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Towards a demographic risk profile for sedentary behaviours in middle-aged British adults: a cross-sectional population study

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ABSTRACT

Objectives In response to a call from the American Heart Association to more clearly identify the demographic factors associated with sedentary behaviours, this study aimed to identify the hierarchy of demographic characteristics associated with the sedentary behaviours of television viewing, recreational computer use and driving.

Design Cross-sectional analysis of baseline data collected as part of the UK Biobank. The UK Biobank is a population cohort recruited from 22 centres across the UK. Participants aged between 37 and 73 years were recruited between 2006 and 2010.

Methods Decision tree models were generated for the sedentary behaviour outcomes of hours/day spent television viewing, recreational computer use and all driving; a sum of time spent in these sedentary behaviours ('overall') was computed. Age, sex, race, college attendance, employment, shift-work, urban versus rural residence as well as physical activity were considered as predictors.

Results The analytic sample comprised 415 666 adults who were mostly female (54.2%), white (95.2%), non-college attendee (64.5%), employed (61.7%), lived in an urban centre (85.5%), with a mean age of 56.6 (SD=8.1) years. Television viewing was most common sedentary behaviour (2.7 hour/day vs 1.1 for recreational computer use and 1.0 for all driving). Males (tier 1), who did not attend college (tier 2) were the highest risk group for overall sedentary time. Adults with no college attendance (tier 1) and were retired (tier 2) were the most high-risk demographic group for television viewing. College attendees (tier 1) were highest risk for recreational computer use. Adults who were employed (tier 1), male (tier 2) and did not attend college (tier 3) were most at risk for driving

Conclusions Daily time spent in different sedentary behaviours varies by sex, employment status and college attendance status. The development of targeted interventions to reduce sedentary behaviour in different demographic subgroups is needed.

Strengths and limitations of this study

- ► This study uses a large population cohort of middle-age adults from the UK.
- ► Hierarchical decision tree modelling is used to identify a demographic risk profile for sedentary behaviours.
- ► The study relies on self-report, cross-sectional data.
- ► Work-based sedentary behaviour is not considered.

expenditure of <1.5 metabolic equivalents (METs) performed in a sitting or reclining posture.[1 2] High levels of sedentary behaviour have been associated with cardiovascular disease morbidity and mortality, even after adjustment for time spent in light and moderate-to-vigorous physical activity.[3–5] For example, participants who reported more than 10 hours of riding in a car per week had a 50% greater risk of cardiovascular disease mortality than those riding less than 4 hours, even after adjustment for physical activity and other cardiovascular risk factors.[6] Given that interventions to address other, 'established' behavioural cardiovascular risk factors such physical inactivity, tobacco use and poor dietary behaviours may have limited long-term efficacy,[7] there is an opportunity for sedentariness, as a common modifiable behaviour, to be a potentially potent intervention target with which to ameliorate cardiovascular disease risk across time.

In addition to quantifying the independent relationship between sedentary behaviour time with disease outcomes, research has also been dedicated to identifying predictors of sedentary time.[8] Expected outcomes of this work is the capacity to define subgroups that are associated with higher levels of sedentary behaviour, and in turn, high-priority intervention targets. Examinations into demographic variables associated with sedentary behaviour

INTRODUCTION

Sedentary behaviour is defined as any waking activity characterised by an energy

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has yielded mixed evidence.[1] For example, while studies have generally shown older adults (>60 years) to be more sedentary than younger adults,[9–11] there is less consensus around other demographic variables. Some studies show that males are more sedentary,[12 13] while others show that, on average, females are,[14] and still others report no gender differences in sedentary time.[15 16] Examinations of racial differences in sedentary time also yield inconsistent results, with some studies showing Black/African American adults to be more sedentary,[17] others show no racial differences[18] and still others show Non-Hispanic Whites to be more sedentary than other racial groups examined.[10] Increased sitting time in adults with higher levels of education have been shown by some studies,[8 13 19] but not all.[20]

There are several possible reasons to account for the inconsistencies in the literature examining demographic correlates and determinants of sedentary time. One reason is the range of self-report tools used to assess sedentary behaviour in smaller community samples that may yield different results.[21] Another reason is that many studies only report on one form of sedentary behaviour (ie, television viewing). Studies comparing different forms of sedentary behaviour may therefore identify different relationships with demographic factors. In addition, the consideration of individual demographic correlates and determinants of sedentary time[22] may oversimplify or not fully consider the hierarchy of demographic factors that combine to present a high-risk profile for different forms of sedentary behaviours.

