Archives of Gerontology and Geriatrics 85 (2019) 103913

Contents lists available at ScienceDirect

Archives of Gerontology and Geriatrics

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

Relationship between peak expiratory flow and incidence of frailty, deaths and falls among nursing home residents: Results of the SENIOR cohort

Alexia Charles[a,*], Fanny Buckinx[a], Didier Cataldo[b], Xavier Rygaert[a], Bastien Gruslin[a], Jean-Yves Reginster[a,c], Olivier Bruyère[a,d]

[a] Department of Public Health, Epidemiology and Health Economics, University of Liège, WHO Collaborating Center for Public Health Aspects of Musculoskeletal Health and Ageing, Avenue Hippocrate 13, Liège, Belgium
[b] Department of Respiratory Diseases and Laboratory of Tumor Biology and Development, University of Liège and CHU Liege, Avenue de l'Hôpital 11, Liège, Belgium
[c] Chair for Biomarkers of Osteoporosis, Biochemistry Department, College of Science, King Saud University, Riyadh, Saudi Arabia
[d] Department of Rehabilitation and Sport Sciences, University of Liège, Allée des Sports 4, Liège, Belgium

ARTICLE INFO

Keywords:
Respiratory function
Frailty
Adverse outcomes
Institutionalization

ABSTRACT

Objective: To correlate peak expiratory flow (PEF) with the incidence of frailty, deaths and falls among nursing home residents.
Methods: This is a 1-year longitudinal analysis performed on the clinical data of the SENIOR cohort. PEF, measured by peak flow meter, was considered as "low" when the observed value was ≤80% of the theoretical value. Physical capacity was evaluated using Short Physical Performance Battery, balance and gait using Tinetti test and muscle strength using a dynamometer. The incidence of frailty was defined as the transition from a "robust" or "prefrail" status to a "frail" status following Fried's criteria. Deaths and falls were also collected.
Results: Among 646 subjects included at baseline (83.2 ± 9 years and 72.1% women), 297 (45.7%) displayed a low PEF. In this subgroup, physical capacity (p-values from 0.01 to < 0.001), muscle strength (p < 0.001), balance and gait score (p < 0.001) were significantly lower compared to subjects displaying normal PEF. Subjects who became frail after one year displayed a lower % of the theoretical PEF value compared to those that did not (88.52 ± 45.06 vs 102.78 ± 50.29, respectively, p = 0.03). After adjustment for potential confounding variables (calf circumference, Tinetti test, SPPB test and handgrip strength), PEF was no longer associated with the occurrence of frailty. There was no association between PEF and mortality and falls.
Conclusion: In a nursing home setting, PEF is not an independent factor associated with the incidence of frailty, deaths and falls.

1. Introduction

Frailty is a major public health issue in older people (Buckinx, Rolland et al., 2015). This geriatric syndrome is defined as a state of increased vulnerability to stressors accompanied by a loss of reserves of different physiological systems (Fried et al., 2001; Rockwood, 2016). Screening and diagnosing frailty in the older population is important to prevent its related negative consequences, such as mortality, falls and loss of autonomy (Leng, Chen, & Mao, 2014). Practical indicators are then used to identify frail people or subjects at risk of becoming frail. Because frailty is associated with a decrease in muscle strength and physical capacity (Tabue-Teguo et al., 2018), their assessment seems to be highly relevant in clinical practice (Furtado, Patrício, Loureiro, Teixeira, & Ferreira, 2017; Xie et al., 2017). For some muscle and physical capacity assessments, different tools are needed, limiting their use in particular settings, such as nursing homes.

Lung function and respiratory muscle strength are known to decrease with age and are associated with reduced physical capacity, occurrence of death and health status (Vaz Fragoso, Gahbauer, Van Ness, Concato, & Gill, 2008) and consequently could be interesting markers of frailty and its consequences (Marengoni et al., 2018). The gold standard technique to evaluate lung function is spirometry (Miller et al., 2005), but it is not applicable in the specific setting of nursing homes since it necessitates complex training and specific equipment

* Corresponding author at: University of Liège, Department of Public Health, Epidemiology and Health Economics, WHO collaborating center for Public Health Aspects of Musculoskeletal Health and Ageing, CHU-Sart-Tilman, B23, Quartier Hôpital, Avenue Hippocrate, 13, Liège, Belgium.
E-mail addresses: alexia.charles@uliege.be (A. Charles), fanny.buckinx@uliege.be (F. Buckinx), didier.cataldo@uliege.be (D. Cataldo), xavier.rygaert@hotmail.com (X. Rygaert), bastien.gruslin@student.uliege.be (B. Gruslin), jyreginster@uliege.be (J.-Y. Reginster), olivier.bruyere@uliege.be (O. Bruyère).

https://doi.org/10.1016/j.archger.2019.103913
Received 7 January 2019; Received in revised form 1 July 2019; Accepted 11 July 2019
Available online 19 July 2019
0167-4943/

(Bellia et al., 2000). Peak expiratory flow (PEF), defined as the maximum instantaneous flow achieved during a forced expiration maneuver from maximal lung inflation (Quanjer, Lebowitz, Gregg, Miller, & Pedersen, 1997), is very easy to obtain from non-trained individuals and can be a practical lung function measurement to obtain from older people in large studies.

