Experimental Gerontology 135 (2020) 110941

Contents lists available at ScienceDirect

Experimental Gerontology

journal homepage: www.elsevier.com/locate/expgero

Short communication

Peak expiratory flow, walking speed and survival in older adults: An 18-year longitudinal population-based study

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ARTICLE INFO

Section Editor: Emanuele Marzetti

Keywords:
Respiratory function
Walking speed
Survival
Aging

ABSTRACT

Background: Peak expiratory flow (PEF) and walking speed (WS) have been proposed as indicators of robustness and are independent predictors of health-related outcomes. We aimed to investigate how the co-occurrence of respiratory and physical impairments changes as a function of age, and to quantify the association of the combination of low PEF and slow WS on survival in older people.

Methods: This prospective study analyzes data from 2656 community-dwelling participants (age ≥ 60 years) from the SNAC-K study. At baseline, we assessed: (1) sociodemographic, lifestyle and medical data; (2) respiratory function, estimated through PEF and expressed as standardized residual (SR) percentile; and (3) WS at usual pace, categorized as no (> 1.2 m/s), mild (0.8–1.2 m/s) and moderate-to-severe (< 0.8 m/s) walking impairment. Participants' vital status over an 18-year follow-up was derived from registers. The association of different combinations of PEF and WS on median survival time was estimated through Laplace regression adjusted for potential confounders.

Results: Respiratory and walking impairments co-occurred more frequently with increasing age. Among individuals with PEF SR-percentiles < 10th, the percentage of moderate-to-severe walking impairment was 12.1% in sexagenarians, 35.7% in septuagenarians, and 75–80% in the oldest old. The greatest reduction in median survival time (−5.4 [95%CI: −6.4; −4.4] years, $p < 0.001$) was observed among people with combined respiratory and moderate-to-severe walking impairments, compared with those with no dysfunctions, who had a median survival time of 17.4 (95%CI: 17.0; 17.8) years.

Conclusions: Impaired PEF and WS co-occur more frequently with advancing age, and their co-occurrence is associated with shorter survival.

1. Introduction

Peak expiratory flow (PEF) and walking speed (WS) are two easily accessible measures of fitness that physiologically decline with age, along with the accumulation of health deficits (Abellan van Kan et al., 2009; Fried et al., 2001; Vaz Fragoso et al., 2012). These parameters are independently associated with disability and death, and have been shown to improve outcome prediction more than existent risk score tools (Goldman et al., 2014; Lee et al., 2017). To a certain extent, an impairment in PEF and WS may underlie common pathophysiological pathways, as for example muscle weakness or cardiovascular diseases, making their assessment alternative measures of the same phenomena (Guralnik et al., 2000; Kera et al., 2019; Vaz Fragoso et al., 2007). On the other hand, they may reflect specific physiological deficits (e.g., reduced pulmonary compliance the one, joints degeneration the other), representing two potentially complementary measures of global fitness (Buchman et al., 2009; Trevisan et al., 2019).

As a result of the age-related accumulation of deficits, respiratory

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https://doi.org/10.1016/j.exger.2020.110941
Received 15 January 2020; Received in revised form 28 March 2020; Accepted 28 March 2020
Available online 31 March 2020

and motor systems dysfunctions are expected to co-exist in old age and their interplay may be hypothesized to exert an impact on individuals' health that is higher than what expected in presence of single impairments (Calderón-Larrañaga et al., 2016; Vaz Fragoso et al., 2012). If this is the case, the combined assessment of PEF and WS could improve the identification of older adults with poorest prognosis in terms of survival. The aims of this study were: a) to describe the distribution of respiratory and walking impairments as function of age in a sample of community-dwelling older adults; and b) to estimate the impact of their coexistence on participants' survival.

2. Methods

2.1. Study population

This study uses data from the Swedish National Study on Aging and Care in Kungsholmen (SNAC-K), an ongoing prospective study on adults aged 60 years or older, selected through sampling stratified by age, every six (60, 66, and 72) or three years (78, 81, 84, 87, 90, 93, 96 and 99+). The baseline visit was carried out between 2001 and 2004, with a participation rate of 73.3%, resulting in an initial sample of 3363 individuals. Participants undergo clinical follow-up assessments every 3 (i.e. participants aged 78 years or older) or 6 years, while administrative data are used to derive information on the vital status of the study participants over time.

