ORIGINAL ARTICLE

Influence of Age, Physical Performance, and Lung Function on Physical Frailty in Older Adults

Dhayaarschynee Sugumaran[a], Siti Ruzita Mahmod[b], Aizreena Azaman[b,c], Devinder Kaur Ajit Singh[a]

[a] Physiotherapy Programme, Centre for Healthy Ageing and Wellness, Faculty of Health Science, Universiti Kebangsaan Malaysia, Kuala Lumpur, Malaysia.
[b] Rehabilitation Nexus Research Group (REHABNEX), Department of Biomedical Engineering and Health Sciences, Faculty of Electrical Engineering, Universiti Teknologi Malaysia, Johor Bahru, Malaysia.
[c] Department of Biomedical Engineering and Health Sciences, Faculty of Electrical Engineering, Universiti Teknologi Malaysia

ABSTRACT

Introduction: The ageing process often brings about frailty, a condition marked by increased vulnerability to health risks. While previous research has identified physical performance as a key determinant of frailty, the role of age and lung function remains unclear. Understanding the interplay between these factors is crucial for developing early intervention strategies. The present study investigated the influence of age, physical performance, and lung function on physical frailty among older adults. **Methods:** A cross-sectional study was conducted on 27 participants aged 60 and above from three centers. They were assessed for their frailty status using Fried's Frailty Phenotype, physical impairment specifically on balance, lower extremity strength, and functional capacity using Short Physical Performance Battery (SPPB), and lung function using a digital spirometer. **Results:** The findings indicate that only mild physical impairment (SPPB score= 7 to 9) significantly contributed to frailty (OR = 30.802, p = 0.019) compared to moderate (SPPB score= 4 to 6) and severe physical impairment (SPPB score = 0 to 3) that were not significantly associated with frailty (p > 0.05). Additionally, neither age nor lung function showed significant associations with frailty, as the mean age and FEV1/FVC ratio remained similar between pre-frail and frail groups (p > 0.05). **Conclusion:** Mild physical impairment demonstrated a critical turning point of frailty progression; thus, individuals in this category probably be targeted for early interventions more than the other categories. Targeted physical activity interventions focusing on balance, walking speed, and chair stand performance may be crucial in preventing frailty.
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Corresponding Author:
Siti Ruzita binti Mahmod, PhD
Email : sruzita@biomedical.utm.my
Tel : 07-5333743

INTRODUCTION

Frailty in older adults is a critical health concern globally with prevalence rates ranging between 4% to 59% in community-dwelling elderly populations (1, 2). In Malaysia, frailty rates are notably high, with studies reporting prevalence estimates between 5.7% and 56.5%, while pre-frailty affects 57.9% to 72.8% of older adults (3). This condition, characterized by reduced physiological resilience and heightened vulnerability to adverse health outcomes (4,5), is dynamic and multidimensional, with modifiable risk factors such as physical function or performance playing a pivotal role in its progression (6).

Physical performance encompassing lower extremity strength, mobility, balance and endurance (7) is essential for maintaining independence and functional capacity in older adults (8). While interventions like strength training improve physical performance in frail individuals (9), the threshold of physical performance required to prevent frailty remains poorly defined (10). Consequently, early impairments in physical performance often go undetected until frailty becomes clinically evident at a later stage. Frailty is operationalized using Fried's Frailty Phenotype (FFP), which categorizes individuals as frail (≥3 of 5 criteria: unintentional weight loss, low handgrip strength, slow walking speed, self-reported exhaustion, or low physical activity), pre-frail (1–2 criteria), or robust (no criteria) (11). Notably, these criteria may intersect with age-related declines in pulmonary function (12, 13), yet the contribution of lung function to frailty remains underexplored.

Age-related declines in lung function such as forced vital capacity (FVC) and forced expiratory volume in one second (FEV1), are well-documented (14). These changes, attributed to weakened respiratory muscles (15, 16), are quantified by the FEV1/FVC ratio, a spirometric measure expressed as a percentage (%). While a percentage of 75% to 80% is typically considered normal for healthy individuals (17), it decreases with age and varies across populations. Importantly, a clinically significant drop in the actual FEV1/FVC ratio relative to age, sex and height-predicted values may indicate obstructive lung disease. However, this study focuses on the actual ratio as a standalone marker of current lung function, independent of diagnostic thresholds.