Vaz Fragoso et al. found that PEF was a risk assessment tool for frailty, especially for exhaustion and inactivity (Vaz Fragoso, Gahbauer, Van Hess, Gill, & Yu, 2009). Other studies established cross-sectional and longitudinal associations between respiratory function and frailty in community-dwelling older people using spirometry parameters such as FEV_1 (forced expiratory volume) but not taking into account the PEF (Pegorari, Ruas, & Patrizzi, 2013; Vaz Fragoso, Enright, McAvay, Van Ness, & Gill, 2012; Weiss, Hoenig, Varadhan, Simonsick, & Fried, 2010). Low PEF in older people can predict health outcomes such as mortality and cognitive decline (Albert et al., 1995). Little is known about the relationship between PEF and falls (Gale, Cooper, Westbury, & Dennison, 2016). However, no studies were performed in nursing homes.

Moreover, studies of peak flow meter reproducibility in older people or nursing home populations are lacking in the literature. There are also no reference values for very old populations in nursing homes. Studies of the specific population of nursing home residents are scarce, and data are lacking about PEF. The objectives of the present study were to evaluate the reproducibility of the PEF, to calculate normative values of PEF and to investigate, for the very first time, the relationship between low PEF and the incidence of frailty, deaths and falls among nursing home residents.

2. Material and methods

2.1. Population and study design

The present study was performed using the first year of follow-up of the SENIOR (Sample of Elderly Nursing home Individuals: an Observational Research) cohort. The SENIOR cohort is a longitudinal ongoing study conducted in 28 nursing homes in the Liege area (Belgium). This cohort of 662 subjects started in 2013, and all participants were invited every year to participate in the follow-up examination. Anamnestic, sociodemographic and clinical data were collected through individual face-to-face interviews and completed with data collected from medical records. All of the data collected, mainly including the clinical characteristics, physical tests, functional status, quality of life questionnaires and frailty assessments performed in this cohort, have been described in detail previously (Buckinx et al., 2016). The inclusion criteria for the population were being able to provide informed consent and to answer questions; living in a nursing home in the Liege area; and being able to walk with or without a walking aid. The study protocol was approved by the Ethics Committee of the University Teaching Hospital of Liège under the number 2013/178.

2.2. Data collection

2.2.1. Clinical characteristics

Age, sex, and body mass index (BMI) were collected at baseline. Calf circumference and height were measured in centimeters using a measuring tape. We used the Short Physical Performance Battery (SPPB) (Gawel et al., 2012) and Timed up and Go test (TUG) (Podsiadlo & Richardson, 1991) to evaluate physical capacity. The SPPB test is composed of 3 subtests: balance, gait speed and chair stand tests. The TUG test consists of measuring the time that participants take to stand up from their chair, to walk 3 m and then to go back and sit down in their chair. The risk of falls was estimated by the Tinetti test (1986), which is composed of 2 parts: evaluation of balance and walking. Muscle strength parameters were also assessed. Handgrip strength was measured in kilograms using a Jamar grip strength dynamometer (Seahan Corporation, MSD Europe Bvba, Belgium) according to the protocol defined by Roberts et al. (2011). Three measurements were performed with each hand, and the maximum value was recorded. The microFET2 handheld Dynamometer (Hoggan Industries, Inc., West Jordan, UT, USA) allowed us to evaluate the maximal muscle isometric strength of 8 muscle groups (i.e., knee extensors and flexors, hip abductors and extensors, ankle flexors and extensors, elbow flexors and extensors) according to the standardized protocol established by Buckinx, Croisier et al. (2015). Subjects had to contract as much as possible each muscle group 3 consecutive times. The best performance was used for the analysis. Frailty status of the participants was evaluated using the Fried criteria (2001). These criteria include five components: (1) unintentional weight loss of $\geq$4.5 kg or more than 5 percent of body mass in the last year (collected from medical records); (2) Low grip strength (evaluated using a Jamar dynamometer; the results take into account sex and BMI); (3) low energy (based on two questions from the Center for Epidemiological Studies Depression (CES-D) scale; when participants replied: “always or most of the time” to at least one of the two questions, the criterion was met); (4) Slowed walking speed (walking time over a distance of 4.5 m; the results take into account sex and height); and (5) low physical activity (we used the modified “Minnesota Leisure Time Activity” questionnaire to calculate energy expenditure weekly; the results take into account sex). Subjects were classified as nonfrail or robust if they fulfilled none of the criteria, subjects who fulfilled 1 or 2 criteria were considered prefrail, and subjects with a score of 3 or more were categorized as frail.

2.2.2. Peak expiratory flow (PEF)

At baseline, we used a Mini-Wright meter (Clement Clarke International Ltd, Harlow, United Kingdom) to measure peak expiratory flow according to a standardized protocol developed by Vaz Fragoso et al. (2009). In the sitting position, subjects were asked to blow with maximum effort 3 times into the peak flow meter with 30 s for recovery. The maximum PEF value from the 3 trials was used for analyses.

Before beginning this study, a preliminary study was carried out to check the intraindividual reproducibility of the device by evaluating the peak expiratory flow in the nursing home population. The peak flow meter used was the Mini-Wright meter. The inclusion criteria for participants were the same as those for the SENIOR cohort study. Participants performed 2 test sessions one week apart. The maximum PEF and the average PEF achieved in the 3 trials of the 2 sessions were recorded.

2.2.3. Outcomes

The longitudinal outcomes included the incidence of frailty, the occurrence of falls and all-cause mortality. The development of frailty was assessed after one year of follow-up. The incidence of frailty was considered when subjects changed from prefrail or robust to frail. Liu et al. classified it into four categories in their study: “worsening”, “remaining nonfrail and prefrail”, “improvement” and “remaining frail” (Liu et al., 2018). To better highlight the worsening transition, we reduced the results to 2 categories: “becoming frail” (i.e., worsening) and “not becoming frail” (i.e., remaining nonfrail and prefrail, improvement and remaining frail). Data on the occurrence of falls or deaths were collected over a one-year follow-up period from medical records.