For the present work we excluded 191 individuals who lived in a nursing home, 428 with missing data on PEF or body height measures, and 88 with missing data on WS, obtaining a final analytical sample of 2656 older adults. Compared with those included, participants excluded due to missing data were more likely to be older (82.2 ± 11.3 vs 72.3 ± 9.9 years, $p < 0.001$), women (74.8% vs 61.5%, $p < 0.001$), to have worse cognitive status (49.8% vs 13.9% had a Mini-Mental State Examination [MMSE] score < 28, $p < 0.001$), and a higher number of chronic diseases (5.2 ± 2.9 vs 3.7 ± 2.3, $p < 0.001$). No significant differences between included and excluded participants were observed regarding the prevalence of chronic obstructive pulmonary disease (COPD) and asthma (all p-value > 0.05).

SNAC-K was approved by the Regional Ethical Review Board in Stockholm (Sweden). Informed consent was obtained from all study participants and, for those with cognitive impairment, from the next of kin. The study is reported in accordance with the STROBE guidelines.

2.2. Data collection

SNAC-K participants were evaluated by trained nurses and physicians through personal interviews and clinical examinations, collecting information on sociodemographic characteristics, health behaviors, functional, psychological and physical status, and clinical conditions.

PEF (liters/minute) was measured at baseline using a mini-Wright peak flow meter (Airmed Clement Clarke International®), and the highest value among three tests was recorded ("Standardization of Spirometry 1994 Update. American Thoracic Society", 1995). Individuals, while maintaining a standing position, were instructed to breath in as deep as possible, and then to blow as hard and fast as possible into the device. In line with previous works (Trevisan et al., 2019; Vaz Fragoso et al., 2007) and considering that PEF physiologically depends on age, sex, and body height, for each participant we estimated expected PEF by using linear regression equations derived from a subsample of healthy individuals of the same population (i.e. never smokers with no diagnosis of respiratory disorders, cardiovascular diseases or cancer; details in Table S1 in the Supplement). By mean of the formula [(measured-expected PEF) / (standard deviation of the residuals)], we computed standardized residuals (SR), which were then normalized to obtain SR-percentiles, with SR = 0 corresponding to the 50 percentile (Vaz Fragoso et al., 2007). For the current study PEF SR-percentiles were categorized as follows: 80th–100th, 50th–80th, 10th–50th, and < 10th (Vaz Fragoso et al., 2007).

WS (m/s), was measured over 6 m, for participants who considered themselves as normal or fast walkers, or over 2.4 m, for those who defined themselves as slow walkers or for those who were tested at home in case of limited space. As previously demonstrated, measurements of WS over 2.4- and 6-meter distance are comparable, thus the use of the shorter distance in case of practical setting limitations seems to be justifiable (Bohannon, 2008). We used cut-offs of 0.8 and 1.2 m/s to estimate the presence of no (> 1.2 m/s) (Abellan van Kan et al., 2009; Fritz and Lusardi, 2009), mild (0.8–1.2 m/s) or moderate-to-severe (< 0.8 m/s) walking impairment (Abellan van Kan et al., 2009; Cruz-Jentoft et al., 2019).

Covariates. *Educational level* was defined as the highest level of formal education and categorized as elementary, high school, and university or above. *Smoking habits* were categorized as never, former (i.e. having smoked for at least one year over the life course), and current smoking. *Alcohol consumption* was classified as no or occasional, light-to-moderate (1–14 drinks/week for men and 1–7 drinks/week for women), or heavy (≥15 drinks/week for men and ≥8 drinks/week for women) consumption. *Body mass index* (kg/m^2) was computed from the ratio of body weight and height squared. Global *cognitive functions* were evaluated using the Swedish version of MMSE. The ascertainment of clinical conditions was performed by physicians through clinical examinations and by evaluating participants' biochemical data, clinical records, medical history and use of medications. In this study, emphasis was given to the presence of *obstructive respiratory diseases*, i.e. COPD or asthma; and of cardiovascular diseases (CVD), defined as the presence of ischemic heart disease, heart failure, or atrial fibrillation. Moreover, we computed the total number of *chronic diseases* (excluding obstructive respiratory diseases and CVD) from the count of clinical chronic conditions (Calderón-Larrañaga et al., 2016).

All-cause death date was derived from the Swedish Cause of Death Registry until 31 January 2019.

2.3. Statistical analyses

The baseline characteristics of participants by age cohort were compared using Student t-test/ANOVA and the Chi-squared test, as appropriate. Since the frequency of missing values in our covariates was < 5%, we used single imputation through the expectation maximization algorithm for continuous variables, while dummy variables were used for categorical variables.