Although existing studies have established correlations between age and respiratory muscle decline, they have not adequately accounted for frailty status (3, 18). Clarifying the interplay between frailty, physical performance, and lung function could inform targeted rehabilitation strategies for older adults (15). To address this gap, our study employs ordinal logistic regression to investigate the influence of age, physical performance, and lung function on frailty severity in older adults.

METHODS

A cross-sectional study was conducted across three centers in Johor Bahru, Pasir Gudang, and Cheras Malaysia. Participants aged 60 years were recruited, with inclusion criteria requiring a cognitive score of ≥11 on the Intervention for Dementia in Elderly Africans (IDEA) tool and the ability to walk independently. Exclusion criteria included acute illnesses (e.g. common cold, arthritis, asthma attack) and debilitating comorbidities. Ethical approval was obtained from the UTM Medical Research and Ethics Committee (UTMREC-23-22). All participants provided written informed consent after receiving detailed explanations of the study's purpose, procedures, and risks.

The target sample size was calculated a priori using G*Power 3.1 (42). For the primary predictor of interest, physical performance (SPPB category), a one-way ANOVA with four groups was specified. To detect a large effect size ($f = 0.4$) with an alpha of 0.05 and power of 0.80, a total sample size of 76 was indicated. This estimate was then adjusted for the multivariate ordinal regression model planned for the statistical analysis. Based on the common Events Per Variable (EPV) rule for regression models, which recommends a minimum of 10-20 events per predictor variable to ensure stable estimates (43), a minimum of N=60 was targeted (k=3 predictors; 20 EPV).

After the participant's sociodemographic, health concerns and fall history were collected, their frailty status was determined using the well-established and standardized Fried Frailty Phenotype (FFP) which evaluates five criteria: unintentional weight loss (i.e. 4.5 kg or more in the last year), low handgrip strength, slow walking speed, self-reported exhaustion and low physical activity (19). The handgrip strength was measured twice on the dominant hand using a dynamometer (Takei dynamometer, T.K.K. 5401, Japan). In assessing handgrip strength for frailty, the participant were seated upright in a chair without armrests, with feet flat on the floor, shoulder adducted and neutrally rotated, elbow flexed at 90 degrees, and the wrist was neutral positioned. Using a calibrated handgrip dynamometer typically adjusted to fit the participant's hand, they were instructed to squeeze the device with maximum effort for approximately three to five seconds. Then, the average peak values of the handgrip strength (in kg) were recorded. A female participant was considered to have a low handgrip strength when the average value was less than 19.4kg; for a male participant, a low handgrip strength was indicated when the average value was less than 30kg (20). Handgrip strength is a highly valid objective measure for identifying frailty and sarcopenia, a key component of the frailty phenotype. It is explicitly recommended as a diagnostic criterion in major international consensus guidelines (41)

Meanwhile, the slow walking speed was evaluated based on Timed 'Up and Go' (TUG) test (21) with a cut-off of 16.8s (22). During the test, the participant was required to stand up from an armchair, walk at a comfortable and safe speed to a 3-meter mark, turn around, walk back to the chair and sit down. Timing was initiated by the investigator upon the verbal command 'Go' and stopped when the participant made full contact with the chair seat. If the participant's gait speed during the test was less than 16.8s, they were considered to have a slow walking speed (23). A slower TUG time is strongly associated with increased fall risk, muscle weakness, and loss of independence, confirming its construct and predictive validity for identifying frail individuals (21, 44) and has been shown to have excellent reliability (ICC values of >0.8 for assessing functional mobility in older adult populations. (45). The participants-reported exhaustion was assessed verbally, asking whether they have less energy to do things they want over the past month. Their responses were recorded as 0=no exhaustion or 1=yes exhaustion. Physical activity was assessed using an International Physical Activity Questionnaire (IPAQ), with results calculated in Metabolic Equivalent of Task (MET) per minute per week, and the participant was considered having a low physical activity when the IPAQ assessment showed lesser than 600 MET-minutes/week (24). Ultimately, a person was only considered 'frail' if three out of five items were demonstrated. Meanwhile, they were categorised as 'pre-frail' if they fulfilled one or two items; and 'robust' if none of the items in the FFP instrument was fulfilled.