2.3. Statistical analyses

2.3.1. Theoretical values of peak expiratory flow

First, a regression equation to predict theoretical PEF was developed using subjects with a "normal" respiratory function in our cohort. According to recommendations from the Working Party of the European Respiratory Society, PEF is usually compared with reference values in a normal population with the same anthropometric characteristics Quanjer et al. (1997). The regression model was therefore performed by including only participants who were nonsmokers, who had no problems or history of breathing issues and who were not undergoing respiratory therapy (Gregg, Nunn, & Nunn, 1989; Roberts & Mapel, 2012). PEF is dependent on age, sex and height (Miller et al., 2005). These different variables were therefore included in the multiple regression model. The coefficients obtained in this model were used to create an equation which allowed the calculation of an individual theoretical PEF value for each subject. Then, the percentage of the theoretical PEF value was calculated for each subject by dividing the observed PEF value by the individual theoretical PEF value. PEF has usually been reported as the percentage predicted and a fixed cutoff point has been set at 80% of the theoretical value of the lower limit of normal (Quanjer et al., 1997). If scores were lower than 80% of the theoretical value, they were considered low PEF values.

2.3.2. Relationship between peak expiratory flow and incidence of frailty, deaths and falls

The baseline characteristics of the population used in this study were summarized using the mean (± standard deviation) for normally distributed variables and using the median (P25-P75) for variables not normally distributed. Qualitative variables were reported as counts (percentages). A cross-sectional analysis was carried out on the data at baseline. We compared at baseline the characteristics of subjects with low PEF and those with "normal" PEF using the chi-square test for qualitative variables and Student's *t*-test for quantitative variables. The Mann-Whitney nonparametric test was used when quantitative variables had a nonnormal distribution.

Finally, we performed a longitudinal analysis on the first year of follow-up. Logistic regressions were used to evaluate the longitudinal association between the percentage of theoretical PEF and the incidence of frailty, as well as the association between the percentage of theoretical PEF and the incidence of falls and deaths. Variables considered for adjustment were those showing a statistically significant different distribution in the univariate analyses. Data were analyzed using the JMP software package (SAS Institute, Cary, NC). The analyses were performed on the maximum available data, and statistical significance was considered a p value < 0.05.

2.3.3. Reproducibility of peak flow meter

Concerning the reproducibility of the Mini-Wright meter, intraclass coefficients (ICC) were performed using SPSS software (SPSS Inc., Chicago, IL, USA). The closer the ICC value is to 1, the better the reproducibility. ICC values less than 0.5 are considered poor reproducibility, values between 0.5 and 0.75 indicate moderate reproducibility, values between 0.75 and 0.9 indicate good reproducibility, and values higher than 0.90 indicate excellent reproducibility (Portney & Watkins, 2002).

3. Results

3.1. Study population

At baseline, complete data for PEF were available for 646 subjects of the SENIOR cohort (Fig. 1). There were 662 subjects at baseline in the SENIOR cohort, but 16 subjects had missing data for PEF assessment. Longitudinal analyses could be performed on 332 subjects who had both frailty assessments after 1 year of follow-up and PEF assessment at baseline. Mortality and refusals to participate reduced our sample after 1 year of follow-up. The analyses of 1-year mortality and falls were carried out on 568 and 549 subjects, respectively.

Among the 646 subjects included at baseline, the mean age was 83.2 ± 9 years, and 72.1% (466) were women.

3.2. Reproducibility of peak flow meter

In our preliminary study to evaluate Mini-Wright meter reproducibility, a total of 38 nursing home residents participated. They were aged 86.45 ± 7.23 years, and 29 (76%) of them were women. The intraclass coefficients (ICC) were high (ICC = 0.88, IC95% 0.74-0.94) when the maximum values were taken and very high (ICC = 0.94, IC95% 0.84-0.97) for the average values, which means that the reproducibility was very good.

3.3. Theoretical values of peak expiratory flow

Among these 646 subjects, 409 (63.31%) had no respiratory issues and were included in the regression model to develop an equation to calculate the individual theoretical value of PEF. These 409 subjects represented the normal respiratory function group whose average PEF for women was 129.51 ± 61.98 L/min and for men was 200.75 ± 99.29 L/min. Parameter estimates of the predicted PEF regression equation are shown in Table 1. All parameters were significantly associated with PEF values (p-values ranged from 0.02 to < 0.001). The coefficients obtained were used to create a predictive regression equation. The predictive equation obtained was "Theoretical PEF = 86.23 -1.09) x age - 48.38 x sex + 1.19 x height".

3.4. Comparison of characteristics of subjects with low peak expiratory flow and those with "normal" peak expiratory flow

When the predictive equation was applied to all subjects in our population, we found that 297 subjects (46%) had PEF scores less than 80% of the theoretical values. Table 2 shows the baseline clinical characteristics of the subjects with normal PEF and those with low PEF according to the percentage cutoff of 80%. The analysis showed that there were no differences in age, sex and BMI characteristics between subjects with low PEF and those with "normal" PEF, which was expected since these variables were taken into account in the predictive theoretical equation. Subjects with reduced PEF tended to have a smaller calf circumference (p = 0.03), lower physical capacity measured by the SPPB test and the TUG test (p < 0.001 and p = 0.01, respectively), a higher risk of falls (p < 0.001) and lower muscular capacity for each muscle group tested (p from 0.01 to < 0.001) compared to subjects with normal PEF. Those with reduced PEF were also frailer than those with normal PEF (p < 0.001).

