Association Between Physical Activity and Mortality Among Community-Dwelling Stroke Survivors

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Abstract

Background and Objective
To determine the relationship between physical activity (PA) and mortality in community-dwelling stroke survivors.

Methods
The Canadian Community Health Survey was used to obtain self-reported PA across 4 survey years and was linked to administrative databases to obtain prior diagnosis of stroke and subsequent all-cause mortality. PA was measured as metabolic equivalents (METs) per week and meeting minimal PA guidelines was defined as 10 MET-h/wk. Cox proportional hazard regression models and restricted cubic splines were used to determine the relationship between PA and all-cause mortality in respondents with prior stroke and controls, adjusting for socio-demographic factors, comorbidities, and functional health status.

Results
The cohort included 895 respondents with prior stroke and 97,805 controls. Adhering to PA guidelines was associated with lower hazard of death for those with prior stroke (adjusted hazard ratio [aHR] 0.46, 95% confidence interval [CI] 0.29–0.73) and controls (aHR 0.69, 95% CI 0.62–0.76). There was a strong dose–response relationship in both groups, with a steep early slope and the vast majority of associated risk reduction occurring between 0 and 20 MET-h/wk. In the group of stroke respondents, PA was associated with greater risk reduction in those <75 years of age (aHR 0.21, 95% CI 0.10–0.43) compared to those ≥75 years of age (aHR 0.68, 95% CI 0.42–1.12).

Discussion
PA was associated with lower all-cause mortality in an apparent dose-dependent manner among those with prior stroke, particularly in younger stroke survivors. Our findings support efforts towards reducing barriers to PA and implementation of PA programs for stroke survivors in the community.

Classification of Evidence
This study provides Class III evidence that in community-dwelling survivors of stroke, adhering to physical activity guidelines was associated with lower hazard of death.
Physical activity (PA) is strongly associated with reduced risk of cardiovascular disease, stroke, and death in a dose-dependent fashion in studies of the general population.\(^1\)\(^-\)\(^4\) The graded association between PA and outcomes has also been demonstrated among individuals with coronary artery disease,\(^5\)\(^,\)\(^6\) but the beneficial impact among stroke survivors is not well studied.

People with stroke have an excess risk of vascular disease and death in the subacute and chronic phases,\(^7\)\(^,\)\(^8\) and therefore would be suitable candidates for PA-related interventions to reduce this risk. Furthermore, there is a high degree of inactivity among community-dwelling stroke survivors, with more sitting time and less PA than age-matched peers.\(^9\)\(^,\)\(^10\)

Multiple barriers to exercise exist among stroke survivors, including mobility, cognitive, and social,\(^11\) and encouragement alone is typically not successful to improve PA.\(^12\)

Current guidelines recommend PA for stroke survivors but are based in large part on studies in the general population.\(^13\)\(^,\)\(^14\) A better understanding of the role of PA in the health of stroke survivors in the community is needed to design improved public health campaigns and PA interventions, and guidelines on PA in stroke emphasize the need for studies on all-cause mortality in this group.\(^15\) We conducted a population-based study using the Canadian Community Health Survey (CCHS) linked with administrative databases to evaluate the association of PA with long-term risk of mortality among stroke survivors compared to controls, accounting for functional limitations and evaluating differences with age.

### Methods

#### Study Sample: CCHS

The CCHS is an annual cross-sectional survey, representing 97% of the Canadian household population 12 years of age and older.\(^16\) The survey randomly samples households nationwide and selects one respondent per household. The CCHS collects information about health status, health determinants, and health care utilization of the household population. We selected CCHS years 2009, 2010, 2013, and 2014 as the use of the PA module and the Health Utilities Index Mark 3 (HUI3) were both required parts of the questionnaire during these years. Interviews were conducted using computer-assisted personal and telephone interview software. Before releasing the CCHS for use, data are assessed for quality and compared to previous cycles to avoid errors.

