RESPIRATORY CARE Paper in Press. Published on May 21, 2013 as DOI: 10.4187/respcare.02471

Correlations between gait speed, six-minute walk, physical activity, and self-efficacy in severe chronic lung disease

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Conflict of Interest Statement: Z.S.D., C.K., P.J.N, and R.P.B. have no potential conflicts of interest to report.

Funding sources: This work was supported by the National Institutes of Health [Grant NIH NHLBI 1R01CA163293-01 (PI: R. Benzo)].

RESPIRATORY CARE Paper in Press. Published on May 21, 2013 as DOI: 10.4187/respcare.02471

Keywords: gait speed, six minute walk test, exercise capacity, chronic obstructive pulmonary disease, interstitial lung disease

Running head: Gait speed in chronic lung disease

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Abstract:

Background: 4-meter gait speed (4MGS) has been associated with functional capacity and overall mortality in elderly patients and may easily be translated to daily practice. We aimed to evaluate the association of 4MGS with meaningful outcomes in chronic lung disease: 6-minute walk test (6MWT) performance, objectively measured physical activity, dyspnea, quality of life and self-efficacy for walking and routine physical activity.

Methods: Patients completed a 4MGS assessment, the 6MWT, questionnaires assessing subjective dyspnea, self-efficacy, and quality of life, and wore a validated physical activity monitor. Gait speed was also measured within three separate time epochs during the 6MWT to explore variability.

Results: 70 patients were enrolled. Diagnoses included COPD (51.4%), ILD (38.6%), and other pulmonary conditions (10%). Mean 4MGS was 0.85 ± 0.21 m/s, 6MWT distance was 305 ± 115 m, and physical activity level was 1.28 ± 0.17 consistent with severe physical inactivity. Gait speeds during the 6MWT within time epochs 1-2, 3-4 and 5-6 minutes were not significantly different at 1.01 ± 0.29, 0.98 ± 0.31, and 1.00 ± 0.31 m/s respectively ($p > 0.5$). 4MGS had a significant correlation with 6MWT performance ($r = 0.70$, $p < 0.001$). 6MWT performance was the dominant variable for predicting 4MGS. Other significant

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variables in the prediction of 4MGS included subjective dyspnea, self-efficacy, quality of life, and objectively measured physical activity.

Conclusions: 4MGS is significantly and independently associated with 6MWT performance and may serve as a reasonable simple surrogate for the 6MWT in patients with chronic lung disease. Gait speed is remarkably stable throughout the 6MWT providing rationale for the validity of an abbreviated walking test such as 4MGS.

RESPIRATORY CARE Paper in Press. Published on May 21, 2013 as DOI: 10.4187/respcare.02471

Abbreviation List:

4MGS: 4-meter gait speed

6MWT: 6-minute walk test

COPD: chronic obstructive pulmonary disease

ILD: interstitial lung disease

PAL: physical activity level

PAH: pulmonary arterial hypertension

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Introduction:

Usual gait speed measured over 4 meters (4MGS) has been associated with a number of clinically important outcomes in the elderly including perceived wellbeing , disability, cognitive impairment, nursing home admission, falls, exercise capacity, cardiovascular and all-cause mortality.[1-8] In chronic lung disease, particularly COPD, 4MGS has been associated with pulmonary function, functional capacity, and health-related quality of life.[7, 9-11] Measuring gait speed requires little space, time or training making it an attractive measure of exercise capacity for routine use in the clinic. Gait speed is modifiable through strength training and rehabilitation making it a potential marker of functional improvement as well as decline of function indicating approaching end of life.[12-14]

Gait speed has accordingly been promoted as a potential “vital sign” to be recorded at each office visit and trended over time.[15, 16] Much like our patients’ other vital signs, gait speed may provide an objective measure of whole organism functioning and may signal meaningful abnormalities in normal system functions requiring intervention. Alternatively, a reduction in gait speed over time may herald short-term mortality providing an opportunity to address advanced care planning optimizing end-of-life care of our patients.[12, 14]

Little is known about which factors influence or contribute to the “construct” of gait speed in patients with chronic lung disease. Psychosocial factors such as perceived self-efficacy and social support have been influential in determining physical activities[17-20], but their effect on gait speed has not been

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evaluated. Therefore, we set out to characterize the relationship between 4MGS and various psycho-physiologic measures including the 6MWT, objectively measured physical activity, dyspnea perception, quality of life, and task-specific self-efficacy in a well-characterized cohort of patients with chronic lung disease. We also sought to measure gait speed throughout the 6-minute walk test (6MWT) in order to better understand the relationship between gait speed and the 6MWT.