To address these limitations and to respond to a recent call in the literature to more clearly define the demographic determinants of sedentary behaviour,[1] this study used Classification and Regression Trees (CART) decision tree modeling[23] to identify the hierarchy of demographic characteristics that best differentiate between high and low engagement in the sedentary behaviours of television viewing, recreational computer use and driving in a population sample (eg, Roda *et al* 2016).[24]

METHODS
Study design and participants
Data for this analysis were collected by the UK Biobank prospective cohort study that began in 2005. Using patient registers from the UK National Health Service (NHS), adults aged 40–69 years who live within a 10 mile radius of one of the UK Biobank's 35 assessment centres were invited to participate. At a baseline visit, participants provided written informed consent and completed a touch screen questionnaire that assessed sociodemographic, lifestyle and health behaviour variables. Between 2006 and 2010, 502 656 eligible and consenting adults provided baseline data. More expansive details about the rationale, design and survey methods for UK Biobank have been described elsewhere.[25] Study procedures were approved by the UK Biobank Institutional Review Board. Study participants were not involved with the design of the study or the recruitment of cohort members.

Measures
The outcome of interest was sedentary behaviour. Participants self-reported how many hours per day they spent watching television, using a computer for recreation and driving (recreational and work-related) on a typical day. For the purposes of this analysis, an 'overall' sedentary time variable was generated by summing the time spent in each of these sedentary activities. Participants reporting over 16 hours of sedentary time (n=974), were recoded to 16 hours.[26]

The predictors of interest were the demographic variables of age (continuous), sex (male, female), race (White, Asian/Asian British/Chinese, Black/Black British, mixed/other, Do not know/prefer not to answer), attended college (yes, no, prefer not to answer), employment (employed, unemployed or retired), shift-work (yes, no, do not know/prefer not to answer) and urban versus rural residence (urban, rural, no postal code provided).

Physical activity as measured by excess MET hours was considered as a predictor in decision tree models given the demonstrated relationship between physical activity and sedentary behaviour.[27] Participants self-reported how many days in a typical week, and for how many minutes in each of those days, they engaged in walking, moderate and vigorous activity for 10 or more minutes. For each of the three categories of activity, values of >1260 min per week (equivalent to an average of 3 hours per day) were truncated at 1260, while values of <10 min was recoded to 0.[28] Excess MET values of 2.3 for walking, 3.0 for moderate physical activity and 7.0 for vigorous physical activity were multiplied with the time in hours spent in each activity, to generate Excess MET/hours for each category.[29]

Generation of analytic sample
Baseline data from 502 623 participants were obtained. Participants with overall sedentary time greater than 24 hours (n=76) and those who withdrew from the study (n=4) were initially excluded, leaving 502 543 participants. Further, participants with missing data for any of the study variables were excluded (n=86 877), leaving 415 666 participants in the final analytic sample. Although significant differences between participants with complete and incomplete data were observed for all study variables (table 1), this is due to our large sample size and high power. As a result, Cohen's d were calculated and were deemed either very small (<0.20) or small (0.20–0.49) in size for all study variables, indicating negligible differences between participants with complete and incomplete data.[30] Thus, all analyses in this study reflect data from participants with complete information for all study variables.

Statistical analysis
Descriptive statistics were generated to characterise all variables. Frequencies and percentages were used to

