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ORIGINAL ARTICLE

Strength training is associated with better functional fitness and perceived healthy aging among physically active older adults: a cross-sectional analysis of the Canadian Longitudinal Study on Aging

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Abstract

Background Regular participation in strength exercise is important to promote healthy aging. However, much of the available evidence on physical activity and older adults has focused on aerobic activity, while there is less research on the benefits of exercise that is performed specifically to strengthen muscles.

Aims Using cross-sectional data from the Canadian Longitudinal Study on Aging, the purpose of this study was to determine if strength training is associated with better functional fitness and health among older adults who meet the minimum guidelines for aerobic physical activity.

Methods Older adults who met guidelines for aerobic physical activity ($\geq$60 years, N=9100) completed performance-based assessments of physical function and self-reported their physical activity, perceived health, and chronic conditions. Body fat was determined using DEXA. Logistic regression analyses were used to determine whether strength training was associated with better functional fitness, body composition, and health.

Results 32.5% of active older adults reported engaging in strength training 1–7 days per week. Participating in any strength training was associated with better scores on measures of balance (OR 1.17, CI 1.04, 1.32), mobility (OR 1.32, CI 1.18, 1.47), body fatness (OR 1.58, CI 1.38, 1.81), and better perceived health (OR 1.34, CI 1.19, 1.51), and healthy aging (OR 1.26, CI 1.12, 1.42).

Discussion These results suggest that all older adults, even those who are active and have good mobility, may benefit from strength training.

Conclusion Physical activity guidelines should place a greater emphasis on strength training for older adults.

Keywords Aging · Resistance training · Mobility · Function · CLSA

Introduction

By the year 2050, more than 2 billion people worldwide will be over the age of 60 [1]. Given the prevalence of chronic disease and multi-morbidity among older adults [2, 3], there is growing concern about the potential rise in direct and indirect health care costs associated with an aging population. Specifically, the ability to function independently is an important public health issue that has consequences to both the health and quality of life of older adults [4]. In fact, longitudinal studies clearly indicate that physical function, as measured by functional fitness tests, can predict the health and longevity of older adults [5, 6].

Functional fitness may influence health directly since having greater muscle mass can positively affect glycaemic control [7] and risk of cardiovascular disease [8]. It can also affect health through more indirect pathways. For example, functional limitations can negatively affect social contact among older adults, and social relationships are important predictors of a variety of health outcomes [9]. There is clearly a need to identify and promote strategies that are effective in maintaining functional fitness among older adults.

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Physical activity, particularly strength training, may be one such strategy. However, much of the available evidence on the benefits of physical activity has focused on aerobic activities, and there is comparatively less research on the benefits of exercise that is performed specifically to strengthen muscles. Recently, strength exercise has been associated with lower all-cause mortality [10, 11] and experimental studies have demonstrated that 12–16 weeks of strength training can improve physical function, muscle strength, and insulin sensitivity [12, 13]. Even a very low volume of strength exercise appears to be beneficial to physical function [12] with some research suggesting that higher volumes of strength training do not have additional benefit to functional capacity [14]. There is also evidence that aerobic activities and strengthening exercise may have additive benefits. Kamada et al. [10] reported that older women who did strength training in addition to aerobic exercise had lower all-cause mortality over 12 years of follow-up than women who only did aerobic activity. Nevertheless, public health strategies have primarily focused on the promotion of aerobic activity.

Despite the growing evidence of the benefits, there are few data showing the prevalence of strength training among older adults. Furthermore, it is not clear if strength exercise and aerobic activity have additive benefits for functional fitness. While much of the research on strength training has focused on musculoskeletal outcomes, there may be additional benefits, such as improved cardiometabolic health. For example, a recent study showed that 4 weeks of strength training in overweight men improved cardiovascular risk factors including waist circumference, blood pressure, and VO_2 peak [15]. Given the potential for strength training to have a broad impact on the health of older adults, we chose to explore associations with other health outcomes in addition to functional fitness, including cardiometabolic disease, adiposity, perceived health, and healthy aging. Thus, this study had two primary objectives: (1) to describe the prevalence of self-reported strength training among a large sample of older Canadians and (2) to determine if participating in strength exercise is associated with better functional fitness and better health outcomes among older adults who also meet the minimum guidelines for aerobic physical activity.

