPA_{it}$ represents work-related physical activity undertaken by individual i at time t, τ is a time trend and X_{it} is a vector of observable characteristics of individual i at time t; u_i is the individual-specific unobserved heterogeneity term; and ε_{it} is the error term with assumptions that $E(\varepsilon_{it}) = 0$ and $Var(\varepsilon_{it}) = \sigma_\varepsilon^2$. The vector X_{it} includes age, gender, educational status, employment status, household income, children in the family, province of residence and time dummies.

If there are no unobserved individual-effects (or unobserved effects are uncorrelated with regressors), the pooled ordinary least squares estimator (or random-effects estimator) will be consistent and efficient. If the unobserved individual-effects are correlated with the included explanatory variables, the random-effects estimator will produce inconsistent parameter estimates

(Wooldridge, 2010). In the analysis of obesity, there are intuitive reasons to suspect that the unobserved individual-effects may be correlated with physical activity due to factors such as motivation, time preference, individual idiosyncratic factors, genetics, metabolism, risk aversion and other unmeasured confounders as mentioned above. The advantage of having panel data is to allow for the individual-effects to be correlated with the included explanatory variables, so the fixed-effects estimator is the logical starting point for our empirical analysis.[2]

Application of a fixed effects estimator to the model specified in Eq. (1) will produce consistent parameter estimates under the assumption of exogeneity of covariates (Wooldridge, 2010). The socio-economic variables are generally exogenous. The WRPA is also exogenous as it is primarily governed by educational attainment. However, LTPA is discretionary on the part of individuals, hence it may not satisfy the exogeneity assumption, especially if $LTPA_{i,t+1}$ is correlated with ε_{it} – a feedback effect. To rule out this type of feedback effect and hence test for the exogeneity of LTPA, a simple test suggested by Wooldridge (2010), p. 325 is used. The test proceeds in estimating the following regression model:

$$BMI_{i,t} = \alpha + \lambda(LTPA)_{i,t} + \eta(LTPA)_{i,t+1} + \delta(WRPA)_{i,t} + \gamma\tau + \beta' X_{i,t} + u_i + \varepsilon_{i,t}. \qquad (2)$$

where $LTPA_{i,t+1}$ in Eq. (2) refers to the value of LTPA at time $t+1$. After running the fixed-effects regression, a test of the significance of η (H_0: $\eta = 0$) is performed. A rejection of the null hypothesis would suggest absence of this type of feedback effect.

Incorporating the dynamic effect of obesity, the dynamic model can be specified as:

$$BMI_{i,t} = \alpha + \rho BMI_{i,t-1} + \lambda(LTPA)_{i,t} + \delta(WRPA)_{i,t} + \gamma\tau + \beta' X_{i,t} + u_i + \varepsilon_{i,t}, \qquad (3)$$

where $BMI_{i,t-1}$ in Eq. (3) refers to previous period's BMI. Fixed-effects estimation of Eq. (3) results in dynamic panel bias (Nickell, 1981), but the bias is expected to be small with 8 time periods in this study. Thus, in order to obtain consistent estimates, the individual fixed effects must be removed first. The common procedure to eliminate the fixed effects is either by taking first differences or forward orthogonal deviations (Arellano and Bond, 1991; Bond, 2002). First differencing Eq. (3) gives[3]:

$$\Delta BMI_{i,t} = \rho\Delta BMI_{i,t-1} + \lambda\Delta LTPA_{i,t} + \delta\Delta WPA_{i,t} + \gamma\Delta\tau + \beta'\Delta X_{i,t} + \Delta\varepsilon_{i,t}, \qquad (4)$$

where Δ is the difference operator. In Eq. (4), individual fixed effects are differenced out, but there is still correlation between the right-hand side variables and the error term because $BMI_{i,t-1}$ in $\Delta BMI_{i,t-1}$is by construction correlated with $\varepsilon_{i,t-1}$in $\Delta\varepsilon_{it}$. So, the first difference procedure does not remove the endogeneity of $BMI_{i,t-1}$. Instrumental variables can purge this correlation since lags of $BMI_{i,t-1}$ ($BMI_{i,t-2}$ or $\Delta BMI_{i,t-2}$ are correlated with $\Delta BMI_{i,t-1}$ but not with the error term $\Delta\varepsilon_{i,t}$ under the assumption that $\varepsilon_{i,t}$ are serially uncorrelated) can serve as valid instruments (Arellano and Bond, 1991; Arellano and Bover, 1995; Baltagi, 2005).

Fortunately, the assumption of no serial correlation can be tested using the autocorrelation test developed by Arellano and Bond (1991). A negative first-order serial correlation is expected in the differenced equation, the evidence of which is uninformative. In order to check for serial correlation in levels, a test for the presence of second order autocorrelation in the differenced equation is needed. As the number of time-periods increase, the number of available instruments also increases. The validity of instruments is tested using Hansen's J test which is robust to serial correlation and heteroscedasticity (Roodman, 2009). In order to deal with instrument proliferation, two strategies are generally employed to limit the number of instruments. The first is to limit only specific lags instead of all available lags as instruments and the second is to collapse instruments into smaller sets by restricting one instrument for each variable and lag distance rather than one for each time period, variable and lag distance (Roodman, 2009, 2007). Eq. (4) can be estimated using the Arellano-Bond estimator based on Generalized Methods of Moments (GMM) modelling framework known as the Difference GMM (Arellano and Bond, 1991).[4] The Difference GMM typically proceeds after first differencing the data in order to eliminate the fixed effects – one weakness of this procedure is that it magnifies loss of observations in unbalanced panels. An alternative to the first differencing approach is the forward orthogonal deviations, which also purges fixed effects (Arellano and Bover, 1995). Instead of subtracting the previous observation in the first difference method, the model transformed by the forward orthogonal deviations subtracts the average of all future observations of a variable. Simulation results suggest that the dynamic panel model transformed by the forward orthogonal

[2] In order to account for u_i in Eq. (1), one can think of including a dummy variable for every individual in the regression model. However, this is inefficient as it would require inclusion of thousands of dummy variables and the model cannot be estimated. Fortunately, the within estimator, popularly known as the fixed-effects estimator, is more convenient than the dummy variables approach which produces numerically identical results. The idea behind the within estimator is to solely use the variation in BMI_{it} and the right-hand side variables within the same individual over time by subtracting the within-individual average of each variable in the equation. That is, ordinary least squares estimation of the equation: $BMI_{it} - \overline{BMI_{it}} = \alpha + \lambda(LTPA_{it} - \overline{LTPA_{it}}) + \delta(WRPA_{it} - \overline{WRPA_{it}}) + \beta'(X_{it} - \overline{X_{it}}) + \gamma(\tau - \overline{\tau}) + u_i - \overline{u_i} + \varepsilon_{it} - \overline{\varepsilon_{it}}$. Since u_i is constant over time for each individual, the within estimator eliminates individual fixed-effects, i.e., $u_i - \overline{u_i} = 0$ and it is generally consistent compared to the standard difference estimator in panels with more than two time periods.

[3] That is, $BMI_{i,t} - BMI_{i,t-1} = \rho(BMI_{i,t-1} - BMI_{i,t-2}) + \lambda(LTPA_{i,t} - LTPA_{i,t-1}) + \delta(WRPA_{i,t} - WRPA_{i,t-1}) + \gamma(t_t - t_{t-1}) + \beta'(X_{i,t} - X_{i,t-1}) + \varepsilon_{i,t} - \varepsilon_{i,t-1}$.

[4] Eq. (4) can also be estimated by the System GMM procedure (Blundell and Bond, 1998). The System GMM combines first differences model where lagged differences are used as instruments. The System GMM is likely to perform better if changes in the instrumenting variables are uncorrelated with the individual-specific fixed effects (Roodman, 2009); this assumption is unlikely to hold, so the System GMM approach is not pursued.

deviations performs better compared to that transformed by the first difference (Hayakawa, 2009). Thus, we apply the forward orthogonal deviations transformation to the model specified in Eq. (4) using the xtabond2 procedure written in STATA (Roodman, 2007). The main drawback of the GMM modelling approach, however, is that the instruments may not pass weak identification requirements. To mitigate this problem, we considered a fixed effects instrumental variable (IV) method of estimation, using only lags of LTPA and WRPA as excluded instruments.

The existing literature suggests that the effect of socio-demographic variables and physical activity on obesity differs by gender in Canada (Chen and Mao, 2006; Godley and McLaren, 2010; PHAC and CIHI, 2011; Ross et al., 2007; Tjepkema, 2006), thus we conducted separate analyses by gender to capture the distinct behaviour of males and females.

