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THE EFFECT OF LEISURE-TIME PHYSICAL ACTIVITY ON OBESITY, DIABETES, HIGH BP AND HEART DISEASE AMONG CANADIANS: EVIDENCE FROM 2000/01 TO 2005/06

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ABSTRACT

The Effect of Leisure-time Physical Activity on Obesity, Diabetes, High BP and Heart Disease among Canadians: Evidence from 2000/01 to 2005/06

Although many papers have looked at the effect of physical activity on obesity and other health outcomes, the causal nature of this relationship remains unclear. We try to fill this gap by investigating the impact of leisure-time physical activity (LTPA) and work-related physical activity (WRPA) on obesity and chronic conditions in Canadian adults aged 18-75 using instrumental variable and recursive bivariate probit approaches. Average local temperatures surrounding the respondents' interview month are used as a novel instrument to help identify the causal relationship between LTPA and health outcomes. We find that an active level of LTPA (i.e. walking ≥ 1 hour/day) reduces the probability of obesity by five percentage points, which increases to eleven percentage points if also combined with some work-related physical activity. WRPA exhibits a negative effect on the probability of obesity and chronic conditions.

JEL Classification: I10; I12; I18; J18; C23

Keywords: obesity; physical activity; chronic disease; probit; instrumental variable; recursive bivariate probit; canada

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1. Introduction

A growing body of research shows that leisure-time physical activity (LTPA) is associated with lower risks of obesity, preventable chronic diseases and premature mortality (U.S Department of Health and Human 1996; Craig et al. 2005; Warburton et al. 2006; Tjepkema 2006; Chen & Mao 2006; Brown et al. 2007; Ross et al. 2007; Godley & McLaren 2010). Although interesting, the identified associations may not be casual, mainly because the decision to participate in LTPA and its duration are correlated with unobservable factors like the enjoyment of physical activity, time preference, opportunity cost of time and risk aversion (Komlos et al. 2004; Smith et al. 2005; Norton & Han 2008). Moreover, obese people may not engage in physical activity precisely because they are obese rather than the contraire. As result, physical activity is potentially an endogenous variable in the health-related outcome equations, similar to that found between other lifestyle variables and health (Contoyannis & Jones 2004; Balia & Jones 2008; Schneider & Schneider 2012).

If individuals could be randomly assigned into different physical activity levels, the limitation of unobservable confounders being correlated with LTPA and the health outcome of interest could be overcome. However, such large scale experiments are difficult to conduct. Thus, one has to rely on observational data to estimate the effect of LTPA on obesity and chronic diseases. The use of an instrumental variables method of estimation can be employed to purge this type of endogeneity bias if exogenous instruments can be found that are correlated with LTPA but uncorrelated with the error term in the relevant health outcome equations.

To the best of our knowledge, only Humphreys et al. employed such a methodology in their recursive bivariate probit modelling framework (Humphreys et al. 2013). Using self-reported "sense of belonging to the local community" as an exclusion restriction, they show that participation in LTPA reduces the probability of diabetes, high blood pressure (BP), heart disease, asthma, arthritis and self-reported poor health using the 2005/06 Canadian Community Health Survey data. Although they demonstrate the validity of their exclusion restriction through a falsification test, numerous studies have shown that the 'sense of belonging to the local community' is associated with better health outcomes in Canada (Ross 2002; Wister & Wanless 2007; Shields 2008; Romans et al. 2011; Kitchen et al. 2011) and higher social capital (Wister & Wanless 2007; Laporte et al. 2008; Kitchen et al. 2011). Thus, the exogeneity of the sense of belonging to the local community variable is called into question as it appears to be correlated with both the LTPA and health outcomes. Our study employs a strong and hitherto unexploited exogenous instrument, the monthly average temperatures in the respondents' local neighbourhood, which is highly correlated with LTPA but uncorrelated with the error term in the obesity or chronic disease equations. We demonstrate the relevance of this instrument based on several identification tests proposed in the econometrics literature.

A second limitation with existing studies is that most fail to consider the role of work related physical activities (WRPA) while examining the effects of LTPA, and vice versa (Fogelholm & Kukkonen-Harjula 2000; Wareham et al. 2005; Summerbell et al. 2009). For instance, Humphreys et al. acknowledge the importance of WRPA but ignore it in their analysis (Humphreys et al. 2013). The exclusion of WRPA in these types of analyses may cause specification bias. In this paper, we include WRPA variables and examine the effects of both LTPA and WRPA on obesity and chronic diseases. In addition, we look at how the effect of LTPA varies across three distinct levels of WRPA based on reported usual daily activities or work habits: a) Sedentary, b) Stand/Walk and c) Lift heavy or light loads, with the view to guiding policy discussions regarding the role of overall physical activity in reducing obesity or chronic diseases.

Finally, our paper contributes to the existing literature by the use of consistent and high quality information on LTPA over time. A number of studies rely on a global self-reported physical activity measure which may be a good proxy for healthy lifestyle, but does not capture the intensity, frequency and duration of physical activity (Wareham et al. 2005). Our study examines the effect of LTPA on these outcomes from both the extensive margin (i.e. participation) and intensive margin (i.e. frequency and duration) perspective.

The data for this study come from the confidential master files of three large nationally representative surveys, the Canadian Community Health Survey (CCHS) Cycles 1.1 (2000/01), 2.1 (2003/04) and 3.1 (2005/06), conducted by Statistics Canada. We focus on key health outcome variables that are modifiable to a certain extent and are demonstrated to be linked to physical inactivity in the literature: overweight, obesity, diabetes, high blood pressure and heart disease.

The rest of the paper is organized as follows. Section 2 develops the empirical frameworks for analyzing the effect of physical activity on obesity and chronic diseases. Section 3 presents our data and variables construction for the empirical investigation. The results are presented and discussed in section 4. Finally, section 5 concludes with a discussion of the study contributions, limitations, and potential policy implications.

2. Theoretical Motivation and Empirical Methodology

The theoretical underpinning of this study is based on Grossman's model in which rational individuals make decisions about how to allocate their time to produce health in order to maximize lifetime utility, subject to time and budget constraints (Grossman 2000). The opportunity costs of time and preferences will influence the decisions regarding whether or not to exercise as well as the intensity and duration of exercise (Mullahy & Robert 2010; Humphreys & Ruseski 2011; Brown & Roberts 2011; Maruyama & Yin 2012). While time spent on physical activity is generally considered to be a source of disutility because its opportunity costs, it may increase discounted lifetime utility by increasing the availability of healthy days in future periods. Thus, time-preference is likely to play an important role in influencing the LTPA participation decision. Furthermore, the opportunity cost of time will be lower for those who enjoy physical activity (Hatziandreu et al. 1988; Hagberg & Lindholm 2010). The key point is that unobservable factors will likely affect both physical activity and health outcomes.

Our empirical specification is similar to the reduced-form model of Humphreys et al. (Humphreys et al. 2013). To investigate the effect of LTPA and WRPA on obesity and chronic diseases, we use three econometric approaches: a univariate probit model, an instrumental variable (IV) model, and a recursive bivariate probit model.

2.1 Univariate Probit Model

We begin with a reduced-form model of obesity (or chronic disease) a la Humphreys et al. (2013), but in which we include WRPA:

$$H_i^* = \alpha + \delta_1 (LTPA)_i + \delta_2 (WRPA)_i + \beta' X_i + \varepsilon_i . \qquad (1)$$

In equation (1), for each individual *i*, H_i^* is the latent health stock, $LTPA_i$ and $WRPA_i$ represent the measures of leisure-time physical activity and work-related physical activity, X_i is a vector of demographic and socio-economic characteristics and ε_i is the standard disturbance term. The vector X_i includes age, gender, marital status, immigration status, educational status, presence of small children in the family, employment status, household income, home ownership, geographical location and province of residence.

We do not observe H_i^*, instead we observe $H_i = 1$ if $H_i^* \geq 1$ and 0 otherwise. We consider five dichotomous H_i variables: overweight (overweight or obese = 1, 0 normal weight), obesity (obese = 1, 0 normal weight), diabetes (diagnosed with diabetes = 1, 0 otherwise), high BP (diagnosed with high blood pressure = 1, 0 otherwise) and heart disease (diagnosed with heart disease = 1, 0 otherwise). Similar to Humphreys et al., we use three variables reflecting participation and the intensity of LTPA (Humphreys et al. 2013): (i) daily, (ii) moderate and (iii) active. The 'daily' variable takes the value of one if the respondent participated in LTPA daily lasting at least 15 minutes based on responses over the past 3 months and zero otherwise. Moderate and active refer to the intensity of LTPA participation.

Our WRPA is based on responses to the following question in each survey: "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 (defined as sedentary) ii) stand or walk quite a lot during the day but don't have to carry or lift things very often (defined as stand/walk), iii) usually lift or carry light loads, or have to climb stairs or hills often (defined as light load), and iv) do heavy work or carry very heavy loads (defined as heavy load). We include three dummy variables each for stand/walk, light load and for heavy load, with sedentary as the reference category.

A probit regression model of equation (1) provides our baseline analysis. The estimated coefficient, $\hat{\delta}_1$, measures the impact of LTPA on H_i. Given that LTPA is a dichotomous variable, the average partial effect of participating in physical activity (or the intensity of LTPA participation) on the probability of being obese or diagnosed with a chronic condition is the sample average of changes in the predicted probability of being obese or having a chronic condition with discrete changes in LTPA, while evaluating all other variables, X_i, at their observed values. Specifically, the average partial effect is computed as:

$$\frac{1}{n}\sum_{1}^{n}\left[\Phi\left(\hat{\beta} X_i + \hat{\delta}_2(WRPA_i) + \hat{\delta}_1(LTPA_i) \mid LTPA = 1\right) - \Phi\left(\hat{\beta} X_i + \hat{\delta}_2(WRPA_i) + \hat{\delta}_1(LTPA_i) \mid LTPA = 0\right)\right], \quad (2)$$

where Φ is the standard normal distribution function and $\Phi\left(\hat{\beta} X + \delta_1 L\hat{T}PA + \delta_2 W\hat{R}PA\right)$ is the marginal predicted probability of participating in LTPA (or the intensity of LTPA participation) and is computed for each observation using the estimated coefficients from equation (1), and n is the sample size. In a similar fashion, the average partial effects of WRPA can be computed.

2.2 Instrumental Variable Model

The main drawback of the univariate probit model is that the decision to participate in LTPA or the intensity of LTPA participation is not likely to be exogenous to obesity or chronic conditions.[1] As argued earlier, unobservable factors like the enjoyment of physical activity, time preference and the opportunity cost of time are likely to be correlated with both LTPA and H_i. Allowing LTPA to be endogenous, we can re-specify equation (1) as:

$$H_i^* = \alpha + \delta_1(LTPA^*)_i + \delta_2(WRPA)_i + \beta' X_i + \varepsilon_i, \quad (3)$$

where $LTPA^*_i$ is the latent variable that determines the extent of physical activity undertaken by individual i (participation or intensity) and is specified as:

$$LTPA_i^* = \eta + \lambda' Z_i + \gamma' X_i + u_i, \quad (4)$$

where Z_i is the vector of characteristics that influence the decision to participate in physical activity but which are uncorrelated with ε_i, η is the intercept term, and u_i is the error term. The parameters to be estimated are: α, η, β, λ, δ_1, δ_2 and γ; we are particularly interested in the consistent estimate of the δs. The observed realization of the latent variable $LTPA^*_i$ takes the following form: $LTPA_i = 1$ if $LTPA_i^* \geq 1$ and 0 otherwise.

[1] Note that WRPA is likely to be exogenous as it is primarily governed by occupational attainment. It is highly unlikely that individuals choose occupations in an attempt to do more exercise at the workplace.

A common approach is to estimate the model characterized by equations (3) – (4) by employing a linear IV procedure if one or more exogenous instruments can be found that are correlated with LTPA but uncorrelated with ε_i conditional on X_i (Imbens & Angrist 1994; Angrist et al. 1996). A linear IV procedure generally yields consistent estimates for the local average treatment effect, that is the average treatment effect on the treated for compliers (Imbens & Angrist 1994; Angrist et al. 1996).

Finding instruments that have no direct effect on obesity or chronic disease but which are strongly correlated with LTPA is a challenge, rendered all the more so by the fact that the exogeneity assumption is not directly testable. Researchers typically rely on convincing theoretical justifications and statistical tests for the validity of instruments. The theoretical basis for our instrument is premised on the idea that an individual's decision to participate in LTPA or its intensity is governed by unobservable preferences, like the enjoyment of physical activity, which is partly determined by local weather conditions. In a country like Canada with extreme weather conditions throughout the year, the average monthly temperature in the respondents' local neighbourhood is likely to be correlated with LTPA but uncorrelated with the error terms in the obesity or chronic disease equations. The basic idea is that the levels of LTPA will tend to fluctuate in jurisdictions where extreme weather patterns are experienced. Indeed, a systematic review on this subject finds that physical activity levels are considerably lower during colder months in countries with extreme weather (Tucker & Gilliland 2007). Merchant et al., report that during the winter season, 64% of Canadians are inactive compared to 49% in the summer, varying considerably across geographical jurisdictions (Merchant et al. 2007). Studies also suggest that weather accounts for over 40% of all measured physical activity (Tucker & Gilliland 2007). Thus, variations in the local temperature around the respondent's neighbourhood provide an appropriate natural experiment setting in Canada to study the effect of physical activity on health outcomes. Since our LTPA variable is constructed based on physical activity undertaken by the respondents over a three month period in each survey, we use the local temperature data during the corresponding periods as our relevant instruments.[2]

One important advantage of the CCHS micro data files is that we have access to 6-digit residential postal codes and the date of interview for all respondents. Consistent monthly weather data for over 1200 weather stations in each year along with the longitude and latitude coordinates of each weather station are compiled by Environment Canada and are publicly available.[3] The 6-digit postal codes in the CCHS data allow us to obtain the longitude and latitude coordinates of the respondents' residences and to link them to the nearest local weather station using ArcGIS software. After assigning a local weather station to each respondent, we then link local temperature data for every respondent back three months beginning with the interview month.[4] We restrict our analysis to those observations where we found a weather station within a 0.5 degree distance (about 55 kilometers) from the respondent's home based on the centroid of his/her 6-digit postal code.[5] Since CCHS data were collected over 12 months by Statistics Canada (typically from March to April), large variations in temperatures around the interview months were found and we exploit this exogenous variation as the source of identification. It can be seen from Table 1 the temperatures vary widely in our data.