Methods

Data source and participants

The Canadian Longitudinal Study on Aging (CLSA) is a nationally representative, stratified, random sample of 51,338 Canadian women and men aged 45–85 years (at baseline). The purpose of this survey is to collect data on the health and quality of life of Canadians to better understand the processes and dimensions of aging. The study contains two samples: the CLSA Comprehensive, and the CLSA Tracking. Data from participants in the first sample were collected through questionnaires, physical examinations, and biological samples. These participants live within a 25–50 km radius of one of the 11 data collection sites across Canada [Vancouver/Surrey (two sites), Victoria, Calgary, Winnipeg, Hamilton, Ottawa, Montreal, Sherbrooke, Halifax, and St. John's]. This sample contains approximately 30,000 participants, recruited between 2012 and 2015, and was used for the current study.

Inclusion in the CLSA was limited to those who were able to read and speak either French or English. Residents in the three territories and some remote regions, persons living on federal First Nations reserves and other First Nations settlements in the provinces, and full-time members of the Canadian Armed Forces were excluded. Individuals living in long-term care institutions (i.e., those providing 24-h nursing care) were excluded at baseline; however, those living in households and transitional housing arrangements (e.g., seniors' residences, in which only minimal care is provided) were included. Finally, those with a cognitive impairment at the time of recruitment were excluded.

The protocol of the CLSA has been reviewed and approved by 13 research ethics boards across Canada. Changes to the CLSA protocol are reviewed annually. Written consent is obtained from all participants. The University of Ontario Institute of Technology Research Ethics Board approved secondary analysis of the CLSA dataset (REB #1367).

For the purposes of the present study, only adults over the age of 60 years ($n = 17{,}849$) with complete data for strength training ($n = 16{,}950$), all outcome variables ($n = 13{,}795$), covariates ($n = 12{,}772$) and those who reported at least 150 min/week of some combination of walking, moderate intensity, and strenuous intensity physical activity ($n = 9100$) were used for analysis.

Outcome variables

Chronic conditions

We chose to focus on type 2 diabetes and ischemic heart disease for this analysis, due to their prevalence in the aging population [2, 16]. Participants were asked whether a physician had ever told them that they had diabetes, borderline diabetes, or high blood sugar. Those who responded yes were then asked whether they had type 2 diabetes. Those who said yes were considered to have type 2 diabetes. For ischemic heart disease, those who answered yes to having physician-diagnosed angina, myocardial infarction, or blockage of the arteries were considered to have ischemic heart disease.

Physical measures

Dual energy X-ray absorptiometry was used to conduct whole body scans. Scans were used to assess total body fat and trunk fat; these variables were provided in the CLSA dataset. Participants also completed a 4-m walk (timed; higher time indicates worse aerobic fitness), a Timed Up and Go (timed stand and walk 3 m and return; higher time indicates worse agility), one-legged balance (timed; higher time indicates better balance), chair rise (five repetitions, timed; higher time indicates worse lower body strength), and grip strength (using a handheld dynamometer, higher score indicates greater upper body strength). Scores on all physical assessments were categorized using tertiles and participants in the best tertile were compared to the worst two-thirds. For grip strength, sex-specific tertiles were used. The cut-off score for the lowest two-thirds for each variable can be seen in Table 3.

Self-reported measures

Participants were asked to rate their perceived health and healthy aging using the following categories: excellent, very good, good, fair, or poor. Each variable was re-categorized in to “Good” (excellent, or very good,) and “Poor” (good, fair, or poor) based on an approximate median split.

Exposure variable

A modified version of the Physical Activity Scale for Elderly (PASE) was used to collect information on sitting time and physical activity. The PASE is a valid, reliable tool for assessing physical activity and sitting time among older adults. It has been shown to have good test–retest reliability over a 3- to 7-week interval (0.75, 95% CI 0.69–0.80). Construct validity has also been established [17].

