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# Social Determinants of Adherence to Pulmonary Rehabilitation for Chronic Obstructive Pulmonary Disease

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## Abstract

Adherence to pulmonary rehabilitation (PR) is low. Previous studies have focused on clinical predictors of PR completion. We aimed to identify social determinants of adherence to PR. A cross-sectional analysis of a database of COPD patients ($N = 455$) in an outpatient PR program was performed. Adherence, a ratio of attended-to-prescribed sessions, was coded as low (<35%), moderate (35-85%), and high (>85%). Individual-level measures included age, sex, race, BMI, smoking status, pack-years, baseline 6-minute walk distance (6MWD: <150,150-249, ≥250), co-morbidities, depression, and prescribed PR sessions (≤20,21-30, >30). Fifteen area-level measures aggregated to Census tracts were obtained from the U.S. Census after geocoding patients' addresses. Using exploratory factor analysis, a neighborhood socioeconomic disadvantage index was constructed, which included variables with factor loading >0.5: poverty, public assistance, households without vehicles, cost burden, unemployment, and minority population. Multivariate regression models were adjusted for clustering on Census tracts. Twenty-six percent of patients had low adherence, 23% were moderately adherent, 51% were highly adherent. In the best fitted full model, each decile increase in neighborhood socioeconomic disadvantage increased the risk of moderate vs high adherence by 14% ($p < 0.01$). Smoking tripled the relative risk of low adherence ($p < 0.01$), while each increase in 6MWD category decreased that risk by 72% ($p < 0.01$) and 84% ($p < 0.001$), respectively. These findings show that, relative to high adherence, low adherence is associated with limited functional capacity and current smoking, while moderate adherence is associated with socioeconomic disadvantage. The distinction highlights different pathways to suboptimal adherence and calls for tailored intervention approaches.

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**Keywords**

adherence; pulmonary rehabilitation; social determinants; socioeconomic disadvantage

## Introduction

Completion of pulmonary rehabilitation (PR) for chronic obstructive pulmonary disease (COPD) has been associated with a decrease in exacerbations and hospitalizations (1) and improvement in dyspnea, functional capacity, and quality of life (2). Despite these benefits, many patients with COPD do not complete prescribed PR, with attrition rates up to 60% (3–5). Research on adherence to PR has focused on clinical and demographic characteristics (3, 6). Although the contribution of socioeconomic factors for completion of PR has been acknowledged (7–9), the associations are poorly understood. Few studies have investigated the social determinants affecting the ability of patients to complete prescribed treatments.

The scarcity of social research on adherence to PR stems from a narrow understanding of the ways in which social context impacts adherence to medical recommendations. Studies investigating social predictors of adherence to PR have used measures limited to demographic characteristics, marital and employment status, and educational attainment (10). The social context, however, is a multidimensional construct defined by access to financial, human, and social resources and capital (11). This premise, well-established in the sociological literature (12), has not been applied to research on PR in COPD.

The social, economic, and cultural contexts influence the health-related behaviors of individuals, as evidenced by the social patterning of tobacco and alcohol use, diet and physical activity, or preventive care utilization (13–16). Nevertheless, predictors of PR adherence have seldom been assessed from a sociological perspective. The purpose of this study was to identify predictors of adherence to PR by applying the Health Lifestyle Theory (17, 18), which correlates individual health practices with structural factors such as class circumstances (income, wealth, education, occupational prestige) and living conditions. Based on this framework, we hypothesized that socioeconomic disadvantage is associated with decreased adherence to PR in patients with COPD.

## Methods

### Study design and population sample

We performed a cross-sectional analysis of a prospectively maintained clinical database of patients ($N$ = 455) who had attended an outpatient PR program at the University of Alabama at Birmingham (UAB) between 1996 and 2013. Due to the large span of the program, analyses controlled for year of PR. The database, described in detail elsewhere (19), included patients with a primary diagnosis of COPD (International Classification of Diseases Codes 491, 492, and 496) at the time of enrollment in PR. PR sessions were prescribed by an exercise physiologist with the number of sessions determined based on medical history review, severity of disease, and walk test distance. Participants attended two to three sessions per week, for a maximum of 36 sessions over 12 weeks. Exercise regimens

followed standard PR guidelines (20) and included aerobic exercises such as treadmill walking, cycle, and arm ergometry; resistance training such as machine weights, hand weights, and elastic bands; and breathing training techniques such as diaphragmatic breathing and pursed lips breathing. Regimens were individualized according to patients' exercise tolerance indicated by a baseline 6-minute walk distance test (6MWD) as well as their subjective sense of dyspnea. Those who continued to smoke were allowed to participate in the program.

