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Respiratory function and self-reported functional health: EPIC-Norfolk population study

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ABSTRACT: Respiratory function is known to be associated with mortality. However, its association with health related quality of life (HRQoL) has not yet been examined.

A population-based cross sectional study was conducted in 16,738 subjects aged 40–79 yrs and resident in Norfolk, to examine the association between forced expiratory volume in one second (FEV1) and HRQoL measured by the 36-item short form questionnaire.

Individuals who were in the highest quintiles of FEV1 were more likely to report good physical functional health (odds ratio (OR) 1.60; 95% confidence interval (CI) 1.28–2.01 and OR 1.71; 95% CI 1.40–2.10 for males and females, respectively) controlling for age, height, weight or body mass index, smoking, physical activity, prevalent illness and social class. Being in the highest quintile for FEV1 was associated with significantly lower likelihood of poor self-reported mental functional health status in males (OR 0.78; 95% CI 0.61–0.99), but not in females (OR 1.00; 95% CI 0.82–1.22).

In conclusion, forced expiratory volume in one second independently predicts self perceived physical well being in a general population across the whole normal distribution of respiratory function.

KEYWORDS: Forced expiratory volume in one second, mental functional health, physical functional health, respiratory function

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Many epidemiological studies have reported an association between respiratory function, measured using forced expiratory volume in one second (FEV1), and mortality [1–4]. Not all these studies have been able to consider adequately whether this relationship was independent of smoking [5], physical activity and prevalent disease [6, 7], which are all associated with lung function [8, 9].

The short form 36-item questionnaire (SF-36) is a widely used validated generic measure of self-reported health related quality of life (HRQoL) [10]. The relationship between respiratory illness and self-reported functional health [11, 12], and its use in people with respiratory illnesses has been well documented [13–15].

Previous evidence suggests that there is considerable under-diagnosis of obstructive airways disease in the community, which only becomes apparent when FEV1 is used as an objective measure of airways obstruction in a population sample [16]. This has been partly explained by the fact that people may only consult their general practitioners when the quality of their every day life becomes affected [17]. However, the association of FEV1 with self-reported functional health in the general population is less well known. In the present study, the relationship between FEV1 and physical and mental well being was examined, and measured by a generic HRQoL measure (SF-36) in males and females living in the general community.

MATERIALS AND METHODS

The study population was based on males and females recruited between 1993–1997 as part of the Norfolk (UK) component of the European Prospective Investigation into Cancer (EPIC-Norfolk). Detailed descriptions of the recruitment and study methodology have been previously reported [18]. Males and females aged 40–79 yrs were identified from collaborating general practice registers and were invited by mail to participate. Between 1993 and 1997, 25,639 participants attended a clinic for a baseline assessment. All participants filled in a self-completed questionnaire about their lifestyle and health.

At the clinic visits, assessments were made by trained nurses according to standard protocols [19]. Respiratory function was assessed by spirometry [20]. FEV1 was measured twice using a portable spirometer (Micro medical, Rochester, UK), the better of the two measures was used for analyses. Participants' height and weight were measured with participants dressed in light clothing and with their shoes removed. Height was measured to the nearest 0.1 cm using a stadiometer while weight was measured to the nearest 100 g using Salter scales. Body mass index (BMI) was calculated as weight in kilograms divided by the square of the height in metres: weight (kg)/height (m^2). Cigarette smoking status was derived from responses to the questions ''Have you ever smoked as much as one cigarette a day for as long as a year?'' and ''Do you smoke cigarettes now?'' From these smoking status was classified as current smoker, ex-smoker or those who had never smoked.

Occupational social class was classified according to the Registrar General's occupation-based classification scheme in which people with similar levels of occupational skill are allocated into one of five groups [21]. Social class I consists of professionals, social class II includes managerial and technical occupations, social class III is subdivided into nonmanual skilled workers and manual skilled workers, social class IV consists of partly skilled workers, and social class V comprises unskilled manual workers.

Physical activity was categorised into four physical activity index groups, with level I designated as inactive (most sedentary) and level IV as the most active person. A detailed description of the physical activity index scoring, its validity and its repeatability has been assessed and reported elsewhere [22].

On the health questionnaire, the participants were asked, ''Has the doctor ever told you that you have any of the following?'' followed by a list of various conditions. For the present study purpose prevalent illness was defined as presence of self-reported major chronic illnesses, including cancer, stroke, myocardial infarction, diabetes mellitus and presence of respiratory illnesses, which include asthma and bronchitis/ emphysema.

