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Abstract

Background: Sitting time and physical activity may be modifiable determinants of lung function. The purpose of this study was to assess the effect that replacing various movement behaviours has on lung function among individuals with and without obstructive lung disease.

Data and methods: For analysis, data were used from participants of the Canadian Longitudinal Study on Aging, recruited between 2012 and 2015. Lung function was assessed using spirometry. A modified version of the Physical Activity Scale for the Elderly was used to assess sitting time and physical activity levels. Isotemporal substitution analysis was performed to analyze the effects of replacing 30 minutes per day of one movement behaviour with another, keeping the total time constant. Analyses were run separately for individuals with an obstructive lung disease (asthma, chronic obstructive pulmonary disease, or forced expiratory volume in 1 second [FEV_1] < 5th percentile lower limit of normal; n=3,398), and healthy adults (n=14,707).

Results: When sitting time was replaced with 30 minutes per day of any type of physical activity or sleep, an increase in percent (%) of predicted FEV_1 (i.e., β=0.65, confidence interval [CI]: 0.43, 0.88 for replacing sitting time with strenuous or strengthening activity) was observed among healthy adults. Among adults with obstructive lung disease, replacing 30 minutes per day of sitting time or sleep duration with strenuous or strengthening activity was associated with an improvement in the percent of predicted FEV_1 (i.e., β=0.98, CI: 0.13, 1.82 for replacing sleep duration with strenuous or strengthening activity).

Interpretation: Replacing sitting time with physical activity leads to significant improvements in lung function among adults with an obstructive lung disease, as well as among adults without a respiratory disease.

Keywords: asthma, COPD, pulmonary disease, exercise, sedentary time
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Lung function declines steadily with increasing age.[1] It has been suggested that smoking, environmental and occupational factors, nutrition, comorbidity, and physical activity may affect this age-associated decline.[2] Physical activity, in particular, shows promise as a modifiable risk factor, since longitudinal evidence suggests that it may reduce the decline in lung function associated with smoking.[3] Cross-sectional studies have also identified a positive association between physical activity levels and lung function.[4]

Recent analysis from the Canadian Longitudinal Study on Aging (CLSA) indicates a strong association between lung function and both physical activity and sitting time among healthy middle-aged and older adults,[5] as well as among adults with diagnosed obstructive lung diseases such as asthma and chronic obstructive pulmonary disease (COPD).[6] Of particular novelty, these studies found that different intensities of physical activity and sitting time were associated with lung function, where sitting time, strength training and strenuous physical activity may be modifiable determinants of lung function. Evidence from intervention research supports these findings: engaging in regular exercise leads to improved disease management and quality of life among individuals with existing respiratory disease. Specifically, exercise leads to improvements in symptoms such as dyspnea, the ventilatory response to exercise, and disease control levels among those with asthma and COPD, which suggests that exercise may influence lung function.[7-11] However, little research has examined the effect of the intensity of physical activity on these outcomes. Research is also needed on sitting time, since evidence suggests that sitting time could affect lung function.[12] Sitting time may be a particularly relevant clinical target, given that physical activity of moderate to vigorous intensity leads to an increase in ventilation and dyspnea, which serves as a barrier to engagement in regular physical activity, particularly among individuals who are deconditioned.

Isotemporal substitution analysis provides the opportunity to assess the replacement effects that different movement behaviours have on lung function, in which the time and intensity in other activities are kept constant. Specifically, this type of analysis allows the changes in lung function to be modelled in terms of what may be expected in a sample if one behaviour were replaced with another (e.g., the improvement in lung function when replacing 30 minutes of sitting with 30 minutes of walking, keeping time in other behaviours constant). By providing estimates of associations at the population level, it also

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provides the opportunity to generate hypotheses that can be tested in intervention trials. The purpose of this study was to use data from the CLSA to assess the replacement effects of different movement behaviours on lung function among both individuals with an existing obstructive lung disease and individuals who were healthy.

Data and methods

Data source and participants: The CLSA is a nationally representative, stratified, random sample of 51,338 Canadian women and men aged 45 to 85 years at baseline. The purpose of this survey is to collect data on the health and quality of life of Canadians. These data are used 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 km to 50 km radius of one of the 11 data collection sites across Canada (Vancouver/Surrey [two sites], Victoria, Calgary, Winnipeg, Hamilton, Ottawa, Montréal, Sherbrooke, Halifax and St. John's). This sample contains 30,097 participants, recruited between 2012 and 2015, and was used for the proposed research.

Inclusion in the CLSA was limited to individuals 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., institutions providing 24-hour 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, individuals with a cognitive impairment at the time of recruitment were excluded.

Only individuals with complete data for spirometry (n=20,049), sleep, physical activity and sitting time (n=19,475) were included in the analysis. Furthermore, only individuals who had not taken a bronchodilator prior to spirometry, did not have a sleep disorder and had no history of lung cancer were included (all described below). The final sample size used, accounting for valid data on all covariates, included 18,105 individuals. Of these, 1,822 had asthma, 609 had COPD and 1,494 were below the lower limit of normal (LLN).