Table 1 Study sample characteristics

Variable	Complete data (n=415 666)	Incomplete data (n=86 877)	P values*	d
Mean age, years (SD)	56.64 (8.14)	56.01 (7.85)	<0.0001	0.08
Sex, n (%)			<0.0001	0.02
Female	225 456 (54.2%)	47 979 (55.2%)		
Male	190 210 (45.8%)	38 898 (44.8%)		
Race, n (%)			<0.0001	0.15
Mixed/Other	5284 (1.3%)	2233 (2.6%)		
Asian	8267 (2.0%)	3184 (3.7%)		
Black	5439 (1.3%)	2618 (3.0%)		
White	395 506 (95.2%)	77 235 (88.9%)		
Do not know/Prefer not to answer	1170 (0.3%)	1607 (1.9%)		
Education, n (%)			<0.0001	0.19
College	144 599 (34.8%)	16 585 (19.1%)		
No college	268 275 (64.5%)	62 947 (72.5%)		
Prefer not to answer	2792 (0.7%)	2699 (3.1%)		
Missing	0 (0.00%)	4646 (5.4%)		
Employment status, n (%)			<0.0001	0.26
Employed	256 588 (61.7%)	30 593 (35.2%)		
Unemployed	12 079 (2.9%)	1780 (2.1%)		
Retired	146 999 (35.4%)	19 998 (23.0%)		
None of the above/Prefer not to answer	0 (0.00%)	4886 (5.6%)		
Missing	0 (0.00%)	29 620 (34.1%)		
Shift work, n (%)			<0.0001	0.14
Yes	42 285 (10.2%)	7266 (8.4%)		
No	372 902 (89.7%)	44 865 (51.6%)		
Do not know/Prefer not to answer	479 (0.1%)	240 (0.3%)		
Missing	0 (0.00%)	34 506 (39.7%)		
Residence, n (%)			<0.0001	0.13
Urban	355 222 (85.5%)	73 587 (84.7%)		
Rural	60 429 (14.5%)	8232 (9.5%)		
No postal code provided	15 (0.00%)	3 (0.00%)		
Missing	0 (0.00%)	5055 (5.8%)		
Season of assessment, n (%)			<0.0001	0.04
Fall (September–November)	100 142 (24.1%)	19 257 (22.2%)		
Winter (December–February)	86 848 (20.9%)	17 815 (20.5%)		
Spring (March–May)	119 536 (28.8%)	26 949 (31.0%)		
Summer (June–August)	109 140 (26.3%)	22 853 (26.3%)		
Missing	0 (0.00%)	3 (0.00%)		
Mean TV Use, hours/day (SD)	2.69 (1.6)	3.35 (2.1)	<0.0001	0.40
Mean computer use, hours/day (SD)	1.08 (1.4)	1.10 (1.5)	0.0009	0.01
Mean driving time, hours/day (SD)	0.99 (1.2)	0.89 (1.3)	<0.0001	0.08
Mean overall sedentary behaviour, hours/day (SD)	4.76 (2.3)	4.98 (2.8)	<0.0001	0.09
Mean total physical activity, excess MET-hours/week (SD)	31.78 (33.0)	27.65 (32.0)	<0.0001	0.13
Categorised total physical activity, n (%)			<0.0001	0.18

Continued

Table 1 Continued

Variable	Complete data (n=415 666)	Incomplete data (n=86 877)	P values*	d
Low activity (<10 excess MET-hours/week)	109 215 (26.3%)	13 809 (15.9%)		
Moderate activity (10–49.9 excess MET-hours/week)	223 597 (53.8%)	19 142 (22.0%)		
High activity (≥50 excess MET-hours/week)	82 854 (19.9%)	6436 (7.4%)		
Missing	0 (0.00%)	47 490 (54.7%)		

Column percentages do not always add up to 100% because of rounding.
*P values based on χ² tests for categorical variables and two-sample t-tests for continuous variables.
d, Cohen's d effect size; MET, metabolic equivalents; n, frequency.

describe categorical variables. Since all continuous variables were normally distributed, means and SD were used to describe these variables. To examine hierarchical clusters of demographic variables associated with each sedentary outcome, a separate decision tree model that included all demographic predictors and physical activity were generated for each of the study outcomes. Specifically, the CART growing method was used for all decision tree analyses, which split the data into binary segments that were as homogeneous as possible with respect to the outcome until no predictors could improve the homogeneity of the nodes given a complexity parameter of 0.01 for all decision tree models.[23 24] In this study, the between-group sum of squares (or R-squared) is maximised in splitting nodes and pruning the tree. If the increase in R-squared is less than the complexity parameter, splitting will stop. The analytic sample was randomly split into 60% training (n=249 399) and 40% testing sets (n=166 267). Decision trees were constructed using the training data and were validated using 10-fold cross validation. The performance of the decision trees was then evaluated using the testing data. R-squared for both the training and testing data were reported. Descriptive statistics were generated using SAS V.9.4 (SAS, Cary, North Carolina, USA) and decision tree analyses were conducted using the *rpart* package in R V.3.4.3.

Patient and public involvement

The current study is a secondary analysis of the UK Biobank. Study design and development was not informed by patient input. We are not aware of the UK Biobank plans for dissemination of results to study participants.