With regard to strength training, participants were asked how often they engaged in exercises specifically to increase muscle strength and endurance. Given the relatively small proportion participants who engaged in strength training, and evidence that even very low volumes of strength exercise are associated with health benefits [12, 14, 18], we chose to classify strength training as those individuals reporting any strength training. A binary variable was created to categorize participants as either “no strength training” or “1–7 days per week” of strength training. For aerobic training, participants were asked how often they took a walk outside, engaged in moderate sports or recreational activities, and engaged in strenuous sports or recreational activities. The frequency of activity was recorded in categories of never, seldom (1–2 days), sometimes (3–4 days), or often (5–7 days) for frequency, and the duration of activities was recorded in categories of < 30 min, 30 min to < 1 h, 1 h to < 2 h, 2 h to < 4 h, or 4 h or more. The midpoint of each frequency and duration category (except for the 4 h or more hours category, which was coded as 4 h), was used to estimate weekly total activity in hours per week. Those who completed more than 150 min per week (at least 157 min) of aerobic activity were classified as physically active and were included in analyses.

Covariates

Participants were asked to report their age and sex, and provided information on several additional relevant covariates. For income, participants reported their total annual household income in categories of < $20,000, $20,000–$49,999, $50,000–$99,999, $100,000–$149,999, and > $150,000. Height and weight were measured by trained professionals, and used to calculate body mass index (kg/m^2). Moderate to vigorous intensity physical activity (MVPA) was calculated as the sum of time spent in moderate sports or recreational activities and time engaged in strenuous sports or recreational activities.

Statistical analysis

Means and frequencies were used to describe the sample. Using logistic regression models with strength training as the exposure variable, crude and adjusted odds ratios were calculated for being in the best tertile of scores for each of the functional fitness and body composition outcomes (one-legged balance, grip strength, chair rise, timed up and go, 4 m walk, total fat %, trunk fat %). For health outcomes, logistic regression models were used to calculate the odds of having good perceived health and healthy aging and the odds of not having ischemic heart disease or diabetes. Adjusted models included age, sex, total household income, minutes per week of MVPA, and body mass index; body mass index was excluded as a covariate when relative body fat and trunk fat were the outcomes. All analyses were performed using SPSS v.24. To ensure national representation and to compensate for under-represented groups, sampling weights were applied to regression models. Significance was set at $p < 0.05$. Additional details on sampling, methods, and weighting on the CLSA can be found in the protocol document [19, 20].

Results

Of the total group of older adults with complete data for strength training ($N = 16{,}950$), 28.3% (29.7% of men and 26.8% of women) reported engaging in 1–7 days of strength exercise over the previous week and 71.7% reported no strength exercise. When the sample was limited to only adults who meet at least minimum guidelines for aerobic physical activity ($N=9100$), the prevalence of strength training was higher at 32.4% (Table 1). Among those who did engage in strength exercise, the majority reported participating in weight lifting and using hand weights, while fewer reported engaging in calisthenics or activities like push-ups and sit-ups (Table 1).

Sample characteristics are provided in Table 2. Older adults who participated in strength training reported higher income, had a lower BMI, lower body fat, and better scores on all assessments of functional fitness compared to those who did no strength training. There was no difference between groups in age or the prevalence of ischemic heart disease, although among men the proportion of people with type 2 diabetes was lower in the strength training group. The proportion of people reporting good self-perceived health and good healthy aging was higher in the strength training group among both men and women.

Table 3 shows the results of the logistic regression analyses. Adjusted models showed that participating in strength training was associated with greater odds of having higher scores for all functional fitness outcomes, except for grip strength (OR 1.03, CI 0.92, 1.15). In unadjusted models, strength training was associated with lower odds of having type 2 diabetes or ischemic heart disease, but after adjusting for covariates these associations were no longer significant (type 2 diabetes OR 0.94, CI 0.78, 1.14; ischemic heart disease OR 0.94, CI 0.78, 1.13).