3% of the general population that is excluded from the survey target population includes those living on indigenous reserves, those living in foster care, full-time members of the Canadian Armed Forces, the institutionalized population, and the remote Région du Nunavik and Région des Terres-Cries-de-la-Baie-James. Data were collected by Statistics Canada using a multistage sample allocation strategy to support estimation at the health region and provincial level.\(^17\)\(^,\)\(^18\)

#### Administrative Linkages

CCHS Sharelink is a CCHS subsample with approximately 85% of total respondents who agreed to have their responses linked to administrative records. Statistics Canada created sample weights for CCHS Sharelink to retain population representativeness. Linkages were performed by Statistics Canada and included the Canadian Institutes of Health Discharge Abstract Database (CIHI-DAD) for hospitalizations, the National Ambulatory Care Reporting System (NACRS) for emergency department visits, and the Canadian Vital Statistics Database for deaths, including date of death.\(^17\)\(^,\)\(^18\) CIHI-DAD was linked back to 1999/2000 and NACRS back to 2002/2003 to identify episodes of stroke between 1999 and the CCHS interview (conducted in 2009, 2010, 2013, or 2014) and define separate stroke and stroke-free cohorts. Participants were then followed for deaths after the CCHS interview until December 31, 2017. Therefore, all participants had a minimum of 3 years and a maximum of 9 years of full follow-up and were censored if alive on December 31, 2017. See eFigure 1 for study design chart (doi.org/10.5061/dryad.47d7wm3d4).

#### Case Definition

We first excluded respondents from the province of Quebec, as Quebec does not contribute data to CIHI-DAD. We also excluded respondents under 40 years of age, due to very few stroke cases in that age group. All first episodes of stroke were identified in CIHI-DAD and NACRS from 1999 to 2014 using ICD-10-CA codes (ischemic stroke: I63.x, I64.x, H34.1; intracerebral hemorrhage: I61.x) and ICD-9 codes (ischemic stroke: 434.01, 434.11, 434.91, 436; intracerebral hemorrhage: 431). We included H34.1 (central retinal artery occlusion) as it has been validated as part of case definitions of stroke in Canada using administrative data\(^19\)\(^,\)\(^21\) and is included in definitions of central nervous system infarction.\(^22\) Individuals who were identified as having stroke in the administrative databases and participated in the CCHS in the selected years were included in the stroke cohort. Control respondents comprised the remainder of individuals in the CCHS in the selected years without a prior stroke linkage and without self-reported stroke.
As such, those with a self-reported stroke but without a confirmed administrative linkage for stroke were not included in either stroke or control groups.

**Primary Exposure and Outcome**

The primary exposure was PA, obtained using a telephone interview adaptation of the Minnesota Leisure Time Physical Activity Questionnaire. The instrument has favorable test–retest reliability and criterion validity.23 PA was calculated from a series of questions about a variety of activities such as walking, running, gardening, weight training, bicycling, swimming, or various sports (eTable 1, doi.org/10.5061/dryad.47d7wm3d4). Respondents were asked questions such as “In the past 3 months, how many times did you walk for exercise? About how much time did you spend on each occasion?” The responses were used to measure average weekly energy expenditure, calculated using the frequency and duration of each type of PA as well as the metabolic equivalent (MET) value of the activity (kilocalories expended per kilogram of body weight per hour). The MET is a value of metabolic energy cost expressed as a multiple of the resting metabolic rate. The CCHS questions did not ask the respondent to specify the intensity level of the activities. Therefore, the MET values adopted correspond to the low intensity value of each activity. Energy expenditure is obtained with the following formula: (N) × (D) × (MET value), where N is the number of times a respondent engaged in an activity over a 3-month period and D is the average duration in hours of the activity. Three-month average energy expenditure was calculated for both transportation (walking and bicycling) and leisure physical activities and combined as a single continuous variable, then divided by 12 to obtain average MET-h/wk. PA information was only obtained once at the time of the CCHS interview. We defined achieving minimum guideline recommendations as ≥10 MET-h/wk as per the World Health Organization and the International Physical Activity Questionnaire.24,25

As an alternate assessment of PA, we also evaluated frequency of leisure time activity episodes per week lasting >15 minutes.

Our outcome was all-cause mortality during follow-up.