Measures

Lung conditions: Spirometry was conducted using the TrueFlow EasyOne Air spirometer. Only individuals with major contraindications did not perform the test.[13] Maximal inspiratory and expiratory maneuvers were performed to obtain forced expiratory volume in 1 second (FEV_1) and forced vital capacity (FVC) values. Each participant's data were graded to indicate repeatability. Further detail on the procedures can be found in the CLSA spirometry standard operating procedures.[13]

Only individuals who were able to complete three acceptable FVC maneuvers were included: that is, the difference between the best two FEV_1 and FVC values was within 150 mL. The best results for FEV_1 and FVC were used for analysis. Participants with extreme data outside of normal physiological limits were also excluded (i.e., FEV_1 or FVC > 10 L). Predicted FEV_1 ($FEV_{1\%pred}$), predicted FVC ($FVC_{\%pred}$), $FEV_1/FVC_{\%pred}$, and 5th percentile LLN were calculated based on age, height, ethnicity and sex using formulas developed by the Global Lung Function Initiative.[14] The LLN for each participant was calculated using the following formula:

LLN = predicted value – (1.645 × standard error of the estimate)

Individuals who responded positively to "Have you taken any long-acting inhalers in the last 12 hours?" or "Have you taken any short-acting inhalers in the last 6 hours?" were excluded (n=1,581).

Asthma and COPD were determined using self-reported physician diagnosis. Participants were asked whether a doctor had ever told them that they have asthma or emphysema, chronic bronchitis, COPD, or chronic changes in their lungs from smoking. Participants who reported having asthma, COPD, or who were below the LLN for FEV_1 were considered to have an obstructive lung disease. All other participants, that is, those who did not have an obstructive lung disease, are herein referred to as "healthy adults."

Participants with "sleep," "apnea," or "insomnia" in their answer to "Do you have any other long-term physical or mental condition that has been diagnosed by a health professional?" were considered to have a sleep disorder and were removed from the sample (n=358). Those who reported a history of lung cancer (n=103) were also excluded from the sample.

Physical activity and sitting time: A modified version of the Physical Activity Scale for the Elderly (PASE) was used to collect information on sitting time and physical activity. The PASE is a valid and reliable tool for measuring physical activity and sitting time among older adults. It has been shown to have good test-retest reliability over a three- to seven-week interval (0.75, 95% CI = 0.69 to 0.80). Construct validity has also been established.[15]

For sitting time, specifically, participants were asked the questions, "Over the past 7 days, how often did you participate in sitting activities such as reading, watching TV, computer activities or doing handicrafts?" and "On average, how many hours per day did you engage in these sitting activities?" The frequency of individual sitting activities was recorded in categories of never, seldom (1 to 2 days), sometimes (3 to 4 days), and often (5 to 7 days). The duration of individual sitting activities was recorded in categories of less than 30 minutes, 30 minutes but less than 1 hour, 1 hour but less than 2 hours, 2 hours but less than 4 hours, and 4 hours or more. The midpoint of each frequency and duration category (except for the 4 hours or more duration category, which was coded as 4 hours), was used to estimate weekly total sitting time in hours per week.

The PASE also asks a series of questions pertaining to physical activity over the past seven days. Specifically, participants were asked how often they walked outside and how often they engaged in light sports or recreational activities, moderate sports or recreational activities, strenuous sports or recreational activities, and exercises specifically to increase endurance or muscle strength. The frequency and duration for each activity were recorded in the same way as for sitting time: the same midpoints were used to calculate hours per week spent in each type and intensity of activity.

Time spent performing light and moderate activities was grouped together since some examples provided in the questions may have been misleading. For example, badminton was used as an example for light intensity, while softball was provided as an example of moderate intensity. Strenuous activity (e.g., jogging, swimming, snowshoeing, cycling, aerobics and skiing) and exercise to increase endurance and muscle strength (e.g., weightlifting or push-ups) were grouped together because of the number of respondents who engaged in these activities. Thus, the movement behaviour categories that were examined included sitting time, walking, light or moderate intensity physical activity, and strenuous or strengthening activity.

Sleep: Participants were asked, "During the past month, on average, how many hours of actual sleep did you get at night?" A whole integer was recorded and any responses greater than 12 hours were set to 12 hours.

Covariates: Participants were asked to report their age and sex, and to provide information on several additional relevant covariates. For smoking status, participants were categorized as never smoked, < 10 pack years, or 10 or more pack years based on responses to questions about the number of cigarettes smoked per day and total years smoked (further detail provided elsewhere[5]). For retirement status, participants were asked, "At this time, do you consider yourself to be completely retired, partly retired or not retired?" Participants who responded as partly retired were merged with the not retired group for sample size. For education levels, participants were asked four questions about their highest level of education. The responses were combined and used to categorize the participant under less than secondary school graduation, secondary school graduation, no postsecondary education, some postsecondary education, or postsecondary degree or diploma. Height and weight were measured by trained professionals and used to calculate body mass index (kg/m^2). Ethnicity was used for the lung function equations. The derived variable provided the following categories for ethnicity: White, Black, Korean, Filipino, Japanese, Chinese, South Asian, Southeast Asian, Arab, West Asian, Latin American, other racial or cultural origin, and multiple racial or cultural origins. These were recategorized to align with the Global Lung Function Initiative formulas as follows: Caucasian (White, Arab and Latin American), Black, Southeast Asian (Filipino, South Asian and Southeast Asian), Northeast Asian (Korean, Japanese and Chinese), and other (other, multiple and West Asian).[14]

Statistical analysis

Means and frequencies were used to describe the sample. Independent samples t-tests were used to detect differences in continuous sample characteristics between adults with obstructive lung disease and healthy adults. Chi-square tests were used to detect differences in categorical variables.

Linear regression models were used to determine the association between movement behaviours and lung function. Separate models were created for adults with obstructive lung disease and for healthy adults. $FEV_{1\%pred}$, $FVC_{\%pred}$, and $FEV_1/FVC_{\%pred}$. were used as outcomes. For all models, movement behaviours were converted into units of 30 minutes per day to aid with interpretation. For isotemporal substitution analyses, a total time variable was created, representing the sum of sleep duration and time spent in each movement behaviour. Total time reported by all participants was less than 24 hours per day (10.6 ± 1.8 hours). There was no evidence of multicollinearity among sleep and movement behaviour variables (all correlation coefficients < 0.11 and variance inflation factors < 1.8).