Discussion

The primary finding of this study is that older adults who participate in strength training have greater odds of being in the highest tertile of scores on tests of balance, mobility, and lower body fatness, as well as greater odds of reporting good perceived health and healthy aging. These favorable associations with strength exercise were significant among older adults who were all meeting the minimum guidelines for aerobic physical activity. These findings provide population-level data to support the conclusions of experimental studies showing that strength training can be beneficial to health and physical function among older people [12–14]. It is notable that although there is evidence that all older adults could potentially benefit from engaging in strength training, more than two-thirds of the present sample reported never participating in any exercise specifically to strengthen muscles.

Active older adults in this study who participated in strength training did not have significantly lower odds of diabetes or heart disease. This may be due to the fact that these participants were engaging in regular aerobic activity, so they may already have a lower than usual prevalence of cardiometabolic disease. Although regular strength exercise can be beneficial for improving glycemic control [7] and lowering risk factors for heart disease such as hypertension and waist circumference [15, 21], those effects may require a higher volume of strength exercise and we were unable to accurately quantify the total volume in this particular sample.

The favorable association that we observed with functional outcomes may ultimately be more important to older adults than the presence of chronic conditions such as diabetes. Poor mobility has been previously shown to be a predictor of mortality among older adults [5] and Koroukian et al., [6] found that functional limitations were stronger predictors of mortality and self-reported health than the presence of chronic conditions including cardiometabolic disease. Prospective studies have shown that scores on these functional assessments are highly predictive of disability and mobility limitations over 4 years of follow-up [22]. Furthermore, Shumway-Cook et al. [23] showed that performance on the TUG test is an indication of risk of falls among community-dwelling older adults. Because we focused on older adults who were accumulating at least 150 min per week of physical activity, scores on these functional assessments were expected to be relatively high and among individuals in the "worst" two-thirds of the present sample, scores were not all low enough to be indicative of disability [22]. But even within a normal range, higher scores on these tests are better, as this will provide a functional reserve that may serve to delay the age-associated development of functional impairments. Thus, our finding that strength training is associated with higher scores on these performance-based physical function assessments has important implications for older adults and their ability to maintain their independence.

We also observed higher odds for good self-rated health among older adults who participate in strength training. Self-rated health is a strong predictor of mortality and may

Table 1 Proportion of active individuals ≥ 60 years reporting strength training ($n=9100$)

	Women ($n=4132$) (%)	Men ($n=4968$) (%)	Total (%)
Proportion of individuals reporting strength training (% of sample)			
Never	69.2	66.2	67.5
1–2 days	11.5	9.2	10.2
3–4 days	10.6	12.8	11.8
5–7 days	8.7	11.8	10.4
Percent participating in calisthenics	29.3	26.9	27.9
Percent participating in push-ups	17.0	26.6	22.5
Percent participating in sit-ups	18.9	27.2	23.6
Percent participating in weight lifting and hand weights	69.9	68.9	69.3

Table 2 Sample characteristics for physically active older adults (means and SD for continuous variables; frequencies for categorical variables)