3. Data and variables

Data for this study are taken from the eight cycles (1994/95–2008/09) of the longitudinal National Population Health Survey (NPHS) conducted by Statistics Canada. The NPHS is a nationally representative longitudinal survey of the Canadian population in 1994/95, the target population of which consists of individuals aged 12 years and over in Canada's ten provinces except those living on Aboriginal reserves, Canadian Forces Bases, or remote areas. The survey collected detailed information on self-reported height and weight, LTPA, WRPA, other health related information and rich socio-demographic information every two years since 1994/95. This paper uses confidential micro data on the longitudinal cohort aged 18–50 years in 1994/95. We specifically choose this age cut-off in order to avoid the undue influence of retirement on physical activity. There are two important reasons why including retirees would be problematic: (a) the opportunity cost of time and time preference are quite different for working adults and retirees and (b) BMI is a poor measure of adiposity for elderly populations. After excluding incomplete records and missing cases (including BMI $<$ 12 12 and BMI $>$ 70), a sample of 8783 respondents, consisting of 51,499 person-year observations, is available for analysis. Longitudinal sampling weights adjusting for non-response bias provided by Statistics Canada are applied to all descriptive and regression analyses conducted in this study.

The outcome variable of interest in this study is BMI. We analyzed the effect of four alternative measures of LTPA variables. First, LTPA is a continuous variable (LTPA_EE) measured by the average daily energy expended on leisure time activities undertaken by respondents in the past three months. The respondents were asked to report participation, frequency and duration of the following leisure-time activities: walking for exercise, gardening and yard work, swimming, bicycling, popular or social dance, home exercises, ice hockey, ice-skating, downhill skiing or snowboarding, jogging or running, golfing, exercise class or aerobics, cross-country skiing, bowling, baseball or softball, tennis, weight-training, fishing, volleyball, basketball, in-line skating or roller-blading, yoga or tai-chi, and all other reported activities.[5]

Statistics Canada calculated the average daily energy expended (expressed as total kilocalories per kilogram of body weight) on all leisure time activities undertaken by each respondent in every cycle. Energy expenditure values for all activities in a day are calculated as: $\sum_i((N_i * D_i * MET_i)/365)$, where N_i is the number of times a respondent engaged in an activity i over a 12 month period, D_i is the average duration in hours of the activity i, and MET_i is a value of metabolic energy cost of an activity i expressed as a multiple of the resting metabolic rate. For example, for an adult who reports that he swam 15 times in his leisure-time during the past 3 months (average of 1 h each time), energy expenditure due to swimming for 3 months would be calculated as: 1 h/session $\times$ 15 sessions $\times$ 3 MET. To calculate swimming energy expenditure for the 12 months, this figure is multiplied by 4. This is repeated for each activity, added across all activities and then divided by 365 to produce the average energy expenditure per day. Since the *MET* values can be of three intensity levels (high, medium and low) and the NPHS did not collect information on the intensity of activities, Statistics Canada adopted the low intensity value for each activity.[6] This is a very conservative estimate of the intensity expended in each activity and is consistent with the widely accepted guidelines of *Canadian Fitness and Lifestyle Research Institute*: www.cflri.ca. This seems a reasonable approximation since it is well known that individuals have a tendency to overestimate the intensity, frequency and duration of their physical activity events (Statistics Canada, 2010). For additional details regarding the MET values and construction of the LTPA measure in the NPHS, see Statistics Canada's documentation (Statistics Canada, 2010).

Second, LTPA is defined as a dummy variable (LTPA_DUM) that takes a value of 1 if an individual's energy expenditure is considered physically active or moderately active and 0 if physically inactive. According to Statistics Canada's NPHS documentation (Statistics Canada, 2010), a person is considered physically inactive or sedentary if the daily leisure-time energy expenditure is less than 1.5 kilocalories per kilogram of body weight per day (i.e., walk less than 30 min), moderately active if the energy expenditure is 1.5–2.9 (i.e., walk 30–59 min, yielding some health benefits other than cardiovascular benefit),

[5] Over the years, the following minor changes have been made to the LTPA questions: skating in 1994/95 was changed to ice skating in 1996/1997; yoga or tai-chi was dropped and basketball was added in 1996/97; cross-country skiing was dropped and in-line skating or roller-blading was added in 1998/1999; and snowboarding was included with downhill skiing in 2000/0 (Statistics Canada, 2010).

[6] Statistics Canada adopted the following MET values in each cycle. Walking for exercise: 3, gardening and yard work; 3, swimming; 3, bicycling; 4, popular or social dance; 3, home exercises; 3, ice hockey; 6, ice-skating; 4, downhill skiing or snowboarding; 4, jogging or running; 9.5, golfing; 4, exercise class or aerobics; 4, cross-country skiing; 5, bowling; 2, baseball or softball; 3, tennis; 4, weight-training; 3, fishing; 3, volleyball; 5, basketball; 6, in-line skating or roller-blading; 5, yoga or tai-chi; 2, and other activities; average MET of all reported activities except for jogging or running.

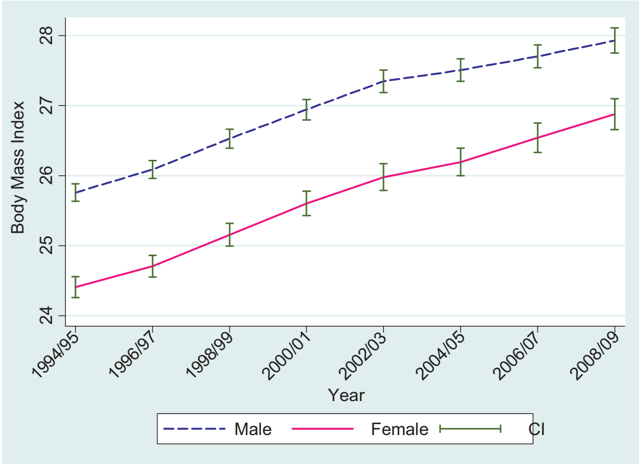

Fig. 2. Body mass index (BMI) of the respondents (aged 18–50 in 1994/95).

and active if the energy expenditure is 3.0 or more (i.e., walk more than hours, yielding cardiovascular health benefits). Third, another LTPA dummy variable (LTPA_-DAILY) takes a value of 1 if the respondent participated in daily physical activity lasting over 15 min and 0 otherwise. Finally, the average monthly frequency of physical activity (LTPA_MONTH) is a continuous variable indicating the number of times in the past month that a respondent engaged in a physical activity lasting more than 15 min.

For WRPA, the NPHS respondents answered the following question: "thinking back over the past 3 months, which of the following best describes your usual daily activities or work habits?" The options given to the respondents were: "(i) usually sit during the day and don't walk around very much (ii) stand or walk quite a lot during the day but don't have to carry or lift things very often, (iii) usually lift or carry light loads, or have to climb stairs or hills often, and (iv) do heavy work or carry very heavy loads" (Statistics Canada, 2010). The reference category for work-related physical activity is those who were sedentary at work (i.e., those who answered (i) above).

Consistent with the extant literature (Brown and Roberts, 2011; Chen and Mao, 2006; Craig et al., 2005; Fogelholm and Kukkonen-Harjula, 2000; Godley and McLaren, 2010; PHAC and CIHI, 2011; Ross et al., 2007; Tjepkema, 2006), the following explanatory variables are included in our regression model. Age and age squared are continuous variables. Educational status of the respondent is characterized by dummies for those respondents who have a secondary school education, some post-secondary education and a post-secondary degree, leaving those with less than secondary education as the reference category. Marital status is characterized by two dummy variables (currently married or common-law = 1, 0 otherwise, and widowed, separated and divorced = 1, 0 otherwise), which implies that singles are the reference category. Having small children in the family is captured by two dummy variables: children <6 years old and children <12 years.

Differences in incomes of the households in relation to the number of household members and standards of living in the provinces are represented by 9 income ratio dummy variables, leaving the poorest income ratio dummy as the reference category. Statistics Canada derived this variable based on the ratio of Canadians' total household income (a distribution at the provincial level in deciles) to their corresponding low income cut-offs.[7] Home ownership is a dummy variable that takes a value of 1 if a household owns a home with or without mortgage. Employment status is characterized by two dummies (unemployed = 1, 0 otherwise, and not in the labour force = 1, 0 otherwise), which implies that full- or part-time employed are the reference category. The influence of time trends on obesity are captured by a series of year dummies with 1994/95 as the reference category. The definitions of all variables are presented in Appendix.

4. Results and discussion

4.1. Descriptive results

The estimated average BMI for our male (female) cohort increased from 25.58 kg/m^2 (24.18 kg/m^2) in 1994/95 to 27.83 kg/m^2 (26.6 kg/m^2) in 2008/09. Consequently, the obesity rate of the male cohort increased from 12% to 26% while for the female cohort it increased from 12% to 24%. Fig. 2 displays the increasing trends in BMI for males and females during this period.