**Health Utilities Index Mark 3**

We used the HUI3, obtained from the CCHS interview, to account for differences in impairment across multiple domains that may affect adherence to PA. The HUI3 is a generic, preference-based measure of health status that includes the attributes of vision, hearing, speech, ambulation, dexterity, emotion, cognition, and pain, with 5 or 6 levels for each attribute (eTable 2, doi.org/10.5061/dryad.47d7wm3d4) and incorporates utility weights based on standard gamble studies in a general population sample. The summary index score ranges from −0.36 (state worse than dead) through 0 (similar to dead) to 1 (perfect health)26 and is obtained by multiplying each individual attribute rank by its multiattribute weight, then using the following equation: HUI3 score = 1.371 *(vision*hearing*speech*dexterity*mobility*emotion *cognition*pain) − 0.371.27

**Additional Covariates**

Covariates were obtained from the CCHS interview, including age, sex, rural residence, self-report of ethnicity (Caucasian, Asian, First Nations, or other), education level (less than secondary school, secondary school graduation, any postsecondary education), total household income quartile, marital status (married/common law, single, widowed/separated/divorced), body mass index (underweight or normal [<24.9 kg/m²], overweight [25.0–29.9 kg/m²], obese [≥30 kg/m²]), current smoking status (daily, occasionally, none), hypertension, diabetes, heart disease, respiratory disease (chronic obstructive lung disease or asthma), binge drinking (drinking ≥5 alcoholic beverages once or more per month), fruit and vegetable consumption (eating 5 or more servings per day), cancer, and arthritis. Due to known biases in self-report of body mass index, we employed a correction developed for the CCHS.28

**Analysis**

We used survey weights for linked data provided by Statistics Canada to deal with design effects and minimize selection bias. The weights include adjustment for nonresponse. The CCHS survey years were pooled for analysis and survey weights were rescaled to account for the proportion of individuals contributed by each year. We calculated the proportion of baseline characteristics for stroke respondents and controls. We calculated mean PA amount and frequency for stroke and control respondents. To protect confidentiality, we rounded numbers of observations in tables according to Statistics Canada’s rules on analysis of linked data.

We used Cox proportional hazard models to determine the association between achieving PA minimum guidelines (≥10 MET-h/wk) and all-cause mortality in stroke and control groups. Our simple model contained only age (continuous), sex, and HUI3 index score (continuous). Our main model had age, sex, and HUI3 as forced variables and any variable that met significance (p < 0.05) for stroke and control groups. As there was significant modification by age for the stroke group only, all models were stratified by age <75 and ≥75. We evaluated the proportional hazards assumption by assessing the significance (p < 0.05) of an interaction term of PA and follow-up time.

We assessed for modification by age (continuous or categorized as <75 and ≥75 years of age), sex, and HUI3 (categorized as <0.7 and ≥0.7) for stroke and control groups. As there was significant modification by age for the stroke group only, all models were stratified by age <75 and ≥75. We evaluated the proportional hazards assumption by assessing the significance (p < 0.05) of an interaction term of PA and follow-up time.
Sensitivity Analyses

We performed multiple sensitivity analyses. We repeated analyses excluding participants (1) with heart disease or cancer, (2) with severe mobility impairment (HUI3 mobility attribute level 5–6), (3) reporting 0 energy expenditure, and (4) with death in the first year after survey (to minimize the potential impact of reverse causation). We also repeated the main model with these changes: (5) removed heart disease as a variable (due to possibly being on the causal pathway between PA and mortality), (6) adjusted for the HUI3 mobility attribute instead of HUI3 index score, (7) used multiple imputation of HUI3 missing values, (8) restricted follow-up time to 3 years, and (9) changed PA threshold from 10 to 20 MET-h/wk. In the stroke group, we also adjusted for time since stroke.

Multiple Imputation

The HUI3 score was missing in 3.9% of controls and 6.7% of people with stroke. The majority of cases were due to non-answer of 1 attribute on the HUI3. We conducted a multiple imputation analysis with ordinal regression to replace the missing HUI3 attribute values, using all covariates and the remaining 7 attributes as predictors in the model. The missing HUI3 index scores were then calculated for sensitivity analysis number 7.

Restricted Cubic Splines

To measure the graded association of PA with outcomes, we generated predicted hazard of mortality for each individual respondent using Cox regression, adjusted for the same variables above, and fit restricted cubic splines and 95% confidence intervals (CIs) using 3 knots at the 10th, 50th, and 90th percentiles. Weekly energy expenditure of 0 was standardized to a hazard ratio of 1. We performed this analysis for the control, stroke, and age-specific groups and for the exposures of weekly PA amount (MET-hours) and weekly activity frequency.

Analyses were done in the Prairie Regional Research Data Centre at the University of Calgary using Stata 16.0.