Next, a Short Physical Performance Battery (SPPB) was used to assess three timed tasks: standing balance, gait speed and chair stand tests. The total score for the three tasks ranged from 0 as the worst performance to 12 as the best performance. Scores range from 0 (worst) to 12 (best), with physical performance categorized as severe (0–3), moderate (4–6), mild (7–9), or good (10–12) (25, 26). The SPPB was a reliable tool with an excellent inter-rater reliability of an ICC value of 0.82 (27).

Next, the participants underwent spirometry testing, where they were instructed to rest for at least 5 minutes before their lung functions were assessed. The assessment measured forced vital capacity (FVC) predicted (%), forced expiratory volume in one second (FEV1) predicted (%), and the FEV1/FVC ratio (%) using a digital spirometer (Spirobank II, MIR, Italy), adhering to Global Initiative for Chronic Obstructive Lung Disease (GOLD) guidelines (28). Data were recorded using MIR Spiro software on a tablet via a Bluetooth connection and saved in PDF format for further analysis. Spirometry is widely recognized as a highly valid method for measuring lung function, established as the gold standard for diagnosing and monitoring obstructive and restrictive lung diseases (McCarthy & Hallstrand, 2021). It has strong criterion validity, as it directly measures volumes and flow rates of air expelled from the lungs, providing an objective physiological assessment that correlates strongly with clinical outcomes.

Statistical Analysis

Demographic differences between pre-frail and frail groups were analysed using independent t-Test or Fisher's Exact Test, with statistical significance set at $p < 0.05$ with the Statistical Package for Social Sciences version 29 (SPSS Inc., Chicago, IL, USA). Ordinal logistic regression evaluated associations between frailty status (pre-frail, frail, robust) and predictors (age, SPPB category, FEV1/FVC ratio). SPPB category that represented physical performance had 4 ordered levels: severe disability, moderate disability, mild disability and good. Model fit was assessed via Pearson chi-square and deviance tests, with proportional odds confirmed by likelihood ratio testing (39).

RESULTS

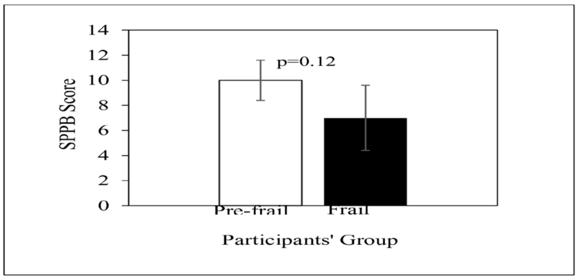
This study initially targeted a sample size of 60 based on a priori power calculations. However, the final sample size was pragmatically limited to 27 participants (mean age: 65 ± 2.4 years; 63% male, 37% female) due to constraints in eligibility and recruitment availability across the 3 participating centers within the operational timeframe. Based on FFP, 77.8% were pre-frail and 22.2%. There were no significant demographic differences between groups (Table 1) except the unintentional weight loss was more prevalent in frail participants ($p = 0.04$).