Fig. 3 through 6 present the trends in four LTPA variables for our cohort over the 16 year period. As can be seen from Fig. 3, the increasing trends in energy expenditure are very similar for both genders, but females on average expended fewer calories compared to males. The proportion of respondents reported as physically active or

[7] For details on household income ratio methodology, see the online documentation available at: http://www.statcan.gc.ca/imdb-bmdi/document/3225_D10_T9_V3-eng.pdf.

Fig. 3. Average energy expenditure (kcal/kg/day) of respondents.

Fig. 4. Proportion of respondents physically active or moderately active.

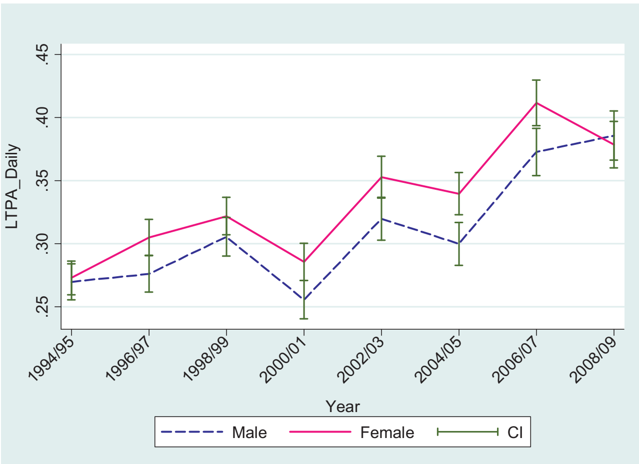

Fig. 5. Proportion of respondents participated in daily physical activity.

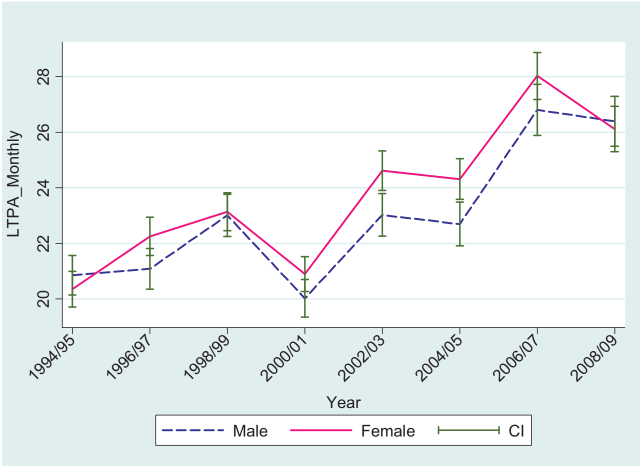

Fig. 6. Average monthly frequency of physical activity of respondents.

moderately active increased over the years with similar increasing trends seen for both males and females in Fig. 4. The proportion of individuals participating in daily LTPA lasting over 15 min also increased during the study period. Although increasing trends in daily physical activity for both males and females are seen in Fig. 5, a slightly higher proportion of females are participating in daily physical activity. The monthly frequency of LTPA (each activity lasting over 15 min) also increased during this period. Fig. 6 shows that monthly frequency of physical activity is

Table 1a
Weighted means of all variables: males.

Variable	1994/95	1996/97	1998/99	2000/01	2002/03	2004/05	2006/07	2008/09
BMI	25.58	25.89	26.34	26.77	27.19	27.35	27.67	27.83
Obese	0.12	0.13	0.15	0.18	0.21	0.22	0.24	0.26
LTPA_EE	1.89	1. 92	2.08	1.81	2.08	2.06	2.32	2.32
LTPA_DUM	0.45	0.44	0.50	0.46	0.53	0.51	0.57	0.56
LTPA_Daily	0.27	0.27	0.30	0.25	0.33	0.31	0.38	0.39
LTPA_Monthly	20.89	21.12	23.08	19.81	23.83	23.60	27.47	27.48
Usually sit	0.20	0.22	0.22	0.29	0.27	0.27	0.28	0.26
Stand/walk	0.44	0.43	0.43	0.39	0.40	0.40	0.37	0.40
Light loads	0.21	0.22	0.23	0.22	0.22	0.21	0.24	0.24
Heavy loads	0.14	0.13	0.12	0.10	0.11	0.12	0.11	0.10
Age	34.08	36.20	38.23	40.34	42.51	44.55	46.63	48.97
<Secondary	0.17	0.14	0.14	0.13	0.12	0.11	0.11	0.11
Secondary	0.17	0.15	0.14	0.14	0.13	0.12	0.12	0.12
<Post-secondary	0.28	0.31	0.30	0.28	0.28	0.28	0.27	0.26
Post-secondary	0.37	0.40	0.42	0.45	0.47	0.49	0.49	0.51
Children <6	0.24	0.23	0.22	0.18	0.16	0.14	0.12	0.11
Children <12	0.22	0.23	0.24	0.24	0.22	0.21	0.21	0.17
Single	0.32	0.29	0.24	0.22	0.19	0.16	0.14	0.11
Married	0.62	0.64	0.67	0.70	0.72	0.75	0.76	0.79
WSD	0.06	0.07	0.08	0.09	0.09	0.08	0.10	0.10
HIR: decile1	0.08	0.08	0.06	0.05	0.05	0.04	0.05	0.05
HIR: decile2	0.08	0.07	0.06	0.05	0.05	0.04	0.04	0.05
HIR: decile3	0.07	0.08	0.08	0.07	0.07	0.06	0.06	0.06
HIR: decile4	0.08	0.08	0.08	0.07	0.08	0.08	0.09	0.08
HIR: decile5	0.08	0.09	0.09	0.09	0.08	0.10	0.09	0.09
HIR: decile6	0.11	0.09	0.09	0.11	0.09	0.09	0.11	0.11
HIR: decile7	0.10	0.10	0.11	0.10	0.11	0.11	0.10	0.11
HIR: decile8	0.10	0.11	0.12	0.12	0.12	0.13	0.11	0.13
HIR: decile9	0.13	0.12	0.13	0.13	0.13	0.13	0.13	0.13
HIR: decile10	0.11	0.14	0.13	0.15	0.16	0.16	0.16	0.14
HIR: missing	0.06	0.05	0.05	0.05	0.05	0.06	0.05	0.05
Home owner	0.69	0.73	0.73	0.73	0.77	0.78	0.81	0.82
Employed	0.83	0.87	0.89	0.89	0.90	0.90	0.87	0.84
Unemployed	0.08	0.06	0.04	0.04	0.04	0.02	0.03	0.04
NLF	0.09	0.07	0.06	0.06	0.06	0.08	0.10	0.13

Table 1b
Weighted means of all variables: females.

Variable	1994/95	1996/97	1998/99	2000/01	2002/03	2004/05	2006/07	2008/09
BMI	24.18	24.41	24.86	25.29	25.61	25.81	26.20	26.6
Obese	0.12	0.13	0.14	0.17	0.18	0.19	0.21	0.24
LTPA_EE	1.51	1.64	1.71	1.60	1.92	1.89	2. 13	2.01
LTPA_DUM	0.36	0.40	0.43	0.42	0.52	0.49	0.55	0.53
LTPA_Daily	0.25	0.29	0.31	0.28	0.35	0.33	0.41	0.38
LTPA_Monthly	19.43	21.29	22.27	20.35	24.38	23.85	27.76	26.31
Usually sit	0.22	0.24	0.25	0.27	0.27	0.28	0.28	0.30
Stand/walk	0.51	0.54	0.52	0.50	0.49	0.48	0.46	0.43
Light loads	0.24	0.23	0.20	0.20	0.20	0.21	0.22	0.20
Heavy loads	0.03	0.03	0.03	0.03	0.04	0.03	0.04	0.04
Age	34.50	36.39	38.39	40.39	42.31	44.46	46.50	48.84
< Secondary	0.16	0.14	0.12	0.12	0.09	0.09	0.08	0.09
Secondary	0.19	0.17	0.17	0.16	0.16	0.15	0.14	0.16
<Post-secondary	0.29	0.30	0.30	0.28	0.28	0.26	0.28	0.25
Post-secondary	0.36	0.38	0.41	0.44	0.47	0.49	0.50	0.51
Children <6	0.28	0.25	0.22	0.17	0.16	0.13	0.13	0.11
Children <12	0.27	0.28	0.28	0.29	0.26	0.24	0.19	0.16
Single	0.24	0.22	0.19	0.17	0.14	0.12	0.11	0.09
Married	0.65	0.65	0.68	0.69	0.70	0.71	0.72	0.74
WSD	0.11	0.12	0.14	0.15	0.16	0.17	0.17	0.17
HIR: decile1	0.10	0.10	0.09	0.08	0.08	0.08	0.06	0.07
HIR: decile2	0.09	0.08	0.08	0.09	0.07	0.07	0.08	0.07
HIR: decile3	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.09
HIR: decile4	0.09	0.10	0.10	0.09	0.09	0.09	0.09	0.10
HIR: decile5	0.10	0.09	0.10	0.09	0.12	0.09	0.11	0.10
HIR: decile6	0.09	0.10	0.10	0.10	0.10	0.11	0.11	0.11
HIR: decile7	0.10	0.10	0.09	0.11	0.10	0.11	0.10	0.10
HIR: decile8	0.10	0.10	0.11	0.10	0.10	0.10	0.10	0.09
HIR: decile9	0.10	0.10	0.10	0.11	0.10	0.11	0.10	0.10
HIR: decile10	0.09	0.10	0.11	0.10	0.10	0.10	0.09	0.09
HIR: missing	0.06	0.06	0.05	0.05	0.05	0.05	0.06	0.08
Home owner	0.68	0.69	0.72	0.73	0.76	0.79	0.81	0.84
Employed	0.70	0.73	0.76	0.80	0.80	0.79	0.78	0.77
Unemployed	0.04	0.06	0.04	0.04	0.03	0.03	0.04	0.03
NLF	0.26	0.21	0.20	0.16	0.17	0.17	0.19	0.21