Table 1 Weighted Percentages and Means of Sample Characteristics by Stroke Status

|                  | Controls (n = 97,805) | Stroke (n = 895) |
|------------------|-----------------------|-----------------|
| **Age, y**       | 63.0 (62.9–63.0)      | 71.7 (71.4–72.0) |
| <75              | 89.6a                 | 65              |
| 75+              | 10.4                  | 36.9            |
| Female           | 51.5                  | 42.0            |
| **Education**    |                       |                 |
| Less than secondary school | 14.5        | 33.3            |
| Secondary school graduation | 19.5       | 20.5            |
| Postsecondary    | 66.0                  | 46.1            |
| **Income quartile** |                    |                 |
| 1 (lowest)       | 23.0                  | 43.5            |
| 2                | 24.6                  | 29.9            |
| 3                | 24.8                  | 17.7            |
| 4                | 27.6                  | 9.5             |
| Obeseb           | 29.0                  | 33.6            |
| Caucasian        | 70.6                  | 78              |
| **Marital status** |                   |                 |
| Married/common law | 73.5              | 63.8            |
| Single           | 8.1                   | 6.4             |
| Widowed/separated/divorced | 18.4     | 29.3            |
| Rural residence  | 19.6                  | 17.8            |
| Smoking daily or occasionally | 17.9      | 22.9            |
| Cancer           | 7.7                   | 10.7            |
| Hypertension     | 27.5                  | 64.1            |
| Diabetes         | 10.0                  | 28.0            |
| Heart disease    | 6.9                   | 30.8            |
| Respiratory condition | 10.1        | 12.7            |
| Arthritis        | 27.3                  | 45.9            |
| Binge drinkingc  | 13.6                  | 7.6             |
| Regular fruit and vegetable consumption | 39.3 | 35.1 |
| Meeting PA guidelines | 51.9 | 34.4 |
| Weekly PA, MET-h/wk | 14.0 (14.0–14.1) | 9.6 (9.4–9.8)  |
| Frequency of leisure activity/wk | 6.6 (6.5–6.6) | 4.9 (4.8–5.1)  |
| Index HUI3 score | 0.84 (0.83–0.84) | 0.65 (0.62–0.69) |
| **Year**         |                       |                 |
| 2009             | 22.8                  | 21.7            |
| 2010             | 23.7                  | 19.1            |

Table 1 Weighted Percentages and Means of Sample Characteristics by Stroke Status (continued)

|                  | Controls (n = 97,805) | Stroke (n = 895) |
|------------------|-----------------------|-----------------|
| 2013             | 26.7                  | 26.8            |
| 2014             | 26.7                  | 33.1            |

Abbreviations: BMI = body mass index; HUI3 = Health Utilities Index Mark 3; MET = metabolic equivalent; PA = physical activity. Values are mean (95% confidence interval) or %.

a Proportions are obtained by following Statistics Canada procedures on weighting and rounding and categories may not always sum to 100.

b Correction equations used for BMI: male adjustment: −1.07575 + 1.07592*BMI; female adjustment: −0.12374 + 1.05129*BMI.28

c Binge drinking defined as having ≥5 alcoholic drinks one or more times per month in Canadian Community Health Survey years 2009 and 2010. For years 2013 and 2014, the variable was changed to ≥4 alcoholic drinks for women.

Sensitivity Analyses
We performed multiple sensitivity analyses. We repeated analyses excluding participants (1) with heart disease or cancer, (2) with severe mobility impairment (HUI3 mobility attribute level 5–6), (3) reporting 0 energy expenditure, and (4) with death in the first year after survey (to minimize the potential impact of reverse causation). We also repeated the main model with these changes: (5) removed heart disease as a variable (due to possibly being on the causal pathway between PA and mortality), (6) adjusted for the HUI3 mobility attribute instead of HUI3 index score, (7) used multiple imputation of HUI3 missing values, (8) restricted follow-up time to 3 years, and (9) changed PA threshold from 10 to 20 MET-h/wk. In the stroke group, we also adjusted for time since stroke.

Multiple Imputation
The HUI3 score was missing in 3.9% of controls and 6.7% of people with stroke. The majority of cases were due to non-answer of 1 attribute on the HUI3. We conducted a multiple imputation analysis with ordinal regression to replace the missing HUI3 attribute values, using all covariates and the remaining 7 attributes as predictors in the model. The missing HUI3 index scores were then calculated for sensitivity analysis number 7.