Single activity models were conducted to determine associations between lung function outcomes and each movement behaviour (models 1 to 5), adjusting for age, sex, smoking status, retirement status, education and body mass index. Then, a partition model was run to determine associations between lung function outcomes and each movement behaviour, adjusting for other movement behaviours (model 6). Finally, isotemporal substitution analysis was performed to analyze the effect of replacing 30 minutes per day of one movement behaviour with another, while keeping the total time constant (models 7 to 11). Each movement behaviour, except for the behaviour of interest (which is removed from the corresponding model), and a total time variable are included in the model. For example, to examine the effect of replacing 30 minutes of sitting time with another movement behaviour, sitting time was removed, while walking, light or moderate activity, strenuous or strengthening activity, sleep duration, and total time were included. Since total time is constrained, the beta coefficient for each activity represents the effect of replacing 30 minutes per day of the removed activity with the replacement activity. To analyze the effect of replacing 30 minutes per day of one activity with another activity, a different activity was removed from each model.

Descriptive and collinearity statistics were performed using IBM SPSS Statistics 24.0 (Armonk, New York).

Linear regressions for single activity, partition and isotemporal substitution analyses were performed in RStudio (version 1.1.456).[16] As per CLSA recommendations, standard errors were clustered by education level and province to account for within-group error correlation, thus accounting for the sampling design.[17] For all comparisons and models, statistical significance was declared at $p < 0.05$. To ensure national representation and to compensate for underrepresented groups, sampling weights were applied to regression models. Additional details on CLSA sampling, methods and weighting can be found in the protocol document.[18,19]

Table 1
Sample characteristics of adults with obstructive lung disease and of healthy adults

Characteristics	Adults with obstructive lung disease	Standard deviation	Healthy adults	Standard deviation
Sex (%, male)	43.8	…	48.8	…
Age (years)	61.5	9.9	62.2*	10
BMI (kg/m²)	28.9	6.1	27.5*	4.9
FEV_1 (L)	2.4	0.8	2.9*	0.7
FVC (L)	3.2	0.9	3.7*	0.9
FEV_1 % predicted	82.3	18	98.6*	12.7
FVC % predicted	87.4	15.9	98.7*	12
Sleep (hours/night)	6.8	1.3	6.8*	1.2
Seated activities	18.1	6.2	17.7*	6.2
Walking	4.2	4.6	4.5*	4.6
Activity levels (hours/week)				
Light/moderate intensity physical activity	1.5	3.6	1.8*	4
Strenuous/strengthening physical activity	2	3.6	2.4*	4
Smoking status (%)				
Never smoked	43.3	…	51.3	…
< 10 pack years	23.1	…	26.3	…
10 or more pack years	33.6	…	22.3	…
Education (%)				
Less than secondary school graduation	5.1	…	4.0	…
Secondary school graduation, no postsecondary education	8.2	…	9.1	…
Some postsecondary education	7.1	…	7.2	…
Postsecondary degree/diploma	79.6	…	79.8	…
Retirement status (%)				
Retired	40.6	…	41.4	…
Not/partly retired	59.4	…	58.6	…

… not applicable
*significantly different from adults with obstructive lung disease ($p < 0.05$)
BMI= body mass index
FEV_1 = forced expiratory volume in 1 second.
FVC = forced vital capacity
Notes: Sex, smoking status and education distribution are significantly different using chi-square between adults with obstructive lung disease and health adults at $p < 0.05$.
Source: The Canadian Longitudinal Study on Aging.

Results

Sample characteristics are provided in Table 1. Adults with obstructive lung disease had a higher body mass index, were less physically active and had lower lung function than healthy adults. Similarly, more adults with obstructive lung disease were female and had 10 or more pack years of smoking history, compared with healthy adults.