<Insert Table 1 here>

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[2] Note that the 3 months correspond to the questions respondents answered in the survey (i.e. details of physical activity undertaken in past 3 months). When we included the 4th month average temperature in our instruments, it didn't turn out to have any explanatory power in most cases.

[3] http://climate.weatheroffice.gc.ca/prods_servs/cdn_climate_summary_e.html

[4] For instance, if a respondent was interviewed on January 21, 2001, we link the average temperatures in January 2001, December 2000 and November 2000 from the nearest weather station to this person.

[5] We are able to assign more than 87% of respondents to a local weather station where consistent temperature data are available over a three-month period, including the month of interview. Sensitivity analysis suggested that our results are unaffected within a 0.3 degree (about 33 kilometers) to 1 degree (about 111 kilometers) range.

Recent developments in weak instruments methodology enable us to test econometrically the relevance of instruments, over-identifying restrictions and weak-instrument hypotheses for our chosen instruments (Stock & Yogo 2005; Baum et al. 2007; Kleibergen & Paap 2006). Various tests reported in the results section based on linear probability models confirm that our instruments generally satisfy the identification requirements with a few exceptions. The Cragg-Donald F-statistic and the Kleibergen-Paap Wald F-statistic are large in our application, suggesting that our instruments are very strong.

2.3 Recursive Bivariate Probit Model

Although the linear IV method is consistent for estimating the local average treatment effect, it is generally biased; its small sample performance may be inferior to a correctly specified bivariate probit model. For instance, Altonji et al. found that the linear IV model produced large coefficients and standard errors compared to the bivariate probit model in their application (Altonji et al. 2005). Some argue that a correctly specified bivariate probit model is superior to the IV procedure, especially if the error term is non-normal (Bhattacharya et al. 2006; Freedman & Sekhon 2010). Moreover, the average treatment effect can be recovered from correctly specified bivariate probit estimates. Several papers in the health economics literature have utilized the recursive bivariate probit modelling framework to study the relationship between lifestyle variables and health status (Contoyannis & Jones 2004; Balia & Jones 2008; Schneider & Schneider 2012) and physical activity and health outcomes (Humphreys et al. 2013).

Identification in a bivariate probit model rests on exclusion restrictions – that is excluding at least one variable from the structural equation and including it in the reduced form equation. We use instruments as our exclusion restrictions. The IV regression method based on a recursive bivariate probit model is specified as per equations (3) – (4) with the additional assumption that $Cov(\varepsilon, u) = \rho$; ρ is interpreted as the conditional tetrachoric correlation between *H* and *LTPA*.[6] The average partial effects (interpreted as average treatment effects) are obtained similar to the probit model as specified in equation (2), using the estimated parameters from the recursive bivariate probit models.

3. Data and Variables

The data for this study come from three biennial confidential master files of the Canadian Community Health Survey (CCHS), Cycles 1.1 (2000/01), 2.1 (2003/04), 3.1 (2005/06), conducted by Statistics Canada. Each CCHS cycle is a large nationally representative survey of more than 130,000 individuals aged 12 or older living in all provinces and territories in Canada, except those living on Crown lands, Indian reserves, Canadian Forces bases, institutions and some remote areas. All CCHS cycles use a consistent multistage stratified cluster sampling design to collect socio-demographic and health-related information. The surveys were conducted by highly skilled interviewers in multiple languages and the response rates were over 90% in all cycles. Our study sample is restricted to those aged 18 to 75 years. Excluding missing socio-demographic variables other than household income resulted in 315,833 valid observations. Sample sizes for the different regression analyses vary by the type of outcome and the chosen sub-sample criteria. All descriptive and regression analyses are weighted using the sampling weights provided by Statistics Canada to account for the complex survey sampling design.

The CCHS cycles contain information on self-reported weight and height for all respondents 18 years and older, excluding pregnant women. However, the self-reported height

[6] If $\rho \neq 0$ then bivariate probit model is preferable; if $\rho = 0$ then the univariate probit model is appropriate if the same covariates are used (Wooldridge, 2002, p.477). However, in the context of recursive bivariate probit framework, rejection of the bivariate probit model implies that the IV results are preferable provided that the instruments are valid.

and weight, and hence self-reported body mass index (BMI),[7] are likely to be biased because individuals generally tend to over-report their height and under-report their weight. Thus, the correction factors proposed by Gorber et al. which are gender-specific (Gorber et al., 2008), were applied in our analysis of overweight and obese. Overweight takes the value of 1 if BMI ≥ 25 kg/m^2 and 0 if 18.5 kg/m^2 ≤ BMI <25 kg/m^2 (i.e. normal weight). Obese is defined as 1 if BMI ≥ 30 kg/m^2 and 0 if 18.5 kg/m^2 ≤ BMI <25 kg/m^2. Diabetes, high BP and heart disease are dichotomous variables taking on the value of one if the respondent reported having the condition diagnosed by a health professional and zero otherwise. Note that these outcome variables are linked to lifestyle choices and can be modified to a certain extent through physical activity.

We use three derived dummy variables reflecting participation and the intensity of LTPA by Statistics Canada in each Survey: i) daily (participates in LTPA daily, on average, lasting over 15 minutes = 1, 0 otherwise), moderate (average daily energy expenditure value ≥ 1.5 kcal/kg/day, 0 if average daily energy expenditure value <1.5 kcal/kg/day) and Active (average daily energy expenditure value ≥ 3 kcal/kg/day, 0 if average daily energy expenditure value < 1.5 kcal/kg/day). The intensity of LTPA is measured by the average daily energy expended on all leisure activities undertaken by the respondent over a three-month period. In each survey, a list of LTPA options were provided to survey participants to indicate how many times they performed each activity over the past three months and the average duration of each activity. Energy expenditure for each respondent is then calculated as: $LTPA\_EE = \sum_i \left(\left(N_i * D_i * MET \right) / 365 \right)$, where N_i is the number of times a respondent engaged in activity *i* during the past twelve months, D_i is the average duration in hours of the activity *i*, and MET is the metabolic energy cost of the activity (a multiple of the resting metabolic rate

[7] BMI is defined as weight in kilograms divided by height in meters squared.

based on low intensity value for each activity). Thus, *LTPA_EE* is expressed as kilocalories expended per kilogram of body weight per hour of the activity (kcal/kg/day).[8] According to Statistics Canada's CCHS documentation, a person is considered physically inactive if the daily leisure-time energy expenditure is less than 1.5 kcal/kg/day, moderately active if the energy expenditure is 1.5-2.9 kcal/kg/day (yields some health benefits other than cardiovascular benefit), and active if the energy expenditure is 3.0 kcal/kg/day or more (yields cardiovascular health benefits). Two binary variables 'moderate' and 'active' take the value of one if *LTPA_EE* ≥ 1.5 kcal/kg/day and *LTPA_EE* ≥ 3.0 kcal/kg/day, and zero if *LTPA_EE* < 1.5 kcal/kg/day. Practically speaking, physical inactivity refers to walking less than 30 minutes daily, moderate activity is walking 30-59 minutes daily, while walking 60 minutes or more is an "active" person.

Consistent with the existing literature, a wide variety of demographic and socio-economic variables are included in all regression models. Age and age squared are continuous variables in this study. Gender is represented by a dummy variable (female = 1, male = 0). Marital status is characterized by two dummy variables (currently married or common-law = 1, 0 otherwise, and widows, separated and divorced = 1, 0 otherwise), with singles as the reference category. The presence of small children in the family is captured by two dummy variables: children < 6 and children < 12. The immigration status of the respondent is represented by two dummy variables

[8] The following specific activities are considered in the calculation of energy expended in all three surveys: Walking for exercise (MET = 3), Gardening and yard work (MET = 3), Swimming (MET = 3), Bicycling (MET = 4), Popular or social dance (MET = 3), Home exercises (MET = 3), Ice hockey (MET = 6), Ice-skating (MET = 4), In-line skating or roller blading (MET = 5), Jogging or running (MET = 9.5), Golfing (MET = 4), Exercise class or aerobics (MET = 4), Downhill skiing or snowboarding (MET = 4), Bowling (MET = 2), Baseball or softball (MET =3), Tennis (MET = 4), Weight-training (MET = 3), Fishing (MET = 3), Volleyball (MET = 5), Basketball (MET = 6), Soccer (MET = 5) and other activities (MET = 4). The only exception is that soccer was not asked in cycle 1.1, so it was part of other activity. For additional details regarding the derivation of LTPA, see the following documents:
http://www23.statcan.gc.ca/imdb-bmdi/document/3226_D5_T9_V1-eng.pdf (Cycle 1.1)
http://www.statcan.gc.ca/dli-ild/meta/cchs-escc/cycle2-1/derive-derivees-eng.pdf (Cycle 2.1)
http://www23.statcan.gc.ca/imdb-bmdi/document/3226_D5_T9_V3-eng.pdf (Cycle 3.1)

capturing 0-10 and 11 years or more since immigration to Canada, leaving Canadian born as the reference category.

The educational status of the respondent is characterized by dummy variables representing respondents with a secondary education, some post-secondary education and a post-secondary degree, leaving those with less than secondary education as the reference category. Differences in annual household incomes are captured by four household income dummies: \$20,000 to \$50,000, \$50,000 to \$80,000, greater than \$80,000 and a missing category, leaving less than \$20,000 as the reference category. We also include a dummy variable for home ownership (a proxy for household wealth) which takes the value of one if the household owns a home with or without a mortgage and zero otherwise.

The population density of the area in which individual resides is represented by a dummy variable (urban = 1, rural = 0). Provincial differences with respect to the broad structure, delivery, and organization of health care services are captured by a series of provincial dummies, including the three Territories combined, with Ontario as the reference category. Because our data are pooled from three surveys, we include two year dummies to control for the effect of a time trend in our models. Table 2 provides the detailed definitions of all variables used in this paper.

<Insert Table 2 here>

4. Results

4.1 Descriptive Results

The descriptive statistics for all variables are presented in Appendix A. We see that 59% of individuals aged 18 to 75 were overweight or obese in 2000/01, which increased slightly to 62% by 2005/06. About 5% of individuals reported having diabetes and 4% reported having heart disease in these surveys. The percentage of individuals reporting high BP increased from 12% in 2000/01 to 14% in subsequent surveys. The proportion of individuals participating in daily LTPA increased from 31% in 2000/01 to 37% in 2005/06. The proportion of individuals participating to at least a moderate level of LTPA also increased from 45% to 51% over the survey years. The proportion of individuals who undertook some WRPA (i.e., stand or walk) decreased from 46% in 2001/01 to 42% in 2005/06, but the proportion of individuals engaging in light- or heavy-load workplace activities increased from 29% to 34% over the same period. 25% of respondents reported sedentary work in all three surveys. The descriptive statistics for all other variables are stable over the three surveys except for household income and home ownership which increased slightly.

It is informative to look at how physical activity varies across outcomes of interest. Table 3a presents the proportion of individuals with and without obesity and chronic conditions who participate in LTPA and how intensely they participate. We see that 71% of obese individuals do not participate in LTPA daily compared to 63% for normal-weight individuals. Similarly, 68% of individuals diagnosed with diabetes, high BP and heart disease do not participate in LTPA daily. From the intensity of physical activity perspective, a similar pattern emerges. The data show that only 18% of individuals with obesity or a chronic condition are physically active as opposed to 24-26% of those who do not have such conditions. Not surprisingly, about 60% of individuals with obesity and chronic conditions are inactive compared to about 50% without these conditions. Table 3a reveals that the intensity of LTPA is relatively low among individuals with obesity and chronic diseases compared to those without these conditions.

Given the lower intensity of LTPA among individuals with obesity and chronic conditions, it is interesting to see the variations in LTPA across WRPA levels. Table 3b presents the intensity of LTPA stratified across three levels of workplace physical activities. The results show that among obese individuals, only 13% with sedentary WRPA are physically active, whereas 18% with stand/walk WRPA and 25% with light or heavy load WRPA are physically active. The corresponding figures for normal-weight and overweight are: 21%, 27% and 31%, and 21%, 26% and 29%, respectively. Similarly, for those diagnosed with chronic conditions, about 8-9% of individuals with sedentary WRPA are physically active, 19-21% of individuals with stand/walk WRPA are physically active and 24-26% of individual with light or heavy load WRPA are physically active. The corresponding percentages are slightly higher for those without having these chronic conditions. The descriptive results suggest that higher proportions of individuals without obesity and chronic conditions are physically active and the corresponding proportions are higher among those who also undertake some WRPA.

<Insert Tables 3a -3b here>

4.2 Regression Results

Since the effects of physical activity on obesity and chronic conditions are our primary focus, we present the results of LTPA and WRPA in the main part of the paper.[9] The estimated average partial effects of LTPA and WRPA from the probit models are presented in Table 4a. The estimated coefficients from the linear IV models along with the relevant test results are found in Table 4b. The corresponding average partial effects from the recursive bivariate probit models are reported in Table 4c.[10] Each table presents the results of five dichotomous outcomes: overweight, obese, diabetes, high BP and heart disease. Note that the probability of overweight refers to overweight or obesity, and the probability of obesity refers to only obesity in our

[9] The detailed regression results are available from the corresponding author upon request.

[10] The corresponding results without controlling for WRPA are presented in the Appendix B. It can be seen that without controlling for WRPA, the estimated effects of Daily, Moderate and Active are slightly higher in most cases as well as statistically significant in some instances. Thus, without accounting for WRPA, the effects of LTPA on health outcomes might have been subject to upward bias in the previous literature.

analysis, where the comparison group is normal weight in both cases.[11] The results of "Daily" can be interpreted as the marginal effect of daily participation in LTPA on the given outcome compared to no LTPA participation. Similarly, "Moderate" is interpreted as the marginal effect of at least moderate level of LTPA on the given outcome compared to physically inactive. While the results of "Active" can be interpreted as the marginal effect of active level of LTPA compared to physically inactive.