	Women		Men		Total	
	No strength training ($n=2858$)	Strength training 1–7 days per week ($n=1274$)	No strength training ($n=3288$)	Strength training 1–7 days per week ($n=1680$)	No strength training ($n=6146$)	Strength training 1–7 days per week ($n=2954$)
Age (years)	68.6 ± 6.5	68.5 ± 6.5	68.9 ± 6.5	69.1 ± 6.7	68.8 ± 6.5	68.9 ± 6.6
BMI (kg/m^2)	27.6 ± 5.3	26.4 ± 4.7*	28.0 ± 4.2	27.1 ± 3.9*	27.8 ± 4.7	26.8 ± 4.3*
Relative body fat (%)	40.2 ± 5.7	38.7 ± 5.8*	29.0 ± 5.1	27.3 ± 5.1*	34.2 ± 7.8	32.2 ± 7.8*
Trunk fat (%)	46.2 ± 5.9	45.2 ± 6.2*	52.1 ± 5.2	50.8 ± 5.5*	49.4 ± 6.3	48.4 ± 6.4*
Income (% of sample)						
Less than $20,000	7.3%	4.6%^	3.3%	2.8%^	5.2%	3.6%^
$20,000–$49,999	34.8%	31.2%^	22.2%	17.5%^	28.1%	23.4%^
$50,000–$99,999	39.0%	38.1%^	42.5%	41.9%^	40.9%	40.3%^
$100,000–$149,999	12.3%	16.0%^	19.3%	20.4%^	16.1%	18.5%^
$150,000 or more	6.5%	10.2%^	12.6%	17.4%^	9.8%^	14.3%
Type 2 diabetes (% of sample)	7.0%	6.3%	12.3%	8.8%^	9.8%	7.7%^
Ischemic heart disease (% of sample)	5.9%	5.3%	14.5%	12.6%	10.5%	9.4%
4-m walk (s)	4.4 ± 0.9	4.2 ± 0.9*	4.2 ± 0.8	4.2 ± 0.9	4.3 ± 0.9	4.2 ± 0.9*
Timed up and go (s)	9.6 ± 1.8	9.3 ± 1.7*	9.6 ± 1.8*	9.4 ± 1.8*	9.6 ± 1.8	9.3 ± 1.8*
One-legged balance (s)	31.3 ± 23.2	35.5 ± 23.2*	34.3 ± 23.4*	37.7 ± 23.2*	32.9 ± 23.3	36.7 ± 23.2*
Chair rise (s)	13.8 ± 3.6	13.3 ± 3.8*	13.7 ± 3.6*	13.0 ± 3.5*	13.7 ± 3.6	13.1 ± 3.6*
Grip strength (kg)	25.2 ± 5.4	25.6 ± 5.2*	41.6 ± 8.7	41.9 ± 8.6	33.9 ± 11.0	34.8 ± 10.9*
Moderate- to strenuous-intensity physical activity (h/week)	2.2 ± 3.8	3.1 ± 4.2*	2.9 ± 4.9	4.1 ± 5.2*	2.6 ± 4.5	3.7 ± 4.8*
Self-perceived health						
Good (excellent and very good)	68.3%	77.5%^	64.3%	73.8%^	66.2%	75.4%^
Poor (good, fair, and poor)	31.7%	22.5%^	35.7%	26.3%^	33.8%	24.6%^
Healthy aging						
Good (excellent and very good)	70.1%	76.9%^	67.0%	75.1%^	68.5%	75.8%^
Poor (good, fair, and poor)	29.9%	23.1%^	33.0%	24.9%^	31.5%	24.2%^

Data for continuous variables are presented as mean ± standard deviation. *$p<0.05$ for t tests, ^$p<0.05$ for the Chi-square for categorical variables, for differences between those who participated in any strength training and those who did not

provide unique and valuable health information beyond traditional risk factors [24]. Self-rated health has also been shown to predict functional decline [25, 26]. Hirosaki et al. [26] conducted a prospective cohort study of older adults with no disability at baseline, and individuals with low self-rated health had more than double the odds of functional decline over 3 years of follow-up.

Using a large nationally representative sample, our findings support the recent results of Trudelle-Jackson and Jackson [27], who conducted a cross-sectional analysis of a small sample ($N=85$) of older adults and found that those who met the minimum guidelines for both aerobic activity and muscle strengthening activity performed better on functional tests than those who only did aerobic activity. Furthermore, in our study we included older adults who may not meet the minimum guideline of 2 days per week of strength exercise and only participate 1 day per week, and we still found beneficial associations with functional outcomes, body composition, and perceived healthy aging. Collectively, evidence from experimental and epidemiological studies suggest that messaging about strength exercise for older adults should emphasize that even very low volumes can have benefits

Table 3 Associations of health and fitness outcomes with strength training among active older adults