Table I: Descriptive analysis of the study participants' characteristics

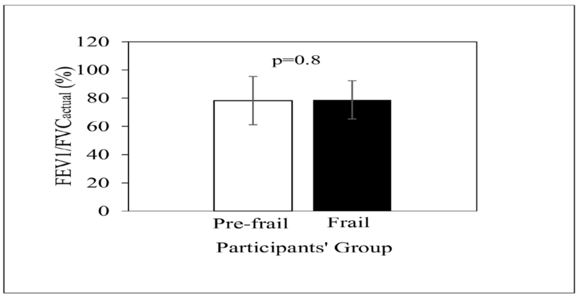
Characteristics	Total (n=27, 100%)	Pre-frail (n=21, 77.8%)	Frail (n=6, 22.2%)	p-value
Age (years), mean (SD)	65.2 (3.6)	65.2 (3.9)	65.2 (2.5)	0.63
Gender				
Male, n (%)	17 (63)	13 (48.2)	4 (14.8)	0.61
Female, n (%)	10 (37)	8 (29.6)	2 (7.4)	
Height (m), mean (SD)	1.6 (6.6)	1.6 (6.8)	1.7 (5)	0.65
Weight (kg), mean (SD)	64.9 (7.5)	64.6 (7.8)	65.7 (7)	0.67
BMI (kg/m_2), mean (SD)	24.5 (2.8)	24.7 (2.8)	23.9 (3.1)	0.31
Education Level, n (%)				
Low	25 (92.6)	19 (70.4)	6 (22.2)	
High	2 (7.4)	2 (7.4)	0 (0)	0.6
Occupational status, n (%)				
Employed	2 (7.4)	2 (7.4)	0 (0)	
Retired/Unemployed	25 (92.6)	19 (70.4)	6 (22.2)	0.6
Living Arrangement, n (%)				
Live alone	0 (0)	0 (0)	0 (0)	-
Live with family/ inmates	27 (100)	21 (77.8)	6 (22.2)	
Fried Frailty Phenotypes				
Unintentional weight loss, n (%)				
No	25 (92.6)	21 (77.8)	4 (14.8)	
Yes	2 (7.4)	0 (0)	2 (7.4)	0.04
Handgrip strength (kg), mean (SD)	22.8 (6.3)	23.5 (6.3)	20.5 (6.3)	0.84
Exhaustion level, n (%)				
High	8 (29.6)	2 (7.4)	6 (22.2)	
Low	19 (70.4)	19 (70.4)	0 (0)	0.6
Physical activity level, n (%)				
Low	6 (22.2)	4 (14.8)	2 (7.4)	0.4
Moderate/High	21 (77.8)	17 (63)	4 (14.8)	
TUG (s), mean (SD)	10.6 (3.4)	9.5 (2.5)	14.7 (3.4)	0.35

SD: standard deviations, n: numbers, BMI: body mass index, kg: kilogram, s: seconds, TUG: timed-up and go test

Short Physical Performance Battery (SPPB) scores and FEV_1/FVC ratios were compared between pre-frail and frail groups. Frail individuals exhibited lower mean SPPB scores (Figure 1a) and comparable FEV1/ FVC ratios (Figure 1b) to pre-frail participants, however neither difference reached statistical significance ($p > 0.05$).



(a)



(b)

Figure 1: Predictor variables (a) Short Physical Performance Battery (SPPB) scores and (b) FEV1/FVC ratios between pre-frail and frail groups.

The ordinal logistic regression model showed no misfit with the observed data (Pearson chi-square (47.757, df = 46, p = 0.401) and deviance statistic (39.041, df = 46, p = 0.757). However, the proportional odds assumption was separately evaluated using a likelihood ratio test (39), which confirmed that the assumption held ($p > 0.05$). This justifies the use of ordinal logistic regression and valid interpretation of its result (35).

Table II: Pearson Chi-Square test results for model fit in the Ordinal Logistic Regression analysis

	Chi-Square	df	p-values
Pearson	47.757	46	0.401
Deviance	39.041	46	0.757

Link function: Logit

Parameter estimates (Table 3) revealed that mild physical impairment (SPPB = 2) significantly predicted frailty (OR = 30.802, p= 0.019). In contrast, moderate (SPPB = 1; OR = 9.863, p= 0.459) and severe (SPPB = 0) physical impairments were not statistically significant predictors. Age (OR = 0.955, p= 0.778) and $\%FEV_1/FVC$ (estimate = -0.017, p> 0.05) also showed no significant association with frailty.

DISCUSSION

The lack of demographic differences between pre-frail and frail groups aligns with prior research suggesting that frailty progression is driven more by functional decline than chronological age or BMI (19, 29, 30). Unintentional weight loss likely reflecting underlying physiological deterioration (31) and biological changes such as inflammation and hormonal dysregulation (32), thus, a predictive of adverse health outcomes, making it a critical marker for identifying frail individuals.