The participants were asked to complete a detailed Health and Life Experiences Questionnaire (HLEQ) 18 months later, which included questions on an anglicised version of SF-36 [10] by mail and 20,921 participants responded [23]. The SF-36 comprises of eight subscales, which measure eight dimensions of health including physical functioning, social functioning, role limitations due to physical problems, role limitations due to emotional problems, mental health, energy/vitality, pain and general health perception. The subscales were scored on a scale of health from 0 (worst) to 100 (best). The physical component summary (PCS) and mental component summary (MCS) scores were derived according to algorithms specified by the original developers. PCS and MCS scores were created by aggregating across the eight SF-36 subscales, transformed to z-scores, multiplied by their respective factor score coefficients and standardised as T-scores with mean $\pm$ SD (50 ± 10) [24, 25]. The factor score coefficients used were based on a USA population as opposed to a UK population on the basis of uniformity for cross-national comparisons.

For the purpose of the current study, percentiles from the SF-36 scores were used to categorise physical functional health status and mental functional health status. Cut-off points of physical component summary scores of 40 and 55, respectively, were used to approximately identify the bottom and top 20% of the sample population dividing them into three physical functional health categories: poor (<40), intermediate ($\geqslant$40 and <55) and good ($\geqslant$55). Mental functional health was divided into similar categories using MCS scores of 45 and 60.

The smoking status was re-categorised as current smokers and ex-/nonsmokers, physical activity index as relatively low physical activity (inactive and moderately inactive groups from physical activity questionnaire) and higher physical activity (active and moderately active groups), and occupational social class as manual (occupational social class III manual, IV and V) and nonmanual (social class I, II and III non-manual) social class to give dichotomous variables for some of the analyses.

People were excluded if they had missing values for age, sex, SF-36 scores and FEV1 measured at first health-check. Participants with missing values for particular covariates entered into different models were excluded in individual regression analyses. Ethical approval was obtained from the Norwich Research Ethics Committee (UK).

Statistical analysis

Statistical analyses were performed separately for males and females. Age at the time of the completion of the SF-36 was included as a covariate in all the models.

The mean summary scores for physical and mental components of SF-36 were tabulated according to the quintiles of FEV1 values. Trend for linearity was tested using ANOVA method.

The relationships between FEV1 and the prevalence and association of poor and good functional health were investigated. Univariate regression models were constructed using SF-36 PCS and SF-36 MCS scores for quintiles of FEV1 and other possible confounding factors, such as height and weight or BMI [26, 27], smoking status [8, 28], physical activity [29, 30] and prevalent illnesses [8, 31].

Multiple logistic regression analysis was performed to assess the odds ratios for having poor or good physical and mental functional health by individual's FEV1 at baseline after adjusting for age at the time of SF-36 and other confounders mentioned above. Analyses were repeated after excluding those who currently smoke and those who reported any illnesses listed above. Multiple logistic regression analysis was also performed to examine the likelihood of being in good functional health associated with: 1) an increase in FEV1 of 100 $mL \cdot s^{-1}$; 2) increase in 5 yrs in age; 3) increase in 5 cm in height; 4) increase in 5 kg in weight or one unit of BMI; 5) being in nonmanual social class; 6) having higher physical activity; 7) not being a current smoker; and 8) having no major prevalent illnesses.

Analyses were repeated using two subscales (physical functioning and mental health) that contributed mainly to summary scores to examine the consistency of findings using crude scores as well as the derived weighted summary scores

[32, 33]. Age-stratified analyses was performed (stratified into three age groups: <55, 55–64 and ⩾65 yrs) for multiple logistic regression models examining the impact per increase in FEV1 of 100 mL·s^{-1}.

RESULTS

There were 19,535 males and females who had SF-36 summary scores available from the HLEQ. The analyses were based on 16,738 participants (7,402 males and 9,336 females), mean±SD age 58.5±9.15 yrs, who had available data on FEV1 at baseline. There were no material differences between who responded to the HLEQ and those who did not in terms of mean age, height and BMI. There were a higher proportion of nonmanual occupational social classes and a lower proportion of people with prevalent illness in responders compared with non-responders. Exclusion of people who currently smoke left 14,906 participants (6,578 males and 8,328 females) and exclusion of males and females who reported any cancer, stroke, myocardial infarction, diabetes, asthma and bronchitis/emphysema left 12,737 participants (5,624 males and 7,113 females) for the subgroup analyses.

Table 1 shows the distribution of characteristics according to FEV1 category classified by sex-specific quintile ranges for males and females. FEV1 category 1 represents the lowest quintile group, whilst category 5 represents the highest. In this unadjusted table, males and females in the higher FEV1 categories were younger, taller, heavier and had higher mean reported physical functional health measured by SF-36 PCS scores. There was no trend for mental functional health measured by SF-36 MCS scores. There were also higher proportions of people with higher physical activity, nonsmokers, in nonmanual occupational social classes, and without prevalent illnesses in the higher FEV1 categories. The patterns were similar in both males and females apart from smoking status. Repeating the analyses using two main subscales of SF-36 showed results consistent with the findings above (data not shown).