<Insert Tables 4a - 4c here>

4.2.1 Univariate Probit Results

From the univariate probit results it is clear that both LTPA and WRPA exert a negative influence on the probability of obesity and chronic conditions. Each of Daily, Moderate and Active level of LTPA participation is associated with a 2.8%, 2.6% and 4.1% decrease in the probability of overweight, and 6.6%, 6.8% and 10.1% decrease in the probability of obesity, respectively. Compared to sedentary WRPA, being able to stand or walk as well as lift light loads is associated with a decrease in the probability of being overweight of three percentage points and a reduction in the probability of obesity by five to six percentage points. However, lifting heavy loads is associated with about a three percentage point decrease in the probability of obesity but it is not statistically significant for individuals who are overweight.

Participation in LTPA is also negatively associated with the probability of chronic conditions. Daily participation in LTPA is linked with a decrease in the probability of diabetes, high BP and heart disease by 0.2%, 1.2% and 0.4%, respectively. While a moderate level of LTPA is associated with a decrease in the corresponding probability of 0.8%, 1.9% and 0.6%, respectively; an active level of LTPA is associated with a decrease in the probability of diabetes, high BP and heart disease of 1.1%, 2.8% and 0.8% respectively. Being able to stand or walk, lift

[11] We did not analyze the probability of obesity compared to overweight.

light loads and heavy loads are associated with a decrease in the probability of diabetes, high BP and heart disease in the range of 1-2% when compared to sedentary WRPA.

The results of the probit models suggest that both LTPA and WRPA tend to reduce the probability of being overweight, obese, or having diabetes, high BP and heart disease. However, the key question is: Can these results be interpreted as causal effects? Although a rich set of control variables are included in our model to deal with confounders, the decision to participate in LTPA and the intensity of LTPA are inherently endogenous in nature. Without accounting for this endogeneity bias, it is difficult to interpret the probit results as casual. We, therefore, turn to the linear IV and recursive bivariate probit results to ascertain the causal effects.

4.2.2 Econometric Test Results

It is first necessary to demonstrate that our instruments satisfy identification requirements. In order for an instrument to be valid, it must be correlated with the included endogenous regressor and orthogonal to the error in the structural equation. As expected, even after controlling for the full set of covariates, our three instruments (i.e. average monthly temperatures in the respondent's local area over three periods) are statistically significant at the 1% level in all models (see Table 4b), indicating that the instruments satisfy the first requirement.[12] Moreover, the coefficients have positive signs suggesting that higher local temperature is positively associated with Daily, Moderate and Active LTPA. The Kleibergen-Paap LM statistic is significant at the 1% level, meaning that the instruments pass the under identification requirement. However, it is also critical to ensure that the instruments are uncorrelated with the error terms in the structural equation using Hansen's *J* test of over-identification (Wooldridge 2010). The *J* statistic follows a χ^2 distribution with degrees of

[12] The first-stage regression results are available upon request from the corresponding author. One set of recursive bivariate probit results are presented in Appendices C-E.

freedom equal to the number of over-identifying restrictions. A rejection of the null hypothesis implies that the instruments do not satisfy the orthogonality conditions (i.e., that the instruments are uncorrelated with the error term and are correctly excluded from the structural equation). We found that the *J* tests of over-identification cannot be rejected at the 5% level of significance in all models but for two of the obesity equations, meaning that our instruments are valid with a couple of exceptions.

It is also necessary to test whether the IV estimates are weakly identified; if the instruments are weak then the IV estimator continues to be biased, the distribution of the estimator is non-normal and the conventional asymptotics fail (Bound et al. 1995). Stock and Yogo developed a weak-identification F-statistic to examine the bias associated with the IV estimator (Stock & Yogo 2005). These weak identification test results presented in Table 4b show that the bias and size distortion are quite small, thus we reject the null hypothesis that the IV estimator is weakly identified in our application. Moreover, the Kleibergen–Paap Wald F-statistic shows that our instruments do not appear to be weak in the presence of arbitrary heteroscedasticity and non-identically and independently distributed errors (Baum et al. 2007; Kleibergen & Paap 2006).

4.2.3 Linear IV and Recursive Bivariate Probit Results

Contrary to the univariate probit results, the linear IV results show that Daily and Moderate LTPA do not reduce the probability of being overweight and obesity. These results are largely confirmed by the recursive bivariate probit models reported in Table 4c except that Moderate reduces the probability of overweight by 2.9% and the effect of Daily is significant at the 10% level. An active level of LTPA reduces the probability of being overweight and obesity by 4.3% and 6.5%, respectively based on the linear IV model; however, the bivariate probit results only support the causal link between LTPA and obesity, with the probability of being obese falling by 5.3% for physically active individuals, but does not support the causal link between LTPA and being overweight. Both linear IV and recursive bivariate probit results show that Daily, Moderate and Active LTPA do not reduce the probability of diabetes, high BP and heart disease.

Similar to the univariate probit results, we find that the WRPA variables are statistically significant predictors of obesity and chronic conditions in both the IV and bivariate probit models. The estimated coefficients on three WRPA variables (stand/walk, lift light load and lift heavy load) from the IV models are qualitatively similar to the univariate probit models. Moreover, the average partial effects from the recursive bivariate probit models are very similar to the IV results.

Our results show that WRPA plays an important role in reducing both obesity and chronic diseases. Given that WRPA is governed by occupational attainment which is not easily adjusted by policy levers, programs aimed at the promotion of workplace wellness especially in sedentary occupations have the potential to reduce the adverse health effects attributed to leisure-time physical inactivity. Contrary to the univariate probit results, we find that LTPA does not reduce the incidence of chronic conditions. Our results suggest that only an active level of LTPA has the potential to reduce the probability of obesity in the range of five to six percentage points. Although the IV results show that a Moderate level of LTPA reduces the probability of being overweight by four percentage points, this finding that cannot be confirmed with the bivariate probit model.

4.3 Interaction of LTPA and WRPA

Given the limited impact of LTPA on overweight and obesity and its lack of impact on chronic conditions in the full sample, it is interesting to examine if there is any role played by

LTPA in combination with WRPA: in other words, we wonder whether or not LTPA and WRPA are substitutes or complements. To explore this question, we estimated the effect of LTPA on obesity and chronic conditions across three WRPA sub-groups: sedentary, stand/walk and lift light or heavy load. Consistent with our empirical modelling framework, the estimated results from the univariate probit, linear IV and recursive bivariate probit models are presented in Tables 5a-5c. It is worth noting that the econometric test results presented in Table 5b are consistent with the full-sample results, suggesting that our instruments are relevant and quite strong in the sub-group analyses. Thus, we are able to ascertain the causal effects of LTPA on our chosen outcomes across these sub-groups.

<Insert Tables 5a – 5c here>

The univariate probit results show that each of the Daily, Moderate and Active LTPA is associated with a decrease in the probability of being overweight and obese in all sub-groups. The overall results for sedentary and stand/walk sub-groups are similar to the full-sample results, but the magnitudes of the associations are a bit smaller in the lift light or heavy load sub-group. Similar results are also found for diabetes, high BP and heart disease except for the lack of statistical significance for diabetes and heart disease in some instances, particularly in the lift light or heavy load sub-group. In short, the overall direction of WRPA sub-group specific results is similar to the univariate probit models.

Now looking at the linear IV and bivariate probit results, we find that except for being overweight and obese in certain sub-groups, the statistical significance of LTPA in all other models disappeared. Clearly, LTPA does not cause a reduction in the probability of diabetes, high BP and heart disease regardless of the level of WRPA. As is seen from Tables 5b-5c, LTPA has no effect on overweight and obesity among those reported having sedentary WRPA, thus even an active level of LTPA does not reduce the probability of being overweight and obese, suggesting that LTPA and WRPA are not substitutes in this sub-group.

We find that the intensity of LTPA has the greatest effect on obesity among those who also undertake some WRPA like standing or walking. An active level of LTPA reduces the probability of being overweight by about five to seven percentage points while it reduces the probability of obesity by 11 - 12 percentage points. We also find that Daily and Moderate tend to reduce the probability of being overweight and obese in this sub-group. An active level of LTPA also reduces the probability of being obese by about seven percentage points among those who report lifting light or heavy loads at their work. These results suggest that LTPA and WRPA are complementary in nature as far as the overweight or obesity risk is concerned: those who report some WRPA and undertake an active level of LTPA reduce the probability of being overweight and obese.

4.4 Other Factors Influencing Obesity and Chronic Conditions

Although the effects of physical activity on obesity and chronic conditions are the main focus of this paper, a number of interesting results with respect to other factors are worth mentioning. We find a concave relationship between age and obesity and chronic conditions; the coefficient on age is positively related to these conditions while age squared is negatively related in all specifications. Biologically, as people age they put on more weight and develop chronic diseases because of a decreasing metabolism, but they also tend to lose lean body mass and hence reduce weight. We find a convex relationship between age and LTPA in all specifications. Similar to the previous studies, we find that females are less likely to be obese and to have chronic conditions.

Those who are married or living in a common-law relationship and those who are widowed, separated or divorced have a higher probability of obesity and chronic conditions compared to singles, though statistically insignificant for diabetes and high BP in some models. Perhaps, these individuals face higher time costs which may reduce the allocation of time towards physical activity (Humphreys & Ruseski 2011; Brown & Roberts 2011; Maruyama & Yin 2012; Farrell & Shields 2002). Indeed, we find that compared to singles, married or common-law and widows, separated and divorced people have reduced LTPA in most cases.

Both recent immigrants and long-term immigrants have a lower probability of being obese and having a chronic condition compared to their Canadian born counterparts. Ironically, recent immigrants and long-term immigrants are also less likely to participate in LTPA and engage in moderate or active LTPA. Although immigrants are highly heterogeneous, several general tendencies might explain these findings. First, we may be picking up a healthy immigration selection effect whereby it is only healthy immigrants who are admitted into Canada (Laroche 2000; McDonald & Kennedy 2004). Second, immigrants are less likely to be obese compared to their Canadian born counterparts (Dogra et al. 2010), and hence less likely to have chronic conditions at the adult stage of their life. Finally, immigrants are less likely to engage in physical activity compared to their Canadian born counterparts (Dogra et al. 2010; Babakus & Thompson 2012).

Having small children in the family might increase the opportunity cost of physical activity. We find that having small children aged less than six years in the household negatively influences LTPA participation as well as the intensity of LTPA participation. But, the presence of children aged 6-11 years has a weak negative association with LTPA as in many instances the estimated coefficients are not statistically significant. The effects of having small children on obesity and chronic conditions are inconsistent as children *per se* seem to have no direct influence on these outcomes except through the opportunity cost of time or physical activity. It has been found in numerous studies that having children negatively affects exercise (Farrell & Shields 2002; Brown & Roberts 2011).

Educated individuals tend to have better health, and this is indeed what we find. Compared to less than a secondary level of education, those with a secondary degree, some post-secondary or diploma education and a post-secondary degree have a lower probability of being obese or having chronic diseases. The magnitudes are often higher for those having a post-secondary degree, consistent with numerous studies in the literature (Tjepkema 2006; Wolff et al. 2006; McLaren et al. 2010). Moreover, educated individuals are more likely to participate in LTPA and are more likely to undertake a moderate or active level of LTPA as seen by the positive and statistically significant estimated coefficients on the education variables in the physical activity equations.

Similar to education, a higher household income and home ownership negatively influence the probability of obesity and chronic conditions in most instances, though statistically insignificant in a number of models. Conversely, home ownership and household income positively influence the probability of LTPA participation and its intensity, suggesting that economically well-off individuals tend to engage in more healthy lifestyle activities, like participation in LTPA. We find that employed individuals have a lower probability of having diabetes, high BP and heart disease compared to the unemployed or those who do not work. As expected, the employed have a lower probability of LTPA participation as well as lower probability of engaging in moderate or active level of LTPA. These results clearly reflect a higher opportunity cost of time for employed individuals.

5. Discussion and Conclusions

Advances in technological innovations often lead to reduction in the energy expended in the workplace and home environments, with potentially dire consequences for population health. Indeed, the lack of physical activity is regarded as an important risk factor for obesity and chronic diseases in the public health literature (Weinsier et al., 1998; Waxman and Assembly, 2004; Wareham et al., 2005; Summerbell et al., 2009; Fogelholm and Kukkonen-Harjula, 2000; PHAC, 2011). While a negative association between measures of LTPA and obesity has been found in Canadian studies (Tjepkema 2006; Chen & Mao 2006; Ross et al. 2007; Godley & McLaren 2010; Craig et al. 2005), the extent to which one can rely on these estimates as adequately capturing a causal relationship is questionable given the endogenous link between obesity and LTPA. To address this problem and thus understand better the causal links between LTPA and being overweight or having chronic conditions, we use an IV method of estimation with strong instruments, and we include the potentially confounding role of WRPA using population-based, large health surveys from Canada.

The findings of our study clearly suggest that WRPA exerts a negative effect on being overweight, obese and having chronic diseases among Canadians aged 18 to 75. Consistent with the previous literature, we uncover negative associations between LTPA participation and its intensity and obesity and chronic conditions; however, once the endogeneity of LTPA is taken into account, the links become more nuanced. For instance, LTPA does **not** reduce the probability of overweight and obesity if the WRPA is sedentary. But an active level of LTPA can cause an important reduction in the probability of being overweight and obesity by five to six percentage points and a reduction in obesity of 11 to 12 percentage points if some WRPA like standing or walking is also in the mix. We also find that intensive WRPA seems to reduce some of the effect of LTPA on obesity, suggesting a reduced marginal effect of LTPA for those engaged in occupations that involve physical strenuousness.