RESULTS

Participant characteristics

The analytic sample comprised 415 666 adults. Of these, 54.2% were female, 95.2% were White and 64.5% reported that they did not attend college. Six out of 10 (61.7%) respondents were employed (full time or part time) while 10.2% reported being shift workers. Most of the sample resided in urban areas (85.5%). In terms of sedentary behaviours, mean daily hours of television viewing was 2.7 (SD=1.6); computer use was 1.1 (SD=1.4), while mean

driving time was 1.0 (SD=1.2) hours per day. Overall mean sedentary time was 4.8 hours per day (SD=2.3). One in five adults (19.9%) reported high activity (≥50 excess MET hours/week), 53.8% reported moderate activity (10–49.9 excess MET hours/week), while 26.3% reported low levels of physical activity (<10 excess MET hours/week) (table 1).

Demographic variables associated with overall sedentary behaviour

In the decision tree model of overall hours of sedentary behaviour each day, being male (tier 1) and not attending college or responding 'prefer not to answer' (tier 2) distinguished the demographic profile with the highest mean daily hours of sedentary behaviours (mean [M]=5.57, SD=2.57, mean squared error (MSE)=6.60) vs the 4.35 hours (SD=2.06, MSE=4.24) recorded by female participants (figure 1A). R-squared for both the training and testing samples was 0.05.

Demographic variables associated with television use

In the decision tree model of daily television viewing, not attending college or responding 'prefer not to answer' (tier 1) and being retired (tier 2) was the demographic risk profile for those that accumulated the highest mean daily hours of television viewing (M=3.49, SD=1.65, MSE=2.72) vs the 1.92 (SD=1.24, MSE=1.53) mean hours (reported by college attendees who were employed or unemployed) (figure 1B). R-squared for both the training and testing samples was 0.13.

Demographic variables associated with recreational computer use

In the decision tree model of daily recreational computer use, only college education emerged as a significant distinguishing factor with college graduates averaging 1.35 hours per day (SD=1.48, MSE=2.18) vs the 0.94 hours (SD=1.25, MSE=1.56) recorded by non-college graduates and those responding 'prefer not to answer' (figure 1C). R-squared for both the training and testing samples was 0.02.

Demographic variables associated with driving

In the decision tree model of all driving time, being employed (tier 1), male (tier 2) and not attending college
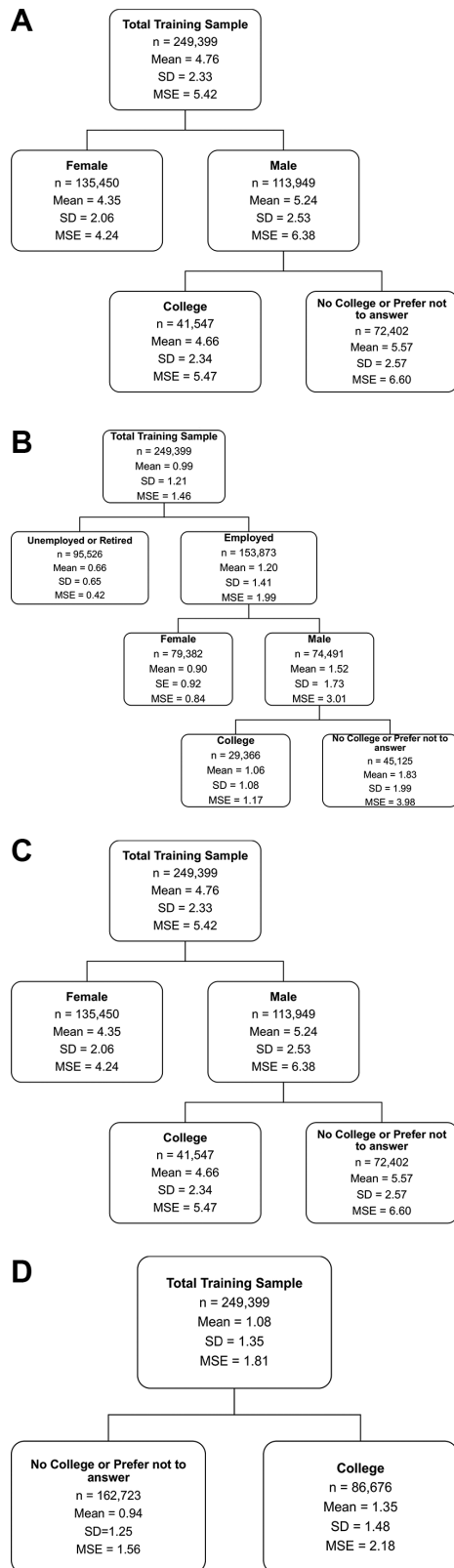
A