Methods:

This study was approved by the Institutional Review Board of the Mayo Clinic College of Medicine (IRB# 11-008157). Patients with chronic lung disease of any etiology were sequentially enrolled by active recruitment from the special pulmonary lab at the time of a previously scheduled 6MWT. Inclusion criteria included age >18 years, diagnosis of any chronic lung disease, ability to complete the 6MWT and gait speed assessments, and ability to complete a series of written questionnaires.[7] Exclusion criteria included having had an acute respiratory illness in the preceding 4 weeks. Baseline demographic information and pulmonary function values from the preceding 12 months were extracted from the electronic medical record. All patients completed the 6MWT, 4MGS and questionnaires measuring dyspnea, quality of life and self-efficacy for physical activity and walking. All patients were also requested to wear a multisensor

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armband activity monitor (SenseWear Pro ArmBand, BodyMedia, Pittsburgh, PA) for 4 days after returning home.

Questionnaires

Dyspnea Status

Dyspnea status was assessed using the modified Medical Research Council (MMRC) dyspnea scale (range 0-4) as previously described.[21]

Self-efficacy for walking (SEW)

In order to assess self-efficacy for walking during the 6MWT we generated a non-validated Likert-style questionnaire specifically for use in this study (Appendix #1). The questionnaire is comprised of 7 items (numbered 1-7) asking patients to rate their confidence from 1 (not at all confident) to 5 (highly confident) for successfully completing a variety of increasing distances during their 6MWT. Distances for the 7 items were 55, 110, 165, 220, 330, 402, and 805 meters respectively. For each distance patients were also provided with a rough equivalency in American football fields and average city blocks to provide a more tangible real-world example of distance. For example, one football field or city block equals roughly 110 meters and two football fields or city blocks equals roughly 220 meters. Patients were also specifically instructed to visualize the

RESPIRATORY CARE Paper in Press. Published on May 21, 2013 as DOI: 10.4187/respcare.02471

length of the 6MWT pathway and informed that it is 105 feet (32 meters) in length prior to completing the questionnaire. The patients completed the questionnaire twice, once prior to completing the 6MWT (pre-test) and then once again following the 6MWT without knowledge of their actual performance (post-test). Scores ranged from 0-7 and were assigned according to the greatest distance (item number) for which the patient rated at least moderate confidence for success (≥4). For example, if an individual rated their confidence for walking up to 165 meters (comprising items 1-3) as 5/5, 220 meters (item 4) as 4/5, 330 meters (item 5) as 3/5, and the remaining distances (items 6-7) as 1/5 they would be given an SEW score of 4 corresponding to the greatest distance (220 meters or item 4) for which they reported a confidence score of at least 4/5.

Self-efficacy for physical activity (SEPA)

Self-efficacy for minimal daily physical activity was assessed using a non-validated Likert-style questionnaire also generated specifically for this study (Appendix #2). The questionnaire is comprised of 5 items asking patients to rate their confidence from 1 (not at all confident) to 5 (highly confident) that they are physically active daily and in the face of a variety of barriers. Item one is “How confident are you that you are physically active every day?” The remaining items were all phrased similarly as follows: “How confident are you that you are physically active even when: 2) your day doesn’t go the way you wanted or expected? 3) you feel tired or fatigued? 4) you are in mild pain or have mild

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respiratory discomfort? 5) you feel depressed, worried, or stressed out?. Scores ranged from 1-5 and were determined by adding the results of each item and dividing by 5 to determine an average of the 5 items.

Linear Analog Self-Assessment (LASA)

The LASA (Appendix #3) is comprised of multiple Likert scales targeting specific domains of quality of life ranging from 0 (as bad as it can be) to 10 (as good as it can be). It has been utilized and validated in various formats.[22-25] For this study we utilized 6 individual items assessing well-being in 4 domains (physical, mental, emotional, and spiritual) in addition to levels of social activity and overall quality of life.