In contrast to Humphreys et al. (2013), we find that neither LTPA participation nor intensity causes a reduction in the probability of diabetes, high BP and heart disease, when appropriate instruments are employed. However, this does not imply that intensive physical activity will have no role in reducing the incidence of chronic conditions. In fact, our results show that moderate work-related physical activities, like standing or climbing stairs, reduce the probability of having these chronic conditions. However, even an active level of LTPA cannot compensate for sedentary work patterns, underscoring the importance of regular physical activity. In other words, the integration of physical activity into daily work lives is a crucial factor in reducing the incidence of preventable diseases, like obesity, diabetes, high BP and heart disease, in modern society.

Although this study has several strengths, there are some limitations. The first concerns the biases introduced by self-reported data. We try to minimize this problem by employing a corrected height and weight measure for the calculation of BMI, although measurement bias will undoubtedly still exist. Similarly, self-reported chronic conditions may also be subject to bias, but it is unlikely that this bias will be large given the confidential nature of the data collection and the strong legal protection accorded health information in Canada. A second weakness is that, unlike LTPA, our WRPA variable was based on the responses to a single item question. Detailed data on energy expenditure associated with work-related activities could improve the study and provide a better basis for specific policy recommendations. A third weakness is that our exogenous instrument captures primarily the outdoor component of LTPA rather than the range of leisure activities undertaken by the respondents. Previous literature suggests that about 40% of measured physical activity is attributed to weather, but separating the indoor and outdoor components of LTPA in future surveys would improve the study. A fourth potential weakness is that the negative relationship between WRPA and obesity and chronic conditions found in this paper could also be attributed to overall healthy lifestyle choices insofar as those who are physically active may also be more inclined to make other healthy choices simultaneously. Finally, our analysis is based on three cross-sectional surveys, thereby limiting our ability to account for time-invariant unobserved heterogeneity. Future studies using longitudinal data can overcome this limitation.

Despite the above limitations, our overall results clearly suggest that policies designed to encourage active leisure-time physical activities combined with the promotion of physical activity in the workplace (or daily routine) will cause a reduction in the risk of being overweight or obese. Moreover, the integration of physical activity into daily work lives, especially for those in sedentary occupations, has the potential to have a considerable impact on reducing the burden of preventable chronic diseases, thus improving the health of the population. Several policy avenues are possible. Fitness programs could be facilitated and/or encouraged in the workplace by, for instance, access to free or subsidized gym memberships, or by designating spaces for physical activities. Change rooms and/or shower facilities could be provided for employees who exercise during breaks or take physically active travel modes (e.g. bicycle or walking) to work. Programs like a "take-the-stairs" type campaign could be launched with various incentives for winning teams, and flexible hours that facilitate early morning or lunch-time activities, can all work towards informing and encouraging a more active work-place environment. The results of our paper suggest that a little effort in this regard has the potential to make a big difference to the health of individuals.

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Table 1
Descriptive Statistics of Monthly Local Temperature

Month of Interview	Obs.	% of CCHS Obs. #	Mean Temperature (°C)	Std. Dev	Min (°C)	Max (°C)
	CCHS Cycle 1.1					
Month (t)	93,162	87.72%	6.87	10.56	-32.6	24
Month (t-1)	93,123	87.68%	6.93	10.73	-31	24
Month (t-2)	93,046	87.61%	6.52	10.97	-31	24
	CCHS Cycle 2.1					
Month (t)	91,798	87.93%	7.29	10.80	-35.2	24.6
Month (t-1)	91,766	87.90%	6.40	11.19	-35.2	24.6
Month (t-2)	91,590	87.73%	5.21	11.49	-35.5	24.6
	CCHS Cycle 3.1					
Month (t)	93,661	89.00%	8.38	10.26	-32.7	24.6
Month (t-1)	93,646	89.99%	7.79	10.89	-32.7	24.6
Month (t-2)	93,288	88.65%	6.87	11.26	-32.5	24.6

Note that missing cases are due to restricting observations within the 0.5 degree distance of finding a weather station from the centroid of respondent's home postal code or the lack of weather data availability during those months.

Table 2
Variable Definitions

Variable	Definition
Overweight	Bias-corrected BMI ≥ 25 kg/m^2 = 1, 0 if bias-corrected BMI is greater than or equal to 18.5 kg/m^2 and less than 25 kg/m^2
Obese	Bias-corrected BMI ≥ 30 kg/m^2 = 1, 0 if bias-corrected BMI is greater than or equal to 18.5 kg/m^2 and less than 25 kg/m^2
Diabetes	Reported having diagnosed with diabetes = 1, otherwise = 0
High BP	Reported having diagnosed with high BP = 1, otherwise = 0
Heart Disease	Reported having diagnosed with heart disease = 1, otherwise = 0
Participation	Daily average LTPA lasting more than 15 minutes = 1, otherwise = 0
Moderate	Average daily energy expenditure on LTPA per kilogram of body weight per day (LTPA_EE) ≥ 1.5 kcal/kg/day (i.e. walk 30 – 50 minutes) = 1, LTPA_EE < 1.5 kcal/kg/day (i.e. walk < 30 minutes) = 0
Active	LTPA_EE ≥ 3.0 kcal/kg/day (i.e. walk ≥ 1 hour) = 1, LTPA_EE < 1.5 kcal/kg/day (i.e. walk < 30 minutes) = 0
Sedentary	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 or heavy 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
Married	Married or common law relationship = 1, Single = 0
WSD	Widow, separated or divorced = 1, Single = 0
Immigrant ≤10	Immigrated to Canada less than or equal to ten years =1, Canadian born = 0
Immigrant >10	Immigrated to Canada more than ten years ago =1, Canadian born = 0
< 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 = 1, otherwise = 0
Children <12	Children in the household aged 6 years or more but less than 12 years, otherwise = 0
Employed	Full- or part-time employed = 1, otherwise = 0
Home owner	Household owned a home with or without mortgage = 1, otherwise = 0
Income: <20k	Household income less than $20,000 = 1, otherwise = 0
Income: 20-50k	Household income greater than $20,000 but less than $50,000 = 1, otherwise = 0
Income: 50-80k	Household income greater than $50,000 but less than $80,000 = 1, otherwise = 0
Income: >80k	Household income greater than $80,000 = 1, otherwise = 0
Income: Missing	Household Income missing = 1, otherwise = 0

Urban	Living in urban area = 1, rural area = 0
NFL	Province: Newfoundland = 1, otherwise = 0
PEI	Province: Prince Edward Island = 1, otherwise = 0
NS	Province: Nova Scotia = 1, otherwise = 0
NB	Province: New Brunswick = 1, otherwise = 0
QUE	Province: Quebec = 1, otherwise = 0
ON	Province: Ontario = 1, otherwise = 0
MAN	Province: Manitoba = 1, otherwise = 0
SAS	Province: Saskatchewan = 1, otherwise = 0
AL	Province: Alberta = 1, otherwise = 0
BC	Province: British Columbia = 1, otherwise = 0
Territories	Province: Yukon, Northwest Territories, or Nunavut = 1, otherwise = 0

Table 3a
Proportion of Respondents with Obesity/Chronic Disease by LTPA Status
(2000/01 – 2005/06)

LTPA	Normal -weight	Over-weight	Obese	Diabetes		High BP		Heart Disease	
				Yes	No	Yes	No	Yes	No
Daily:									
Yes	40,333	38,271	17,950	4,362	101,890	13,452	92,712	3,988	102,220
	[37%]	[36%]	[29%]	[32%]	[35%]	[32%]	[35%]	[32%]	[35%]
No	68,621	68,092	44,253	9,082	191,634	28,064	172,434	8,419	192,240
	[63%]	[64%]	[71%]	[68%]	[65%]	[68%]	[65%]	[68%]	[65%]
Total	108,954	106,363	62,203	13,444	293,524	41,516	265,146	12,407	294,460
Physically	52,295	51,481	36,170	8,099	148,387	23,964	132,362	7,269	149,157
Inactive	[48%]	[48%]	[58%]	[60%]	[51%]	[58%]	[50%]	[59%]	[51%]
Moderately	27,653	27,711	15,005	3,047	73,967	10,032	66,896	2,877	74,124
Active	[25%]	[26%]	[24%]	[23%]	[25%]	[24%]	[25%]	[23%]	[25%]
Physically	29,006	27,171	11,028	2,298	71,169	7,520	65,888	2,261	71,179
Active	[27%]	[26%]	[18%]	[17%]	[24%]	[18%]	[25%]	[18%]	[24%]
Total	108,954	106,363	62,203	13,444	293,524	41,516	265,146	12,407	294,460

Physically Inactive: LTPA_EE < 1.5; Moderately Active: 1.5 ≤ LTPA_EE < 3.0; Physically Active: LTPA_EE≥ 3.0.

Table 3b
Proportion of Respondents with Obesity/Chronic Disease by LTPA and WRPA Status (2000/01 – 2005/06)

WRPA/ LTPA	Normal weight	Over-weight	Obese	Diabetes		High BP		Heart Disease	
				Yes	No	Yes	No	Yes	No
Sedentary									
Physically Inactive	12,754 [53%]	12,374 [53%]	10,199 [66%]	2,834 [75%]	37,6000 [57%]	7,081 [70%]	33,309 [56%]	2,538 [75%]	37,879 [57%]
Moderately Active	6,045 [25%]	5,916 [26%]	3,266 [21%]	618 [16%]	15,935 [24%]	1,941 [19%]	14,596 [24%]	584 [17%]	15,973 [24%]
Physically Active	5,086 [21%]	4,910 [21%]	1,998 [13%]	331 [9%]	12,566 [19%]	1,073 [11%]	11,803 [20%]	279 [8%]	12,608 [19%]
Sub-total	23,885	23,201	15,463	3,783	66,100	10,094	59,709	3,401	66,461
Stand/Walk									
Physically Inactive	22,915 [47%]	21,575 [47%]	14,362 [56%]	3,429 [55%]	63,201 [49%]	10,780 [54%]	55,788 [49%]	3,178 [53%]	63,423 [50%]
Moderately Active	12,537 [26%]	12,275 [27%]	6,575 [26%]	1,597 [26%]	33,367 [26%]	5,240 [26%]	29,703 [26%]	1,547 [26%]	33,403 [26%]
Physically Active	12,950 [27%]	11,680 [26%]	4,688 [18%]	1,179 [19%]	31,187 [24%]	3,875 [19%]	28,474 [25%]	1,252 [21%]	31,097 [24%]
Sub-total	48,402	45,530	25,625	6,205	127,754	19,894	113,965	5,978	127,924
Lift Light/ Heavy Load									
Physically Inactive	16,302 [45%]	17,259 [46%]	11,157 [54%]	1,625 [50%]	46,597 [47%]	5,722 [51%]	42,448 [47%]	1,386 [48%]	46,822 [47%]
Moderately Active	8,989 [25%]	9,487 [25%]	5,124 [25%]	820 [25%]	24,537 [25%]	2,811 [25%]	22,495 [25%]	730 [26%]	24,620 [25%]
Physically Active	11,140 [31%]	10,716 [29%]	4,391 [25%]	804 [25%]	27,801 [28%]	2,616 [24%]	25,966 [29%]	747 [26%]	27,857 [28%]
Sub-total	36,432	37,462	20,671	3,249	98,935	11,151	90,909	2,863	99,299

Physically Inactive: LTPA_EE < 1.5; Moderately Active: 1.5 ≤ LTPA_EE < 3.0; Physically Active: LTPA_EE≥ 3.0. Note that total sample sizes are a bit smaller compared to Table 2a because of missing observations.

Table 4a
Average Partial Effects – Probit Estimates (Full Sample)

Variable	Overweight	Obese	Diabetes	High BP	Heart Disease
Daily	-.028***	-.066***	-.002*	-.012***	-.004***
	(.003)	(.004)	(.001)	(.002)	(.001)
Stand/Walk	-.028***	-.051***	-.012***	-.015***	-.008***
	(.004)	(.004)	(.001)	(.002)	(.001)
Light Load	-.032***	-.058***	-.018***	-.027***	-.015***
	(.004)	(.004)	(.002)	(.003)	(.001)
Heavy Load	-.007	-.026***	-.019***	-.020***	-.017***
	(.006)	(.007)	(.002)	(.004)	(.003)
Observations	269,506	166,284	298,250	297,960	298,154
Moderate	-.026***	-.068***	-.008***	-.019***	-.006***
	(.003)	(.003)	(.001)	(.002)	(.001)
Stand/Walk	-.028***	-.050***	-.011***	-.014***	-.008***
	(.004)	(.004)	(.001)	(.002)	(.001)
Light Load	-.032***	-.057***	-.017***	-.026***	-.014***
	(.004)	(.004)	(.002)	(.003)	(.001)
Heavy Load	-.008	-.026***	-.018***	-.019***	-.017***
	(.006)	(.007)	(.002)	(.004)	(.002)
Observations	269,506	166,284	298,250	297,960	298,154
Active	-.041***	-.101***	-.011***	-.028***	-.008***
	(.004)	(.004)	(.001)	(.002)	(.001)
Stand/Walk	-.032***	-.056***	-.012***	-.015***	-.008***
	(.004)	(.005)	(.001)	(.002)	(.001)
Light Load	-.036***	-.062***	-.018***	-.025***	-.015***
	(.005)	(.006)	(.002)	(.003)	(.002)
Heavy Load	-.011*	-.034***	-.020***	-.019***	-.017***
	(.007)	(.008)	(.003)	(.005)	(.003)
Observations	200,408	124,351	222,557	222,346	222,486

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4b
Estimated Coefficients – Linear IV Estimates (Full Sample)