slightly higher for females and the increasing trends are very similar for both genders.

Regarding WRPA, there has been an increase in the proportion of respondents being inactive from 20% to 26% in males and 22% to 30% in females (i.e., those who usually sit and do not walk much at work) and the proportion of respondents who stand or walk a lot at work declined from 44% to 40% in males and 51% to 43% in females during this period. These descriptive results suggest that the workplace may be tending towards more sedentary. About 35% of males lift light or heavy loads at work while the corresponding percentage for the females is in the neighbourhood of 24–26%. Tables 1a and 1b present the descriptive statistics for males and females, respectively.

4.2. Regression results

The estimated LTPA coefficients from random effects and fixed effects regressions for males are reported in Table 2 and the corresponding results for females are presented in Table 3. First of all, we are unable to reject the null hypothesis of exogeneity of each LTPA measure at 1% level of significance (bottom of Tables 2 and 3). These results suggest that any feedback effect from BMI to LTPA is ruled out.

We begin with the question of whether physical activity is negatively related to adult BMI in Canada. The random effects and fixed-effects results show that the estimated LTPA coefficients are negative and statistically significant at 1% level. However, the magnitudes of the estimated coefficients are relatively smaller compared to the random effects models for females. We also find a negative association between WRPA and BMI at 1% level of significance in all specifications. The Hausman test rejects the random-effects model in all specifications, so the fixed effects results are preferable in the context of static panel data analysis.

Although the negative association between LTPA and BMI in the fixed effects model is an important finding, the above model ignores possible dynamics of obesity. After including lagged BMI in the fixed effects model, it is interesting to see that the negative relationship between LTPA and BMI is largely unaffected and the coefficient of lagged BMI term, ρ, is statistically significant at 1% level. The fixed effects regression results after inclusion of the lagged BMI term in the model are presented in Tables 4 and 5 for males and females, respectively. The corresponding results of the Difference GMM procedure that accounts for the endogenity of lagged BMI are presented in Tables 6 and 7. Our interest lies in the sign and statistical significance of the estimated λs associated with four LTPA variables (i.e., LTPA_EE, LTPA_DUM, LTPA_Daily and LTPA_Monthly) and three WRPA variables (i.e., Stand/Walk, Light Loads and Heavy Loads).

Table 2
Static panel data estimation: males.

Physical Activity	LTPA_EE	LTPA_DUM	LTPA_Daily	LTPA_Monthly
Random effects				
LTPA_EE	−0.039***			
	(0.010)			
LTPA_DUM		−0.089**		
		(0.040)		
LTPA_Daily			−0.089**	
			(0.039)	
LTPA_Monthly				−0.003***
				(0.001)
Stand/walk	−0.175***	−0.181***	−0.181***	−0.177***
	(0.057)	(0.057)	(0.057)	(0.057)
Light loads	−0.221***	−0.229***	−0.230***	−0.224***
	(0.066)	(0.066)	(0.066)	(0.066)
Heavy loads	−0.374***	−0.382***	−0.382***	−0.378***
	(0.079)	(0.079)	(0.079)	(0.079)
Fixed effects				
LTPA_EE	−0.039***			
	(0.010)			
LTPA_DUM		−0.094**		
		(0.040)		
LTPA_Daily			−0.088**	
			(0.039)	
LTPA_Monthly				−0.003***
				(0.001)
Stand/walk	−0.187***	−0.193***	−0.193***	−0.189***
	(0.057)	(0.057)	(0.057)	(0.057)
Light loads	−0.243***	−0.251***	−0.252***	−0.246***
	(0.067)	(0.067)	(0.067)	(0.067)
Heavy loads	−0.408***	−0.415***	−0.416***	−0.411***
	(0.080)	(0.080)	(0.080)	(0.080)
Test of LTPA	0.012	0.044	0.062	0.001
(H_0: $\eta = 0$ in Eq. (2))	(0.011)	(0.042)	(0.042)	(0.001)
R-squared	0.174	0.173	0.173	0.173
Observations	24,395	24,395	24,395	24,395
# of Individuals	4156	4156	4156	4156

The detailed results are available from the corresponding author upon request.
Robust standard errors in parentheses.
** $p < 0.05$.
*** $p < 0.01$.

Although the fixed effects approach applied to the dynamic model specified in Eq. (4) leads to dynamic panel bias, the bias is expected to be small with $T = 8$. The consistency of the Difference GMM estimation, however, relies on the absence of autocorrelation of the idiosyncratic error terms and the validity of the instruments. As expected, statistically significant negative first-order serial correlation in the differenced equation is found (reported at the bottom of Tables 6 and 7). The test results show that the AR(2) statistic is not statistically significant. Another requirement for the Difference GMM rests on the assumption that the instruments are uncorrelated with the error term. Since there are many instruments, they must pass over-identifying restrictions. It is found that Hansen's *J* test of over-identification cannot be rejected at 5% level of significance, suggesting that the set of instruments pass over-identifying restrictions.

The lagged BMI term is statistically significant at 1% level in all fixed effects models – the estimated coefficient of BMI_{t-1} is about 0.17. Theoretically, the estimated ρ is expected to be downward biased with fixed effects models and upward biased with random-effects models. Accounting for the endogeneity of BMI_{t-1} using the Difference GMM procedure increases the magnitude of the coefficient of ρ in the range of 0.29–0.33 for males and 0.64–0.68 for females.

Although the estimated coefficient of ρ is in the theoretically plausible range (i.e., greater than the fixed effects and less than the random effects), further examination of the set of instruments in the fixed effects IV model suggested that it suffers from weak instruments. Thus, we considered an IV method of estimation by considering a subset of instruments and conducted econometric tests for under-identification, over-identifying restrictions and weak instruments. Stock and Yogo (2005) developed a weak-identification F-statistic procedure to examine the bias associated with IV estimator (Stock and Yogo, 2005). These identification test results are presented at the bottom of Tables 8 and 9 for males and females, respectively. For all models, both under-identification over-identification requirements are met, and the bias is within 10% and size distortion is within 15% in most instances, thus the bias is relatively small. The estimated

Table 3
Static panel data estimation: females.

Physical activity	LTPA_EE	LTPA_DUM	LTPA_Daily	LTPA_Monthly
Random effects				
LTPA_EE	−0.095***			
	(0.012)			
LTPA_DUM		−0.228***		
		(0.045)		
LTPA_Daily			−0.223***	
			(0.045)	
LTPA_Monthly				−0.007***
				(0.001)
Stand/walk	−0.252***	−0.255***	−0.256***	−0.251***
	(0.051)	(0.051)	(0.051)	(0.050)
Light loads	−0.260***	−0.270***	−0.272***	−0.262***
	(0.063)	(0.063)	(0.063)	(0.063)
Heavy loads	−0.411***	−0.422***	−0.426***	−0.416***
	(0.105)	(0.105)	(0.105)	(0.105)
Fixed effects				
LTPA_EE	−0.084***			
	(0.013)			
LTPA_DUM		−0.193***		
		(0.046)		
LTPA_Daily			−0.191***	
			(0.045)	
LTPA_Monthly				−0.006***
				(0.001)
Stand/walk	−0.245***	−0.247***	−0.248***	−0.244***
	(0.051)	(0.051)	(0.051)	(0.051)
Light loads	−0.267***	−0.276***	−0.278***	−0.269***
	(0.063)	(0.064)	(0.063)	(0.063)
Heavy loads	−0.441***	−0.450***	−0.453***	−0.445***
	(0.108)	(0.108)	(0.108)	(0.107)
Test of LTPA	−0.001	0.012	−0.033	−0.0003
(H_0: $\eta = 0$ in Eq. (2))	(0.011)	(0.041)	(0.044)	(0.001)
R-squared	0.135	0.133	0.133	0.134
Observations	27,104	27,104	27,104	27,104
# of Individuals	4627	4627	4627	4627

The detailed results are available from the corresponding author upon request.
Robust standard errors in parentheses.
*** $p < 0.01$.

coefficient of ρ increased in the range of 0.33–0.40 for males and 0.67–0.72 for females.