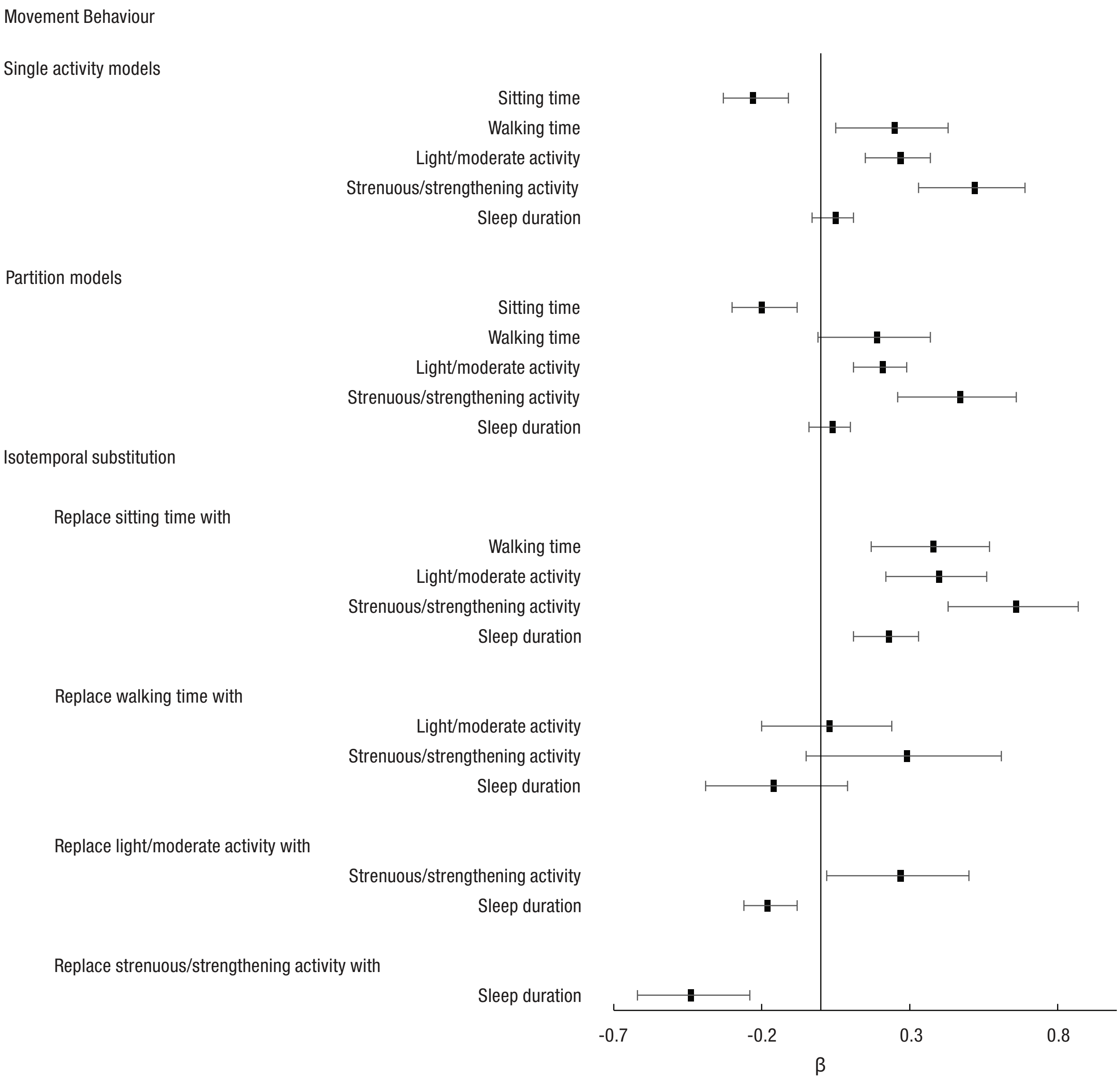
To determine whether analyses should be conducted separately among individuals with healthy and unhealthy sleep habits, the distribution of sleep, in hours, was assessed. Only 11.7% of the total sample reported sleeping for less than six hours per night, while 4.9% of the total sample reported more than eight hours of sleep per night. In addition, modelling the association between hours of sleep and $FEV_{1\%pred}$ with either a linear or a quadratic model did not significantly alter the strength of the relationship. Therefore, the data were not stratified by unhealthy and healthy sleep habits.

Single activity, partition, and isotemporal substitution analysis models for healthy adults are shown in Figure 1. Among healthy adults, all physical activity variables were positively associated with $FEV_{1\%pred}$ and $FVC_{\%pred}$, while sitting time was negatively associated with $FEV_{1\%pred}$ and $FVC_{\%pred}$ after adjustment for covariates (models 1 to 5). Associations remained significant when all movement behaviours were included in the same regression model, that is, the partition model (model 6). However, walking time was no longer significant for either $FEV_{1\%pred}$ or $FVC_{\%pred}$. Sleep was not associated with $FEV_{1\%pred}$ and $FVC_{\%pred}$ in models 1 to 6. When replacing sitting time (model 7) with 30 minutes per day of any type of physical activity or sleep, an increase in $FEV_{1\%pred}$ was observed. For example, replacing sitting time with 30 minutes per day of strenuous or strengthening activity was associated with a 0.65 percentage point higher $FEV_{1\%pred}$ (β=0.65, CI: 0.43, 0.88). Similarly, replacing 30 minutes per day of any movement behaviour, except walking time, with strenuous or strengthening activity was associated with a higher $FVC_{\%pred}$. For example, replacing 30 minutes per day of sleep duration with strenuous or strengthening activity was associated with a 0.49 percentage point higher $FVC_{\%pred}$ (β=0.49, CI: 0.27, 0.71).

Single activity, partition, and isotemporal substitution analysis models for adults with an obstructive lung disease are shown in Figure 2. Among adults with obstructive lung disease, light or moderate activity and strenuous or strengthening activity were positively associated with $FEV_{1\%pred}$ and $FVC_{\%pred}$ in single activity and partition models (models 1 to 6). Conversely, walking was significant only in the single activity model for both outcomes and in the partition model for $FEV_{1\%pred}$. When replacing 30 minutes per day of sitting time (model 7) or sleep duration (model 11) with light or moderate activity or strenuous or strengthening activity, there was an improvement in both $FEV_{1\%pred}$ and $FVC_{\%pred}$. For example, replacing 30 minutes per day of sitting time with light or moderate activity was associated with a 0.71 percentage point higher $FEV_{1\%pred}$ (β=0.71, CI: 0.31, 1.12). Similarly,

Figure 1
Single activity, partition, and isotemporal substitution models for lung function in response to 30 minute per day substitution of movement behaviours in healthy adults

a) Percentage of predicted FEV_1



replacing 30 minutes per day of sleep duration with strenuous or strengthening activity was associated with a 1.13 percentage point higher $FVC_{\%pred}$ (β=1.13, CI: 0.64, 1.63).