Variable	Overweight	Obese	Diabetes	High BP	Heart Disease
Daily	-.040	-.034	.015	.020	-.004
	(.025)	(.032)	(.010)	(.016)	(.009)
Stand/Walk	-.026***	-.053***	-.017***	-.020***	-.013***
	(.004)	(.005)	(.002)	(.003)	(.002)
Light Load	-.032***	-.065***	-.024***	-.033***	-.020***
	(.005)	(.006)	(.002)	(.003)	(.002)
Heavy Load	-.007	-.032***	-.024***	-.024***	-.020***
	(.006)	(.008)	(.002)	(.004)	(.002)
Observations	243,061	150,016	268,825	268,571	268,734
Hansen *J* Statistic	3.93	9.42	3.67	0.61	2.2
	[0.14]	[0.01]	[0.16]	[0.74]	[0.33]
K-P rk LM Statistic+	1645.6***	993.0***	1794.1***	1793.4***	1795.0***
Cragg-Donald F Statistic	1314.7	784.15	1437.0	1436.4	1437.9
K-P rk Wald F Statistic+	561.57	337.9	612.7	612.5	613.0
Moderate	-.032	-.028	.012	.016	-.003
	(.020)	(.025)	(.008)	(.013)	(.008)
Stand/Walk	-.026***	-.053***	-.017***	-.020***	-.013***
	(.004)	(.005)	(.002)	(.003)	(.002)
Light Load	-.032***	-.065***	-.024***	-.033***	-.020***
	(.005)	(.006)	(.002)	(.003)	(.002)
Heavy Load	-.006	-.033***	-.023***	-.024***	-.020***
	(.006)	(.008)	(.002)	(.004)	(.002)
Observations	243,061	150,016	268,825	268,571	268,734
Hansen *J* Statistic	3.86	9.3	3.7	0.61	2.24
	[0.14]	[0.01]	[0.16]	[0.74]	[0.33]
K-P rk LM Statistic +	2221.1***	1377.1***	2394.2***	2394.8***	2394.8***
Cragg-Donald F Statistic	1856.7	1144.9	2004.4	2004.4	2005.8
K-P rk Wald F Statistic+	768.0	475.1	827.7	827.8	828.2
Active	-.043**	-.065**	.016*	.013	.002
	(.022)	(.027)	(.009)	(.013)	(.008)
Stand/Walk	-.030***	-.060***	-.021***	-.021***	-.014***
	(.005)	(.006)	(.002)	(.003)	(.002)
Light Load	-.036***	-.070***	-.028***	-.033***	-.021***
	(.006)	(.007)	(.002)	(.003)	(.002)
Heavy Load	-.011	-.045***	-.027***	-.027***	-.021***
	(.008)	(.009)	(.002)	(.004)	(.002)
Observations	180,887	112,328	200,723	200,539	200,657
Hansen *J* Statistic	2.87	4.83	5.2	0.10	2.1
	[0.24]	[0.09]	[0.07]	[0.95]	[0.35]
K-P rk LM Statistic +	2488.4***	1511.4***	2675.6***	2675.0***	2678.3***
Cragg-Donald F Statistic	1983.4	1191.9	2143.9	2143.6	2146.4
K-P rk Wald F Statistic+	871.4	525.2	936.4	936.3	937.4

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1
Figures in square brackets are p-values
+ K-P: Kleibergen-Paap
Critical values for Cragg-Donald Wald F statistic:

5% maximal IV relative bias	13.91	10% maximal IV size	22.30
10% maximal IV relative bias	9.08	15% maximal IV size	12.83
20% maximal IV relative bias	6.46	20% maximal IV size	9.54
30% maximal IV relative bias	5.31	25% maximal IV size	7.80

Table 4c
Average Partial Effects – Recursive Bivariate Probit Estimates (Full Sample)

Variable	Overweight	Obese	Diabetes	High BP	Heart Disease
Daily	-.050*	-.057*	.005	.010	-.004
	(.026)	(.030)	(.007)	(.013)	(.001)
Stand/Walk	-.025***	-.050***	-.013***	-.018***	-.010***
	(.004)	(.005)	(.002)	(.003)	(.001)
Light Load	-.031***	-.060***	-.019***	-.030***	-.014***
	(.005)	(.006)	(.002)	(.003)	(.002)
Heavy Load	-.006	-.028***	-.020***	-.022***	-.017***
	(.006)	(.008)	(.003)	(.005)	(.003)
Observations	243,061	150,016	268,825	297,960	268,734
Estimated ρ	.04	-.02	-.06	-.08*	0.04
Moderate	-.029***	-.025	.007	.014	-.007
	(.020)	(.025)	(.007)	(.012)	(.007)
Stand/Walk	-.027***	-.052***	-.013***	-.018***	-.009***
	(.004)	(.005)	(.002)	(.003)	(.001)
Light Load	-.033***	-.064***	-.019***	-.031***	-.014***
	(.005)	(.006)	(.002)	(.003)	(.002)
Heavy Load	-.008	-.031***	-.020***	-.022***	-.017***
	(.006)	(.008)	(.003)	(.005)	(.003)
Observations	243, 601	150,016	268,825	268,571	268,734
Estimated ρ	0.04	-0.08*	-0.12***	-0.12***	-.005
Active	-.012	-.053**	.008	.012	-.007
	(.021)	(.027)	(.007)	(.011)	(.007)
Stand/Walk	-.033***	-.060***	-.015***	-.019***	-.009***
	(.005)	(.006)	(.002)	(.003)	(.002)
Light Load	-.040***	-.069***	-.022***	-.031***	-.015***
	(.006)	(.007)	(.002)	(.003)	(.002)
Heavy Load	-.015**	-.043***	-.022***	-.025***	-.017***
	(.007)	(.009)	(.003)	(.005)	(.003)
Observations	180,887	112,328	200,723	200,539	200,657
Estimated ρ	-0.05	-0.09*	-0.14***	-0.14***	-0.02

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5a
Average Partial Effects – Probit Estimates (by WRPA Status)

WRPA/LTPA	Overweight	Obese	Diabetes	High BP	Heart Disease
WRPA: Sedentary					
Daily	-.033***	-.080***	-.002	-.015***	-.008***
	(.006)	(.008)	(.003)	(.004)	(.003)
Observations	61,201	38,953	68,390	68,315	68,370
Moderate	-.037***	-.091***	-.013***	-.023***	-.009***
	(.006)	(.007)	(.003)	(.004)	(.002)
Observations	61,201	38,953	68,390	68,315	68,370
Active	-.047***	-.123***	-.019***	-.037***	-.016***
	(.008)	(.010)	(.004)	(.006)	(.004)
Observations	46,690	29,984	52,710	52,652	52,689
WRPA: Stand/Walk					
Daily	-.033***	-.065***	-.001	-.011***	-.002
	(.004)	(.005)	(.002)	(.003)	(.002)
Observations	116,350	71,834	130,444	130,348	130,390
Moderate	-.028***	-.064***	-.008***	-.020***	-.006***
	(.004)	(.005)	(.002)	(.003)	(.002)
Observations	116,350	71,834	130,444	130,348	130,390
Active	-.046***	-.101***	-.011***	-.028***	-.006***
	(.005)	(.007)	(.002)	(.003)	(.002)
Observations	85,208	52,886	95,695	95,618	95,659
WRPA: Lift Light/ Heavy Load					
Daily	-.017***	-.053***	-.002	-.009***	-.0006
	(.005)	(.006)	(.002)	(0.003)	(.001)
Observations	91,955	55,497	99,416	99,297	99,394
Moderate	-.013***	-.050***	-.002	-.013***	-.002
	(.005)	(.006)	(.002)	(.003)	(.001)
Observations	91,955	55,497	99,416	99,297	99,394
Active	-.028***	-.082***	-.004**	-.019***	-.002
	(.006)	(.007)	(.002)	(.003)	(.002)
Observations	68,510	41,481	74,152	74,076	74,138

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5b
Estimated Coefficients – Linear IV Estimates (by WRPA Status)

WRPA/LTPA	Overweight	Obese	Diabetes	High BP	Heart Disease
WRPA: Sedentary					
Daily	.044	.089	.032	.046	.037
	(.060)	(.079)	(.026)	(.038)	(.025)
Observations	55,044	35,043	61,489	61,428	61,470
Hansen *J* Statistic	3.09	6.83	3.1	1.4	1.9
	[0.21]	[0.03]	[0.21]	[0.50]	[0.38]
K-P rk LM Statistic +	316.4***	180.9***	331.5***	331.6***	331.1***
Cragg-Donald F Statistic	254.0	143.9	267.7	267.8	267.4
K-P rk Wald F Statistic+	108.1	61.54	113.0	113.0	112.8
Moderate	.037	.072	.025	.037	.031
	(.050)	(.063)	(.021)	(.032)	(.020)
Observations	55,044	35,043	61,489	61,428	61,470
Hansen *J* Statistic	3.1	6.8	3.2	1.5	1.8
	[0.21]	[0.03]	[0.20]	[0.48]	[0.41]
K-P rk LM Statistic +	389.0***	232.0***	404.8***	404.5***	404.5***
Cragg-Donald F Statistic	324.8	193.2	337.0	336.5	336.7
K-P rk Wald F Statistic+	133.6	80.1	138.8	138.6	138.6
Active	.031	.054	.050*	.039	.036
	(.055)	(.071)	(.026)	(.036)	(.024)
Observations	42,145	27,091	47,543	47,498	47,522
Hansen *J* Statistic	7.3	8.9	3.0	1.9	1.1
	[0.03]	[0.01]	[0.22]	[0.38]	[0.58]
K-P rk LM Statistic +	416.2***	252.3***	429.2***	429.3***	428.8***
Cragg-Donald F Statistic	349.5	206.7	364.1	364.5	364.0
K-P rk Wald F Statistic+	145.1	87.9	148.9	149.0	148.7
WRPA: Stand/Walk					
Daily	-.064*	-.068	.008	.004	-.020
	(.038)	(.048)	(.015)	(.025)	(.015)
Observations	104,875	64,722	117,515	117,431	117,464
Hansen *J* Statistic	0.7	3.4	1.8	0.8	0.9
	[0.69]	[0.18]	[0.42]	[0.67]	[0.65]
K-P rk LM Statistic +	686.0***	394.4***	753.3***	753.4***	753.7***
Cragg-Donald F Statistic	559.1	319.0	616.0	616.2	616.5
K-P rk Wald F Statistic+	233.8	134.4	257.2	257.2	257.3
Moderate	-.054*	-.056	.006	.004	-.016
	(.031)	(.040)	(.013)	(.020)	(.012)
Observations	104,875	64,722	117,515	117,431	117,464
Hansen *J* Statistic	0.6	3.3	1.8	0.8	0.9
	[0.74]	[0.19]	[0.40]	[0.68]	[0.65]
K-P rk LM Statistic +	943.1***	562.6***	1020.1***	1021.4***	1020.3***
Cragg-Donald F Statistic	793.4	472.8	864.7	865.8	865.0
K-P rk Wald F Statistic+	326.5	194.2	353.1	353.5	353.1
Active	-.072**	-.112***	-.008	-.002	-.004

	(.032)	(.040)	(.013)	(.021)	(.013)
Observations	76,793	47,672	86,173	86,105	86,140
Hansen *J* Statistic	0.6	0.5	1.9	1.7	0.5
	[0.75]	[0.76]	[0.38]	[0.43]	[0.79]
K-P rk LM Statistic +	1097.1***	631.3***	1181.4***	1181.5***	1181.4***
Cragg-Donald F Statistic	873.7	496.8	947.1	947.4	947.4
K-P rk Wald F Statistic+	386.3	219.4	415.5	415.6	415.6
WRPA: Lift Light/ Heavy Load					
Daily	-.062	-.058	.022*	.031	-.001
	(.040)	(.048)	(.012)	(.022)	(.012)
Observations	83,142	50,251	89,821	89,712	89,800
	1.5	1.3	2.0	9.0	3.4
Hansen *J* Statistic	[0.48]	[0.53]	[0.36]	[0.01]	[0.19]
K-P rk LM Statistic +	659.0***	433.8***	736.9***	735.5***	737.8***
Cragg-Donald F Statistic	503.6	324.8	563.3	561.9	564.0
K-P rk Wald F Statistic+	225.2	147.5	252.6	252.1	252.9
Moderate	-.050	-.046	.018*	.023	-.002
	(.032)	(.038)	(.010)	(.018)	(.010)
Observations	83,142	50,251	89,821	89,712	89,800
Hansen *J* Statistic	1.5	1.3	1.9	9.2	3.3
	[0.46]	[0.52]	[0.39]	[0.01]	[0.19]
K-P rk LM Statistic +	920.6***	615.1***	1017.9***	1016.9***	1019.7***
Cragg-Donald F Statistic	752.2	494.8	831.2	830.1	832.6
K-P rk Wald F Statistic+	319.9	211.9	354.7	354.3	355.3
Active	-.049	-.072*	.015	.024	-.003
	(.033)	(.040)	(.010)	(.018)	(.010)
Observations	61,949	37,565	67,007	66,936	66,995
Hansen *J* Statistic	0.5	0.5	2.3	7.1	3.5
	[0.78]	[0.78]	[0.31]	[0.03]	[0.17]
K-P rk LM Statistic +	1005.6***	653.1***	1108.6***	1107.3***	1111.8***
Cragg-Donald F Statistic	769.2	500.2	851.2	849.9	853.4
K-P rk Wald F Statistic+	351.1	226.8	388.7	388.2	389.9

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Figures in square brackets are p-values
+ K-P: Kleibergen-Paap
Critical values for Cragg-Donald Wald F statistic:

5% maximal IV relative bias	13.91	10% maximal IV size	22.30
10% maximal IV relative bias	9.08	15% maximal IV size	12.83
20% maximal IV relative bias	6.46	20% maximal IV size	9.54
30% maximal IV relative bias	5.31	25% maximal IV size	7.80

Table 5c

Average Partial Effects – Recursive Bivariate Probit Estimates (by WRPA Status)