It is to be noted that the results of standard fixed effects models are very similar in most instances even if the estimated ρ is downward biased. The following discussion is based on the fixed effects and fixed effects IV regression results. After accounting for the unobserved heterogeneity bias and the dynamics of BMI, the negative relationship between LTPA and BMI remains statistically significant at 1% level. The results show that an additional unit increase in energy expenditure (kcal/kg per day) is associated with a decrease in BMI in the range of 0.04–0.05 points among males. Compared to physically inactive males, those males who are physically active or moderately active (i.e., LTPA_EE > 1.5 kcal/kg per day) reduce their BMI in the range of 0.11–0.14 points. Males participating in daily leisure time physical activity lasting over 15 min reduce their BMI by 0.09 points in the fixed effects IV model but statistically insignificant in the fixed effects model. An additional physical activity event lasting over 15 min in a month is associated with a decrease in BMI in the range of 0.003–0.004 points.

We find that the effect of LTPA on BMI is much stronger in females. An additional unit increase in energy expenditure is associated with a decrease in BMI among females by about 0.08–0.09 points. Similar to males, those females who are physically active or moderately active reduce their BMI by about 0.20 points compared to physically inactive females. Daily active females also reduce their BMI by about 0.15 points. An additional physical activity event lasting over 15 min in a month is associated with a 0.007–0.007 points decrease in BMI among females. These results provide robust evidence on the negative relationship between LTPA and BMI even after accounting for WRPA, unobserved heterogeneity and the dynamics of obesity. The results show that daily energy expenditure greater than 1.5 kcal/kg per day (i.e. at least 30 min of walking) will have the largest negative effect on obesity.

We find a strong negative relationship between WRPA and BMI in Canada. Compared to those males who are inactive at work, being able to stand or walk a lot at work is associated with a decrease in BMI in the range of 0.16–0.19 points. Similarly, females who stand or walk a lot in their daily work activity reduce their BMI in the range of

Table 4
Dynamic fixed effects panel-data estimation: males.

Variables	(1) LTPA_EE	(2) LTPADUM	(3) LTPA_Daily	(4) LTPA_Mo
BMIt−1	0.170***	0.170***	0.170***	0.170***
	(0.022)	(0.022)	(0.022)	(0.022)
LTPA_EE	−0.041***			
	(0.011)			
LTPA_DUM		−0.113***		
		(0.043)		
LTPA_Daily			−0.068	
			(0.043)	
LTPA_Monthly				−0.003***
				(0.001)
Stand/walk	−0.186***	−0.191***	−0.193***	−0.188***
	(0.060)	(0.060)	(0.060)	(0.060)
Light loads	−0.244***	−0.250***	−0.254***	−0.247***
	(0.070)	(0.070)	(0.070)	(0.070)
Heavy loads	−0.399***	−0.406***	−0.408***	−0.403***
	(0.087)	(0.087)	(0.087)	(0.087)
Age	0.057	0.060	0.062	0.059
	(0.064)	(0.063)	(0.064)	(0.064)
Age squared	−0.001***	−0.001***	−0.001***	−0.001***
	(0.000)	(0.000)	(0.000)	(0.000)
Secondary	−0.475	−0.470	−0.481	−0.481
	(0.345)	(0.336)	(0.340)	(0.344)
<Post-secondary	−0.249	−0.236	−0.238	−0.247
	(0.297)	(0.292)	(0.294)	(0.297)
Post-secondary	−0.116	−0.102	−0.106	−0.114
	(0.301)	(0.295)	(0.298)	(0.300)
Married	0.284***	0.292***	0.298***	0.291***
	(0.092)	(0.091)	(0.091)	(0.091)
WSD	−0.069	−0.065	−0.061	−0.062
	(0.126)	(0.126)	(0.126)	(0.126)
Children <6	−0.009	−0.007	−0.007	−0.010
	(0.062)	(0.062)	(0.062)	(0.062)
Children <12	−0.098**	−0.100**	−0.101**	−0.099**
	(0.049)	(0.049)	(0.049)	(0.049)
HIR: decile2	0.134	0.132	0.136	0.132
	(0.147)	(0.146)	(0.146)	(0.146)
HIR: decile3	0.202	0.197	0.199	0.199
	(0.143)	(0.143)	(0.143)	(0.142)
HIR: decile4	0.336**	0.334**	0.334**	0.334**
	(0.132)	(0.132)	(0.132)	(0.131)
HIR: decile5	0.318**	0.314**	0.313**	0.314**
	(0.129)	(0.129)	(0.129)	(0.128)
HIR: decile6	0.314**	0.315**	0.312**	0.315**
	(0.131)	(0.131)	(0.131)	(0.131)
HIR: decile7	0.337***	0.335**	0.335**	0.335**
	(0.130)	(0.130)	(0.131)	(0.130)
HIR: decile8	0.362***	0.360***	0.358***	0.362***
	(0.131)	(0.131)	(0.131)	(0.131)
HIR: decile9	0.382***	0.380***	0.379***	0.380***
	(0.133)	(0.133)	(0.133)	(0.132)
HIR: decile10	0.390***	0.390***	0.387***	0.389***
	(0.134)	(0.134)	(0.134)	(0.133)
HIR: missing	−0.006	−0.002	0.001	−0.008
	(0.178)	(0.179)	(0.179)	(0.178)
Home owner	0.011	0.008	0.007	0.012
	(0.063)	(0.063)	(0.063)	(0.063)
Unemployed	0.032	0.025	0.019	0.030
	(0.084)	(0.085)	(0.084)	(0.085)
Not in LF	0.038	0.036	0.033	0.037
	(0.110)	(0.110)	(0.110)	(0.110)
Year: 1998/99	0.345***	0.340***	0.333***	0.341***
	(0.127)	(0.126)	(0.126)	(0.127)
Year: 2000/01	0.725***	0.721***	0.714***	0.719***
	(0.248)	(0.245)	(0.247)	(0.247)
Year: 2002/03	1.139***	1.129***	1.116***	1.132***
	(0.360)	(0.357)	(0.359)	(0.360)
Year: 2004/05	1.274***	1.258***	1.245***	1.265***
	(0.474)	(0.469)	(0.473)	(0.474)

Table 4 (*Continued*)

Variables	(1) LTPA_EE	(2) LTPADUM	(3) LTPA_Daily	(4) LTPA_Mo
Year: 2006/07	1.649***	1.623***	1.607***	1.639***
	(0.591)	(0.584)	(0.589)	(0.590)
Year: 2008/09	1.882***	1.852***	1.835***	1.871***
	(0.703)	(0.695)	(0.701)	(0.703)
Constant	21.259***	21.126***	21.056***	21.196***
	(2.248)	(2.226)	(2.241)	(2.246)
Observations	19,757	19,757	19,757	19,757
R-squared	0.169	0.168	0.168	0.169
# of Individuals	3879	3879	3879	3879
Exogeneity of LTPA	−0.002	0.003	−0.001	0.0004
(H_0: $n = 0$ in Eq. (3))	(0.010)	(0.043)	(0.044)	(0.001)

Robust standard errors in parentheses.
** $p < 0.05$.
*** $p < 0.01$.

Table 5
Dynamic fixed effects panel-data estimation: females.