3.5. Incidence of frailty

As shown in Table 3, there was a significant longitudinal association between the baseline percentage of theoretical PEF and the development of frailty after 1 year of follow-up (OR = 2.16, 95% CI 1.20–3.55). Participants with lower percentage of theoretical PEF were at higher risk of becoming frail compared to those who did not become frail after 1 year of follow-up. However, in the adjusted model, the percentage of the theoretical PEF was no longer significantly associated with the incidence of frailty (p = 0.10), while the physical performance evaluated with the SPPB test was significantly associated with the incidence of frailty. The higher the score on the SPPB test is, the lower the risk of becoming frail. In this case, the percentage of the theoretical PEF did not add any value to the SPPB test.

3.6. Occurrence of falls and mortality

We found no association between the percentage of theoretical PEF and the occurrence of mortality (p = 0.05) or falls (p = 0.28) after 1 year of follow-up. In total, 90 subjects died and 213 subjects have fallen at least one time during the year of follow-up. The results showed that 52% (N = 47) of deceased subjects had a PEF value lower than 80% of the theoretical PEF value, while 42% (N = 201) of alive subjects had a PEF vale below this threshold. Moreover, 41% (N = 88) of subjects who have fallen and 45% (N = 150) of subjects who have not fallen, had a PEF value lower than 80% of the theoretical value. After adjustments on calf circumference, Tinetti test, SPPB test and handgrip

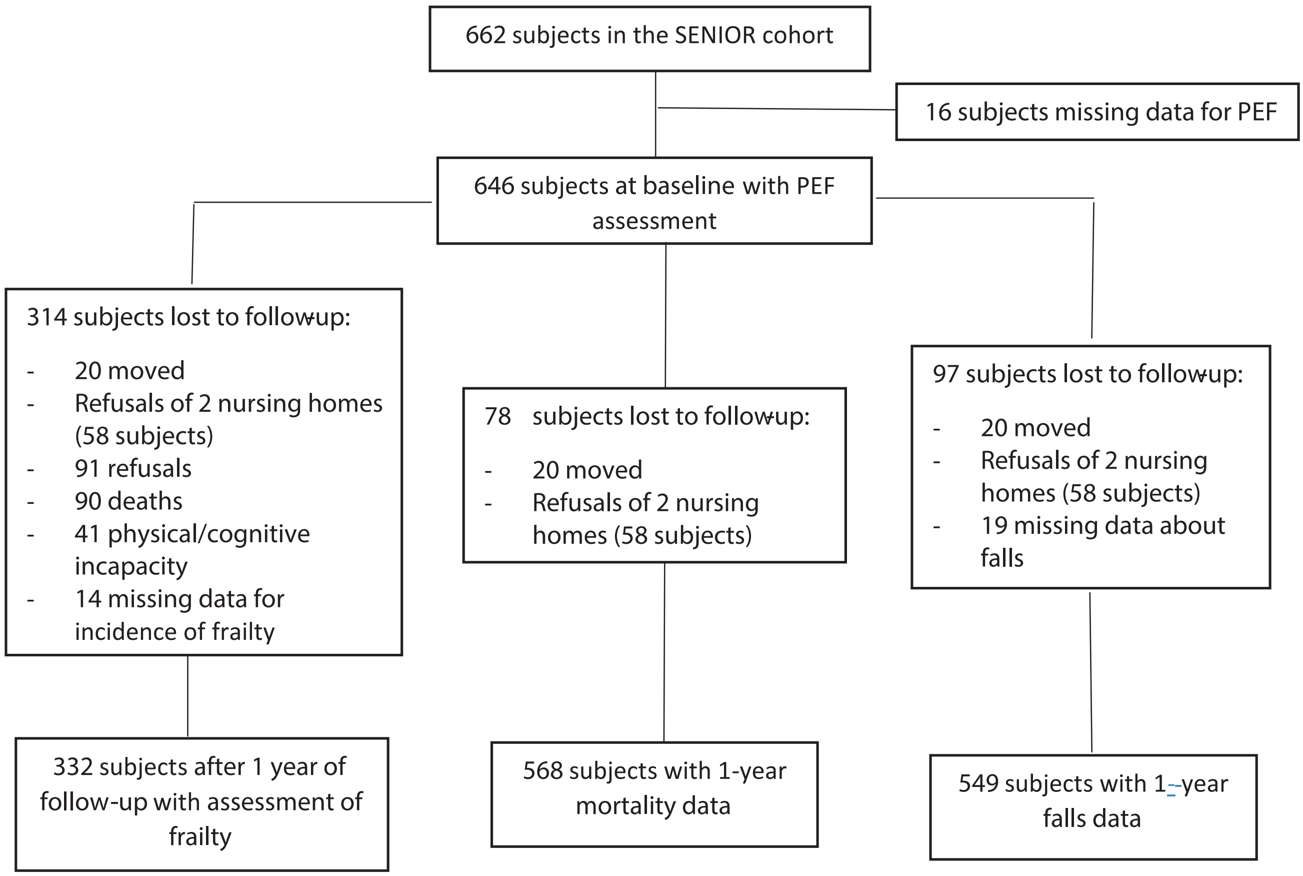

Fig. 1. Flow chart of the study.

Table 1
Multiple regression model for peak expiratory flow in a subgroup of "normal" respiratory function participants.

	Coefficient (β)	Standard Error (SE)	p value
Intercept	86.23	101.10	0.39
Age	−1.09	0.46	0.02
Sex	−48.38	10.72	< 0.001
Height	1.19	0.50	0.02

strength, the association between percentage of theoretical PEF and the occurrence of mortality (p = 0.36) and falls (p = 0.39) stayed non-significant.