Table 2 shows mean scores of SF-PCS and SF-36 MCS scores by FEV1 categories, first age adjusted, then adjusted for age and other covariates which were: weight or BMI, height, physical activity, social class (manual/nonmanual), smoking status and prevalent illness. Physical functional health scores differed significantly between quintile groups of FEV1 in both males and females after age adjustment and differences were only slightly attenuated after adjustment for other covariates. Although, with the large numbers, there were some significant differences in mental functional health measured by SF-36 MCS scores that did not show consistent patterns in comparison with physical scores.

Table 3 shows the likelihood of being in good or poor functional health defined by the lowest and the highest 20th percentile of SF-36 scores in different FEV1 categories in various models. In both males and females, having higher FEV1 in the top fifth compared with the bottom fifth, was associated with approximately a doubling in the likelihood of reporting good physical functional health and halving the likelihood of reporting poor physical health after age adjustment. These were somewhat attenuated, but still highly significant and with consistent trends after adjusting for covariates, or excluding from analyses current smokers, or those with prevalent illnesses (data not shown). In marked contrast, for mental functional health while there also appeared to be lower likelihood of reporting poor mental functional health in those in the four higher FEV1 categories compared with the lowest, there was no consistent or significant trend.

Table 4 shows the multiple logistic regression models, which estimate the likelihood of having good or poor physical and mental functional health for every increase in FEV1 of 100 mL·s^{-1} in comparison with increase in age by 5 yrs, height by 5 cm, weight in 5 kg and/or one unit of BMI, being in nonmanual social class, having higher physical activity, being non/ex-smoker compared with current smoker, and being free of known prevalent illnesses. Age-stratified analyses are presented in table 5 (age and other covariates adjusted as model A (weight in 5 kg) or model B (BMI)).

In both males and females, higher FEV1 was independently associated with higher odds of reporting good physical functional health, and the magnitude of relationship in terms of an increase in FEV1 of 100 mL·min^{-1} was comparable with being in nonmanual occupational social class, having higher physical activity and not being a current smoker. Advancing age appeared to be the factor associated with good mental functional health and a higher FEV1 was not related to good mental functional health.

Repeating the analyses using five levels of occupational social class and three categories of smoking did not alter the findings.

DISCUSSION

The SF-36 is the most well known of the instruments developed from two large-scale studies carried out in the USA (the Rand Health Insurance Experiment and the Medical Outcomes Study) [34–37]. It has been extensively validated against factors such as work capacity, disease symptoms, use of care services and measures of mental health [38]. The SF-36 has been most commonly used to determine: 1) the patients' point of view or an outcome in relation to an intervention on a particular condition (before and after studies) [39]; or 2) the effect of a condition on HRQoL [40]. The instrument has also been used as a multidimensional measure of healthy ageing [41]. It has been shown to be widely acceptable to the patients or participants studied [42].

The independent relationship between respiratory function measured by FEV1 and good or poor functional health measured by the SF-36 was investigated. Higher FEV1, analysed either as a categorical or continuous variable, was found to be associated with a higher likelihood of self-reported good and lower likelihood of poor physical functional health. In contrast, FEV1 was not consistently related to the likelihood of being in good mental functional health. The association with poor mental functional health appeared to be much more a threshold one, with those in the lowest fifth for FEV1 more likely to report poor mental functional health than those in the other four groups, but without the apparent continuous trend. This association was consistent in repeated analyses using the mental health subscale instead of the MCS score, indicating this was independent of any weighting of the different components.

TABLE 1 Distribution of characteristics of the EPIC-Norfolk cohort by forced expiratory volume in one second (FEV1) quintile categories