Pulmonary Function Testing

The most recent pulmonary function results completed within the preceding 12 months were extracted from the electronic medical record for each patient for whom they were available. All pulmonary function tests were performed according to the current guidelines and established reference values.[26] Pre-bronchodilator values were used for all statistical analyses.

RESPIRATORY CARE Paper in Press. Published on May 21, 2013 as DOI: 10.4187/respcare.02471

4-meter Gait Speed (4MGS)

4MGS was measured using a technique similar to that described by Kon et al.[11] Patients were positioned with their toes at the starting line of a 4-meter course clearly demarcated using red tape. The patients were instructed to walk at their normal comfortable walking speed and specifically instructed to “walk as though you are walking out to your mailbox or walking to your car in a parking lot.” They were instructed to begin walking following the audible countdown “3,2,1,go” and a handheld timer was started concurrently with verbalization of the word “go”. The timer was stopped once one foot struck the ground completely beyond the finish line. This process was performed twice consecutively without rest and the faster of the two times was used for data analysis. Patients were allowed to use their usual walking aids and oxygen supplementation. Gait speed was calculated by dividing 4 meters by the time in seconds required to complete the course.

6-Minute Walk Test

The 6MWT was completed according to the standards set forth in the ATS guidelines.[27]

RESPIRATORY CARE Paper in Press. Published on May 21, 2013 as DOI: 10.4187/respcare.02471

Gate speeds during the 6MWT

Gate speed was measured for each patient during the 6MWT within three distinct time epochs (between 1-2 minutes, 3-4 minutes, and 5-6 minutes into the test) as they passed through a 4-meter course that was clearly demarcated using two pieces of red tape in the center of the 32-meter course used for the 6MWT. In each case a handheld timer was started once one foot struck the ground completely beyond the starting line and then stopped once one foot struck the ground completely beyond the finish line. If a patient did not pass through the 4-meter course during a given time epoch no measure was acquired. Gait speed was calculated by dividing 4 meters by the time in seconds required to complete the 4-meter course.

Objective measurement of physical activity: The physical activity level (PAL)

The PAL has been proposed by the World Health Organization as an objective measure of physical activity with a PAL ≥1.70 defining an active person, 1.40-1.69 defining a sedentary person, and <1.40 defining severe physical inactivity. Physical activity was measured in our cohort by a validated multisensor armband (SenseWear Pro ArmBand, BodyMedia Inc., Pittsburgh, PA).[28, 29] Patients were instructed in the use of the activity monitor and were asked to wear it for 23 hours per day (except when bathing) for 4 days. The device was mailed directly to the

RESPIRATORY CARE Paper in Press. Published on May 21, 2013 as DOI: 10.4187/respcare.02471

patient's home and was returned via a pre-paid return envelope. The data from the device was downloaded to a dedicated software package (InnerView Research Software v.2.2, BodyMedia Inc., Pittsburgh, PA). Resting metabolic expenditure was calculated by multiplying a consistent value of energy expenditure during one minute of sleep by 1,440 to estimate daily resting energy expenditure. The PAL was subsequently calculated by dividing total daily energy expenditure by daily resting energy expenditure.[30] Time spent engaged in sedentary (<2 metabolic equivalents [METS]), light (2-4 METS), moderate (4-6 METS), and vigorous (>6 METS) activity was also recorded.[40]

Statistical analysis

Based on prior literature, the expected correlation (r) between 6MWT and gait speed was assumed to be 0.7. Determined with the probability of Type I error (alpha) of 0.05, power (1-beta) of 0.9, and correlation of 0.7, the number of patients needed for the study was calculated at 57. Descriptive summary statistics were reported for all included patients. Associations between variables involved Spearman correlations and Bland-Altman analysis. Comparisons between subgroups were carried out using Wilcoxon tests for continuous variables and chi-square tests for categorical variables. Stepwise multivariate linear regression models were used to explore the associations between gait speed and other patient characteristics. All analyses were done using SAS version 9 (SAS Institute Inc. 2002-2006. *Base SAS 9.1.3 Procedures Guide*).