4. Discussion

The main findings of this study suggest that the percentage of theoretical PEF measured by a peak flow meter is not associated with the incidence of frailty, mortality or falls after 1 year of follow-up after adjustment for confounding variables. These results indicate that this measurement adds no more information as compared to the SPPB test. In the meantime, PEF is a very easy measurement with no need for extensive training. Peak flow meter is a portable device that is non-invasive, easy-to-use and inexpensive (Bellia et al., 2003). It could perhaps be an interesting tool to predict short-term frailty incidence if the SPPB test are not feasible for practical reasons.

With the normal respiratory reference population developed for our SENIOR cohort, we established a regression equation and calculated the theoretical value for each subject according to published guidelines Quanjer et al. (1997), Vaz Fragoso et al. (2009). To our knowledge, this is the first study to perform this type of analysis in a nursing home setting. We included the same variables, namely, age, sex and height, as in most studies establishing a predictive regression equation for PEF in other populations. The only difference was that we did not separate men from women in our regression model because of the low percentage of men in our cohort (Nunn & Gregg, 1989; Smolej Narančić et al., 2009).

Studies assessing the relationship between respiratory function and frailty or its related negative consequences are scarce. The few studies focusing on these relationships use spirometry most of the time and focus on parameters such as MEP (maximum expiratory pressure), FEV_1 (forced expiratory volume), and FVC (forced vital capacity). In addition, these studies are usually conducted with older subjects living in the community (Lahousse et al., 2016; Pegorari et al., 2013; Vaz Fragoso et al., 2012). A Belgian cohort study of 501 community-dwelling subjects (aged 80 years old) reports that FEV_1 predicts mortality over 5 years of follow-up; it also predicts 3-year hospitalizations, and 2-year physical and cognitive decline (Hegendörfer et al., 2017).

In our cohort, the PEF at baseline was predictive of the incidence of frailty after one year of follow-up in univariate analyses. However, after adjusting for confounding variables, PEF was no longer significantly associated with the incidence of frailty, and only the SPPB test remained significant. Therefore, these results show that PEF does not add any value to SPPB test. According to longitudinal analyses by Vaz Fragoso et al. (2012), frail elderly people are at higher risk of developing respiratory dysfunction, and conversely, subjects with low respiratory capacity are at higher risk of developing frailty. These results probably differ from our study because of the pulmonary parameters used and the different populations. In their study, PEF measurement was not part of the lung parameters used. Moreover, their analyses were not adjusted for function on physical tests but only for demographic parameters such as age, sex, height and BMI.

Our results also show that the percentage of the theoretical value of PEF is not predictive of the occurrence of falls or deaths. These results

Table 2
Baseline clinical characteristics of subjects with low PEF and subjects with normal PEF (N = 646).

Baseline characteristics	≤80% of theoretical PEF Mean ± SD Or median (P25-P75)	≤80% of theoretical PEF No. (%)	> 80% of theoretical PEF Mean ± SD Or median (P25-P75)	> 80% of theoretical PEF No. (%)	p value
Age (years)	83.12 ± 9.14		83.28 ± 8.85		0.83
Sex (women)		213 (45.7)		253 (54.3)	0.83
BMI (kg/m^2)	25.86 ± 5.55		26.14 ± 5.51		0.52
Calf circumference (cm)	32.78 ± 4.41		33.52 ± 4.06		0.03
SPPB test (/12)	4.92 ± 3.18		6.17 ± 3.14		< 0.001
Tinetti test (/28)	21.31 ± 6.80		23.35 ± 5.51		< 0.001
TUG test (sec)	22.27 (15.49-35.22)		18.08 (13.03-28.61)		0.01
Max handgrip strength (kg)	16.29 ± 9.16		20.64 ± 11.99		< 0.001
Knee extensor strength (N)	91.61 ± 11.61		116.19 ± 6129		< 0.001
Knee flexor strength (N)	79.52 ± 35.11		96.57 ± 41.62		< 0.001
Ankle flexor strength (N)	64.86 ± 28.40		83.40 ± 37.51		< 0.001
Ankle extensor strength (N)	78.91 ± 35.75		98.58 ± 40.93		< 0.001
Hip abductor strength (N)	71.25 ± 34.02		84.33 ± 35.81		< 0.001
Hip extensor strength (N)	75.67 ± 42.12		91.44 ± 42.74		< 0.001
Elbow flexor strength (N)	82.86 ± 36.33		98.89 ± 41.48		< 0.001
Elbow extensor strength (N)	59.20 ± 27.14		69.25 ± 29.05		< 0.001
Frailty score (Fried)	1.95 ± 1.11		1.50 ± 1.04		< 0.001
Frail subjects		91 (58.3)		65 (41.7)	< 0.001
Prefrail subjects		172 (44.2)		217 (55.8)	0.40
Robust subjects		25 (28.4)		63 (71.6)	0.001

PEF = peak expiratory flow, D = standard deviation, N = newton, cm = centimeter, sec = seconds.

are in agreement with those obtained in another study carried out in the same cohort with the raw values of PEF (Buckinx, Croisier, & Reginster, 2018). However, other studies show that for older people living in the community, PEF is associated with hospitalization, loss of autonomy and mortality (Hansen, Vestbo, Phanareth, Kok-Jensen, & Dirksen, 2001; Roberts & Mapel, 2012; Vaz Fragoso et al., 2008). Another recent study conducted in 748 middle age and older participants (aged between 53–85 years) living in the community found that handgrip strength and peak expiratory flow were significant predictors of 4-year mortality using a Cox regression model adjusted for Framingham risk score (cardiovascular risk), walking speed, and high-sensitivity C-reactive protein (CRP) (Lee, Peng, Chiou, & Chen, 2017). The longer duration of these previous studies and the younger populations living in the community consequently lead to different results than ours.