	FEV1 category					
	1	2	3	4	5	p-value
Males#						
FEV1 quintile ranges mL·s^{-1}	<233	233–274	275–310	311–353	≥354	
Age yrs	65.7±7.8	62.8±8.2	59.3±8.2	56.2±7.9	51.8±6.4	<0.0001
Height cm	171±6.5	172±6.0	174±6.1	176±6.0	178±5.8	<0.0001
Weight kg	78.5±12.0	80.0±11.0	80.0±11.6	81.0±11.0	82.4±10.5	<0.0001
BMI kg·m^{-2}	26.8±3.5	26.8±3.3	26.4±3.2	26.2±3.0	25.9±2.9	<0.0001
FEV1 mL·min^{-1}	188±39	255±12	293±10	332±13	393±31	<0.0001
SF-36 PCS	43.3±11.2	46.9±10.0	47.9±9.4	49.4±8.8	51.76±7.4	<0.0001
SF-36 MCS	53.1±9.5	53.8±8.6	53.2±8.8	52.9±8.9	51.8±9.2	<0.0001
Physical activity category						
Inactive	572 (38.5)	439 (29.8)	375 (25.3)	330 (22.2)	290 (19.6)	<0.0001 (overall)
Moderately inactive	360 (24.2)	374 (25.4)	389 (26.2)	389 (26.2)	407 (27.6)	
Moderately active	298 (20.1)	362 (24.6)	351 (23.7)	389 (26.2)	386 (26.1)	
Active	255 (17.2)	296 (20.1)	367 (24.8)	377 (25.4)	394 (26.7)	
Smoking status						
Current smoker	231 (15.6)	150 (10.3)	167 (11.3)	138 (9.4)	97 (6.6)	<0.0001 (overall)
Ex-smoker	919 (62.2)	864 (59.1)	791 (53.6)	755 (51.2)	680 (46.3)	
Never smoked	327 (22.1)	448 (30.6)	519 (35.1)	582 (39.5)	693 (47.1)	
Occupational social class						
Nonmanual	843 (56.8)	889 (60.4)	894 (60.3)	963 (64.8)	1023 (69.3)	<0.0001 (overall)
Manual	642 (43.2)	583 (39.6)	589 (39.7)	522 (35.2)	454 (30.7)	
Prevalent illness	606 (40.8)	416 (28.3)	298 (20.1)	1228 (17.3)	201 (13.6)	<0.0001
Females¶						
FEV1 quintile ranges mL·s^{-1}	<174	174–203	204–229	230–258	≥259	
Age yrs	65.3±7.7	61.8±8.4	57.7±8.0	54.1±7.3	50.9±6.1	<0.0001
Height cm	158±6.0	159±5.5	161±5.6	163±5.5	165±5.5	<0.0001
Weight (kg)	67.0±12.1	67.9±11.8	68.1±12.1	67.8±11.8	68.2±11.0	0.007
BMI kg·m^{-2}	26.8±4.6	26.8±4.4	26.2±4.3	25.7±4.2	25.0±3.8	<0.0001
FEV1 mL·min^{-1}	145±26	189±8	217±8	244±9	287±23	<0.0001
SF-36 PCS	43.2±11.1	45.8±10.5	48.0±9.6	49.0±9.6	50.6±8.7	<0.0001
SF-36 MCS	52.4±9.8	52.7±9.3	52.0±9.3	51.4±9.6	50.3±9.9	<0.0001
Physical activity category						
Inactive	745 (39.6)	578 (31.7)	420 (22.6)	364 (19.1)	295 (15.9)	<0.0001 (overall)
Moderately inactive	600 (31.9)	597 (32.7)	648 (34.8)	641 (33.6)	608 (32.7)	
Moderately active	334 (17.8)	408 (22.4)	450 (24.2)	520 (27.3)	506 (27.2)	
Active	201 (10.7)	242 (13.3)	344 (18.5)	382 (20.0)	449 (24.2)	
Smoking status						
Current smoker	219 (11.8)	172 (9.5)	193 (10.4)	186 (9.8)	163 (8.8)	<0.0001 (overall)
Ex-smoker	670 (36.1)	571 (31.5)	551 (29.8)	560 (29.5)	571 (30.8)	
Never smoked	967 (52.1)	1067 (59.0)	1103 (59.7)	1150 (60.7)	1118 (60.4)	
Occupational social class						
Nonmanual	1122 (59.6)	1112 (60.9)	1206 (64.7)	1263 (66.2)	1301 (70.0)	<0.0001 (overall)
Manual	759 (40.4)	713 (39.1)	658 (35.3)	644 (33.8)	558 (30.0)	
Prevalent illness	272 (14.5)	210 (11.5)	161 (8.6)	152 (8.0)	117 (6.3)	<0.0001

Data are presented as mean±SD and n (%), unless otherwise stated. BMI: body mass index; SF-36 PCS: short form 36 physical component summary score; SF-36 MCS: short form 36 mental component summary score; Nonmanual: social class I, II and III nonmanual; Manual: social class III manual, IV and V; Prevalent illness: self reported respiratory illness (asthma and bronchitis/emphysema), cancer, stroke, myocardial infarction and diabetes mellitus. Quintile cut-off points for FEV1 categories were 233, 275, 311 and 354 mL·min^{-1} for males, and 174, 204, 230 and 259 mL·min^{-1} for females. #: n=7402; ¶: n=9336.

TABLE 2 Age and other covariates adjusted mean SF-36 physical and mental component summary scores (SF-36 PCS and SF-36 MCS scores) for different categories of FEV1 by quintiles ranges of the EPIC-Norfolk cohort#