Variables	(1) LTPA_EE	(2) LTPADUM	(3) LTPA_Daily	(4) LTPA_M
*BMIt*_1	0.170***	0171***	0.170***	0.170***
	(0.023)	(0.023)	(0.023)	(0.023)
LTPA_EE	−0.081***			
	(0.014)			
LTPA_DUM		−0.184***		
		(0.050)		
LTPA_Daily			−0.145***	
			(0.049)	
LTPA_Monthly				−0.006***
				(0.001)
Stand/walk	−0.241***	−0.244***	−0.246***	−0.241***
	(0.057)	(0.058)	(0.057)	(0.057)
Light loads	−0.290***	−0.299***	−0.303***	−0.292***
	(0.072)	(0.072)	(0.072)	(0.071)
Heavy loads	−0.395***	−0.406***	−0.415***	−0.400***
	(0.122)	(0.122)	(0.122)	(0.122)
Age	0.008	0.009	0.014	0.010
	(0.066)	(0.066)	(0.066)	(0.066)
Age squared	−0.001**	−0.001**	−0.001**	−0.001**
	(0.000)	(0.000)	(0.000)	(0.000)
Secondary	0.557	0.559	0.560	0.552
	(0.392)	(0.395)	(0.393)	(0.392)
<Post-secondary	0.643*	0.634*	0.633*	0.632*
	(0.355)	(0.358)	(0.358)	(0.356)
Post-secondary	0.649*	0.643*	0.634*	0.637*
	(0.356)	(0.359)	(0.358)	(0.357)
Married	0.347***	0.350***	0.355***	0.349***
	(0.119)	(0.119)	(0.120)	(0.120)
WSD	−0.075	−0.073	−0.073	−0.074
	(0.147)	(0.147)	(0.148)	(0.147)
Children <6	0.079	0.089	0.093	0.085
	(0.076)	(0.076)	(0.075)	(0.075)
Children <12	−0.003	−0.009	−0.008	−0.003
	(0.056)	(0.056)	(0.056)	(0.056)
HIR: decile2	0.067	0.065	0.066	0.068
	(0.104)	(0.104)	(0.104)	(0.104)
HIR: decile3	−0.076	−0.077	−0.081	−0.077
	(0.115)	(0.115)	(0.115)	(0.115)
HIR: decile4	−0.058	−0.062	−0.064	−0.059
	(0.114)	(0.114)	(0.114)	(0.115)
HIR: decile5	−0.042	−0.048	−0.049	−0.045
HIR: decile6	−0.069	−0.071	−0.075	−0.070
	(0.115)	(0.115)	(0.115)	(0.115)
HIR: decile7	−0.159	−0.164	−0.162	−0.161
	(0.113)	(0.113)	(0.113)	(0.113)

Table 5 (*Continued*)

Variables	(1) LTPA_EE	(2) LTPADUM	(3) LTPA_Daily	(4) LTPA_M
HIR: decile8	−0.071	−0.076	−0.080	−0.073
	(0.118)	(0.118)	(0.119)	(0.118)
HIR: decile9	−0.080	−0.085	−0.086	−0.082
	(0.124)	(0.124)	(0.124)	(0.124)
HIR: decile10	−0.120	−0.126	−0.127	−0.118
	(0.129)	(0.129)	(0.129)	(0.129)
HIR: missing	−0.250**	−0.247**	−0.254**	−0.253**
	(0.123)	(0.123)	(0.123)	(0.123)
Home owner	0.106	0.108	0.106	0.111
	(0.083)	(0.083)	(0.083)	(0.083)
Unemployed	0.176**	0.161*	0.160*	0.172*
	(0.090)	(0.089)	(0.089)	(0.089)
Not in LF	0.189**	0.183**	0.180**	0.190***
	(0.074)	(0.074)	(0.074)	(0.074)
Year: 1998/99	0.456***	0.452***	0.442***	0.453***
	(0.126)	(0.126)	(0.126)	(0.126)
Year: 2000/01	0.856***	0.856***	0.836***	0.847***
	(0.254)	(0.254)	(0.254)	(0.254)
Year: 2002/03	1.264***	1.254***	1.219***	1.251***
	(0.365)	(0.365)	(0.365)	(0.365)
Year: 2004/05	1.549***	1.534***	1.493***	1.532***
	(0.490)	(0.490)	(0.491)	(0.491)
Year: 2006/07	1.942***	1.918***	1.868***	1.927***
	(0.601)	(0.601)	(0.602)	(0.602)
Year: 2008/09	2.316***	2.293***	2.233***	2.299***
	(0.723)	(0.723)	(0.724)	(0.725)
Constant	20.568***	20.480***	20.276***	20.494***
	(2.347)	(2.346)	(2.353)	(2.352)
Observations	21,329	21,329	21,329	21,329
R-squared	0.144	0.142	0.142	0.143
# of Individuals	4296	4296	4296	4296
Exogeneity of LTPA	−0.012	−0.021	−0.047	−0.001
(H_0: $n = 0$ in Eq. (3))	(0.012)	(0.046)	(0.048)	(0.001

Robust standard errors in parentheses.
* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$

Table 6
Difference GMM panel-data estimation: males.

Variables	(1) LTPAEE	(2) LTPADUM	(3) LTPADaily	(4) LTPAMonthly
BMIt−i	0.285**	0.334**	0.320**	0.322**
	(0.133)	(0.150)	(0.149)	(0.141)
LTPA_EE	−0.067***			
	(0.014)			
LTPA_DUM		−0.172***		
		(0.052)		
LTPA_Daily			−0.134**	
			(0.054)	
LTPA_Monthly				−0.005***
				(0.001)
Stand/walk	−0.208***	−0.210***	−0.215***	−0.206***
	(0.071)	(0.073)	(0.073)	(0.071)
Light loads	−0.176**	−0.174**	−0.182**	−0.173**
	(0.083)	(0.085)	(0.084)	(0.083)
Heavy loads	−0.280***	−0.279***	−0.284***	−0.277***
	(0.100)	(0.101)	(0.102)	(0.099)
Observations	11,551	11,551	11,551	11,551
Number of id	3076	3076	3076	3076
# of instruments	44	44	44	44
A-B test for AR(1) in first differences	−4.38	−4.11	−4.05	−4.32
	[0.00]	[0.00]	[0.00]	[0.00]

Table 6 (*Continued*)

Variables	(1) LTPAEE	(2) LTPADUM	(3) LTPADaily	(4) LTPAMonthly
A-B test for AR(2) in first differences	0.83	0.96	0.88	0.96
	[0.41]	[0.34]	[0.38]	[0.34]
Hansen *J* test of over-identification	19.59	19.64	19.84	19.01
	[0.08]	[0.07]	[0.07]	[0.09]

The detailed results are available from the corresponding author upon request.
Robust standard errors in parentheses; Figures in square brackets are *p*-values.
** $p < 0.05$.
*** $p < 0.01$.
Instruments are: FOD. ((l(0/2).(LTPA, WRPA) Xit Years: 2000/01–2008/09)); gmm((l.BMI), lag(2.) collapse.

0.24–0.28points. Those males who lift light loads at work tend to reduce their BMI by about 0.22–0.25 points compared to those who are sedentary at work. Compared to inactive females at work, those females who lift light loads at work decrease their BMI in the range of 0.30–0.31 points. Those males who lift heavy loads in their daily work activity reduce their BMI in the range of 0.35–0.40 points while the corresponding females reduce their BMI by 0.40 points compared to their inactive counterparts.

4.3. Role of other factors

Now turning to other covariates, a quadratic relationship between age and BMI is found; the coefficient on age is statistically insignificant but both age and age squared terms are jointly significant. Biologically, as people age they put on more weight because of decreasing metabolism and increasing dysregulation of appetite. As adults age, they could also gain weight due to social reasons like

Table 7
Difference GMM panel-data estimation: females.

Variables	(1) LTPA_EE	(2) LTPA_DUM	(3) LTPA_Daily	(4) LTPA_ Monthly
BMIt−i	0.653***	0.637***	0.661***	0.682***
	(0.145)	(0.148)	(0.189)	(0.149)
LTPA_EE	−0.089***			
	(0.019)			
LTPA_DUM		−0.196***		
		(0.064)		
LTPA_Daily			−0.157***	
			(0.060)	
LTPA_Monthly				−0.007***
				(0.002)
Stand/walk	−0.260***	−0.267***	−0.270***	−0.264***
	(0.080)	(0.080)	(0.079)	(0.081)
Lift light loads	−0.299***	−0.312***	−0.314***	−0.302***
	(0.101)	(0.101)	(0.102)	(0.103)
Lift heavy loads	−0.413**	−0.431**	−0.433**	−0.413**
	(0.176)	(0.176)	(0.180)	(0.179)
Observations	12,421	12,421	12,421	12,421
Number of id	3509	3509	3509	3509
# of instruments	44	44	44	44
A-B test for AR(1) in first differences	−6.51	−6.39	−5.70	−6.69
	[0.00]	[0.00]	[0.00]	[0.00]
A-B test for AR(2) in first differences	−1.02	−0.98	−1.01	−1.01
	[0.31]	[0.33]	[0.31]	[0.31]
Hansen *J* test of over-identification	10.45	13.74	16.07	10.17
	[0.56]	[0.32]	[0.19]	[0.60]

The detailed results are available from the corresponding author upon request.
Robust standard errors in parentheses; Figures in square brackets are *p*-values.
** $p < 0.05$.
*** $p < 0.01$.
Instruments are: FOD. ((L(0/2).(LTPA, WRPA) Xit Years: 2000/01– 2008/09)); gmm((L.BMI), lag(2.) collapse.

Table 8
Fixed effects instrumental variables panel-data estimation: males.