Restricted Cubic Splines
To measure the graded association of PA with outcomes, we generated predicted hazard of mortality for each individual respondent using Cox regression, adjusted for the same variables above, and fit restricted cubic splines and 95% confidence intervals (CIs) using 3 knots at the 10th, 50th, and 90th percentiles. Weekly energy expenditure of 0 was standardized to a hazard ratio of 1. We performed this analysis for the control, stroke, and age-specific groups and for the exposures of weekly PA amount (MET-hours) and weekly activity frequency.

Analyses were done in the Prairie Regional Research Data Centre at the University of Calgary using Stata 16.0.
Primary Research Question
The primary research question was whether PA was associated with lower mortality among community-dwelling stroke survivors. This study provides Class III evidence that in community-dwelling survivors of stroke, adhering to PA guidelines was associated with lower hazard of death.

Standard Protocol Approvals, Registrations, and Patient Consents
Under Tri-Council guidelines, this analysis did not require approval by a research ethics board.

Data Availability
The dataset from this study is held securely in coded form at the Prairie Regional Research Data Centre. Access to data may only be granted within the Regional Data Centre after approval by Statistics Canada.

Results
Among 1,015 respondents with stroke and 100,495 controls in the selected survey years 895 respondents with stroke (92% ischemic stroke) and 97,805 controls had PA data and were included in the analysis. Those with missing PA data were older and more likely to be male and had lower education and income, more comorbidities, and lower health utility (eTable 3, doi.org/10.5061/dryad.47d7wm3d4). In those with stroke, median time from diagnosis of stroke until survey response was 4.2 years (interquartile range [IQR] 1.8–6.8 years). Baseline characteristics of both cohorts are shown in table 1 and detailed information on HUI3 scores in eTable 4 (doi.org/10.5061/dryad.47d7wm3d4). Those with stroke were older and had more comorbidities, lower health utility, greater impairment in mobility, and lower amount and frequency of PA per week, and were less likely to meet PA minimal guidelines compared to controls (34.4% vs 51.9%). People with stroke meeting PA guidelines were younger and more likely to be male, have higher income, be married or living common-law and live in a rural residence, and less likely to be obese or a current smoker or have functional limitations compared to people with stroke not meeting guidelines (eTable 5, doi.org/10.5061/dryad.47d7wm3d4).

Median follow-up from survey response until death or censoring was 4.8 years (IQR 3.6–7.8) for controls and 4.2 years (IQR 3.3–7.2) for those with stroke. There was a higher proportion who died in the study period among stroke respondents (24.6%) compared to controls (5.7%). There was a lower mortality among those who met PA guidelines of 10 MET-h/wk compared with those who did not meet guidelines in both the control group (3.6% vs 7.9%) and stroke group (14.6% vs 33.2%), with the largest absolute and relative reduction in mortality among stroke respondents <75 years of age (10.5% vs 29.0%; eTable 6, doi.org/10.5061/dryad.47d7wm3d4).

There was no interaction between PA and follow-up time, suggesting no violation of the proportional hazards assumption. There was a significant interaction with age among

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Figure 1 Adjusted Hazard Ratios (HRs) for All-Cause Mortality When Meeting Minimal Physical Activity Guidelines, Stratified by Age and Sex

| Group            | Adjusted HR (95% CI)       |
|------------------|---------------------------|
| **Control respondents** |                           |
| Overall         | 0.69 (0.62, 0.76)         |
| <75 years       | 0.66 (0.57, 0.77)         |
| 75+ years       | 0.64 (0.57, 0.72)         |
| Male            | 0.71 (0.62, 0.81)         |
| Female          | 0.66 (0.58, 0.75)         |

| **Stroke respondents** |               |
| Overall               | 0.46 (0.29, 0.73) |
| <75 years             | 0.21 (0.10, 0.43) |
| 75+ years             | 0.68 (0.42, 1.12) |
| Male                  | 0.51 (0.29, 0.90) |
| Female                | 0.39 (0.19, 0.75) |

The strongest association is observed among stroke respondents <75 years of age. HRs adjusted for age (except in age-stratified models), sex (except in sex-stratified models), health utility, smoking, respiratory disease, and heart disease. CI = confidence interval.
stroke respondents ($p_{int} = 0.038$ for age categories, $p_{int} = 0.018$ for continuous age) but not controls ($p_{int} = 0.58$ for age categories, $p_{int} = 0.21$ for continuous age). There was no significant modification by sex or HU13.