Other studies focalized their analyses on "sarcopenia" (Bone, Hepgul, Kon, & Maddocks, 2017; Kera et al., 2018), which is a geriatric syndrome like frailty (Cruz-Jentofs et al., 2019). Sarcopenia is linked to physical function impairment (as frailty) and more specifically to skeletal muscle mass disorder. The study of Park et al. showed that decreased skeletal muscle mass was significantly associated with PEF (Park, Yi, Do, Lee, & Yoon, 2018). Moreover, PEF has also been suggested as one of the valid indicators of sarcopenia (Kera et al., 2018). A recent study, realized by Kera et al., has established a PEF cut-off for sarcopenia, which allowed them to introduce the concept of "respiratory sarcopenia" (Kera et al., 2018). Although this study is very interesting, the comparison with our study is difficult and might not be pertinent. First, the design, the population and the outcomes are different (cross-sectional versus longitudinal, community-dwelling population versus nursing home residents, sarcopenia versus frailty). Then, they established a general cut-off for women and men based on the 1 SD below the mean, while our study is based on a cut-off of 80% of the individual theoretical value (calculated according to age, sex and height of subjects). Moreover, they used an electronic spirometer, while a peak flow meter was used in our study. Finally, we notice that the PEF values obtained in our study are globally lower than those obtained in the study of Kera et al., which could be probably explained by the various differences presented previously.

Our study has several main strengths: the large sample of older nursing home residents, the longitudinal data and the inclusion of parameters of physical and muscular capacity as confounding variables. On the other hand, there are limitations to this study, including the exclusion criteria of the SENIOR study (being mobile, oriented and consenting), which probably leads to the exclusion of the frailest residents and reduces the external validity of the sample. Another limitation may be that, because the initial study was not designed for this present analysis, no sample size calculation was performed. Moreover, we have used Fried's criteria to evaluate frailty, but a multitude of frailty definitions exist, including different dimensions. The results

Table 3
Longitudinal association between baseline PEF and incidence of frailty after 1 year (N = 332).

	Participants who became frail (N = 67) Mean ± SD	Participants who did not become frail (N = 265) Mean ± SD	Incidence of frailty Odds Ratio (95% CI): Unadjusted OR (95% CI)	p value	Adjusted[a] OR (95% CI)	p value
% theoretical PEF	88.52 ± 45.06	102.78 ± 50.29	2.06 (1.20-3.55)	0.03	0.99 (0.98-1.00)	0.10
Calf circumference	–	–	–	–	0.96 (0.90-1.03)	0.28
Tinetti test	–	–	–	–	1.03 (0.96-1.11)	0.41
SPPB test	–	–	–	–	0.86 (0.74-0.98)	0.04
Handgrip strength	–	–	–	–	0.99 (0.96-1.02)	0.71

SD = standard deviation, CI = confidence interval, PEF = peak expiratory flow.
[a] Adjusted on percentage of theoretical PEF, calf circumference, Tinetti test, SPPB test, maximum handgrip strength.

could thus change according to the chosen definition. However, Fried's criteria appear to be one of the most robust assessment tools for use by researchers and clinicians (Dent, Kowal, & Hoogendijk, 2016). The dynamic nature of the nursing home population (including the high mortality rate) has the effect of reducing the size of our sample in our longitudinal analyses, and the power of our longitudinal analyses is reduced. The peak flow meter appears to be less accurate than spirometry because of its possible variability and because it is effort-dependent (Hegewald et al., 2007; Quanjer et al., 1997). We must remain cautious about the threshold value of 80%, which is sometimes moot because this limit could vary between 60 and 85 according to the Belgian Society of Pneumology (Société Belge de Pneumologie, 2001). Nevertheless, a peak flow meter has the advantage of being an easy tool to transport in a nursing home.

5. Conclusion

In conclusion, in a sample of nursing home residents, the percentage of the theoretical PEF value, calculated as a function of a predictive equation, is not associated with the incidence of frailty, deaths or falls. However, PEF could be an interesting and practical alternative to collect in the absence of physical tests such as the SPPB test.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Albert, M. S., Jones, K., Savage, C. R., Berkman, L., Seeman, T., Blazer, D., et al. (1995). Predictors of cognitive change in older persons: MacArthur studies of successful aging. *Psychology and Aging, 10*(4), 578–589.

Bellia, V., Pistelli, R., Catalano, F., Antonelli-Incalzi, R., Grassi, V., Melillo, G., et al. (2000). Quality control of spirometry in the elderly. *American Journal of Respiratory and Critical Care Medicine, 161*, 1094–1100. https://doi.org/10.1164/ajrccm.161.4.9810093.

Bellia, V., Pistelli, F., Giannini, D., Scichilone, N., Catalano, F., Spatafora, M., et al. (2003). Questionnaires, spirometry and PEF monitoring in epidemiological studies on elderly respiratory patients. *The European Respiratory Journal, 21*(Supplement 40), 21S–27s. https://doi.org/10.1183/09031936.03.00402303.

Bone, A. E., Hepgul, N., Kon, S., & Maddocks, M. (2017). Sarcopenia and frailty in chronic respiratory disease: Lessons from gerontology. *Chronic Respiratory Disease, 14*(1), 85–99. https://doi.org/10.1177/1479972316679664.

Buckinx, F., Rolland, Y., Reginster, J. Y., Ricour, C., Petermans, J., & Bruyère, O. (2015). Burden of frailty in the elderly population: Perspectives for a public health challenge. *Archives of Public Health, 73*(1), 1–7. https://doi.org/10.1186/s13690-015-0068-x.