Variables	(1) LTPA_EE	(2) LTPADUM	(3) LTPA_Daily	(4) LTPA_Monthly
BMIt−1	0.331**	0.361**	0.397**	0.380***
	(0.138)	(0.155)	(0.162)	(0.143)
LTPA_EE	−0.047***			
	(0.011)			
LTPA_DUM		−0.139***		
		(0.045)		
LTPA_Daily			−0.086*	
			(0.045)	
LTPA_Monthly				−0.004***
				(0.001)
Stand/walk	−0.165***	−0.169***	−0.168***	−0.163***
	(0.056)	(0.056)	(0.057)	(0.056)
Light loads	−0.217***	−0.220***	−0.220***	−0.214***
	(0.068)	(0.067)	(0.068)	(0.068)
Heavy loads	−0.348***	−0.350***	−0.346***	−0.343***
	(0.087)	(0.087)	(0.089)	(0.087)
Observations	18,951	18,951	18,951	18,951
Number of id	3536	3536	3536	3536
Over-identification test				
Hansen *J* statistic	1.678	1.62	1.49	1.54
	[0.64]	[0.65]	[0.69]	[0.67]
Under-identification test				
K-P rk LM statistic+	50.125***	37.79***	34.26***	46.23***
Weak-identification test				
Cragg–Donald *F* statistic	24.914	18.67	16.93	22.68

The detailed results are available from the corresponding author upon request.
Robust standard errors in parentheses; Figures in square brackets are *p*-values.
* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.
+ K-P, Kleibergen-Paap.
Critical values for Cragg–Donald Wald *F* statistic:
5% maximal IV relative bias, 16.85; 10% maximal IV size, 24.58.
10% maximal IV relative bias, 10.27; 15% maximal IV size 13.96.
20% maximal IV relative bias, 6.71; 20% maximal IV size 10.26.
30% maximal IV relative bias, 5.34; 25% maximal IV size 8.31.
Excluded Instruments are: L.(LTPA), L2.(LTPA), L.(Stand/Walk), L.(Light Loads), L.(Heavy Loads)

work-family pressures, lack of availability of time for physical activity and higher opportunity cost of time. As individuals get older, they tend to lose lean body mass and hence reduce weight. Previous cross-sectional Canadian studies found very similar results (Cairney and Wade, 1998; Tjepkema, 2006).

Those who are married or living in a common-law relationship tend to increase their BMI compared to singles. Married individuals may have more financial obligations towards family commitments which may reduce the allocation of time towards physical activity (Brown and Roberts, 2011; Farrell and Shields, 2002; Humphreys and Ruseski, 2011; Maruyama and Yin, 2012). Consequently, a positive association between married and obesity is found in a number of studies (Averett et al., 2008; Cairney and Wade, 1998; Godley and McLaren, 2010; Ross et al., 2007; Tjepkema, 2006).

Although Grossman's model suggests that higher levels of education is expected to have better health (i.e. lower BMI in the present context), education is not statistically significant for males once unobserved heterogeneity is accounted for and it is statistically significant for females at 10% level. Similar to our random-effects results, a number of previous cross-sectional studies suggest a strong negative association between education and BMI (Cairney and Wade, 1998; Godley and McLaren, 2010; McLaren et al., 2010; Tjepkema, 2006; Wolff et al., 2006).

Having small children in the family might increase the opportunity cost of physical activity. It has been found that having children negatively affects exercise (Brown and Roberts, 2011; Farrell and Shields, 2002). We find that having small children aged less than 6 years in the household has no effect on BMI for both genders. However, presence of children aged 6–11 years in the household is associated with a lower BMI among males, and it has no effect on BMI of females. One implication may be that having children aged 6–11 years in the household may decrease the opportunity cost of physical activity for men, as they may be participating in activities with their children.

Household income ratio is found to be positively significant for males and it is not statistically significant

Table 9
Fixed effects instrumental variables panel-data estimation: females.

Variables	(1) LTPAEE	(2) LTPA_DUM	(3) LTPA_Daily	(4) LTPA_ Monthly
BMIt−1	0.688***	0.696***	0.690***	0.724***
	(0.162)	(0.174)	(0.202)	(0.163)
LTPAEE	−0.093***			
	(0.018)			
LTPA_DUM		−0.198***		
		(0.061)		
LTPA_Daily			−0.163***	
			(0.059)	
LTPA_Monthly				−0.007***
				(0.001)
Stand/walk	−0.275***	−0.284***	−0.285***	−0.279***
	(0.077)	(0.078)	(0.077)	(0.078)
Light loads	−0.298***	−0.311***	−0.313***	−0.300***
	(0.100)	(0.100)	(0.101)	(0.101)
Heavy loads	−0.391**	−0.404**	−0.412**	−0.390**
	(0.173)	(0.175)	(0.176)	(0.176)
Observations	15,936	15,936	15,936	15,936
Number of id	3509	3509	3509	3509
Over-identification test				
Hansen *J* statistic	2.01	6.27	7.35	1.9
	[0.73]	[0.18]	[0.12]	[0.75]
Under-identification test				
K-P rk LM statistic+	54.36***	46.46***	35.25***	50.32***
Weak-identification test				
Cragg–Donald *F* statistic	16.26	15.67	11.56	15.99

The detailed results are available from the corresponding author upon request.
Robust standard errors in parentheses; Figures in square brackets are *p*-values.
** $p < 0.05$.
*** $p < 0.01$.
+ K-P: Kleibergen-Paap.
Critical values for Cragg–Donald Wald *F* statistic:
5% maximal IV relative bias, 18.37; 10% maximal IV size, 26.87.
10% maximal IV relative bias, 10.83; 15% maximal IV size, 15.09.
20% maximal IV relative bias, 6.77; 20% maximal IV size, 10.98.
30% maximal IV relative bias, 5.25; 25% maximal IV size, 8.84.
Excluded Instruments are: L.(LTPA), L2.(LTPA), L.(Stand/walk), L.(Light loads), L.(Heavy loads).

for females. Home ownership is not statistically significant for both genders. The cross-sectional literature suggests that the association between income and obesity is positive for males and negative for females (Brown and Roberts, 2011; Godley and McLaren, 2010; Roskam and Kunst, 2008; Ross et al., 2007; Tjepkema, 2006). On the other hand, Ward et al. (2007) find that income is not statistically significantly associated with obesity.

The effect of employment status is found to be statistically significant for females. Those females who are unemployed or out of the labour force tend to increase their BMI compared to their employed counterparts. In particular, those females who are not in the labour market tend to increase their BMI. The literature suggests a positive relationship between unemployment and obesity among females – various explanations are offered in the context of labour market dynamics of obese women in the literature (Greve, 2008; Groth et al., 2009).

5. Conclusions and policy implications

From a health policy perspective, understanding the relationship between physical activity (LTPA and WRPA) and obesity is of considerable importance. Technological innovations continue to lead to a reduction in energy expended at the workplace (e.g., from physical work to desk work and from walking or bicycling to driving, etc.) and have made domestic activities more sedentary, such as watching television, playing video games or using the internet (Lakdawalla and Philipson, 2009, 2007; Philipson and Posner, 2008, 2003; Rosin, 2008). It is argued that individuals working more hours have less time to exercise and have higher BMI (Lakdawalla and Philipson, 2007; Philipson and Posner, 2008). Chou et al. (2002) argue that rise in obesity rates in the US is the result of fundamental changes in social structures – change in individuals' allocation of time between labour market and food preparation at home. Furthermore, the shift from an industrial to a service-based economy combined with the introduction of labour saving technologies in the workplace and home environments generally make modern society obesogenic.

Physical activity has been considered as an important modifiable risk factor for obesity in the public health literature (Fogelholm and Kukkonen-Harjula, 2000; PHAC and CIHI, 2011; Summerbell et al., 2009; Wareham et al., 2005; Waxman and Assembly, 2004; Weinsier et al., 1998), but the empirical evidence on the relationship between changes in physical activity and changes in obesity is mixed in the existing literature. The public health literature suggests a negative association between some measures of physical activity and obesity based on cross-sectional studies (Fogelholm and Kukkonen-Harjula, 2000; PHAC and CIHI, 2011; Summerbell et al., 2009; Wareham et al., 2005). Although some longitudinal studies suggest that those who report higher levels of physical activity tend to reduce their body weight, the findings are generally inconsistent and many studies do not account for unobserved heterogeneity bias (Summerbell et al., 2009; Wareham et al., 2005). A handful of randomized studies on this subject undertaken thus far are not only weak in methodology (because of small convenience samples) but their conclusion regarding whether increase in physical activity will reduce obesity is uncertain at best (Wareham et al., 2005). Thus, understanding the relationship between physical activity and obesity using nationally representative longitudinal data is a valuable contribution.