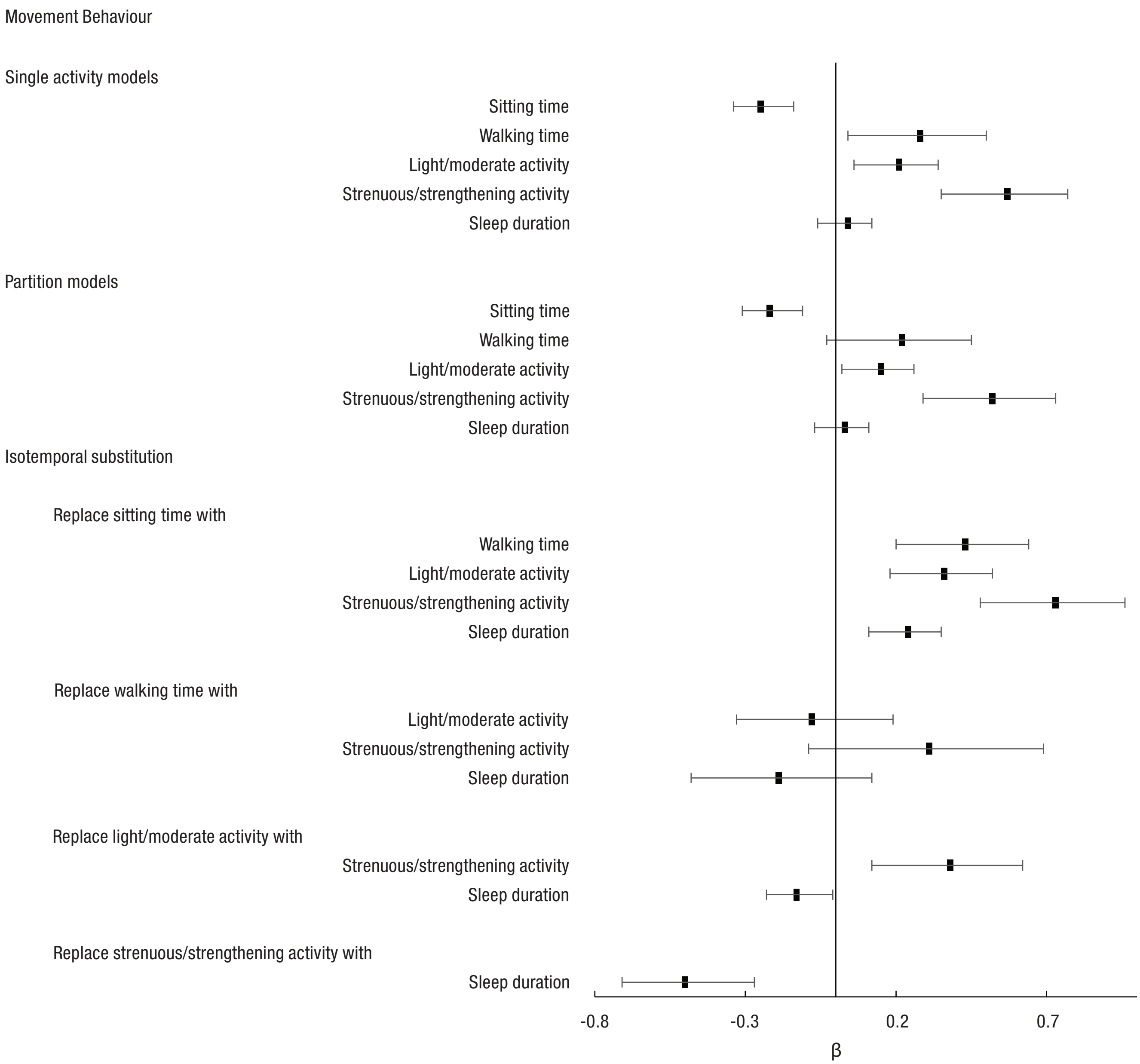
Among healthy adults and adults with an obstructive lung disease, no movement behaviours were significantly associated with $FEV_1/FVC_{\%pred}$ in single activity and partition models (Appendix Table A). In isotemporal substitution models, few replacement effects were observed.

Discussion

This study is the first to assess the effects that replacing sitting time with different intensities of physical activity have on measures of lung function among adults with and without obstructive lung disease. The primary finding is

Figure 1
Single activity, partition, and isotemporal substitution models for lung function in response to 30 minute per day substitution of movement behaviours in healthy adults