The association between PEF SR-percentiles and WS, and the interaction of the former variable with age was tested through linear regression, adjusted for sex. Since we found a significant interaction PEF SR-percentiles and age in influencing WS values ($p < 0.001$), we explored the percent distribution of WS impairments (no, mild, moderate-to-severe) for different PEF SR-percentiles groups, within each age cohort (60–66, 72–78, 81–87, 90+). The combined impact that different PEF SR-percentiles and WS categories had on median survival time (expressed in years) with 95% confidence interval (95%CI), was estimated using Laplace regression(Orsini et al., 2012), adjusted for potential confounders (age, sex, educational level, smoking habits, alcohol consumption, MMSE, number of chronic diseases, CVD, and obstructive respiratory diseases). The presence of an additive interaction between PEF SR-percentiles and WS in the association with survival was tested. As sensitivity analysis, we evaluated the same association only in participants who never smoked (i.e., participants with less likelihood of presenting with an undiagnosed COPD). In analyses stratified by age, we estimated the 30th percentile survival time, considering that less than half of participants in the youngest age groups died over the follow-up. All statistical tests were two-tailed, and statistical significance was set as a p-value < 0.05. Analyses were performed using R, and Laplace regression using Stata.

Table 1
Baseline characteristics of the sample as a whole and stratified by age cohort.

Characteristics	All (n = 2656)	Age cohort 60–66 (n = 1209)	72–78 (n = 819)	81–87 (n = 454)	90+ (n = 174)
Age (years)	72.3 ± 9.9	63.0 ± 2.9	75.3 ± 3.0	83.9 ± 2.4	91.8 ± 2.1***
Sex (female)	1633 (61.5)	681 (56.3)	509 (62.1)	310 (68.3)	133 (76.4)***
Educational level					
Elementary	382 (14.4)	85 (7.0)	126 (15.4)	119 (26.2)	52 (29.9)***
High school	1299 (48.9)	513 (42.4)	448 (54.7)	240 (52.9)	98 (56.3)***
University	975 (36.7)	611 (50.5)	245 (29.9)	95 (20.9)	24 (13.8)***
Body mass index (kg/m^2)	25.7 ± 4.0	26.2 ± 4.0	26.0 ± 4.0	24.8 ± 3.8	23.5 ± 3.8***
Alcohol consumption					
No or occasional	813 (30.6)	232 (19.2)	257 (31.4)	220 (48.5)	104 (59.8)***
Light to moderate	1561 (58.8)	792 (65.5)	493 (60.2)	210 (46.3)	66 (37.9)***
Heavy	274 (10.3)	184 (15.2)	67 (8.2)	21 (4.6)	2 (1.1)***
Smoking habits					
Never	1196 (45.0)	442 (36.6)	386 (47.1)	265 (58.4)	103 (59.2)***
Former	1053 (39.6)	524 (43.3)	321 (39.2)	145 (31.9)	63 (36.2)***
Current	393 (14.8)	237 (19.6)	107 (13.1)	41 (9.0)	8 (4.6)***
Number of chronic diseases	3.7 ± 2.3	2.7 ± 1.7	4.1 ± 2.2	4.9 ± 2.3	5.7 ± 2.3***
COPD	121 (4.6)	37 (3.1)	49 (6.0)	27 (5.9)	8 (4.6)**
Asthma	166 (6.3)	74 (6.1)	59 (7.2)	25 (5.5)	8 (4.6)
Cardiovascular diseases	536 (20.2)	99 (8.2)	212 (25.9)	144 (31.7)	81 (46.6)***
Cognitive deficits	368 (13.9)	45 (3.7)	99 (12.1)	130 (28.6)	94 (54.0)***
Walking speed (m/s)					
> 1.2	1495 (56.3)	970 (80.2)	414 (50.5)	99 (21.8)	12 (6.9)***
0.8–1.2	630 (23.7)	188 (15.6)	254 (31.0)	150 (33.0)	38 (21.8)***
< 0.8	531 (20.0)	51 (4.2)	151 (18.4)	205 (45.2)	124 (71.3)***
PEF SR-percentiles					
80th–100th	341 (12.8)	117 (9.7)	111 (13.6)	81 (17.8)	32 (18.39)***
50th–79th	905 (34.1)	443 (36.6)	278 (33.9)	142 (31.3)	42 (24.14)**
10th–49th	1073 (40.4)	525 (43.4)	315 (38.5)	163 (35.9)	70 (40.23)*
< 10th	337 (12.7)	124 (10.3)	115 (14.0)	68 (15.0)	30 (17.24)**

Values are presented as mean ± standard deviation or absolute number and percentage (%). *Abbreviations*: COPD, chronic obstructive pulmonary disease; PEF, peak expiratory flow; SR, standardized residual. *Notes*: cognitive deficits were defined as a MMSE < 28. Missing data: 8 for alcohol consumption, 14 for smoking habits. *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

3. Results

The baseline characteristics of the sample are reported in Table 1.