Adjusted HRs (aHRs) for overall groups and age- and sex-stratified models are shown in figure 1. Meeting PA guidelines was associated with a reduction in mortality in those with prior stroke (aHR 0.46, 95% CI 0.29–0.73) and controls (aHR 0.69, 95% CI 0.62–0.76; figure 1). In age-stratified analysis among those with stroke, meeting PA guidelines was more strongly associated with lower hazard of death in individuals <75 years of age (aHR 0.21, 95% CI 0.10–0.43) compared to those ≥75 years of age (0.68, 95% CI 0.42–1.12). HRs for control respondents aged <75 and ≥75 were similar. This pattern of associations was consistent across models (eTable 6, doi.org/10.5061/dryad.47d7wm3d4) and all sensitivity analyses (eFigure 2, doi.org/10.5061/dryad.47d7wm3d4). HRs in the stroke group were identical when adding time since stroke as a covariate.

Restricted cubic splines showed an apparent dose–response relationship between weekly PA and lower predicted hazard of mortality for both control and stroke groups (figure 2). The relationship was log-linear with a steep early slope and approximately 40% of associated mortality reduction obtained by 10 MET-h/wk and 60% by 20 MET-h/wk. Weekly frequency of leisure activity showed a similar relationship. Younger individuals with stroke had a more prominent associated reduction in predicted mortality with PA, with a steeper early slope compared to other groups (figure 3). Absolute and relative reductions in mortality associated with achieving at least 10 MET-h/wk of activity are summarized in eFigure 3 (doi.org/10.5061/dryad.47d7wm3d4).

**Discussion**

Our study demonstrates a strong association between PA and reduced risk of death with an apparent dose–response relationship among people with stroke living in the community. Achieving a weekly energy expenditure of at least 10 MET-h/wk (equivalent to 3–4 hours of walking) was associated with substantial mortality reductions for both stroke and control groups. Similar associated reductions were seen with 5 or more episodes of leisure activity per week lasting >15 minutes. However, we found the relationship was modified by age, such that the greatest associated reductions in long-term mortality with PA occurred in stroke respondents <75 years of age. Our results suggest that

**Figure 2** Restricted Cubic Splines With 95% Confidence Intervals Representing the Relationship Between Weekly Physical Activity (PA) and Predicted Hazard of Mortality for Controls and People With Stroke

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A

Control

B

Stroke

C

Control

D

Stroke

Relationship between weekly PA amount and predicted hazard of mortality for controls (A) and people with stroke (B). Similar relationships are observed with weekly frequency of leisure activity (>15 minutes) for controls (C) and people with stroke (D). Models are adjusted for age, sex, health utility, smoking, respiratory disease, and heart disease. MET = metabolic equivalent.
optimizing PA may reduce long-term mortality in stroke survivors, with particular emphasis on those at younger age.

Stroke survivors engage in minimal walking and have high sedentary time postrehabilitation, with low self-reported and accelerometry-measured activity in the chronic phase after stroke. However, evidence for the implementation of PA programs after stroke is limited, in part due to challenges in achieving increases in PA among community-based stroke survivors. The ExStroke trial randomized patients with ischemic stroke to repeated verbal instructions to engage in PA vs control, although it did not lead to an increase in PA, so the beneficial effects could not be assessed. Stroke survivors may have multidimensional impairments, including mobility, aphasia, cognition, self-care, and fatigue, leading to limitations in PA. Our stroke cohort had impairment in multiple health domains including mobility as measured by the HUI3. However, higher PA remained strongly associated with a lower risk of death despite adjustment for HUI3 index scores or specific adjustment and sensitivity analyses for mobility limitations.