WRPA/LTPA	Overweight	Obese	Diabetes	High BP	Heart Disease
WRPA: Sedentary					
Daily	.057	.065	.013	.030	.018
	(.057)	(.078)	(.021)	(.038)	(.027)
Observations	55,044	35,043	61,489	61,428	61,470
Estimated ρ	-0.16	-0.25*	-0.10	-0.15	-0.19
Moderate	.050	.091	.004	.025	.008
	(.050)	(.070)	(.017)	(.033)	(.020)
Observations	55,044	35,043	61,489	61,428	61,470
Estimated ρ	-0.16*	-0.34***	-0.13	-0.16	-0.13
Active	.114**	.103	.010	.052	-.014
	(.050)	(.069)	(.019)	(.036)	(.022)
Observations	42,145	27,091	47,543	47,498	47,522
Estimated ρ	-0.28***	-0.39***	-0.17*	-0.27***	-0.03
WRPA: Stand/Walk					
Daily	-.087**	-.108**	.003	-.006	-.023
Observations	(.040)	(.048)	(.013)	(.022)	(.022)
Estimated ρ	104,875	64,722	117,515	117,431	117,464
	0.09	0.07	-0.04	-0.02	0.16
Moderate	-.056*	-.055	.002	.001	-.018
	(.031)	(.038)	(.010)	(.020)	(.010)
Observations	104,875	64,722	117,515	117,431	117,464
Estimated ρ	0.05	-0.02	-0.08	-0.07	0.08
Active	-.052*	-.121***	-.0005	-.004	-.012
	(.010)	(.044)	(.011)	(.011)	(.011)
Observations	76,793	47,672	86,173	86,105	86,140
Estimated ρ	0.01	0.03	-0.08	-0.09	0.03
WRPA: Lift Light/ Heavy Load					
Daily	-.082**	-.079*	.010	.021	-.002
	(.041)	(.043)	(.009)	(.019)	(.010)
Observations	83,142	50,251	89,821	89,712	89,800
Estimated ρ	0.11*	0.05	-0.10	-0.13*	0.01
Moderate	-.030	-.032	.013*	.022	-.004
	(.032)	(.035)	(.007)	(.016)	(.009)
Observations	83,142	50,251	89,821	89,712	89,800
Estimated ρ	0.03	-0.04	-0.15**	-0.15**	0.01
Active	-.049	-.076**	.006	.013	-.007
	(.034)	(.034)	(.007)	(.016)	(.009)
Observations	61,949	37,565	67,007	66,936	66,995
Estimated ρ	0.04	-0.01	-0.10	-0.14**	0.04

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Appendix A
Descriptive Statistics

Variable	CCHS Cycle 1.1 (2000/01)		CCHS Cycle 2.1 (2003/04))		CCHS Cycle 3.1 (2005/06)	
	Sample Size	**Weighted Mean (SD)**	**Sample Size**	**Weighted Mean (SD)**	**Sample Size**	**Weighted Mean (SD)**
Overweight	84017	0.59	99576	0.61	100619	0.62
Obese	51908	0.35	61251	0.36	62052	0.37
Diabetes	106166	0.04	104303	0.05	105144	0.05
High BP	106049	0.12	104194	0.14	105035	0.14
Heart Disease	106154	0.04	104267	0.04	105081	0.04
Participation	100304	0.31	102795	0.36	104077	0.37
Moderate	100304	0.45	102795	0.51	104077	0.51
Active	75697	0.28	76555	0.34	77076	0.34
Sedentary	100180	0.25	102397	0.25	103700	0.25
Stand/Walk	100180	0.46	102397	0.43	103700	0.42
Light Loads	100180	0.22	102397	0.24	103700	0.25
Heavy Loads	100180	0.07	102397	0.08	103700	0.09
Age	106206	42.82 (15.01)	104394	43.13 (15.05)	105233	43.45 (15.15)
Female	106206	0.5	104394	0.51	105233	0.5
Married	106206	0.65	104394	0.65	105233	0.66
WSD	106206	0.11	104394	0.11	105233	0.1
Single	106206	0.24	104394	0.24	105233	0.24
Canadian born	106206	0.79	104394	0.79	105233	0.78
Immigrant ≤10	106206	0.06	104394	0.06	105233	0.07
Immigrant >10	106206	0.15	104394	0.15	105233	0.15
< Secondary	106206	0.21	104394	0.17	105233	0.15
Secondary	106206	0.21	104394	0.2	105233	0.17
< Post-secondary	106206	0.09	104394	0.09	105233	0.09
Post-secondary	106206	0.5	104394	0.54	105233	0.59
Children <6	106206	0.16	104394	0.15	105233	0.14
Children <12	106206	0.17	104394	0.17	105233	0.16
Employed	106206	0.7	104394	0.7	105233	0.71
Home owner	106206	0.71	104394	0.76	105233	0.76
Income: <20k	106206	0.11	104394	0.09	105233	0.08
Income: 20-50k	106206	0.3	104394	0.27	105233	0.25
Income: 50-80k	106206	0.26	104394	0.25	105233	0.24
Income: >80k	106206	0.24	104394	0.28	105233	0.31
Income: Missing	106206	0.09	104394	0.11	105233	0.11
Urban	106206	0.82	104394	0.81	105233	0.82
NFL	106206	0.02	104394	0.02	105233	0.02
PEI	106206	<0.01	104394	<0.01	105233	<0.01
NS	106206	0.03	104394	0.03	105233	0.03
NB	106206	0.02	104394	0.02	105233	0.02

QUE	106206	0.25	104394	0.24	105233	0.24
ON	106206	0.38	104394	0.39	105233	0.39
MAN	106206	0.03	104394	0.03	105233	0.03
SAS	106206	0.03	104394	0.03	105233	0.03
AL	106206	0.09	104394	0.1	105233	0.1
BC	106206	0.13	104394	0.13	105233	0.13
Territories	106206	<0.01	104394	<0.01	105233	<0.01

Appendix B
Table a
Average Partial Effects – Probit Estimates without WRPA (Full Sample)

LTPA	Overweight	Obese	Diabetes	High BP	Heart Disease
Daily	-.030***	-.070***	-.004***	-.014***	-.005***
	(.003)	(.004)	(.001)	(.002)	(.001)
Observations	270,328	166,791	299,159	298,867	299,062
Moderate	-.028***	-.073***	-.010***	-.021***	-.008***
	(.003)	(.003)	(.001)	(.002)	(.001)
Observations	270,328	166,791	299,159	298,867	299,062
Active	-.044***	-.108***	-.014***	-.030***	-.010***
	(.003)	(.004)	(.001)	(.002)	(.001)
Observations	201,038	124,744	223,257	223,043	223,184

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table b

Estimated Coefficients – Linear IV Estimates without WRPA (Full Sample)

LTPA	Overweight	Obese	Diabetes	High BP	Heart Disease
Daily	-.042*	-.042	.011	.016	-.007
	(.025)	(.031)	(.009)	(.015)	(.009)
Observations	243,807	150,466	269,653	269,398	269,563
Hansen *J* Statistic	3.69	9.16	3.43	0.59	2.3
	[0.16]	[0.01]	[0.18]	[0.74]	[0.32]
K-P rk LM Statistic+	1679.3***	1016.9***	1836.0***	1835.8***	1837.3***
Cragg-Donald F Statistic	1339.5	802.58	1467.1	1466.8	1468.3
K-P rk Wald F Statistic+	573.29	346.2	627.3	627.2	627.7
Moderate	-.035*	-.034	.009	.013	-.006
	(.020)	(.025)	(.008)	(.013)	(.007)
Observations	243,807	150,466	269,653	269,398	269,563
Hansen *J* Statistic	3.62	9.04	3.45	0.59	2.33
	[0.16]	[0.01]	[0.18]	[0.74]	[0.31]
K-P rk LM Statistic +	2247.8***	1395.5***	2432.3***	2433.3***	2434.1***
Cragg-Donald F Statistic	1877.8	1162.4	2032.0	2032.4	2033.7
K-P rk Wald F Statistic+	777.7	481.8	841.3	841.7	841.9
Active	-.044**	-.072**	.013	.010	-.001
	(.021)	(0.027)	(.008)	(.013)	(.008)
Observations	181,460	112,677	201,361	201,175	201,294
Hansen *J* Statistic	2.602	4.59	5.11	0.09	2.1
	[0.27]	[0.10]	[0.08]	[0.96]	[0.35]
K-P rk LM Statistic +	2525.2***	1528.7***	2721.6***	2721.8***	2724.8***
Cragg-Donald F Statistic	2005.5	1206.1	2169.7	2169.8	2172.5
K-P rk Wald F Statistic+	884.8	531.6	953.0	953.1	954.2

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Figures in square brackets are p-values

+ K-P: Kleibergen-Paap

Critical values for Cragg-Donald Wald F statistic:

5% maximal IV relative bias	13.91	10% maximal IV size	22.30
10% maximal IV relative bias	9.08	15% maximal IV size	12.83
20% maximal IV relative bias	6.46	20% maximal IV size	9.54
30% maximal IV relative bias	5.31	25% maximal IV size	7.80

Table C
Average Partial Effects – Recursive Bivariate Probit Estimates without WRPA

LTPA	Overweight	Obese	Diabetes	High BP	Heart Disease
Daily	-.056**	-.070**	.0004	.004	-.013
	(.026)	(.030)	(.007)	(.013)	(.008)
Observations	243,807	150,466	269,653	269,398	269,563
Estimated ρ	0.05	-0.001	-0.04	-0.07	-0.06
Moderate	-.034*	-.033	.002	.010	-.010
	(.020)	(.025)	(.006)	(.012)	(.007)
Observations	243,807	150,466	269,653	269,398	269,563
Estimated ρ	0.01	-0.08*	-0.10**	-0.11***	0.003
Active	-.020	-.068**	.0001	.006	-.012*
	(.007)	(0.027)	(.002)	(.007)	(.007)
Observations	181,460	112,677	201,361	201,175	201,294
Estimated ρ	-0.04	-0.07	-0.11**	-0.12***	0.004

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Appendix C
Panel A
Bivariate Probit Estimates – Daily LTPA Participation

Variables	**Overweight** (1)	**Obese** (2)	**Diabetes** (3)	**High BP** (4)	**Heart Disease** (5)
Temperature (t)	0.004***	0.004***	0.004***	0.004***	0.004***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Temperature (t-1)	0.006***	0.006**	0.006***	0.006***	0.006***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Temperature (t-2)	0.007***	0.007***	0.007***	0.007***	0.007***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Age	-0.020***	-0.021***	-0.019***	-0.019***	-0.019***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Age^2	0.0002***	0.0002***	0.0002***	0.0002***	0.0002***
	(0.00002)	(0.00003)	(0.00002)	(0.00002)	(0.00002)
Female	0.022***	0.061***	0.0003	-0.0003	0.0003
	(0.008)	(0.011)	(0.008)	(0.008)	(0.008)
Married	-0.077***	-0.090***	-0.077***	-0.077***	-0.077***
	(0.012)	(0.015)	(0.012)	(0.012)	(0.012)
WSD	-0.042***	-0.027	-0.051***	-0.051***	-0.050***
	(0.016)	(0.020)	(0.015)	(0.015)	(0.015)
Immigrant ≤ 10	-0.266***	-0.245***	-0.264***	-0.265***	-0.264***
	(0.023)	(0.029)	(0.022)	(0.022)	(0.022)
Immigrant >10	-0.104***	-0.101***	-0.095***	-0.095***	-0.095***
	(0.014)	(0.018)	(0.013)	(0.013)	(0.013)
Children <6	-0.100***	-0.091***	-0.103***	-0.103***	-0.104***
	(0.013)	(0.016)	(0.012)	(0.012)	(0.012)
Children <12	-0.024*	-0.014	-0.026**	-0.026**	-0.026**
	(0.012)	(0.015)	(0.012)	(0.012)	(0.012)
Secondary	0.135***	0.123***	0.136***	0.137***	0.137***
	(0.014)	(0.018)	(0.013)	(0.013)	(0.013)
<Post-secondary	0.157***	0.131***	0.149***	0.149***	0.149***
	(0.018)	(0.022)	(0.017)	(0.017)	(0.017)
Post-secondary	0.204***	0.202***	0.201***	0.201***	0.202***
	(0.012)	(0.015)	(0.011)	(0.011)	(0.011)
Employed	-0.207***	-0.186***	-0.206***	-0.207***	-0.206***
	(0.011)	(0.014)	(0.010)	(0.010)	(0.010)
Home owner	0.042***	0.023*	0.042***	0.042***	0.041***
	(0.011)	(0.013)	(0.010)	(0.010)	(0.010)
Income: 20-50k	-0.027*	-0.023	-0.023	-0.023*	-0.023
	(0.015)	(0.018)	(0.014)	(0.014)	(0.014)
Income: 50-80k	0.016	0.022	0.017	0.017	0.017
	(0.016)	(0.021)	(0.016)	(0.016)	(0.016)
Income: >80k	0.129***	0.140***	0.128***	0.127***	0.128***
	(0.017)	(0.022)	(0.017)	(0.017)	(0.017)
Income: Missing	0.017	0.041*	0.019	0.020	0.019

	(0.019)	(0.023)	(0.017)	(0.017)	(0.017)
Urban	0.001	-0.013	0.000	-0.000	-0.000
	(0.010)	(0.012)	(0.009)	(0.009)	(0.009)
NFL	-0.190***	-0.176***	-0.203***	-0.202***	-0.202***
	(0.022)	(0.028)	(0.021)	(0.021)	(0.021)
PEI	-0.173***	-0.178***	-0.168***	-0.168***	-0.168***
	(0.027)	(0.034)	(0.025)	(0.025)	(0.025)
NS	-0.092***	-0.084***	-0.088***	-0.088***	-0.088***
	(0.020)	(0.026)	(0.019)	(0.019)	(0.019)
NB	-0.174***	-0.177***	-0.176***	-0.174***	-0.176***
	(0.020)	(0.025)	(0.019)	(0.019)	(0.019)
QUE	-0.178***	-0.171***	-0.172***	-0.171***	-0.172***
	(0.011)	(0.014)	(0.011)	(0.011)	(0.011)
MAN	0.035*	0.063**	0.030	0.030	0.030
	(0.021)	(0.027)	(0.020)	(0.020)	(0.020)
SAS	0.066***	0.087***	0.064***	0.065***	0.065***
	(0.017)	(0.022)	(0.016)	(0.016)	(0.016)
AL	0.091***	0.106***	0.096***	0.096***	0.096***
	(0.014)	(0.018)	(0.014)	(0.014)	(0.014)
BC	0.118***	0.145***	0.123***	0.123***	0.123***
	(0.013)	(0.017)	(0.012)	(0.012)	(0.012)
Territories	0.248***	0.264***	0.255***	0.257***	0.255***
	(0.025)	(0.031)	(0.024)	(0.024)	(0.024)
Cycle2: 2003/04	0.164***	0.161***	0.160***	0.160***	0.160***
	(0.011)	(0.013)	(0.010)	(0.010)	(0.010)
Cycle3: 2005/06	0.145***	0.152***	0.144***	0.144***	0.144***
	(0.010)	(0.013)	(0.009)	(0.009)	(0.009)
Constant	-0.139***	-0.173***	-0.158***	-0.157***	-0.156***
	(0.042)	(0.053)	(0.038)	(0.038)	(0.038)
Observations	243,807	150,466	269,653	269,398	269,563