The mean age of the study participants was 72.3 ± 9.9 years, 1633 (61.5%) were women, and 36.7% had a university degree. < 15% of the sample reported risky behaviors, such as heavy alcohol consumption and current smoking, and those frequencies were lower in the oldest age classes. On the other hand, the average number of chronic diseases increased with advancing age. Similar trends were observed for the presence of CVD and cognitive deficits, which affected 20.2% and 13.9% of the study sample, respectively. At baseline, 56.3% participants showed a WS > 1.2 m/s, while 23.7% had mild and 20% had moderate-to-severe walking impairment. The prevalence of moderate-to-severe walking impairment increased with age, ranging from 4.2% among the sexagenarians to 71.3% among those aged 90 years or older.

Fig. 1 illustrates the prevalence of walking impairment by PEF category and by age class (details in Table S2 in the Supplement). As reported, low respiratory function seemed to more frequently co-occur with walking impairment with advancing age. Indeed, among individuals with the poorest expiratory performance (PEF SR-percentiles < 10th), the percentage of those with moderate-to-severe walking impairment significantly increased from 12.1% in sexagenarians, to 35.7% in septuagenarians, up to 75–80% in the oldest age classes.

During the follow-up (median 15 [IQR: 8–16] years), 51.2% (541 men, 820 women) participants died. After adjusting for potential confounders, median survival time significantly decreased from participants with normal PEF and normal WS to those with only one impaired parameter (−1.9 [95%CI: −3.1; −0.7] years, for participants with PEF SR-percentiles < 10th and WS > 1.2, p = 0.002; and −4.2 [95%CI: −5.5; −2.8] for those with PEF SR-percentiles > 50th and WS < 0.8, $p < 0.001$), up to those with both impairments (−5.4 [95%CI: −6.4; −4.4] years, for participants with PEF SR-percentiles < 10th and WS < 0.8, $p < 0.001$; Fig. 2). No significant additive interaction between PEF SR-percentiles and walking speed was observed (p = 0.41). Similar results were found among those who never smoked (Fig. S1 in the Supplement) and when we considered the 30th percentile survival time in participants stratified by age (Fig. S2 in the Supplement). However, among never smokers and individuals in the oldest age cohorts, we observed a higher survival time for those with PEF SR-percentiles < 10th but no walking impairments.

4. Discussion

Our study shows that both WS and PEF impairments become frequent in old age, and that the combined assessments of such parameters may help in identifying older individuals with poorer survival. To the best of our knowledge, this is the first study exploring the prognostic role of slow WS and poor PEF in terms of survival, over 18-years of follow-up.

In evaluating the distribution of combined PEF and WS deficits, we found that at the same degree of respiratory dysfunction, the oldest age cohorts were more likely to present walking impairments compared with the youngest ones. The transitional phase when the co-occurrence of low PEF and slow WS was more marked corresponded to the 80th decade. This is in line with previous studies observing that major changes in several health indicators occur in such decade, and accelerate the transition to functional dependence (Jacobs et al., 2012; Santoni et al., 2015). The co-occurrence of PEF and WS impairments