Total Training Sample
n = 249,399
Mean = 4.76
SD = 2.33
MSE = 5.42

Female
n = 135,450
Mean = 4.35
SD = 2.06
MSE = 4.24

Male
n = 113,949
Mean = 5.24
SD = 2.53
MSE = 6.38

College
n = 41,547
Mean = 4.66
SD = 2.34
MSE = 5.47

No College or Prefer not to answer
n = 72,402
Mean = 5.57
SD = 2.57
MSE = 6.60

B

Total Training Sample
n = 249,399
Mean = 0.99
SD = 1.21
MSE = 1.46

Unemployed or Retired
n = 95,526
Mean = 0.66
SD = 0.65
MSE = 0.42

Employed
n = 153,873
Mean = 1.20
SD = 1.41
MSE = 1.99

Female
n = 79,382
Mean = 0.90
SE = 0.92
MSE = 0.84

Male
n = 74,491
Mean = 1.52
SD = 1.73
MSE = 3.01

College
n = 29,366
Mean = 1.06
SD = 1.08
MSE = 1.17

No College or Prefer not to answer
n = 45,125
Mean = 1.83
SD = 1.99
MSE = 3.98

C

Total Training Sample
n = 249,399
Mean = 4.76
SD = 2.33
MSE = 5.42

Female
n = 135,450
Mean = 4.35
SD = 2.06
MSE = 4.24

Male
n = 113,949
Mean = 5.24
SD = 2.53
MSE = 6.38

College
n = 41,547
Mean = 4.66
SD = 2.34
MSE = 5.47

No College or Prefer not to answer
n = 72,402
Mean = 5.57
SD = 2.57
MSE = 6.60

D

Total Training Sample
n = 249,399
Mean = 1.08
SD = 1.35
MSE = 1.81

No College or Prefer not to answer
n = 162,723
Mean = 0.94
SD = 1.25
MSE = 1.56

College
n = 86,676
Mean = 1.35
SD = 1.48
MSE = 2.18

Figure 1 (A) Decision tree model results for overall sedentary time using training set (n=249 399). (B) Decision tree models results for daily hours of television viewing using training set (n=249 399).(C) Decision tree models results for daily hours of recreational computer use using training set (n=249 399). (D) Decision tree models results for daily hours of all driving using training set (n=249 399). MSE, mean squared error.

or responding 'prefer not to answer' (tier 3) was the demographic profile that distinguished the highest mean daily hours of driving (M=1.83, SD=1.99, MSE=3.98) vs the 0.90 (SD=0.92, MSE=0.84) mean hours reported by employed, female participants (figure 1D). R-squared for both the training and testing samples was 0.12.

DISCUSSION

Sedentary behaviour is a common behaviour, increasingly being recognised as an independent risk factor for cardiovascular disease.[1] To advance the development of targeted interventions to reduce sedentary behaviours,[1] the current study used decision tree modelling to identify the hierarchy of demographic characteristics that most related to different sedentary behaviours. The key findings from this population study were that males with no college education accrued the most overall sedentary time. Adults with no college education and who were retired (vs employed or unemployed) reported the highest mean for television viewing, adults with a college education reported more daily hours of recreational computer use, while employed males, who did not attend college reported more hours per day of all driving. Together, these results indicate that sex, college attendance and employment status are key demographic correlates of sedentary behaviour and that the demographic risk-profile varies for different sedentary behaviours.

Decision tree modelling of overall sedentary time showed that males with no college education were the highest risk group for sedentary behaviour with a mean of 5.57 hours of sedentary time per day vs 4.35 hours reported by females (see figure 1A). These data may go towards clarifying a body of mixed evidence in which some studies have shown males to be more sedentary than females,[12] females to be more sedentary than males[14] or no gender difference at all.[31] Likewise, low educational attainment has been associated with greater sedentary time,[32] while higher education has been associated with sitting >7.5 hours per day.[8]

One reason for the inconsistent findings in the association between education levels and sedentary behaviour may be that sitting at work for >7.5 hours per day is more common in managerial-level desk jobs that are more characteristic of higher education subgroups.[33] The current study queried about 'recreational' sedentary behaviours (ie, recreational computer use). Thus, these data underscore how demographic risk profiles for work, and non-work, based sedentary behaviours may be different, and the importance of considering work and non-work-related sedentary time separately.