b) Percentage of predicted FVC

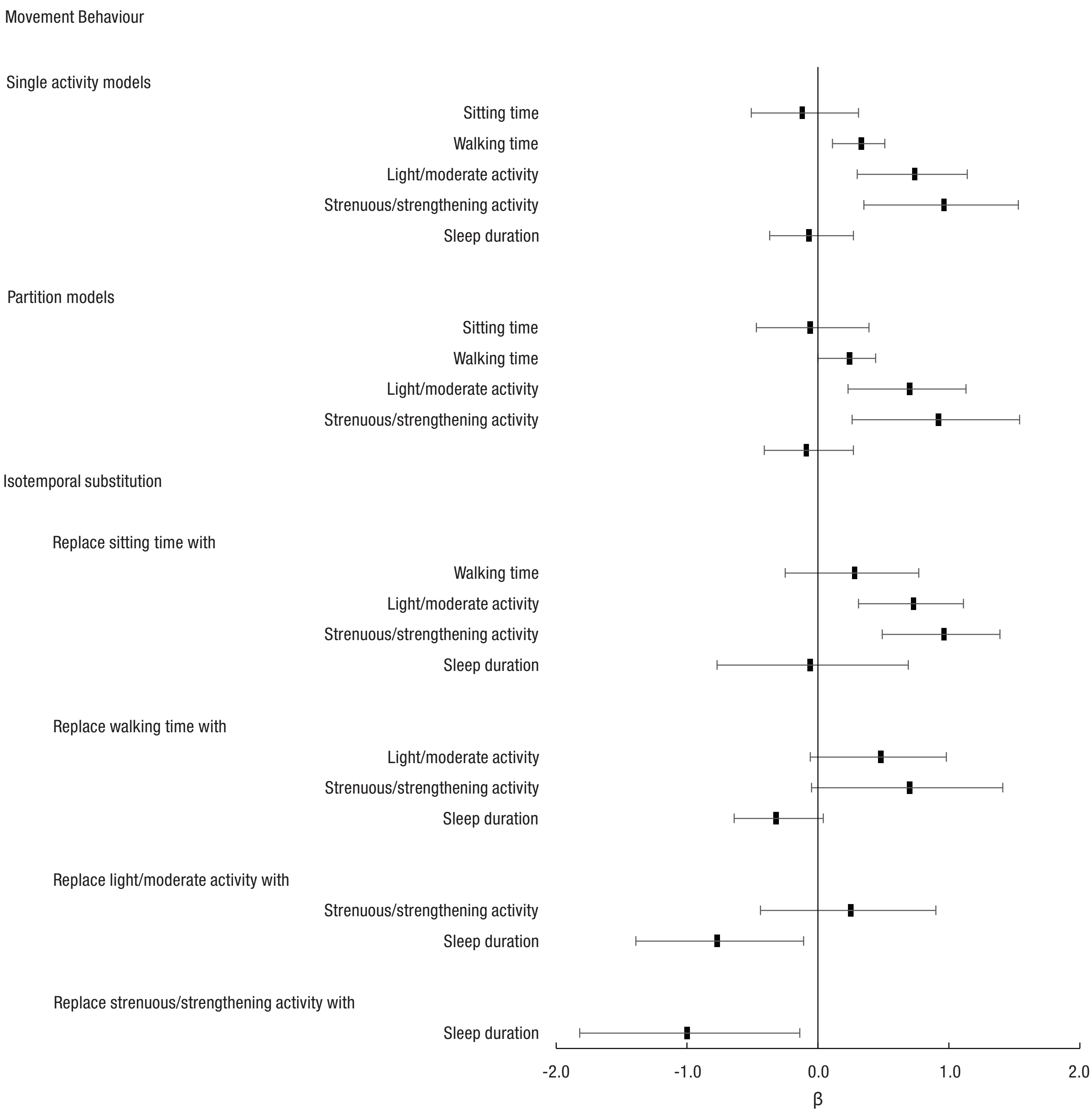


FEV_1 = forced expiratory volume in 1 second
FVC = forced vital capacity
Source: The Canadian Longitudinal Study on Aging.

that replacing 30 minutes of sitting time with 30 minutes of either sleep, walking, light or moderate activity, or strenuous or strengthening activity is consistently associated with improved lung function (0.2 to 0.8 percentage points) among individuals who do not have an existing chronic lung disease. Among individuals who do have an existing chronic obstructive lung disease, replacing 30 minutes of sleep or sitting time with 30 minutes of strenuous or strengthening activity was associated with 0.9 to 1.2 percentage points of improvement in lung function outcomes. These data

Figure 2
Single activity, partition, and isotemporal substitution models for lung function in response to 30 minute per day substitution of movement behaviours in adults with obstructive lung disease