Outcome (referent category)	Crude		Adjusted	
	OR	CI	OR	CI
One-legged balance time (time less than 60 s)	1.35*	(1.21, 1.49)	1.17*	(1.04, 1.32)
Grip strength (males: less than 45.25 kg, females: less than 27.45 kg)	1.05	(0.94, 1.17)	1.03	(0.92, 1.15)
Chair rise total time (more than 11.82 s)	1.41*	(1.27 1.57)	1.32*	(1.18, 1.47)
Timed up and go time (more than 8.66 s)	1.27*	(1.14, 1.41)	1.15*	(1.03, 1.29)
4 m walk (more than 3.82 s)	1.24*	(1.12, 1.38)	1.13*	(1.02, 1.27)
Total fat percentage (greater than 29.23%)	1.54*	(1.38, 1.71)	1.58*	(1.38, 1.81)
Trunk fat percentage (greater than 46.57%)	1.26*	(1.13, 1.40)	1.35*	(1.20, 1.51)
Self-perceived health (poor self-perceived health)	1.54*	(1.38, 1.73)	1.34*	(1.19, 1.51)
Self-perceived healthy aging (poor self-perceived healthy aging)	1.45*	(1.29, 1.63)	1.26*	(1.12, 1.42)
Type 2 diabetes (not having type 2 diabetes)	0.78*	(0.65, 0.94)	0.94	(0.78, 1.14)
Any IHD (not having any IHD)	0.89	(0.74, 1.06)	0.94	(0.78, 1.13)

Odds ratios indicate the odds of being in the best tertile for each outcome for individuals who reported any strength training relative to those who reported none. Adjusted odds ratios adjusted for age, sex, BMI, MVPA, and income. For total fat percentage and trunk fat percentage, BMI is not included as a covariate in adjusted models *$p<0.05$

and that these benefits go beyond risk of chronic disease to affect factors associated with independence and autonomy, such as mobility.

Current physical activity guidelines suggest that older adults should accumulate at least 150 min per week of moderate-to-vigorous aerobic activity, and then provide a secondary recommendation to do muscle strengthening activities on 2 or more days per week [28]. In the World Health Organization information sheet on global recommendations on physical activity for health 65 years and above, the recommendation to do strength exercise is fifth in a list of six recommendations. The guidelines also suggest that "older adults with poor mobility should perform activity to enhance balance" [28, 29], yet the results of our study suggest that all older adults, even those who are active and have good mobility, could obtain benefits to balance from strength training. We posit that physical activity guidelines for older adults should place a stronger emphasis on the potential benefits of strength exercise and provide practical examples; all examples of activities in the current Canadian guidelines are of aerobic-type activities [28]. This is especially important given we found that only a small proportion of older adults meet both these guidelines.

Strengths of this study include the large representative sample and the use of a validated questionnaire for physical activity, although device-measured activity may provide more valid data given the tendency of individuals to overestimate physical activity. One limitation to the study is the inability to capture detailed and valid information about the dose of strength exercise, which precluded us from determining if there is evidence of a dose response association. Future studies should consider better ways to assess the dose of strength exercise in large population-based samples. We chose to include older adults who self-reported even just 1 day a week of strength exercise in the strength training group, and it is possible that individuals were misclassified based on this liberal interpretation of participation. However, previous studies have shown that even low volumes of resistance training can be beneficial to functional outcomes and that there are essentially no non-responders to this type of exercise stimulus [12, 14]. Finally, it is important to note that data from the CLSA are cross-sectional, thus, reverse-causality is possible. Prospective longitudinal studies are needed to confirm the benefits of strength training at a population level.

In conclusion, active older adults who engage in strength training have better scores on a number of important functional and health-related outcomes compared to those who only report aerobic-type activity. Thus, even physically active older adults may achieve additional important benefits from strength training. Given the low self-reported prevalence of this type of activity, strategies are needed to encourage all older adults to regularly participate in exercise specifically to improve muscular strength.

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Compliance with ethical standards

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest. The opinions expressed in this manuscript are the author's own and do not reflect the views of the Canadian Longitudinal Study on Aging.

Ethical approval The protocol of the CLSA has been reviewed and approved by 13 research ethics boards across Canada. Changes to the CLSA protocol are reviewed annually. The University of Ontario Institute of Technology Research Ethics Board approved secondary analysis of the CLSA dataset (REB #1367).

Informed consent Written consent is obtained from all participants.

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