RESPIRATORY CARE Paper in Press. Published on May 21, 2013 as DOI: 10.4187/respcare.02471

Results:

Patient characteristics are listed in Table 1. Patients were older and slightly overweight in general. The most common diagnosis was COPD (51.4%) followed by ILD (38.6%), PAH (7.1%), and other miscellaneous conditions (2.9%). In the ILD group, twenty patients (74%) had usual interstitial pneumonia and three (11%) had non-specific interstitial pneumonia. Disease burden was severe overall reflected by a mean percent of predicted forced expiratory volume in 1 second ($FEV_{1\ \%pred}$) of 31.5% in patients with COPD and a mean percent of predicted total lung capacity ($TLC_{\%pred}$) of 60.4% in patients with ILD. 6MWT performance was fair overall with a mean of 305 meters, but varied widely from extremely poor (minimum 40 meters) to excellent (maximum 568 meters).[31] Mean self-efficacy for physical activity was moderate (3.2 / 5) and self-efficacy for walking was generally low (3.1 / 7). Objectively measured daily physical activity was very low with a mean PAL of 1.28 for the 58 patients that wore the monitor for the 4 days required for data extraction.[32] When patients were divided into those with COPD versus all other diagnoses there was no difference in age, gender, MMRC dyspnea grade, 4MGS, 6MWT performance, time spent in various levels of activity (sedentary, light, moderate, and vigorous), or PAL (all p-values >0.15).

RESPIRATORY CARE Paper in Press. Published on May 21, 2013 as DOI: 10.4187/respcare.02471

Gait speeds

The mean 4MGS was 0.85 ± 0.21 m/s. Gait speeds during the 6MWT were 1.01 ± 0.29, 0.98 ± 0.31, and 1.00 ± 0.31 m/s during three well pre-defined time points during the test: between the first and second minutes, third and fourth minutes, and fifth and sixth minutes of the 6MWT respectively (as the patients passed through a 4-meter path marked in the hallway). Bland-Altman analyses performed in a pair-wise fashion demonstrated no significant difference per patient between the gait speeds measured during the 6MWT (all p-values >0.5).

4MGS correlations

Statistically significant Spearman correlation coefficients between 4MGS and all other measures are shown in Table 3. The strongest correlation was between 4MGS and 6MWT performance at 0.70 (p <0.001) followed by a correlation of -0.44 (p <0.001) with MMRC dyspnea grade. Five of the six items in the LASA had significant correlations with 4MGS, the highest of which was 0.42 (p <0.001) for patient level of social activity. Both self-efficacy measures correlated fairly with 4MGS; self-efficacy for walking at 0.38 (p = 0.001) and self-efficacy for physical activity at 0.35 (p = 0.003). A significant but modest correlation was present between 4MGS and PAL (*r* = 0.35, p = 007) and time spent in moderate and vigorous physical activity were also both correlated with 4MGS with coefficients of 0.41 (p = 0.003) and 0.32 (p = 0.025) respectively. The correlation

RESPIRATORY CARE Paper in Press. Published on May 21, 2013 as DOI: 10.4187/respcare.02471

between 4MGS and time spent in light activity was weak (*r* = 0.25, p = 0.077) and approached, but did not reach, statistical significance.

Multivariate modeling for predicting 4MGS

The construct of gate speed was explored by fitting multivariate linear regression models to predict 4MGS including the following variables: age, gender, MMRC dyspnea grade, diagnosis (COPD vs other), body mass index, diffusing capacity of the lung for carbon monoxide (DLCO), six individual LASA items (overall health, physical, spiritual, emotional, intellectual and mental domains), self-efficacy for walking score, self-efficacy for physical activity score, and 6MWT performance. The first model showed that only the 6MWT was significant with an adjusted R^2 value of 0.49 (p <0.001). A second model excluding the 6MWT to determine which other variables may be contributing to 4MGS showed that SEW score (p = 0.022), SEPA score (p = 0.044), a diagnosis of COPD (p = 0.029), and the LASA item assessing level of social activity (p = 0.016) were associated with 4MGS with a combined R^2 value of 0.30 (p <0.001).