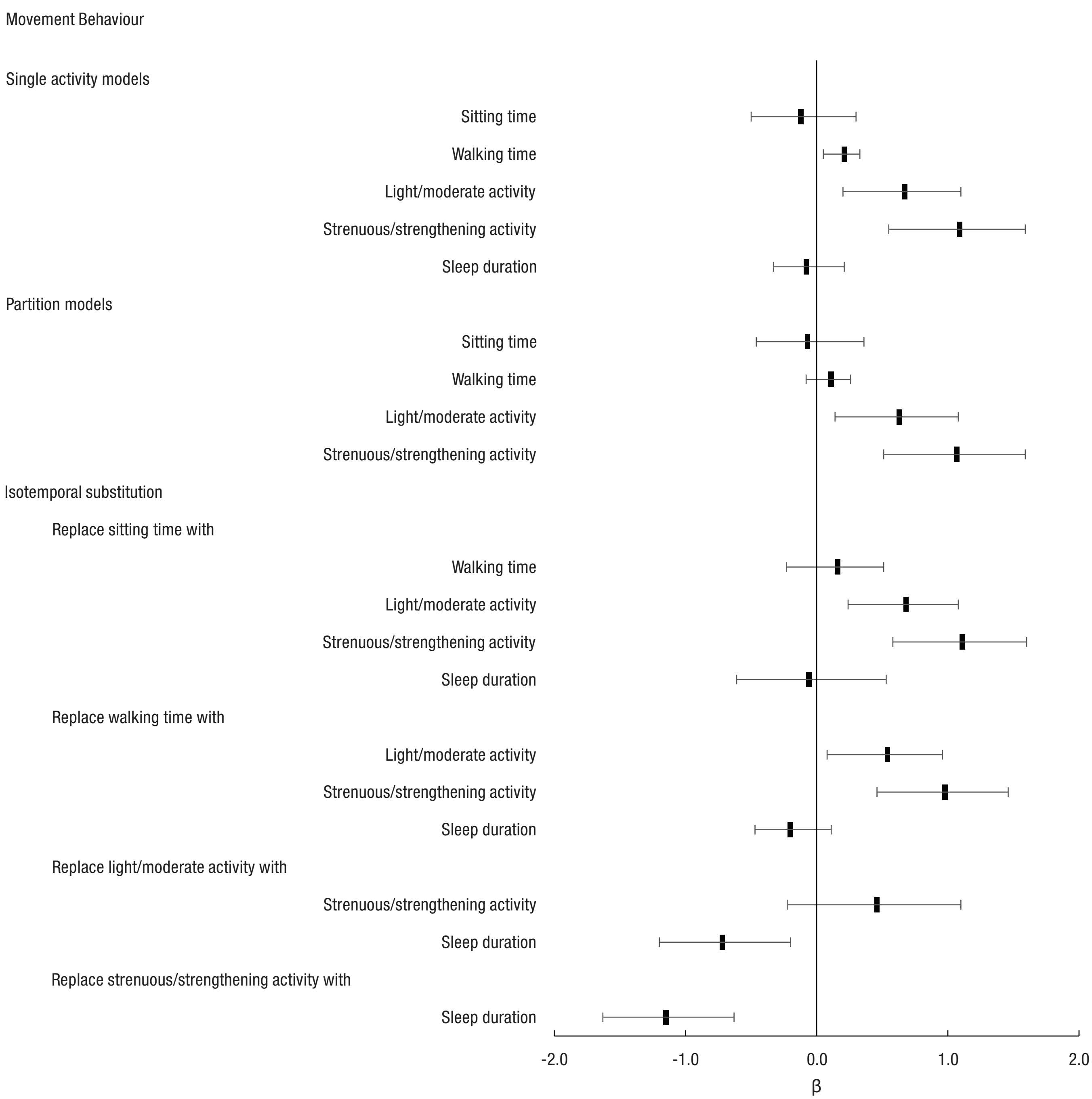
a) Percentage of predicted FEV_1



support the notion that movement behaviours may be predictors of lung function and are therefore important in preventing and managing chronic obstructive lung diseases.[4,5] Although the replacement effects of individual movement behaviours would not be considered clinically meaningful, the additive effect of these movement behaviours may lead to clinically significant improvements in lung

Figure 2
Single activity, partition, and isotemporal substitution models for lung function in response to 30 minute per day substitution of movement behaviours in adults with obstructive lung disease

b) Percentage of predicted FVC



FEV_1 = forced expiratory volume in 1 second
FVC = forced vital capacity
Source: The Canadian Longitudinal Study on Aging.

What is already known on this subject?

- The age-associated decline in lung function may be modifiable.
- Cross-sectional data indicate that sitting time and different intensities of physical activity may be associated with several outcomes among adults with and without a diagnosed respiratory disease.

What does this study add?

- Replacing sitting time with sleep or physical activity positively affects measured lung function among adults without lung disease.
- Replacing sleep or sitting time with strenuous or strengthening activity positively affects measured lung function among adults with asthma, COPD or airflow limitation.
- Counselling individuals at risk for or with an existing obstructive lung disease on movement behaviours could lead to improvements in their lung function. This is a finding that has implications for clinical practice.

function or significantly reduce age-related decline in lung function. These findings highlight the need for intervention work assessing the clinical impact of replacing sedentary time with physical activity.

Healthy sample

One other study has used isotemporal substitution analysis to assess the effects, among healthy adults, of replacing sitting time with physical activity on lung function. This study was conducted among children aged 5 to 15 years and considered a variety of health outcomes, including peak expiratory flow. No associations were found between any activity category (as assessed by an accelerometer) and peak expiratory flow. It is important to note that this was a sample of healthy children and that conditions such as asthma were not controlled for in the methods or analysis.[20] Similarly, a published abstract on adults without respiratory disease found that replacing 10 minutes of sedentary time with moderate to vigorous intensity physical activity (as measured by an accelerometer) was associated with a 2.4 percentage points higher predicted FVC and FEV_1.[21] Based on these two studies and this analysis, it is possible that movement behaviours are more important for lung function in adulthood. The results of this study may also be considered as conservative estimates, since physical activity and sitting time were assessed via self-report instead of with an accelerometer.

A particularly interesting finding among the healthy group in this study was that sitting time was consistently associated with lung function, such that replacing sitting with sleep or any type or intensity of physical activity benefitted lung function. In other words, sitting for prolonged periods of time can be detrimental to respiratory health. This is important since there is a cyclical relationship between shortness of breath and deconditioning. Sedentary time has been associated with an increase in inflammatory cytokines such as C-reactive protein,[22,23] which is also connected to respiratory diseases such as asthma and COPD.[24] For sleep, longer sleep duration may reflect fewer symptoms related to sleep apnea common in aging adults with and without COPD.[25] Additionally, less sedentary time provides more sleep opportunity within a 24-hour day. Thus, it is possible that simply sitting for prolonged periods is causing physiological changes that accelerate the age-associated decline in lung function and, therefore, increase the risk of developing these diseases. This should be further investigated in laboratory-based studies or with longitudinal data.

Respiratory disease sample

Among adults with a diagnosed respiratory disease or lung function below the LLN, no studies to date have assessed replacement effects using isotemporal substitution analysis. However, given the strong cyclical relationship between dyspnea, inactivity and deconditioning observed among individuals with a diagnosed obstructive respiratory disease,[26] it seems plausible that engaging in regular physical activity, and thus having a higher exercise capacity, would be associated with better lung function. In fact, evidence from exercise interventions indicates that increasing strength and cardiorespiratory fitness results in better respiratory outcomes for adults with COPD.[9,27] Furthermore, recent evidence suggests that among older adults, lower levels of prolonged sitting time are associated with higher cardiorespiratory fitness.[28] Therefore, reducing sitting time could affect cardiorespiratory fitness and measures of lung function. It appears, then, that any movement along the continuum from sitting to vigorous intensity would influence lung function among individuals with a chronic obstructive lung disease.