Buckinx, F., Croisier, J. L., Reginster, J. Y., Petermans, J., Goffart, E., & Bruyere, O. (2015). Relationship between isometric strength of six lower limb muscle groups and motor skills among nursing home residents. *The Journal of Frailty & Aging, 4*(4), 184–187. https://doi.org/10.14283/jfa.2015.70.

Buckinx, F., Reginster, J. Y., Petermans, J., Croisier, J. L., Beaudart, C., Brunois, T., et al. (2016). Relationship between frailty, physical performance and quality of life among nursing home residents: The SENIOR cohort. *Aging Clinical and Experimental Research, 28*(6), 1149–1157. https://doi.org/10.1007/s40520-016-0616-4.

Buckinx, F., Croisier, J. L., Reginster, J. Y., Lenaerts, C., Brunois, T., Rygaert, X., et al. (2018). Prediction of the incidence of falls and deaths among elderly nursing home residents: The SENIOR study. *Journal of the American Medical Directors Association, 19*(1), 18–24. https://doi.org/10.1016/j.jamda.2017.06.014.

Cruz-Jentofs, A. J., Bahat, G., Bauer, J., Boirie, Y., Bruyère, O., Cederholm, T., et al. (2019). Sarcopenia : Revised European consensus on definition and diagnosis. *Age and Ageing,* (September 2018), 16–31. https://doi.org/10.1093/ageing/afy169.

Dent, E., Kowal, P., & Hoogendijk, E. O. (2016). Frailty measurement in research and clinical practice: A review. *European Journal of Internal Medicine, 31*, 3–10. https://doi.org/10.1016/j.ejim.2016.03.007.

Fried, L. P., Tangen, C. M., Walston, J., Newman, A. B., Hirsch, C., Gottdiener, J., et al. (2001). Frailty in older adults: Evidence for a phenotype. *Journal of Gerontology, 56*(3), 146–157.

Furtado, G., Patrício, M., Loureiro, M., Teixeira, A. M., & Ferreira, J. P. (2017). Physical fitness and frailty syndrome in institutionalized older women. *Perceptual and Motor Skills, 124*(4), 754–776. https://doi.org/10.1177/0031512517709915.

Gale, C. R. G., Cooper, C. C., Westbury, L. D., & Dennison, E. (2016). Prevalence and risk factors for falls in older men and women: The English Longitudinal Study of Ageing. *Age and Ageing,* 1–6. https://doi.org/10.1093/ageing/afw129.

Gawel, J., Vengrow, D., Collins, J., Brown, S., Buchanan, A., & Cook, C. (2012). The short physical performance battery as a predictor for long term disability or institutionalization in the community dwelling population aged 65 years old or older. *The Physical Therapy Review, 17*(1), 37–44. https://doi.org/10.1179/1743288X11Y.0000000050.

Gregg, I., Nunn, A. J., & Nunn, M. (1989). Peak expiratory flow in symptomless elderly smokers and ex-smokers. *British Medical Journal, 298*(April), 1071–1072.

Hansen, E. F., Vestbo, J., Phanareth, K., Kok-Jensen, A., & Dirksen, A. (2001). Peak flow as predictor of overall mortality in asthma and chronic obstructive pulmonary disease. *American Journal of Respiratory and Critical Care Medicine, 163*(3 Pt 1), 690–693. https://doi.org/10.1164/ajrccm.163.3.2006120.

Hegendörfer, E., Vaes, B., Andreeva, E., Matheï, C., Van Pottelbergh, G., & Degryse, J. M. (2017). Predictive value of different expressions of forced expiratory volume in 1 second (FEV1) for adverse outcomes in a cohort of adults aged 80 and older. *Journal of the American Medical Directors Association, 18*(2), 123–130. https://doi.org/10.1016/j.jamda.2016.08.012.

Hegewald, M. J., Lefor, M. J., Jensen, R. L., Crapo, R. O., Kritchevsky, S. B., Haggerty, C. L., et al. (2007). Peak expiratory flow is not a quality indicator for spirometry. *Chest, 131*(5), 1494–1499. https://doi.org/10.1378/chest.06-2707.

Kera, T., Kawai, H., Hirano, H., Kojima, M., Fujiwara, Y., Ihara, K., et al. (2018). Relationships among peak expiratory flow rate, body composition, physical function, and sarcopenia in community-dwelling older adults. *Aging Clinical and Experimental Research, 30*(4), 331–340. https://doi.org/10.1007/s40520-017-0777-9.

Lahousse, L., Ziere, G., Verlinden, V. J. A., Zillikens, M. C., Uitterlinden, A. G., Rivadeneira, F., et al. (2016). Risk of frailty in elderly with COPD: A population-based study. *Journals of Gerontology Series A: Biological Sciences and Medical Sciences, 71*(5), 689–695. https://doi.org/10.1093/gerona/glv154.

Lee, W.-J., Peng, L.-N., Chiou, S.-T., & Chen, L.-K. (2017). Physical health indicators improve prediction of cardiovascular and all-cause mortality among middle-aged and older people: A national population-based study. *Scientific Reports, 7*, 40427. https://doi.org/10.1038/srep40427.

Leng, S., Chen, X., & Mao, G. (2014). Frailty syndrome: An overview. *Clinical Interventions in Aging, 9*, 433–441. https://doi.org/10.2147/CIA.S45300.

Liu, Z., Wei, Y., Wei, L., Jiang, X., Wang, X., Shi, Y., et al. (2018). Frailty transitions and types of death in Chinese older adults: A population-based cohort study. *Clinical Interventions in Aging, 13*, 947–956. https://doi.org/10.2147/CIA.S157089.