	FEV1 categories					
	1	2	3	4	5	p-value
SF-36 PCS scores						
Males						
Age adjusted	44.8±0.3	47.7±0.2	47.9±0.2	48.7±0.2	50.1±0.3	<0.0001
Age and other covariate adjusted	45.8±0.3	48.0±0.2	47.8±0.2	48.3±0.2	49.4±0.3	<0.0001
Age and other covariate adjusted¶	45.8±0.3	48.0±0.2	47.8±0.2	48.2±0.2	49.4±0.3	<0.0001
Females						
Age adjusted	44.9±0.2	46.7±0.2	47.9±0.2	48.0±0.2	48.9±0.2	<0.0001
Age and other covariate adjusted	45.7±0.2	47.0±0.2	47.9±0.2	47.7±0.2	48.3±0.2	<0.0001
Age and other covariate adjusted¶	45.7±0.2	47.0±0.2	47.9±0.2	47.7±0.2	48.3±0.2	<0.0001
SF-36 MCS scores						
Males						
Age adjusted	51.9±0.2	53.2±0.2	53.1±0.2	53.5±0.2	53.1±0.3	<0.0001
Age and other covariate adjusted	52.3±0.3	53.2±0.2	53.1±0.2	53.3±0.2	52.9±0.3	0.019
Age and other covariate adjusted¶	52.3±0.3	53.2±0.2	53.1±0.2	53.3±0.2	52.9±0.3	0.019
Females						
Age adjusted	50.9±0.2	51.9±0.2	52.0±0.2	52.1±0.2	51.6±0.2	0.002
Age and other covariate adjusted	51.4±0.2	52.1±0.2	52.0±0.2	51.9±0.2	51.3±0.2	0.042
Age and other covariate adjusted¶	51.4±0.2	52.1±0.2	51.9±0.2	51.9±0.2	51.3±0.2	0.042

Data presented as mean±SE unless otherwise stated. Covariates: participants' height (cm), weight (kg), physical activity, social class category (manual and nonmanual), smoking status and self reported physical illnesses including asthma, bronchitis/emphysema, myocardial infarction, stroke, cancer and diabetes mellitus. FEV1: Forced expiratory volume in one second. #: males n=7402, females n=9336; ¶: Adjustment made for body mass index instead of weight. Quintile cut-off points for FEV1 categories were 233, 275, 311 and 354 mL·s^{-1} for males, and 174, 204, 230 and 259 mL·s^{-1} for females.

Nature of associations

The possible confounding effects of age, height, weight, BMI, smoking, illnesses and social class on the relationship between FEV1 and self-rated health were examined. In particular, it is possible that factors such as smoking and prevalent illness may both affect respiratory function measured by FEV1, as well as self-perceived health. Although residual confounding cannot be excluded from these, or other unknown confounders, adjustment for these major factors, as well as stratified analyses by age and after excluding those who currently smoke and those who reported physical illnesses including respiratory illness, such as asthma and bronchitis/emphysema, showed consistent findings. Additionally, FEV1 was measured 18 months prior to assessing self-reported functional health and, although due to the short follow-up, this was considered a cross-sectional analysis, the prospective relationship between earlier FEV1 and later functional health assessment reduces the likelihood of reverse causality.

It is plausible that the relationship between FEV1 and self-reported functional health reflects both FEV1 and functional health being indicators of respiratory disease, such as undiagnosed chronic obstructive airway disease [43]. However, it is unlikely this is the only explanation as the association between lower FEV1 and poorer self-reported functional health not only remained after adjusting for, or excluding those with, prevalent illnesses including obstructive airway diseases (asthma, bronchitis/emphysema), but was apparent across the whole normal distribution of FEV1 in the population.

The current findings suggest that there may be a direct association between respiratory function and functional health. It is possible that FEV1 indicates the capacity to perform a physical task and may explain why it is a stronger determinant of physical functional health compared with mental functional health. Since FEV1 measures large airways resistance, lower FEV1 (*i.e.* increase in large airway resistance or reduced elasticity of the airways in normal physiological state) may result in poor physical functional health to a certain and similar extent, which is associated with an equivalent amount of decline in lung function secondary to physical insult such as smoking or respiratory illness, such as asthma/bronchitis. The plausible biological mechanism behind this phenomenon is beyond the scope of the present study and highlights the need for further evaluation.

Limitations

There were limitations in the current study. As participants who were willing to provide detailed information and participate in a long-term follow-up study were required, there was only a population response rate of 40–45% for the baseline and follow-up survey. Nevertheless, the characteristics of this population were comparable with national samples, except with slightly lower prevalence of smokers [18]. The study population's observed summary scores for functional health outcome are comparable with two other UK studies, the health survey for England and the Omnibus Survey in Great Britain, but with a slightly lower mean PCS score compared with the Oxford Health Life Survey (OHLS) [42]. However, OHLS

TABLE 3 Poor or good functional health status defined using SF-36 PCS and SF-36 MCS 20th and 80th percentile scores for corresponding models of the EPIC-Norfolk cohort for four categories of FEV_1 compared with the first quintile group