In order to ascertain the causal relationship between physical activity and obesity, some authors attempted to use an instrumental variable method of estimation. Utilizing pooled cross-sectional data from the US, Rashad finds that adjusted caloric intake has a strong and positive effect on BMI in her ordinary least squares regression model (Rashad, 2006). But this strong effect disappeared after accounting for the endogeneity of adjusted caloric intake in her instrumental variable estimation with the exception of females.[8] Analyzing the effect of physical activity on obesity, a study from Australia (Maitra and Sharma, 2007) corroborates the results of Rashad (2006). The duration of exercise exhibits a negatively significant effect on the probability of being overweight or obese in their ordinary least squares regressions, but this effect disappeared once they account for the endogeneity of exercise (Maitra and Sharma, 2007). In some instances, they even find a positive relationship between the duration of exercise and obesity after the endogeneity of exercise is accounted for in their instrumental variable estimation procedure. The authors interpret the statistically significant positive result as those who perceive themselves overweight or obese conduct more exercise.

The findings of our study clearly suggest that LTPA exerts a negative effect on BMI of Canadian adults. Specifically, participation in LTPA exceeding 1.5 kcal/kg per day (e.g., at least 30 min of walking) reduces BMI by about 0.11–0.14 points in males and 0.20 points in females relative to physically inactive counterparts. Clearly, had there not been an increase in LTPA, obesity rates in Canada might have been even larger. Indeed, our descriptive data show that the average BMI of physically active ($LTPA\_EE \geq 3.0$), moderately active ($1.5 \leq LTPA\_EE \leq 2.9$) and physically inactive ($LTPA\_EE < 1.5$) respondents increased from 24.52 kg/m^2 to 26.50 kg/m^2, 24.78 kg/m^2 to 26.96 kg/m^2 and 25.03 kg/m^2 to 27.84 kg/m^2, respectively over the study period. Although a negative association between measures of LTPA and obesity has been found in previous Canadian cross-sectional studies (Chen and Mao, 2006; Craig et al., 2005; Godley and McLaren, 2010; Ross et al., 2007; Tjepkema, 2006), the estimated effects from these studies cannot be relied upon as they generally tend to overestimate the effects. This paper provides robust empirical evidence on the effects of LTPA and WRPA on BMI after accounting for time-invariant unobserved heterogeneity and the dynamics of obesity while controlling for a wide range of socio-economic factors. The results based on dynamic models suggest that the estimated effect of LTPA may be interpreted as causal if the reverse causality bias is absent. The reverse causality bias does not appear to be present in our data as the feedback effect of BMI to LTPA is ruled out even at 10% of level of significance.

We find that WRPA is negatively related to BMI in Canada. Compared to those who are inactive at work in their usual daily activity, being able to stand or walk reduces BMI by about 0.17 points in males and 0.30 points in females. And those who perform intensive physical activity (lift light or heavy loads) reduce their BMI substantially. Technological innovations have generally made the modern workplace and home environments sedentary and the trend is irreversible. Moreover, shift of the modern economy from industrial to service sector jobs will continue to make the workplace more sedentary in the future. From a policy perspective, promotion of physical activity in workplaces, such as providing access to and availability of physical activity facilities and encouraging employees to remain physically active through various wellness programmes may mitigate some of the unintended consequences of a sedentary workplace.

Although this study has several strengths, there are some limitations which can be improved in future research. First, self-reported height and weight data used in this study are subject to bias, but accurate adiposity and energy expenditure data in nationally representative longitudinal surveys are not available for Canada. Second, like elsewhere, caloric intake data at the individual-level over time are not available in Canada, thus making it difficult to assess the contribution of the energy intake explicitly. Third, the intensity of physical activity at the individual-level was not collected in the NPHS and hence it was based on the guidelines of the *Canadian Fitness and Lifestyle Research Institute*. Although it is the lower bound of the intensity of physical activity in populations, measuring actual intensity of physical activity at the individual-level in future studies could help address plausible residual confounding arising from this source. Fourth, unlike LTPA, WRPA was based on a single item question. Fifth, the

[8] She suggests that genetic and behavioural factors might have influenced obesity, but some authors rule out the genetic factors because the rise in obesity happened too quickly to be consistent with gene modifications (Philipson and Posner, 2008).

negative relationship between LTPA and BMI as well as WRPA and BMI found in this paper can also be attributed to overall healthy lifestyle as those who are healthy and physically active may also be making other healthy choices simultaneously. Finally, our results are suggestive of a causal relationship between physical activity and obesity but not definite as the Arellano-Bond estimator is limited in addressing the structural endogeneity in the absence of time-varying strictly exogenous instruments; future studies can improve using plausible exogenous variations in physical activity, if available, as excluded instruments.

Despite these limitations, our overall results clearly suggest that policies designed to encourage LTPA exceeding 1.5 kcal/kg per day (i.e., at least 30 min of walking) among adults and promotion of physical activity at workplace will help reduce obesity risks in adults. Although the negative effect of physical activity on BMI is relatively small in this study, the overall benefits of physical activity are numerous. Recent evidence suggests that the benefits of physical activity include reduced risk of several chronic diseases, increased overall health status and premature mortality (Humphreys et al., 2014; PHAC and CIHI, 2011; US Department of Health and Human Services, 1996; World Health Organization, 2010).

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Appendix

Variable definitions.

Variable	Definition
BMI	Body mass index (self-reported weight in kilograms divided by self-reported height in metres squared)
LTPA_EE	Average daily energy expenditure per kilogram of body weight on all leisure time activities by the respondent
LTPA_DUM	Physically active (LTPA_EE ≥ 3.0) or moderately active (1.5 ≤ LTPA_EE ≤ 2.9) = 1, physically inactive (LTPA_EE < 1.5) = 0
LTPA_Daily	Daily average LTPA lasting more than 15 min = 1, otherwise = 0
LTPA_Monthly	Frequency of average monthly LTPA lasting more than 15 min
Usually sit	Usually sit during the day and don't walk very much = 1, otherwise = 0
Stand/walk	Usually stand or walk quite a lot during the day but don't have to carry or lift things very often = 1, otherwise = 0
Light loads	Usually lift or carry light loads, or have to climb stairs or hills often = 1, otherwise = 0
Heavy loads	Usually do heavy work or carry very heavy loads = 1, otherwise = 0
Female	Female = 1, male = 0
Age	Age in completed years
Age squared	Age squared
<Secondary	Less than secondary school = 1, otherwise = 0
Secondary	Secondary school graduation = 1, otherwise = 0
<Post-secondary	Some post-secondary education =1, otherwise = 0
Post-secondary	College or University degree = 1, otherwise = 0
Children <6	Children in the household aged less than 6 years
Children <12	Children in the household aged 6 years or more but less than 12 years
Married	Currently married or common law relationship = 1, otherwise = 0
WSD	Widow, separated or divorced = 1, otherwise = 0
Single	Single =1, otherwise = 0
HIR: decile1	Household income ratio: decile 1 = 1, otherwise = 0
HIR: decile2	Household income ratio: decile 2 = 1, otherwise = 0
HIR: decile3	Household income ratio: decile 3 = 1, otherwise = 0
HIR: decile4	Household income ratio: decile 4 = 1, otherwise = 0
HIR: decile5	Household income ratio: decile 5 = 1, otherwise = 0
HIR: decile6	Household income ratio: decile 6 = 1, otherwise = 0
HIR: decile7	Household income ratio: decile 7 = 1, otherwise = 0
HIR: decile8	Household income ratio: decile 8 = 1, otherwise = 0
HIR: decile9	Household income ratio: decile 9 = 1, otherwise = 0
HIR: decile10	Household income ratio: decile 10 = 1, otherwise = 0
HIR: Missing	Household income ratio: missing = 1, otherwise = 0
Home owner	Household owned a home with or without mortgage = 1, 0 otherwise
Employed	Full- or part-time employed in the past year = 1, 0 otherwise
Unemployed	Unemployed in the past year = 1, 0 otherwise
NLF	Not looking for work in the past year = 1, 0 otherwise
Year: 1994/95	Survey cycle in 1994/95 = 1, otherwise = 0
Year: 1996/97	Survey cycle in 1996/97 = 1, otherwise = 0
Year: 1998/99	Survey cycle in 1998/99 = 1, otherwise = 0
Year: 2000/01	Survey cycle in 2000/01 = 1, otherwise = 0
Year: 2002/03	Survey cycle in 2002/03 = 1, otherwise = 0

(*Continued*)

Variable	Definition
Year: 2004/05	Survey cycle in 2004/05 = 1, otherwise = 0
Year: 2006/07	Survey cycle in 2006/07 = 1, otherwise = 0
Year: 2008/09	Survey cycle in 2008/09 = 1, otherwise = 0

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