Table III: Parameter Estimates from the Ordinal Logistic Regression Model Predicting Physical Frailty

Variables	Estimate (β)	OR (exp(β))	p-value
Age	-0.046	0.955	0.778
FEV1/FVC actual (%)	-0.017	0.983	0.517
SPPB = 0 (severe physical impairment)	21.372	0.998	0.998
SPPB = 1 (moderate physical impairment)	2.289	9.863	0.459
SPPB = 2 (mild physical impairment)	3.428	30.802	0.019
SPPB = 3 (good physical performance)	0		

FVC (Forced Vital Capacity); FEV1 (Forced Expiratory Volume in 1 second); OR (Odds Ratio); SPPB (Short Physical Performance Battery). SPPB=0: 0–3 points; SPPB=1: 4–6 points; SPPB=2: 7–9 points; SPPB=3: 10–12 points.

The non-significant trend toward lower SPPB scores in frail participants supports the link between reduced physical performance and frailty (25, 27). However, the absence of statistical significance may reflect limited sample size or heterogeneity in adaptive strategies among moderately impaired individuals. Similarly, preserved FEV_1/FVC ratios in both groups suggest that lung function may not directly contribute to frailty, consistent with studies emphasizing functional decline over pulmonary metrics (14, 18). Although the results of actual FEV_1/FVC ratio and predicted FEV_1/FVC ratio were not statistically significant, the observed trends suggest that declines in physical performance contribute more to frailty progression than lung function decline, even though both may indicate similar vulnerabilities. The trend suggests that frailty progression is associated with worsening physical performance, aligning with previous research showing that lower extremity function strongly predicts disability and frailty (34). The normal or elevated FEV_1/FVC ratios in restrictive lung diseases (33) require further caution against overinterpreting these values.

The strong association between mild physical impairment (SPPB = 2) and frailty highlights a critical threshold for early intervention. Based on the odds ratio indicated, individuals with mild impairment are over 30 times more likely to progress into frailty compared to those with normal physical performance. This highlights the importance of early intervention strategies to prevent further physical decline due to its critical role in frailty progression (27, 34). Our results on mild physical impairment and frailty were not influenced by cognitive impairment, as the study participants with cognitive impairment were screened and excluded On contrary, the non-significant findings for moderate and severe impairments may stem from compensatory strategies (e.g., assistive devices) that mitigate frailty progression (9) or insufficient sample representation (25). The number of participants classified as severely impaired may be too small or underrepresented to generate statistically significant results. This is common in studies with limited sample sizes, where extreme categories (severe impairment) lack sufficient observations to establish strong statistical relationships (25). Studies in (9) suggest that individuals with moderate impairment may be more noticeable and benefit from early intervention strategies that prevent further decline, thereby masking direct associations with frailty (9). In contrast, mild physical impairment significantly predicted frailty (OR = 30.8, p = 0.019), indicating that even minor physical decline increases frailty risk. This finding is supported by a study (25), who demonstrated that lower extremity function is a strong predictor of disability and frailty progression.

The lack of age-frailty association contradicts some literature but aligns with studies emphasizing heterogeneous aging trajectories (36, 37), particularly in health-conscious cohorts (38). Heterogeneous aging trajectories refer to the observation of that individuals age in diverse and variable ways, with significant differences in the rate, pattern, and manifestations of biological, cognitive, and functional changes over time (40). This concept challenges the traditional view of aging as a uniform, linear process and emphasizes that aging is shaped by a complex interplay of genetic, environmental, lifestyle, and socioeconomic factors.

Future studies should explore larger, diverse populations and integrate neuroimaging or longitudinal designs to clarify causal pathways. Apart from that, we acknowledge that the limited sample size reduces the statistical power to detect smaller effect sizes and increases the risk of Type II errors, particularly for the non-significant associations observed with age and lung function. Nevertheless, the study was still sufficiently powered to detect a very large and statistically significant effect of mild physical impairment on frailty status (OR = 30.8, p = 0.019), providing valuable preliminary findings for hypothesis generation. Despite these constraints, the findings emphasize prioritizing early interventions for mild physical decline to mitigate frailty progression.

CONCLUSION

Physical performance with mild impairment represents a critical threshold for frailty progression, underscoring the need for early interventions targeting functional decline among older adults. While age and lung function showed no direct associations, neuromuscular factors likely dominate frailty etiology. Future longitudinal studies with larger, diverse cohorts are warranted to validate these findings and explore causal pathways.

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