	FEV_1 Category					
	1#	2	3	4	5	p-value
Poor physical functional health status						
Males	507 (35.5)	331 (23.2)	264 (18.5)	219 (15.3)	107 (7.5)	
A	1.00	0.62 (0.52–0.73)	0.54 (0.45–0.64)	0.49 (0.40–0.60)	0.27 (0.21–0.36)	<0.0001
B	1.00	0.73 (0.61–0.86)	0.69 (0.57–0.84)	0.68 (0.55–0.84)	0.39 (0.30–0.52)	<0.0001
C	1.00	0.73 (0.61–0.86)	0.69 (0.57–0.84)	0.68 (0.55–0.83)	0.39 (0.30–0.52)	<0.0001
Females	661 (32.8)	465 (23.1)	345 (17.1)	321 (15.9)	223 (11.1)	
A	1.00	0.70 (0.60–0.81)	0.54 (0.46–0.64)	0.57 (0.48–0.68)	0.44 (0.36–0.54)	<0.0001
B	1.00	0.79 (0.68–0.92)	0.65 (0.55–0.77)	0.72 (0.60–0.86)	0.58 (0.47–0.71)	<0.0001
C	1.00	0.79 (0.68–0.92)	0.66 (0.55–0.78)	0.72 (0.60–0.86)	0.58 (0.46–0.71)	<0.0001
Good physical functional health status						
Males	189 (10.4)	304 (16.7)	330 (18.2)	435 (23.9)	560 (30.8)	
A	1.00	1.56 (1.27–1.91)	1.39 (1.13–1.70)	1.73 (1.41–2.13)	2.03 (1.64–2.53)	<0.0001
B	1.00	1.39 (1.13–1.70)	1.15 (0.94–1.43)	1.40 (1.13–1.73)	1.60 (1.28–2.01)	<0.0001
C	1.00	1.39 (1.13–1.71)	1.15 (0.94–1.43)	1.40 (1.13–1.73)	1.60 (1.28–2.01)	<0.0001
Females	247 (10.6)	346 (14.9)	485 (20.8)	571 (24.5)	678 (29.1)	
A	1.00	1.35 (1.13–1.62)	1.69 (1.41–2.03)	1.73 (1.44–2.09)	2.03 (1.67–2.47)	<0.0001
B	1.00	1.27 (1.05–1.52)	1.50 (1.25–1.81)	1.50 (1.24–1.82)	1.71 (1.40–2.10)	<0.0001
C	1.00	1.27 (1.05–1.53)	1.50 (1.25–1.81)	1.50 (1.24–1.81)	1.71 (1.40–2.10)	<0.0001
Poor mental functional health status						
Males	268 (22.7)	209 (17.7)	223 (18.9)	219 (18.6)	260 (22.1)	
A	1.00	0.69 (0.56–0.84)	0.66 (0.54–0.81)	0.59 (0.48–0.73)	0.65 (0.51–0.81)	<0.0001
B	1.00	0.75 (0.61–0.92)	0.76 (0.62–0.94)	0.70 (0.56–0.88)	0.78 (0.61–0.99)	0.01
C	1.00	0.75 (0.61–0.92)	0.76 (0.62–0.94)	0.70 (0.56–0.87)	0.78 (0.61–0.99)	0.01
Females	399 (21.4)	330 (17.7)	340 (18.3)	379 (20.4)	414 (22.2)	
A	1.00	0.76 (0.64–0.90)	0.71 (0.60–0.85)	0.74 (0.62–0.89)	0.82 (0.67–0.99)	0.001
B	1.00	0.83 (0.70–0.98)	0.81 (0.68–0.97)	0.87 (0.72–1.04)	1.00 (0.82–1.22)	0.02
C	1.00	0.83 (0.70–0.98)	0.81 (0.68–0.97)	0.87 (0.72–1.04)	1.00 (0.82–1.22)	0.02
Good mental functional health status						
Males	328 (25.7)	300 (23.5)	259 (20.3)	226 (17.7)	165 (12.9)	
A	1.00	1.07 (0.90, 1.29)	1.12 (0.92, 1.36)	1.16 (0.94–1.44)	1.12 (0.87–1.44)	0.70
B	1.00	1.07 (0.89, 1.29)	1.10 (0.90, 1.34)	1.16 (0.93–1.44)	1.14 (0.88–1.47)	0.75
C	1.00	1.07 (0.89, 1.29)	1.10 (0.90, 1.34)	1.16 (0.93–1.44)	1.13 (0.87–1.46)	0.76
Females	394 (28.4)	354 (25.5)	259 (18.7)	225 (16.2)	156 (11.2)	
A	1.00	1.09 (0.92, 1.29)	0.92 (0.77, 1.11)	0.96 (0.78–1.17)	0.81 (0.63–1.03)	0.12
B	1.00	1.06 (0.90, 1.26)	0.89 (0.73, 1.07)	0.92 (0.74–1.13)	0.76 (0.59–0.98)	0.07
C	1.00	1.06 (0.90, 1.26)	0.89 (0.73, 1.07)	0.92 (0.74–1.13)	0.76 (0.59– 0.98)	0.07