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Panel B

Bivariate Probit Estimates – Effect of Daily LTPA on Obesity and Chronic Diseases

Variables	**Overweight**	**Obese**	**Diabetes**	**High BP**	**Heart Disease**
	(1)	(2)	(3)	(4)	(5)
Daily	-0.159**	-0.206**	0.005	0.022	-0.168*
	(0.074)	(0.089)	(0.085)	(0.073)	(0.101)
Age	0.053***	0.072***	0.064***	0.062***	0.023***
	(0.002)	(0.003)	(0.004)	(0.003)	(0.004)
Age^2	-0.0004***	-0.001***	-0.003***	-0.0002***	0.00008*
	(0.00002)	(0.00003)	(0.00004)	(0.00003)	(0.00004)
Female	-0.530***	-0.421***	-0.155***	-0.017*	-0.263***
	(0.009)	(0.011)	(0.014)	(0.010)	(0.015)
Married	0.138***	0.130***	0.021	0.018	0.097***
	(0.013)	(0.016)	(0.023)	(0.018)	(0.026)

WSD	0.046*** (0.016)	0.028 (0.020)	-0.032 (0.024)	0.020 (0.019)	0.085*** (0.027)
Immigrant ≤ 10	-0.403*** (0.024)	-0.660*** (0.034)	-0.188*** (0.052)	-0.083** (0.036)	-0.154** (0.066)
Immigrant>10	-0.150*** (0.014)	-0.225*** (0.019)	0.039* (0.022)	0.020 (0.016)	-0.075*** (0.022)
Children <6	0.093*** (0.013)	0.104*** (0.017)	0.013 (0.029)	-0.034 (0.021)	-0.128*** (0.035)
Children <12	-0.015 (0.012)	-0.031** (0.016)	-0.046* (0.026)	-0.066*** (0.018)	-0.073** (0.031)
Secondary	-0.082*** (0.015)	-0.166*** (0.018)	-0.122*** (0.021)	-0.089*** (0.016)	-0.078*** (0.022)
<Post-secondary	-0.070*** (0.019)	-0.152*** (0.023)	-0.069** (0.028)	-0.095*** (0.022)	-0.042 (0.030)
Post-secondary	-0.150*** (0.014)	-0.262*** (0.017)	-0.133*** (0.019)	-0.146*** (0.014)	-0.053*** (0.019)
Employed	0.005 (0.012)	-0.019 (0.015)	-0.173*** (0.019)	-0.121*** (0.014)	-0.272*** (0.020)
Home Owner	-0.005 (0.011)	-0.041*** (0.014)	-0.133*** (0.018)	-0.022 (0.014)	-0.078*** (0.019)
Income: 20-50k	0.018 (0.015)	0.009 (0.018)	-0.094*** (0.020)	-0.013 (0.016)	-0.106*** (0.020)
Income: 50-80k	0.026 (0.017)	-0.004 (0.020)	-0.173*** (0.024)	-0.041** (0.019)	-0.167*** (0.025)
Income: >80k	-0.012 (0.018)	-0.091*** (0.022)	-0.288*** (0.028)	-0.104*** (0.021)	-0.222*** (0.029)
Income: Missing	-0.054*** (0.019)	-0.118*** (0.024)	-0.138*** (0.027)	-0.067*** (0.021)	-0.182*** (0.026)
Urban	-0.048*** (0.010)	-0.065*** (0.012)	0.022 (0.015)	0.020* (0.012)	0.021 (0.016)
NFL	0.201*** (0.023)	0.243*** (0.028)	0.098*** (0.034)	0.073*** (0.026)	-0.091*** (0.034)
PEI	0.181*** (0.028)	0.189*** (0.034)	0.039 (0.040)	-0.013 (0.030)	-0.051 (0.043)
NS	0.108*** (0.021)	0.136*** (0.025)	0.034 (0.029)	0.106*** (0.023)	0.047 (0.029)
NB	0.111*** (0.021)	0.151*** (0.025)	0.026 (0.031)	0.083*** (0.024)	0.024 (0.032)
QUE	-0.171*** (0.012)	-0.245*** (0.016)	-0.100*** (0.020)	-0.083*** (0.015)	-0.074*** (0.020)
MAN	0.074*** (0.021)	0.078*** (0.026)	-0.049 (0.032)	-0.013 (0.026)	-0.152*** (0.039)
SAS	0.105*** (0.018)	0.152*** (0.021)	-0.028 (0.028)	-0.056*** (0.020)	-0.156*** (0.028)
AL	0.041*** (0.015)	0.039** (0.018)	-0.054** (0.025)	-0.054*** (0.019)	-0.139*** (0.027)

BC	-0.086***	-0.139***	-0.040*	-0.130***	-0.138***
	(0.014)	(0.018)	(0.023)	(0.017)	(0.023)
Territories	0.069***	0.142***	-0.096**	-0.062*	-0.038
	(0.025)	(0.031)	(0.044)	(0.034)	(0.043)
Cycle2: 2003/04	0.035***	0.042***	0.058***	0.076***	-0.002
	(0.011)	(0.014)	(0.018)	(0.013)	(0.018)
Cycle3: 2005/06	0.054***	0.075***	0.086***	0.097***	-0.021
	(0.011)	(0.014)	(0.017)	(0.013)	(0.018)
Constant	-0.726***	-1.570***	-3.384***	-3.296***	-2.510***
	(0.056)	(0.069)	(0.106)	(0.077)	(0.119)
Observations	243,807	150,466	269,653	269,398	269,563
Estimated ρ	0.05	-0.001	-0.04	-0.07	0.06

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Appendix D
Panel A
Bivariate Probit Estimates – Moderate LTPA

Variables	Overweight (1)	Obese (2)	Diabetes (3)	High BP (4)	Heart Disease (5)
Temperature (t)	0.005***	0.006***	0.005***	0.005***	0.005***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Temperature (t-1)	0.006***	0.006**	0.006***	0.006***	0.006***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Temperature (t-2)	0.009***	0.009***	0.008***	0.008***	0.008***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Age	-0.035***	-0.034***	-0.032***	-0.032***	-0.032***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Age^2	0.0003***	0.0003***	0.0003***	0.0003***	0.0003***
	(0.0002)	(0.00003)	(0.00002)	(0.00002)	(0.00002)
Female	-0.091***	-0.034***	-0.116***	-0.116***	-0.116***
	(0.008)	(0.011)	(0.008)	(0.008)	(0.008)
Married	-0.088***	-0.097***	-0.094***	-0.095***	-0.095***
	(0.012)	(0.015)	(0.012)	(0.012)	(0.012)
WSD	-0.043***	-0.033*	-0.058***	-0.058***	-0.058***
	(0.015)	(0.019)	(0.015)	(0.015)	(0.015)
Immigrant ≤10	-0.345***	-0.317***	-0.348***	-0.348***	-0.347***
	(0.023)	(0.029)	(0.022)	(0.022)	(0.022)
Immigrant >10	-0.154***	-0.153***	-0.145***	-0.145***	-0.145***
	(0.014)	(0.017)	(0.013)	(0.013)	(0.013)
Children <6	-0.142***	-0.130***	-0.148***	-0.148***	-0.148***
	(0.012)	(0.016)	(0.012)	(0.012)	(0.012)
Children <12	0.000	0.008	0.001	-0.000	0.001
	(0.012)	(0.015)	(0.012)	(0.012)	(0.012)
Secondary	0.172***	0.162***	0.170***	0.170***	0.170***
	(0.014)	(0.017)	(0.013)	(0.013)	(0.013)
<Post-secondary	0.227***	0.201***	0.222***	0.221***	0.221***
	(0.017)	(0.022)	(0.016)	(0.016)	(0.016)
Post-secondary	0.313***	0.308***	0.306***	0.306***	0.306***
	(0.012)	(0.015)	(0.011)	(0.011)	(0.011)
Employed	-0.182***	-0.160***	-0.178***	-0.178***	-0.178***
	(0.011)	(0.014)	(0.010)	(0.010)	(0.010)
Home owner	0.105***	0.085***	0.105***	0.104***	0.104***
	(0.011)	(0.013)	(0.010)	(0.010)	(0.010)
Income: 20-50k	0.022	0.016	0.028**	0.027**	0.028**
	(0.014)	(0.018)	(0.013)	(0.013)	(0.013)
Income: 50-80k	0.127***	0.118***	0.128***	0.129***	0.129***
	(0.016)	(0.020)	(0.015)	(0.015)	(0.015)
Income: >80k	0.304***	0.311***	0.303***	0.303***	0.303***
	(0.017)	(0.022)	(0.016)	(0.016)	(0.016)
Income: Missing	0.055***	0.068***	0.058***	0.059***	0.059***

	(0.018)	(0.023)	(0.017)	(0.017)	(0.017)
Urban	0.001	-0.016	0.001	0.001	0.001
	(0.009)	(0.012)	(0.009)	(0.009)	(0.009)
NFL	-0.131***	-0.130***	-0.139***	-0.138***	-0.138***
	(0.021)	(0.027)	(0.020)	(0.020)	(0.020)
PEI	-0.147***	-0.164***	-0.142***	-0.141***	-0.141***
	(0.026)	(0.033)	(0.024)	(0.024)	(0.024)
NS	-0.054***	-0.046*	-0.053***	-0.054***	-0.053***
	(0.020)	(0.025)	(0.019)	(0.019)	(0.019)
NB	-0.114***	-0.137***	-0.116***	-0.115***	-0.116***
	(0.019)	(0.024)	(0.018)	(0.018)	(0.018)
QUE	-0.088***	-0.069***	-0.081***	-0.081***	-0.081***
	(0.011)	(0.014)	(0.011)	(0.011)	(0.011)
MAN	0.050**	0.041	0.045**	0.045**	0.045**
	(0.020)	(0.026)	(0.019)	(0.019)	(0.019)
SAS	0.056***	0.074***	0.060***	0.060***	0.060***
	(0.017)	(0.021)	(0.016)	(0.016)	(0.016)
AL	0.115***	0.135***	0.121***	0.122***	0.121***
	(0.014)	(0.018)	(0.014)	(0.014)	(0.014)
BC	0.206***	0.237***	0.210***	0.209***	0.209***
	(0.013)	(0.017)	(0.013)	(0.013)	(0.013)
Territories	0.229***	0.235***	0.230***	0.233***	0.230***
	(0.024)	(0.031)	(0.023)	(0.023)	(0.023)
Cycle2: 2003/04	0.142***	0.148***	0.139***	0.139***	0.139***
	(0.010)	(0.013)	(0.010)	(0.010)	(0.010)
Cycle3: 2005/06	0.115***	0.127***	0.111***	0.111***	0.111***
	(0.010)	(0.013)	(0.009)	(0.009)	(0.009)
Constant	0.453***	0.363***	0.397***	0.400***	0.399***
	(0.042)	(0.052)	(0.037)	(0.037)	(0.037)
Observations	243,807	150,466	269,653	269,398	269,563

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Panel B
Bivariate Probit Estimates – Effect of Moderate LTPA on Obesity and Chronic Diseases

Variables	Overweight (1)	Obese (2)	Diabetes (3)	High BP (4)	Heart Disease (5)
Moderate	-0.095*	-0.097	0.027	0.053	-0.126
	(0.058)	(0.073)	(0.075)	(0.064)	(0.091)
Age	0.053***	0.072***	0.064***	0.063***	0.023***
	(0.002)	(0.003)	(0.004)	(0.003)	(0.004)
Age^2	-0.0004***	-0.001***	-0.0004***	-0.0002***	0.0001*
	(0.0002)	(0.0003)	(0.00004)	(0.00003)	(0.00004)
Female	-0.535***	-0.427***	-0.153***	-0.015	-0.269***
	(0.009)	(0.011)	(0.014)	(0.011)	(0.015)
Married	0.140***	0.134***	0.023	0.021	0.099***
	(0.013)	(0.016)	(0.023)	(0.018)	(0.026)