Discussion:

This study shows that 4MGS, a reproducible and easily performed measurement, is significantly associated with 6MWT performance. Our results suggest that 4MGS may represent a reasonable surrogate for the underutilized 6MWT, an

RESPIRATORY CARE Paper in Press. Published on May 21, 2013 as DOI: 10.4187/respcare.02471

unquestionable measure of morbidity in chronic lung disease.[33-40] Given that a reduction in gait speed during the 6MWT by 0.15m/s in one year is associated with a significant increase in mortality over the ensuing year in patients with severe COPD, our results demonstrating the association between 4MGS and 6MWT performance have relevance and are seminal for prompting further investigation. [12, 14]

Kon et al previously found that 4MGS correlated well with the incremental shuttle walk test in patients with COPD.[11] Our results are corroborative; however, we have extended upon their findings by demonstrating an association with a much more widely utilized measure of exercise capacity and wellness: the 6MWT. Furthermore, our demonstration of the remarkable stability of gait speed during the 6MWT provides further rationale for the value and predictive abilities of a shorter walking test utilizing gait speed analysis. Leung et al have previously shown that a 2-minute walk test had a very high correlation (r = 0.937) with the 6MWT in patients with COPD.[41] Furthermore, they found that the 2-minute walk test was equally responsive to improvement following completion of a pulmonary rehabilitation program indicating that an abbreviated walking test can still be sensitive to change. Their findings in conjunction with ours suggest that an abbreviated walking test like 4MGS may be acceptable for routine use in the clinic.

The *construct* of gait speed and the possible influence of psychosocial factors such as self-efficacy, emotional well-being, social activity, and spiritual well-being have not been extensively evaluated previously. After testing an

RESPIRATORY CARE Paper in Press. Published on May 21, 2013 as DOI: 10.4187/respcare.02471

extensive number of important psychological and physiological factors we found that 6MWT performance was the strongest predictor of 4MGS ($r = 0.70$) indicating that 4MGS is more related to a self-paced exercise test than objectively measured physical activity or perception measures including dyspnea, self-efficacy and quality of life. This was evidenced by a fairly informative multivariate regression model including only the 6MWT ($R^2 = 0.49$). We speculate that the dominance of the 6MWT in our multivariate model indicates that the 6MWT(a test in which the patient self-regulates walking velocity) intrinsically accounts for volitional and perceptive factors like self-efficacy, subjective dyspnea, and overall well-being. We also found that self-efficacy for walking and physical activity, level of social activity, and a diagnosis of COPD were contributing to the construct of gait speed in an alternative but less informative model excluding the 6MWT ($R^2 = 0.30$).

To our knowledge this is the first study to report on the correlation between usual gait speed and objectively measured physical activity. Interestingly, we found that the correlation between gait speed and overall physical activity was relatively weak (r = 0.35). More specifically, 4MGS was associated with vigorous (>6 METS, r = 0.41) and moderate (4-6 METS, r = 0.32) activity but not light daily activity (2-4 METS). The inherent limitation of using any measure of exercise capacity as a surrogate for physical activity is that patient preferences and priorities towards physical activity are left unaccounted. Patients may choose to live sedentary lifestyles despite relatively high exercise capacities and, conversely, patients with exercise limitations may still make daily physical

RESPIRATORY CARE Paper in Press. Published on May 21, 2013 as DOI: 10.4187/respcare.02471

activity a priority. This is a limitation that is unlikely to be overcome by any simple measure of exercise capacity making the prediction of physical activity a challenging goal that will likely require both physical and psychosocial assessments.

There are limitations to our study. First is that the sample size prevented generation of more robust prediction models. However, the comprehensiveness of our measures begins to fill the knowledge gap regarding the construct of gait speed and helps in the design of future longitudinal studies in which gait speed studied. Second, we only measured 4MGS using the most commonly employed normal velocity “static start” methodology. We are, therefore, unable to comment on methodologic advantages of “usual” versus “fast” gait speed. Given that a decline in maximal sustainable gait speed derived from 6MWT performance is related to end of life in COPD, additional work in this area is needed. Finally, our self-efficacy questionnaires were created specifically for this study and are therefore not validated tools; nonetheless, we believe they performed the desired goal of assessing patient confidence for the tasks in question (walking during the 6MWT and minimal physical activity).