The known association between obstructive lung disease and deconditioning also explains why strenuous and strengthening activities have significant replacement effects, such that replacing sitting time or sleep with strenuous or strengthening activity was associated with better lung function. In fact, research clearly demonstrates that strength training is associated with improved outcomes among individuals with COPD[27] and among obese adults with asthma.[29] There is also research to suggest that higher intensity exercise is beneficial for individuals with asthma or COPD.[8,11] Further research is needed to better understand how much of this type of activity is needed to have a clinically meaningful effect on lung function, as well as to identify the separate effects of strength training and strenuous physical activity on lung function.

There are two additional limitations of this study. First, the data currently available from the CLSA are cross-sectional. Therefore, a temporal analysis could not be conducted at this time. Longitudinal data will be available in five years for such analyses. Second, physical activity and sitting time were measured by self-report. Device-measured movement would have provided more accurate estimates of physical activity intensity. However, it would not allow for distinguishing between modes of physical activity, such as walking and strength training.

These data are the first to show that replacing sitting time with physical activity could have a significant effect on lung function in both healthy individuals and those with a diagnosed obstructive lung disease. To better understand the effects that engaging in regular physical activity of different intensities and breaking up sedentary time have on measures of lung function, longitudinal observational data are needed in future research. Randomized control trials are also needed to determine the optimal dose of activity for reducing the age-associated decline in lung function. In terms of clinical practice, it appears to be valuable to assess the amount of sitting time and physical activity among patients at risk for obstructive lung disease, or among individuals with existing obstructive lung disease. This is because replacing sitting time or increasing physical activity could significantly reduce age-associated decline in lung function. This study further supports the use of exercise as a vital sign in clinical practice,[30, 31] and supports the prescription of light intensity physical activity.[32]

In conclusion, this analysis of the CLSA indicates that replacing sitting time with physical activity leads to significant improvements in lung function among adults with an obstructive lung disease, as well as among adults without a respiratory disease.

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Appendix

Table A
Single activity, partition, and isotemporal substitution models for percentage of predicted FEV_1/FVC in response to 30 minute per day replacement of movement behaviours in adults with and without obstructive lung disease

a) Healthy adults

	Sitting time			Walking time			Light/moderate activity			Strenuous/ strengthening activity			Sleep duration		
		95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval	
	β	from	to	β	from	to	β	from	to	β	from	to	β	from	to
Single activity models															
Models 1 to 5	0.03	-0.02	0.07	-0.03	-0.11	0.06	0.05	-0.03	0.14	-0.06	-0.14	0.01	0.01	-0.02	0.04
Partition model															
Model 6	0.03	-0.02	0.07	-0.02	-0.11	0.06	0.06	-0.01	0.14	-0.06	-0.13	0.01	0.01	-0.02	0.04
Isotemporal substitution															
Replace sitting time (Model 7)	Removed			-0.05	-0.14	0.03	0.03	-0.03	0.10	-0.09*	-0.15	-0.02	-0.02	-0.08	0.04
Replace walking time (Model 8)	0.05	-0.03	0.14	Removed			0.09*	0.01	0.17	-0.04	-0.15	0.07)	0.03	-0.08	0.14
Replace light/moderate activity (Model 9)	-0.03	-0.10	0.03	-0.09*	-0.17	-0.01	Removed			-0.12*	-0.18	-0.07	-0.05	-0.14	0.04
Replace strenuous/strengthening activity (Model 10)	0.09*	0.02	0.15	0.04	-0.07	0.15	0.12*	0.07	0.18	Removed			0.07	-0.02	0.16
Replace sleep duration (Model 11)	0.02	-0.04	0.14	-0.03	-0.14	0.08	0.05	-0.04	0.14	-0.07	-0.16	0.02	Removed		

b) Adults with obstructive lung disease

	Sitting time			Walking time			Light/moderate activity			Strenuous/ strengthening activity			Sleep duration		
		95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval	
	β	from	to	β	from	to	β	from	to	β	from	to	β	from	to
Single activity models															
Models 1 to 5	-0.02	-0.16	0.12	0.18	-0.01	0.37	0.09	-0.10	0.27	-0.09	-0.46	0.28	0.01	-0.21	0.22
Partition model															
Model 6	-0.01	-0.16	0.14	0.18	-0.03	0.39	0.07	-0.13	0.27	-0.11	-0.51	0.29	0.01	-0.22	0.24
Isotemporal substitution															
Replace sitting time (Model 7)	Removed			0.20	-0.10	0.49	0.09	-0.06	0.23	-0.10	-0.42	0.22	0.02	-0.31	0.35
Replace walking time (Model 8)	-0.22	-0.49	0.10	Removed			-0.11	-0.41	0.19	-0.29	-0.87	0.28	-0.17*	-0.32	-0.03
Replace light/moderate activity (Model 9)	-0.09	-0.23	0.06	0.11	-0.19	0.41	Removed			-0.18	-0.58	0.21	-0.06	-0.44	0.32
Replace strenuous/strengthening activity (Model 10)	0.10	-0.22	0.42	0.29	-0.28	0.87	0.18	-0.21	0.58	Removed			0.12	-0.44	0.69
Replace sleep duration (Model 11)	-0.02	-0.35	0.31	0.17*	0.03	0.32	0.06	-0.32	0.44	0.12	-0.69	0.44	Removed		

* refers to $p < 0.05$
FEV_1 = forced expiratory volume in one second.
Notes: **β** represents the change in FEV1/FVC%pred with a 30-minute increase per day in the movement behaviour for single activity and partition models, and for a 30-minute substitution in isotemporal substitution models. All models were adjusted for age, sex, smoking status, retirement status, education and body mass index.
Source: The Canadian Longitudinal Study on Aging.