WSD	0.047***	0.030	-0.031	0.022	0.086***
	(0.016)	(0.020)	(0.024)	(0.019)	(0.027)
Immigrant ≤10	-0.402***	-0.655***	-0.184***	-0.078**	-0.154**
	(0.024)	(0.035)	(0.052)	(0.036)	(0.067)
Immigrant >10	-0.149***	-0.223***	0.042*	0.022	-0.075***
	(0.014)	(0.019)	(0.022)	(0.016)	(0.022)
Children <6	0.094***	0.107***	0.016	-0.032	-0.130***
	(0.013)	(0.017)	(0.030)	(0.021)	(0.035)
Children < 12	-0.014	-0.030*	-0.046*	-0.067***	-0.073**
	(0.012)	(0.016)	(0.026)	(0.018)	(0.031)
Secondary	-0.083***	-0.169***	-0.122***	-0.091***	-0.079***
	(0.015)	(0.018)	(0.021)	(0.016)	(0.023)
<Post-secondary	-0.071***	-0.154***	-0.071**	-0.098***	-0.041
	(0.019)	(0.024)	(0.029)	(0.023)	(0.030)
Post-secondary	-0.150***	-0.266***	-0.136***	-0.150***	-0.051**
	(0.014)	(0.017)	(0.020)	(0.015)	(0.021)
Employed	0.010	-0.011	-0.173***	-0.120***	-0.269***
	(0.012)	(0.014)	(0.018)	(0.013)	(0.019)
Home owner	-0.004	-0.039***	-0.132***	-0.022	-0.073***
	(0.011)	(0.014)	(0.018)	(0.014)	(0.020)
Income: 20-50k	0.020	0.011	-0.094***	-0.013	-0.103***
	(0.015)	(0.018)	(0.020)	(0.016)	(0.020)
Income: 50-80k	0.029*	-0.002	-0.174***	-0.043**	-0.162***
	(0.017)	(0.021)	(0.024)	(0.019)	(0.025)
Income: >80k	-0.009	-0.091***	-0.291***	-0.109***	-0.216***
	(0.019)	(0.024)	(0.028)	(0.022)	(0.031)
Income: Missing	-0.053***	-0.119***	-0.139***	-0.068***	-0.181***
	(0.019)	(0.024)	(0.027)	(0.021)	(0.026)
Urban	-0.048***	-0.064***	0.022	0.020*	0.021
	(0.010)	(0.012)	(0.015)	(0.012)	(0.016)
NFL	0.208***	0.252***	0.099***	0.075***	-0.086**
	(0.022)	(0.027)	(0.033)	(0.025)	(0.034)
PEI	0.185***	0.196***	0.039	-0.012	-0.049
	(0.028)	(0.034)	(0.040)	(0.030)	(0.043)
NS	0.112***	0.140***	0.032	0.106***	0.048*
	(0.021)	(0.025)	(0.029)	(0.023)	(0.029)
NB	0.117***	0.159***	0.026	0.083***	0.027
	(0.020)	(0.025)	(0.030)	(0.024)	(0.032)
QUE	-0.164***	-0.235***	-0.098***	-0.082***	-0.067***
	(0.012)	(0.015)	(0.019)	(0.014)	(0.019)
MAN	0.075***	0.077***	-0.051	-0.014	-0.152***
	(0.021)	(0.026)	(0.032)	(0.026)	(0.039)
SAS	0.104***	0.151***	-0.029	-0.056***	-0.158***
	(0.018)	(0.021)	(0.028)	(0.020)	(0.028)
AL	0.041***	0.038**	-0.055**	-0.055***	-0.141***
	(0.015)	(0.018)	(0.025)	(0.019)	(0.027)

BC	-0.086***	-0.143***	-0.043*	-0.135***	-0.137***
	(0.014)	(0.019)	(0.023)	(0.018)	(0.024)
Territories	0.066***	0.136***	-0.099**	-0.063*	-0.043
	(0.025)	(0.030)	(0.044)	(0.034)	(0.043)
Cycle2: 2003/04	0.031***	0.037***	0.056***	0.074***	-0.006
	(0.011)	(0.014)	(0.018)	(0.013)	(0.018)
Cycle3: 2005/06	0.050***	0.069***	0.084***	0.096***	-0.024
	(0.011)	(0.014)	(0.017)	(0.013)	(0.017)
Constant	-0.736***	-1.600***	-3.397***	-3.318***	-2.509***
	(0.059)	(0.072)	(0.109)	(0.079)	(0.124)
Observations	243,807	150,466	269,653	269,398	269,563
Estimated ρ	0.01	-0.08*	-0.10**	-0.11***	0.003

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Appendix E
Panel A
Bivariate Probit Estimates – Active LTPA

Variables	Overweight (1)	Obese (2)	Diabetes (3)	High BP (4)	Heart Disease (5)
Temperature (t)	0.006***	0.006***	0.005***	0.005***	0.005***
	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)
Temperature (t-1)	0.008***	0.007**	0.008***	0.008***	0.008***
	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)
Temperature (t-2)	0.012***	0.012***	0.011***	0.011***	0.011***
	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)
Age	-0.045***	-0.043***	-0.043***	-0.042***	-0.043***
	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)
Age^2	0.0004***	0.0004***	0.0004***	0.0004***	0.0004***
	(0.00002)	(0.00003)	(0.00002)	(0.00002)	(0.00002)
Female	-0.171***	-0.098***	-0.198***	-0.199***	-0.198***
	(0.010)	(0.013)	(0.009)	(0.009)	(0.009)
Married	-0.129***	-0.134***	-0.134***	-0.135***	-0.134***
	(0.015)	(0.018)	(0.014)	(0.014)	(0.014)
WSD	-0.068***	-0.054**	-0.085***	-0.086***	-0.085***
	(0.019)	(0.024)	(0.018)	(0.018)	(0.018)
Immigrant ≤10	-0.388***	-0.348***	-0.389***	-0.389***	-0.389***
	(0.027)	(0.034)	(0.026)	(0.026)	(0.026)
Immigrant >10	-0.155***	-0.155***	-0.146***	-0.146***	-0.145***
	(0.016)	(0.021)	(0.016)	(0.016)	(0.016)
Children <6	-0.174***	-0.172***	-0.183***	-0.182***	-0.182***
	(0.015)	(0.020)	(0.015)	(0.015)	(0.015)
Children <12	-0.002	0.009	0.000	-0.001	0.000
	(0.015)	(0.018)	(0.014)	(0.014)	(0.014)
Secondary	0.176***	0.164***	0.175***	0.175***	0.175***
	(0.017)	(0.021)	(0.016)	(0.016)	(0.016)
<Post-secondary	0.231***	0.198***	0.221***	0.221***	0.220***
	(0.021)	(0.026)	(0.019)	(0.019)	(0.019)
Post-secondary	0.326***	0.312***	0.313***	0.313***	0.312***
	(0.014)	(0.018)	(0.013)	(0.013)	(0.013)
Employed	-0.236***	-0.209***	-0.229***	-0.230***	-0.230***
	(0.013)	(0.016)	(0.012)	(0.012)	(0.012)
Homeowner	0.115***	0.086***	0.116***	0.115***	0.115***
	(0.013)	(0.016)	(0.012)	(0.012)	(0.012)
Income: 20-50k	-0.010	-0.018	-0.006	-0.006	-0.005
	(0.018)	(0.022)	(0.016)	(0.016)	(0.016)
Income: 50-80k	0.101***	0.097***	0.100***	0.100***	0.101***
	(0.020)	(0.024)	(0.018)	(0.018)	(0.018)
Income: >80k	0.307***	0.315***	0.301***	0.301***	0.302***
	(0.021)	(0.026)	(0.020)	(0.020)	(0.020)
Income: Missing	0.058***	0.087***	0.057***	0.057***	0.057***

	(0.022)	(0.028)	(0.020)	(0.020)	(0.020)
Urban	-0.014	-0.017	-0.014	-0.014	-0.014
	(0.011)	(0.015)	(0.011)	(0.011)	(0.011)
NFL	-0.193***	-0.164***	-0.206***	-0.206***	-0.205***
	(0.026)	(0.033)	(0.025)	(0.025)	(0.025)
PEI	-0.194***	-0.220***	-0.187***	-0.186***	-0.187***
	(0.032)	(0.041)	(0.030)	(0.030)	(0.030)
NS	-0.100***	-0.082***	-0.093***	-0.094***	-0.092***
	(0.024)	(0.030)	(0.023)	(0.023)	(0.023)
NB	-0.182***	-0.191***	-0.185***	-0.184***	-0.185***
	(0.024)	(0.030)	(0.023)	(0.023)	(0.023)
QUE	-0.139***	-0.120***	-0.133***	-0.132***	-0.133***
	(0.014)	(0.017)	(0.013)	(0.013)	(0.013)
MAN	0.032	0.036	0.023	0.022	0.023
	(0.024)	(0.031)	(0.023)	(0.023)	(0.023)
SAS	0.082***	0.115***	0.080***	0.081***	0.080***
	(0.021)	(0.026)	(0.020)	(0.019)	(0.020)
AL	0.150***	0.164***	0.156***	0.156***	0.156***
	(0.017)	(0.022)	(0.016)	(0.016)	(0.016)
BC	0.258***	0.296***	0.259***	0.259***	0.259***
	(0.016)	(0.020)	(0.015)	(0.015)	(0.015)
Territories	0.296***	0.301***	0.295***	0.299***	0.295***
	(0.029)	(0.037)	(0.028)	(0.028)	(0.028)
Cycle2: 2003/04	0.186***	0.198***	0.175***	0.175***	0.175***
	(0.012)	(0.016)	(0.011)	(0.011)	(0.011)
Cycle3: 2005/06	0.152***	0.167***	0.145***	0.145***	0.145***
	(0.012)	(0.015)	(0.011)	(0.011)	(0.011
Constant	0.325***	0.197***	0.292***	0.293***	0.294***
	(0.050)	(0.062)	(0.044)	(0.044)	(0.044)
Observations	181,460	112,677	201,361	201,175	201,294

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Panel B
Bivariate Probit Estimates – Effect of Active LTPA on Obesity and Chronic Diseases

Variables	Overweight (1)	Obese (2)	Diabetes (3)	High BP (4)	Heart Disease (5)
Active	-0.054	-0.199**	0.007	0.032	-0.152*
	(0.060)	(0.080)	(0.077)	(0.063)	(0.090)
Age	0.052***	0.068***	0.061***	0.065***	0.022***
	(0.002)	(0.003)	(0.004)	(0.003)	(0.005)
Age^2	-0.0004***	-0.0006***	-0.0003***	-0.0003***	0.0009**
	(0.00003)	(0.00003)	(0.00004)	(0.00004)	(0.00005)
Female	-0.508***	-0.401***	-0.139***	0.011	-0.255***
	(0.011)	(0.013)	(0.017)	(0.012)	(0.018)
Married	0.138***	0.132***	0.035	0.004	0.087***

	(0.015)	(0.019)	(0.026)	(0.020)	(0.030)
WSD	0.049***	0.027	-0.028	0.007	0.085***
	(0.018)	(0.023)	(0.028)	(0.022)	(0.031)
Immigrant ≤10	-0.390***	-0.654***	-0.177***	-0.058	-0.186***
	(0.027)	(0.039)	(0.057)	(0.040)	(0.072)
Immigrant >10	-0.143***	-0.222***	0.050**	0.031*	-0.076***
	(0.017)	(0.022)	(0.025)	(0.018)	(0.026)
Children <6	0.091***	0.080***	-0.009	-0.026	-0.094**
	(0.015)	(0.020)	(0.034)	(0.024)	(0.041)
Children <12	-0.020	-0.036**	-0.057*	-0.056***	-0.077**
	(0.014)	(0.018)	(0.030)	(0.021)	(0.036)
Secondary	-0.080***	-0.150***	-0.133***	-0.088***	-0.081***
	(0.017)	(0.021)	(0.024)	(0.018)	(0.025)
<Post-secondary	-0.078***	-0.144***	-0.066**	-0.106***	-0.037
	(0.021)	(0.027)	(0.033)	(0.025)	(0.035)
Post-secondary	-0.149***	-0.250***	-0.122***	-0.137***	-0.051**
	(0.016)	(0.019)	(0.022)	(0.016)	(0.022)
Employed	0.017	-0.013	-0.196***	-0.127***	-0.285***
	(0.014)	(0.016)	(0.021)	(0.015)	(0.022)
Homeowner	-0.009	-0.045***	-0.128***	-0.011	-0.068***
	(0.013)	(0.016)	(0.021)	(0.016)	(0.022)
Income: 20-50k	0.016	0.008	-0.106***	-0.018	-0.098***
	(0.017)	(0.020)	(0.023)	(0.018)	(0.023)
Income: 50-80k	0.019	-0.002	-0.158***	-0.042*	-0.153***
	(0.019)	(0.024)	(0.028)	(0.022)	(0.029)
Income: >80k	-0.008	-0.075***	-0.301***	-0.100***	-0.209***
	(0.022)	(0.027)	(0.032)	(0.024)	(0.035)
Income: Missing	-0.040*	-0.078***	-0.144***	-0.064***	-0.180***
	(0.021)	(0.027)	(0.031)	(0.024)	(0.030)
Urban	-0.056***	-0.064***	0.022	0.024*	0.018
	(0.011)	(0.014)	(0.017)	(0.013)	(0.018)
NFL	0.198***	0.228***	0.088**	0.061**	-0.088**
	(0.026)	(0.031)	(0.038)	(0.028)	(0.038)
PEI	0.188***	0.197***	0.035	-0.009	-0.047
	(0.031)	(0.039)	(0.046)	(0.034)	(0.050)
NS	0.126***	0.160***	0.044	0.117***	0.052
	(0.024)	(0.029)	(0.032)	(0.027)	(0.033)
NB	0.129***	0.187***	0.020	0.087***	0.019
	(0.023)	(0.028)	(0.034)	(0.027)	(0.037)
QUE	-0.153***	-0.233***	-0.093***	-0.069***	-0.057**
	(0.014)	(0.018)	(0.022)	(0.016)	(0.022)
MAN	0.064***	0.062**	-0.045	-0.015	-0.200***
	(0.024)	(0.030)	(0.037)	(0.030)	(0.044)
SAS	0.088***	0.133***	-0.032	-0.062***	-0.177***
	(0.021)	(0.025)	(0.033)	(0.023)	(0.033)
AL	0.034**	0.022	-0.062**	-0.072***	-0.137***

	(0.017)	(0.021)	(0.028)	(0.021)	(0.032)
BC	-0.095***	-0.143***	-0.054**	-0.116***	-0.150***
	(0.017)	(0.022)	(0.026)	(0.020)	(0.027)
Territories	0.056**	0.116***	-0.079	-0.031	-0.048
	(0.028)	(0.035)	(0.050)	(0.039)	(0.051)
Cycle2: 2003/04	0.024*	0.031*	0.070***	0.080***	-0.003
	(0.013)	(0.016)	(0.020)	(0.015)	(0.021)
Cycle3: 2005/06	0.058***	0.081***	0.103***	0.099***	-0.022
	(0.013)	(0.016)	(0.019)	(0.014)	(0.020)
Constant	-0.770***	-1.533***	-3.316***	-3.382***	-2.492***
	(0.063)	(0.078)	(0.120)	(0.082)	(0.137
Observations	181,460	112,677	201,361	201,175	201,294
Estimated ρ	-0.04	-0.07	-0.11**	-0.12***	0.004

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1