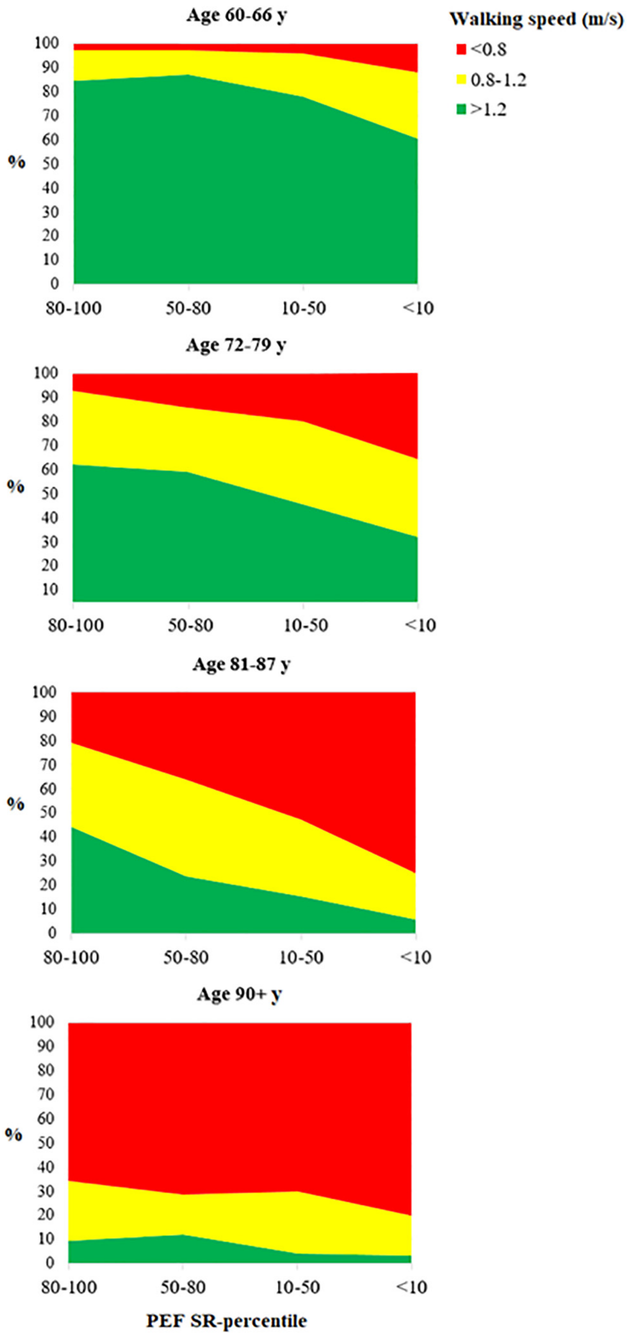

Fig. 1. Percent distribution of walking performance by peak expiratory flow and by age cohort
Abbreviations: y, years; PEF, peak expiratory flow; SR, standardized residual.

may be justified by several issues. First, both parameters present a physiological age-related decline that could be accelerated by the same risk factors, as for example unhealthy behaviors. Second, the reduction of both PEF and WS may be exacerbated by the same acute triggers (e.g. acute diseases, hospitalizations, or injurious falls) (Gill et al., 2010) and can be chronically maintained through similar mechanisms (e.g. chronic inflammation, neuroendocrine dysfunction, or sarcopenia) (Cruz-Jentoft et al., 2019; Fried et al., 2001). Third, impairments in PEF and WS can influence each other. Low respiratory function, in fact, may limit individuals' physical activities and leads to reduce muscle mass and performance. In turn, low WS may gradually affect cardiopulmonary fitness and can be an indicator of frailty, which has demonstrated to increase the risk of developing respiratory impairment (Vaz Fragoso et al., 2012). Aging and its related deficit accumulation may exacerbate such mutual relationship so that, irrespective of the *primum movens*, older individuals with prevalent respiratory dysfunctions are more likely to present also a reduced physical performance, and vice versa.

The complex interplay between respiratory and physical functions can have a substantial influence on health-related outcomes. As hypothesized, we found that the combination of low PEF and WS conditions had a stronger impact on survival than the presence of only one or no dysfunction, and median survival time showed to drop by 30% in the worst category compared with the healthiest one. In line with our findings, despite considering slightly different exposures and outcomes, Vaz Fragoso et al. showed that people with both frailty and respiratory impairment had an almost four-fold increased mortality risk over a median follow-up of 13.2 years, compared with the healthiest ones (Vaz Fragoso et al., 2012). As in that study, in our population impairments in physical performance seemed to have a greater impact on survival compared with respiratory dysfunctions. Moreover, in the subsample of oldest old individuals, as well as among never smokers, we observed an increased survival time among individuals with PEF SR-percentiles < 10th but normal walking speed. Such effect may be due to selective survival of the most resilient older adults who, despite the presence of respiratory impairments, were able to maintain a satisfactory physical performance level. Overall, our findings support the potential usefulness of preventive and rehabilitative interventions aimed at maintaining and improving respiratory and physical performance in older adults, since they could have beneficial effects on both these health domains.