Marengoni, A., Vetrano, D. L., Manes-Gravina, E., Bernabei, R., Onder, G., & Palmer, K. (2018). The relationship between chronic obstructive pulmonary disease and frailty: A systematic review and meta-analysis of observational studies. *Chest, 154*(1), 21–40. https://doi.org/10.1016/j.chest.2018.02.014.

Miller, M. R., Hankinson, J., Brusasco, V., Burgos, F., Casaburi, R., Coates, A., et al. (2005). Standardisation of spirometry. *The European Respiratory Journal, 26*(2), 319–338. https://doi.org/10.1183/09031936.05.00034805.

Nunn, A. J., & Gregg, I. (1989). New regression equations for predicting peak expiratory flow in adults. *BMJ, 298*(6680), 1068–1070. https://doi.org/10.1136/bmj.298.6680.1068.

Park, C., Yi, Y., Do, J. G., Lee, Y., & Yoon, K. J. (2018). Relationship between skeletal muscle mass and lung function in Korean adults without clinically apparent lung disease. *Medicine, 97*(37), e12281.

Pegorari, M. S., Ruas, G., & Patrizzi, L. J. (2013). Relationship between frailty and respiratory function in the community-dwelling elderly. *Brazilian Journal of Physical Therapy, 17*(1), 9–16. https://doi.org/10.1590/S1413-35552012005000065.

Podsiadlo, D., & Richardson, S. (1991). The timed "up & go": A test of basic functional mobility for frail elderly persons. *Journal of the American Geriatrics Society, 39*(2), 142–148.

Portney, L., & Watkins, M. (2002). In P. Hall (Ed.). *Foundations of clinical research: Applications to practice*(3rd edition). Upper Saddle River.

Quanjer, P. H., Lebowitz, M. D., Gregg, I., Miller, M. R., & Pedersen, O. F. (1997). Peak expiratory flow: Conclusions and recommendations of a Working Party of the European Respiratory Society. *The European Respiratory Journal, 10*(24), 2S–8S.

Roberts, M. H., & Mapel, D. W. (2012). Limited lung function: Impact of reduced peak expiratory flow on health status, health-care utilization, and expected survival in older adults. *American Journal of Epidemiology, 176*(2), 127–134. https://doi.org/10.1093/aje/kwr503.

Roberts, H. C., Denison, H. J., Martin, H. J., Patel, H. P., Syddall, H., Cooper, C., et al. (2011). A review of the measurement of grip strength in clinical and epidemiological studies: Towards a standardised approach. *Age and Ageing, 40*(4), 423–429. https://doi.org/10.1093/ageing/afr051.

Rockwood, K. (2016). Conceptual models of frailty: Accumulation of deficits. *The Canadian Journal of Cardiology, 32*(9), 1046–1050. https://doi.org/10.1016/j.cjca.2016.03.020.

Smolej Narančić, N., Pavlović, M., Žuškin, E., Milicic, J., Skaric-Juric, T., Barbalic, M., et al. (2009). New reference equations for forced spirometry in elderly persons. *Respiratory Medicine, 103*(4), 621–628. https://doi.org/10.1016/j.rmed.2008.10.013.

Société Belge de Pneumologie (2001). *Normes de qualite, indications et standardisation des épreuves fonctionnelles respiratoires: Document de consensus.* Published (Accessed 12 December 2018) https://www.bvp-sbp.org/index.php/en/guidelines.

Tabue-Teguo, M., Dartigues, J. F., Simo, N., Kuate-Tegueu, C., Vellas, B., & Cesari, M. (2018). Physical status and frailty index in nursing home residents: Results from the INCUR study. *Archives of Gerontology and Geriatrics, 74*(October 2017), 72–76. https://doi.org/10.1016/j.archger.2017.10.005.

Tinetti, M. E. (1986). Performance-oriented assessment of mobility problems in elderly patients. *Journal of the American Geriatrics Society, 34*(2), 119–126. https://doi.org/10.1111/j.1532-5415.1986.tb05480.x.

Vaz Fragoso, C. A., Gahbauer, E. A., Van Ness, P. H., Concato, J., & Gill, T. M. (2008). Peak expiratory flow as a predictor of subsequent disability and death in community-living older persons. *Journal of the American Geriatrics Society, 56*(6), 1014–1020.

https://doi.org/10.1111/j.1532-5415.2008.01687.x.
Vaz Fragoso, C., Gahbauer, E., Van Hess, P., Gill, & Yu, T. (2009). Reporting peak expiratory flow in older persons. *The Journals of Gerontology Series A, Biological Sciences and Medical Sciences, 62*(10), 1147–1151.
Vaz Fragoso, C. A., Enright, P. L., McAvay, G., Van Ness, P. H., & Gill, T. M. (2012). Frailty and respiratory impairment in older persons. *The American Journal of Medicine, 125*(1), 79–86. https://doi.org/10.1016/j.amjmed.2011.06.024.
Weiss, C. O., Hoenig, H. H., Varadhan, R., Simonsick, E. M., & Fried, L. P. (2010). Relationships of cardiac, pulmonary, and muscle reserves and frailty to exercise capacity in older women. *Journals of Gerontology Series A: Biological Sciences and Medical Sciences, 65 A*(3), 287–294. https://doi.org/10.1093/gerona/glp147.
Xie, B., Larson, J. L., Gonzalez, R., Pressler, S. J., Lustig, C., & Arslanian-Engoren, C. (2017). Components and indicators of frailty measures: A literature review. *The Journal of Frailty & Aging, 6*(2), 76–82. https://doi.org/10.14283/jfa.2017.11.