When the individual sedentary behaviours of television viewing, recreational computer use, and all driving were considered, television viewing emerged as the most time-absorbing sedentary behaviour. This converges with previous literature showing television viewing to account for at least 50% of total sitting time[34] as well as a robust marker of overall sedentary time in women.[35] That adults

who had not attended college and were retired were the highest risk group for television viewing by accruing a full 1.57 more hours per day of television time than those who went to college and were employed or unemployed (figure 1B) is somewhat of a departure from previous work. Specifically, low educational attainment has consistently been associated with lower levels of overall sedentary time,[36] most likely because adults with lower levels of education are more likely to have more active, less-sedentary occupations.[37] These data extend this work by showing that as one form of sedentary behaviour, television viewing is greater in those without a college degree. As expected, older, retired, adults reported more television viewing; together, these data give a novel risk profile for television viewing.

The demographic risk profiles for recreational computer use and driving time could be related to employment type. For example, as might be expected, recreational computer use time was higher in those with a college education versus those without.[38] That employed males who did not attend college were the high-risk demographic group for increased daily driving time could be related to blue-collar service jobs (ie, plumber, electrician) that require driving and no college education.

These data have several implications for clinical and population health efforts. First, that the mean hours per day of non-work specific sedentary behaviour was 4.60 indicates that a considerable proportion of adult disposable time is dedicated to being sedentary. Given that the sedentary time queried in this study was not work-specific, this time may be more under the control of the individual and more amenable to change. Changes such as replacing sedentary time with heart-health enhancing behaviours including light to moderate physical activity and/or achieving adequate sleep duration, can reduce mortality and improve cardiovascular markers.[39 40]

Second, previous data have shown that independent of physical activity and other cardiovascular disease events, every additional hour of sedentary time increases the odds of an incident cardiovascular disease event by 1.06.[41] In the current study, where males with no college education accrued 1.28 more hours of overall sedentary time each day (vs females), this magnitude of difference is considerable, especially when one considers that males have a higher age-standardised mortality rate in cardiovascular disease (205.2 per 100 000) than females (129.0 per 100 000)[42] and that in higher-income countries, lower educational attainment is associated with higher rates of cardiovascular disease events.[43] Given that physical activity was not retained by any of the decision tree models in this study as a key correlate, these data underscore the independence of physical activity and sedentary behaviours as independent constructs[44] and support the need to reduce sedentary time in the high-risk demographic groups identified here as a strategy to ameliorate cardiovascular disease.

Third, each of the sedentary behaviours studied emerged with a different high-risk demographic profile.

This finding suggests that 'sedentary behaviour' is not a homogeneous behaviour and that different sedentary behaviours may have different determinants. These data also suggest that reducing sedentary time in one demographic group may require focusing on a specific form of sedentary behaviour. For example, in retired adults who did not attend college, interventions to reduce and/ or replace television viewing may have a bigger impact on reducing overall sedentary time than targeting recreational computer use.

Although the current study is one of the largest population-level studies into the individual correlates and hierarchy of demographic characteristics associated with sedentary behaviours, these data should be interpreted with consideration of some methodological limitations. Given that the sample comprised mostly middle-age and White adults, the findings may not be generalisable to adults who are younger and/or non-White. From a measurement perspective, the data are based on self-reports and in most cases, self-reports on single-survey items. For the sedentary behaviour assessments, survey respondents provided typical hours of time in sedentary behaviour and not minutes, and thus the precision of the self-reported sedentary time is limited. These data also did not distinguish between sedentary behaviour at work versus outside of work, sedentary behaviour during weekend versus weekdays or include sitting time as a passenger versus just driving time. Future studies should consider these contextual features as well as the association between other demographic characteristics including family structure (ie, number of children in the home) and disability status with objectively measured sedentary behaviour. Consideration of a greater array of predictors of sedentary time is also likely to explain a greater proportion of the variance in this outcome as was achieved in the current study where the R^2 values were ≤5%. It would also be informative to examine how demographic factors interact with environmental characteristics (ie, residence area) to yield different levels of sedentary time. The efficacy of demographically targeted interventions to reduce and replace sedentary behaviour with heart-healthy behaviours is also needed. Given the strong association between time spent being sedentary and the prevalence of cardiovascular diseases,[6 45] this line of inquiry could ultimately inform cardiovascular disease prevention efforts.

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