In summary, our data show that 4MGS is strongly associated with 6MWT performance and may serve as a reasonable surrogate for the 6MWT in patients with chronic lung disease. We feel that demonstrating an association between 4MGS and 6MWT performance is an advantage of this study since the 6MWT is an unquestionable measure of wellness in all lung diseases. This represents the first report regarding the association of usual gate speed, maximal sustainable

RESPIRATORY CARE Paper in Press. Published on May 21, 2013 as DOI: 10.4187/respcare.02471

walking velocity and different levels of physical activity. Also, our demonstration of the stability of gait speed during the 6MWT further suggests that an abbreviated walking test may provide much of the same information as the full 6MWT. We believe the value of our study is that it sheds light on the construct of 4MGS, a novel tool with the potential to offer health care providers an objective measure of functional status and exercise capacity longitudinally, allowing for optimization in the care of patients with chronic lung disease.

RESPIRATORY CARE Paper in Press. Published on May 21, 2013 as DOI: 10.4187/respcare.02471

Acknowledgments:

Funding sources: This work was supported by the National Institutes of Health [Grant NIH NHLBI 1R01CA163293-01 (PI: R. Benzo)].

Author contributions:

Dr. DePew: contributed to the design of the study, data collection, data analysis, and writing the manuscript.

Dr. Karpman: contributed to data analysis and writing the manuscript.

Mr. Novotny: contributed to the statistical analysis and writing the manuscript.

Dr. Benzo (guarantor): contributed to the design of the study, data collection, data analysis, and writing the manuscript.

We would like to thank Mrs. Marnie Wetzstein and Mrs. Johanna Hoult for their assistance with logistical management of the study.

RESPIRATORY CARE Paper in Press. Published on May 21, 2013 as DOI: 10.4187/respcare.02471

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RESPIRATORY CARE Paper in Press. Published on May 21, 2013 as DOI: 10.4187/respcare.02471

Table 1: Patient characteristics

Characteristic	N = 70
Female	37 (53%)
Age (years)	61.4 ± 9.6
BMI (kg/m^2)	28.6 ± 7.6
MMRC dyspnea grade (scale 0-4)	2.6 ± 0.73
SEW	3.11 ± 2.15
SEPA	3.18 ± 1.04
$FEV_{1\ \%pred}$ (COPD)	31.5 ± 13.9
TLC $_{\%pred}$ (ILD)	60.4 ± 12.2
DLCO	42 ± 18.6
Physical Activity Level	1.28 ± 0.17
6MWT distance (meters)	305 ± 115
4-meter gait speed (m/s)	0.85 ± 0.21
Gait speeds during 6MWT (m/s)	1-2 min – 1.01 ± 0.29 3-4 min – 0.98 ± 0.31 5-6 min – 1.00 ± 0.31

Data are presented as n (%) or mean ± SD. BMI: body mass index; MMRC: modified Medical Research Council; SEW: self-efficacy for walking; SEPA: self-efficacy for physical activity; FEV_1: forced expiratory volume in one second; $_{\%pred}$: percent predicted; COPD: chronic obstructive pulmonary disease; TLC: total lung capacity; ILD: interstitial lung disease; DLCO: diffusing capacity of the lung for carbon monoxide; 6MWT: 6-minute walk test.

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Table 2: Spearman correlation coefficients between 4-meter gait speed and all other significant variables

	4MGS
6MWT	0.70 (p <0.001)
MMRC dyspnea grade	-0.44 (p <0.001)
LASA 5 (social activity)	0.42 (p <0.001)
Time in moderate activity (4-6 mets)	0.41 (p = 0.003)
SEW	0.38 (p = 0.001)
LASA item 1 (quality of life)	0.36 (p = 0.002)
SEPA	0.35 (p = 0.003)
Mean PAL	0.35 (p = 0.007)
LASA item 4 (emotional well-being)	0.32 (p = 0.006)
Time in vigorous activity (> 6 mets)	0.32 (p = 0.025)
LASA item 2 (mental well-being)	0.30 (p = 0.011)
LASA item 3 (physical well-being)	0.27 (p = 0.025)

6MWT: 6-minute walk test; MMRC: modified Medical Research Council; LASA: Linear Analog Self Assessment; SEW: self-efficacy for walking; SEPA: self-efficacy for physical activity; PAL: physical activity level