Data presented as odds ratio (95% confidence interval) or n (%), unless otherwise stated. Model A: based on participants' age at the time of SF-36, height, and weight (7,402 males and 9,336 females). Model B: based on participants' age at the time of SF-36, height, weight, smoking status, social class category, physical activity and prevalent illnesses (7,361 males and 9,261 females). Model C: same as model B except body mass index was entered into the model instead of weight. All the variables were included in the same model. SF-36 PCS: Short form 36 physical component summary; SF-36 MCS: short form 36 mental component summary; FEV_1: forced expiratory volume in one second. #: Reference FEV_1 category.

comprises a younger cohort and the mean observed scores for the younger (41–65 yrs) EPIC-HLEQ cohort and expected mean scores age-sex standardised to population norms from OHLS were similar [44]. It is likely that the current study population had a narrow range of physical and mental health than would be expected in a general population, as those who were severely compromised physically or mentally would be less likely to participate in the study contributing some selection bias towards healthier people. However, truncation of the distribution, with loss of people in poor functional health or with poor respiratory function, would result only in attenuation of the relationships. This would not explain the

TABLE 4 Good and poor functional health arbitrarily defined by using SF-36 PCS and SF-36 MCS 80th and 20th percentile scores in males and females of EPIC-Norfolk cohort

	Good physical functional health		Good mental functional health		Poor physical functional health		Poor mental functional health	
	Males	**Females**	**Males**	**Females**	**Males**	**Females**	**Males**	**Females**
FEV1 100 mL·s^{-1} model A	1.20 (1.09–1.33)§	1.47 (1.29–1.67)§	1.07 (0.95–1.19)	0.85 (0.73–0.99)*	0.63 (0.56–0.70)§	0.64 (0.56–0.74)§	0.86 (0.77–0.96)**	0.97 (0.85–1.11)
FEV1 100 mL·s^{-1} model B	1.20 (1.09–1.33)§	1.47 (1.29–1.67)§	1.07 (0.95–1.19)	0.85 (0.73–0.99)*	0.63 (0.56–0.70)§	0.64 (0.56–0.74)§	0.86 (0.77–0.96)**	0.97 (0.85–1.11)
Age per increase in 5 yrs	0.75 (0.72–0.78)§	0.80 (0.77–0.83)§	1.38 (1.32–1.44)§	1.32 (1.27–1.38)§	1.24 (1.19–1.29)§	1.24 (1.20–1.29)§	0.85 (0.82–0.89)§	0.89 (0.86–0.92)§
Height per increase in 5 cm	1.06 (1.00–1.12)*	1.05 (1.00– 1.10)*	0.94 (0.89–0.99)*	0.98 (0.92–1.03)	0.94 (0.89–0.99)**	0.99 (0.94–1.04)	0.99 (0.93–1.05)	0.93 (0.89–0.98)**
Weight per increase in 5 kg	0.90 (0.87–0.92)§	0.85 (0.83–0.87)§	1.05 (1.02–1.08)**	1.07 (1.04–1.10)§	1.14 (1.10–1.17)§	1.16 (1.14–1.19)§	1.03 (1.00–1.06)	1.03 (1.00–1.05)*
Nonmanual *versus* manual#	1.37 (1.21–1.54)§	1.09 (0.98–1.21)	0.94 (0.83–1.08)	1.12 (0.99–1.27)	0.62 (0.55–0.70)§	0.77 (0.70–0.86)§	0.88 (0.77–1.00)	0.95 (0.85–1.05)
Physically active *versus* inactive#,¶	1.33 (1.21–1.54)§	1.29 (1.17–1.43)§	0.97 (0.85–1.10)	0.90 (0.80–1.02)	0.68 (0.60–0.78)§	0.71 (0.63–0.79)§	0.74 (0.65–0.85)§	0.80 (0.72–0.89)§
Non/ex-smoker *versus* current smoker#	1.15 (0.96–1.39)	1.18 (1.00–1.39)*	0.90 (0.73–1.11)	1.18 (0.95–1.47)	0.72 (0.59–0.87)**	0.76 (0.64–0.90)**	0.75 (0.62–0.91)**	0.57 (0.49–0.67)§
No prevalent illness *versus* prevalent illness#,+	1.90 (1.63–2.21)§	1.64 (1.44–1.87)§	1.13 (0.97–1.31)	1.18 (1.03–1.36)*	0.49 (0.43–0.56)§	0.51 (0.46–0.58)§	0.71 (0.62–0.83)§	0.75 (0.66–0.84)§

Data presented as odds ratio (95% confidence interval). SF-36 PCS: short form 36 physical component summary; SF-36 MCS: short form 36 mental component summary; FEV1: forced expiratory volume in one second. #: Reference category; ¶: physical activity index level I and II: physically inactive, level III and IV: physically active; +: self reported respiratory illnesses namely asthma and bronchitis/emphysema and other major long standing or life threatening illnesses such as myocardial infarction, stroke, cancer and diabetes mellitus. *: $p<0.05$; **: $p<0.01$; §: $p<0.0001$.