Some studies have reported small benefits in motor gains and fitness when increases in PA are achieved in people with stroke. However, the Life After Stroke study showed that patients with first-ever stroke randomized to regular coaching on PA performed similarly to controls. Systematic reviews assessing the effect of interventions in promoting PA in stroke survivors could not report pooled estimates due to significant heterogeneity in studies. A more recent Cochrane systematic review found an improvement in disability but no difference in mortality with cardiorespiratory training, although patients were only followed until the end of the intervention so the number of deaths was very low and the evidence was graded as low certainty. A secondary analysis of the Stenting vs. Aggressive Medical Management for Preventing Recurrent Stroke in Intracranial Stenosis (SAMMPRIS) trial showed that higher physical activity, measured on an 8-point scale, was associated with lower odds of a composite outcome of recurrent stroke, myocardial infarction, or vascular death in patients with intracranial arterial stenosis. Current guidelines are based on the assumption that benefits of PA to mortality seen in the general population should also extend to community members with stroke, but this has not been adequately shown. We found a log-linear relationship between PA and mortality such that 10 MET-h/wk was associated with large reductions in mortality with most benefit achieved by 20 MET-h/wk. These thresholds could be considered for use in future
guidelines for stroke. Further clinical trials are underway to provide evidence for the implementation of exercise programs after stroke, and offering PA programs to stroke survivors in the community is an increasing priority in the United States, Canada, and Europe.15,40-43

We found PA had a greater association with mortality in younger individuals with stroke. This finding may be due to multiple reasons, including selective survival in older populations (those susceptible to adverse effects of low PA have already died), shorter time in follow-up due to high rates of mortality in the elderly, and accumulated confounding throughout the lifespan which could decrease the measurable influence of PA. Prior studies have shown that associations between vascular risk factors such as obesity or diabetes and adverse outcomes are also greater at younger age.44,45 While the reasons for age modification of vascular risk are unclear, our study suggests that younger individuals with prior stroke who are at high risk of long-term mortality with inactivity may have substantially lower mortality when achieving PA guidelines.

Our analysis has numerous strengths, particularly with the quality and reliability of the data and the availability of a large number of baseline variables. The linkages of CCHS with the Canadian Vital Statistics Database and the Discharge Abstract Database are of high quality, with few false links.18,46 The CCHS provides a large sample size, which can be generalized to the Canadian household population. Because Canada has a universal health care system, we were able to link CCHS respondents with medically diagnosed stroke history. There were also some limitations to the study. First, self-reported variables may be associated with response biases, although variables like hypertension and diabetes have shown high reliability in self-report.47 Questionnaire-obtained PA has been compared to accelerometry-measured activity in Canada with modest correlation, although there was no systematic positive or negative difference.18,49 In addition, self-reported PA and accelerometry measure different constructs. Whereas self-reported PA may be subject to recall and social desirability bias, it is a more comprehensive measure of activity and physical behavior compared to accelerometry data, which cannot adequately record activities such as swimming, bicycling, or weight training.18,49 Self-reported PA may be overestimated, but such misclassification is likely to be non-differential and would bias our estimates towards the null. Second, individuals with stroke underwent the survey at various times from the stroke, although this is a realistic portrayal of the heterogeneity of stroke survivors living in the community. Third, we could not identify individuals hospitalized with stroke prior to 1999, although this provided a 10-year period from the earliest survey. Fourth, the survey excludes people in long-term care homes and therefore is not representative of the most disabled individuals who required institutionalization. However, any intervention for PA would likely be targeted to stroke survivors living in the community. Fifth, we could not capture PA from occupational or domestic work, although PA from leisure or transportation is the most modifiable. Lastly, we acknowledge the potential for residual confounding in our association of PA and outcomes due to varying degrees of disability poststroke. We were able to adjust for functional impairment in multiple health domains using the HUI3, which is correlated with the modified Rankin Scale score.50 The advantage of the HUI3 over conventional disability scales is the inclusion of other important domains in addition to mobility such as vision, emotion, pain, and cognition, all of which may affect the tendency to participate in physical activities. We attempted to account for reverse causation through a sensitivity analysis, but it nevertheless may have influenced our results.

Our study demonstrates that participation in PA is associated with reduced mortality in stroke survivors. Existing guidelines for the general population can be reasonably applied to those with a history of stroke, with a minimal threshold of 10 MET-h/wk. Specifically, greater emphasis should be placed on regular exercise for younger stroke survivors, as even small weekly amounts of exercise, in either total amount or frequency, were associated with mortality reductions. Our findings, together with previous data indicating that encouragement alone is not enough, support efforts towards understanding and reducing barriers to PA and implementation of structured programs for PA among community-dwelling stroke survivors.

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