Among the limitations of this study, the unavailability of data on pulmonary function assessed through spirometry and the possible underestimation of COPD diagnosis did not allow us to disentangle the age-related vs. disease-related reductions in PEF. However, spirometry is often not accessible for large cohort studies, and our sensitivity analysis only including never smokers most likely excluded the underdiagnosed COPD participants. Moreover, although the assessments of walking speed over 2.4 and 6 m have shown to be comparable (Bohannon, 2008), we cannot rule out the possibility that, at the same degree of respiratory dysfunction, people assessed over 2.4 m could have performed better compared with those who walked longer distance. In our study, however, the 2.4-m walking test was performed in individuals tested at home (often because of cognitive or mobility problems) or in those who defined themselves as slow walkers. This aspect limits possible misclassification bias that, in case, may have led to slightly underestimate our results both concerning the co-occurrence of respiratory and walking impairments and the impact of such dysfunctions on survival. On the other hand, the large study population, the long follow-up and the use of data from objective assessments and registers may represent strengths of our work.

5. Conclusions

The co-occurrence of PEF and WS impairments increases along with passing age. In both clinical and research settings the combined assessment of such parameters may help in evaluating the vulnerability and prognosis of community-dwelling older adults.

Funding

The SNAC-K study was supported by the Ministry of Health and Social Affairs, Sweden; the Participating County Councils and Municipalities; and the Swedish Research Council (VR). In addition, study collaborators DR and AKW were supported by specific grants from VR (grant number 2017-06088, and 521-2014-21-96), and the Swedish Research Council for Health, Working Life and Welfare (FORTE, grant numbers 2017-01768, and 2016-07175). The sponsors had no role in the design, execution, interpretation, or writing of the

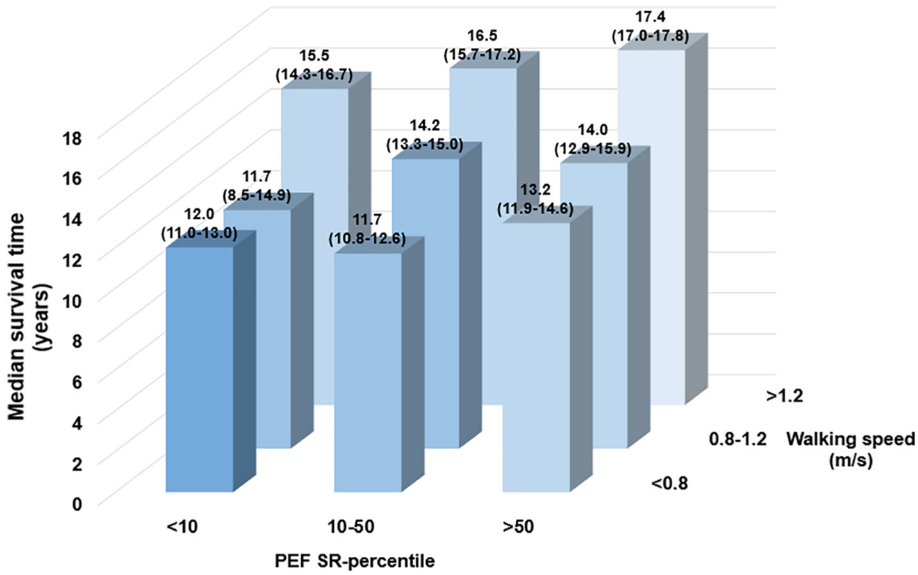

Fig. 2. Median adjusted survival time as a function of peak expiratory flow and walking speed values Model adjusted for age, sex, educational level, smoking habits, alcohol consumption, Mini-Mental State Examination, number of chronic diseases, cardiovascular diseases, and obstructive respiratory diseases. Covariates were centered on their average values. Survival time is counted since the baseline assessment. *Abbreviations*: PEF, peak expiratory flow; SR, standardized residual.

study.

CRediT authorship contribution statement

Caterina Trevisan: Conceptualization, Methodology, Investigation, Visualization, Formal analysis, Writing - original draft.**Debora Rizzuto:**Formal analysis, Writing - review & editing.**Giuseppe Sergi:**Writing - review & editing.**Stefania Maggi:**Writing - review & editing.**Anna-Karin Welmer:**Conceptualization, Methodology, Investigation, Visualization, Supervision, Writing - review & editing.**Davide Liborio Vetrano:**Conceptualization, Methodology, Investigation, Visualization, Supervision, Writing - review & editing.

Declaration of competing interest

None.

Acknowledgments

The authors thank all participants, interviewers, nurses, and physicians who took part in the SNAC-K study.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.exger.2020.110941.

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