TABLE 5 Good and poor functional health arbitrarily defined by using SF-36 PCS and SF-36 MCS 80th and 20th percentile scores of the EPIC-Norfolk cohort for the three age groups#

Age	Model	Good physical functional health		Good mental functional health		Poor physical functional health		Poor mental functional health	
		Males	**Females**	**Males**	**Females**	**Males**	**Females**	**Males**	**Females**
<55 yrs	A	1.16 (0.99–1.36)	1.33 (1.09–1.62)**	1.17 (0.87–1.57)	0.90 (0.62–1.31)	0.73 (0.56–0.95)*	0.58 (0.45–0.76)¶	0.97 (0.82–1.21)	1.05 (0.85–1.30)
	B	1.16 (0.99–1.36)	1.33 (1.09–1.62)**	1.17 (0.87–1.56)	0.90 (0.62–1.31)	0.73 (0.56–0.95)*	0.58 (0.45–0.76)¶	1.00 (0.82–1.21)	1.05 (0.85–1.30)
55–64 yrs	A	1.24 (1.05–1.47)*	1.70 (1.36–2.13)¶	1.02 (0.83–1.26)	0.81 (0.62–1.06)	0.55 (0.45–0.67)¶	0.67 (0.53–0.85)**	0.80 (0.66–0.97)*	0.96 (0.76–1.22)
	B	1.24 (1.05–1.48)*	1.71 (1.36–2.13)¶	1.02 (0.83–1.26)	0.81 (0.62–1.06)	0.55 (0.45–0.67)¶	0.67 (0.53–0.85)**	0.79 (0.65–0.96)*	0.96 (0.76–1.22)
⩾65 yrs	A	1.13 (0.93–1.39)	1.42 (1.08–1.88)*	1.07 (0.92–1.25)	0.85 (0.68–1.06)	0.64 (0.56–0.75)¶	0.66 (0.54–0.82)¶	0.79 (0.65–0.95)*	0.90 (0.71–1.16)
	B	1.14 (0.93–1.39)	1.42 (1.08–1.88)*	1.07 (0.92–1.25)	0.85 (0.68–1.06)	0.65 (0.56–0.75)¶	0.66 (0.54–0.82)¶	0.79 (0.65–0.95)*	0.90 (0.71–1.16)

Data presented as odds ratio (95% confidence interval). SF-36 PCS: short form 36 physical component summary; SF-36 MCS:PI: short form 36 mental component summary. #: Every increase in 100 mL·s^{-1} in forced expiratory volume controlling for age (age at the time of SF-36), every increase in 5 cm in height, 5 kg in weight (model A) and 1 unit of body mass index (model B), social class (manual/nonmanual), physical activity (physically inactive/active), smoking (current/ex- or nonsmoker), prevalent illness (yes/no). *: $p<0.05$; **: $p<0.01$; ¶: $p<0.0001$.

significant associations within the cohort found in this study. Another limitation of using functional health outcome derived from the SF-36 is due to its subjectivity. Nevertheless, subjective health outcomes are relevant to the individual and have been shown to relate to mortality [25].

Implications

Although the difference in the mean functional component summary scores by FEV1 categories in the present sample was not large in absolute terms, the magnitude was approximately half of the standard deviation of the population mean. To explore how these mean differences translate in practical terms categories were defined with poor and good functional health status using arbitrary percentile cut-off points. Relatively small differences in mean SF-36 PCS and MCS scores were associated with substantial differences in the prevalence and likelihood of being in poor or good physical functional health (table 3). The association was independent of potential confounders and was also consistent after exclusion of people who currently smoke or people with self-reported illnesses.

The magnitude of reduction in mean PCS scores of SF-36 being in the bottom fifth compared with the top fifth for FEV1 was comparable with the reduction in functional health scores associated with a chronic medical condition, such as diabetes, cancer, stroke and myocardial infarction or prevalent mood disorder [23]. Moreover, the present findings also indicate that the estimated magnitude of effect on self-reported physical functional health of being in the bottom fifth compared with the top fifth for FEV1 was greater than that of manual *versus* nonmanual social class estimated in the regression analyses.

Respiratory function declines with age. The impact of health-related behaviours, which are potentially modifiable, such as smoking [5], physical activity [6] and obesity [45] on respiratory function has been well documented. Nutritional factors, such as fruit and vegetable intake, have been suggested to be protective for respiratory function [46, 47]. While these factors may have effects on health independent of respiratory function, they raise the intriguing possibility that it may be possible to attenuate the decline of respiratory function with age. As can be seen from the analyses, even a relatively modest increase in respiratory function is associated with a measurable impact on the prevalence and likelihood of being in either poor or good physical functional health. Identifying whether it is possible to attenuate the decline of respiratory function with age through modest changes in behaviours, such as physical activity, and diet, may have potential in improving health.

In conclusion, maintaining good health in an ageing population is a major challenge in society. The present results highlight the importance of respiratory function for functional health even within the normal population distribution. Understanding the nature of this association may help us understand how to improve health in the ageing population.

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