Demographic and clinical data were obtained prior to the initial PR session. To obtain socioeconomic data, we geocoded patients' residential addresses and assigned a Census tract identifier to each record. Data at the Census tract level were downloaded from the U.S. Census Factfinder website (https://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml) and matched to patients: year 2000 Census data were used for patients with first PR attended between 1996 and 2005, while year 2010 Census data were used for those with first PR attended between 2006 and 2013. The distance from a patient's residence to the outpatient PR facility was calculated using the driving directions provided by Google Maps (https://www.google.com/maps) and selecting the fastest driving route. Ethical approval for this study was obtained from the UAB Institutional Review Board, Protocol X160907008.

## Measures

**Individual characteristics—**Adherence to PR was calculated as a ratio of attended-to-prescribed sessions for the first PR series on record. Adherence rates were not normally distributed, with 44% of participants being 100% adherent. We therefore coded adherence rates as low (<35%), moderate (35–85%), and high (>85%), using cut-offs from previous adherence studies (21–24).

Demographic characteristics included age, sex, and race (White/Black/Other). Clinical characteristics included body mass index (BMI, $kg/m^2$), current smoking (Yes/No based on self-report at the PR enrollment visit), smoking pack-years, and number of co-morbidities (simple count based on physician diagnosis). Depression (Yes/No based on physician diagnosis) was included separately because of its established role in adherence. Baseline functional capacity, assessed with the 6-minute walk distance test (6MWD, in meters), was coded in three categories: < 150, 150–249, ≥250 (25). The number of prescribed PR sessions was coded in three categories: ≤20, 21–30, >30.

**Neighborhood characteristics—**Census tracts, which are small, socio-demographically homogenous geographic units, served as proxies for neighborhoods. Fifteen socioeconomic variables were obtained from the U.S. Census: 1) % Adults age 25+ without high-school diploma; 2) % Adults age 25+ with college degree; 3) Median household income; 4) % Households with interest, dividend, or rental income; 5) Median value of owner-occupied housing; 6) % Households on public assistance or food stamps; 7) % Households in poverty; 8) % Cost-burdened households (with housing costs >30% income); 9) Civilian unemployment rate; 10) % Households without vehicles; 11) Mean number of household vehicles; 12) % Minority population; 13) % Disabled population; 14) % Households with seniors (age 65+) living alone; and 15) % Single-parent households with children. These

variables reflect various aspects of income, wealth, education, occupation, housing, and family structure and are comparable to measures used previously to examine the effects of neighborhood disadvantage on health (26–29).

### Statistical analysis

Following other studies (27, 30–33), exploratory factor analysis with orthogonal VARIMAX rotation was used to construct an index of neighborhood socioeconomic disadvantage from the 15 candidate variables above. Individual variables were retained if they had a factor loading (i.e., standardized regression coefficient) >0.5. One primary factor emerged, which explained 71% of the total variance and was defined by six variables: public assistance or food stamps, poverty, cost-burden, unemployment, households without a vehicle, and minority population (Table 1). This factor was identified as “socioeconomic disadvantage.”

Next, we constructed a socioeconomic disadvantage index (SDI) by summing the standardized z-scores of the six variables clustered in factor 1 (Cronbach's alpha = 0.91), with higher scores indicating higher disadvantage (range 2.0-59.6, mean = 15.3, SD 11.30). The scores were then categorized into deciles to create a scale of 1 to 10 (mean = 4.52, SD 2.89), which was used continuously. Neighborhoods with SDI scores in the bottom decile were least disadvantaged, while neighborhoods with SDI scores in the top decile were most disadvantaged.

Univariate statistics – means, standard deviations, frequencies, and proportions – were obtained for all non-missing observations. The distribution of individual and neighborhood characteristics was obtained by adherence categories and overall. Bivariate relationships between adherence and every covariate were estimated using simple multinomial logistic regression. Multiple multinomial logistic regression was used to estimate adherence models of individual and neighborhood characteristics. Because the data featured a sparsely populated cluster structure where 49% of clusters represented by Census tracts had a singleton observation, multilevel modeling was not feasible. Instead, we accounted for clustering on Census tracts by adjusting for standard errors and the variance–covariance matrix of estimates to allow for intra-group correlation, relaxing the requirement of independence within clusters (34). Model fit was determined by the difference in Bayesian Information Criterion (BIC) between models. Statistical tests were two-sided and were performed using a 5% significance level ($\alpha = 0.05$). Analyses were performed using Stata software, version 12.

## Results

### Study population

The dataset included 455 patients diagnosed with COPD who had participated in a pulmonary rehabilitation program between 1996 and 2013. We excluded patients ($n =$ 40,8.8%) for whom a Census tract of residence could not be reliably determined due to the use of a P.O. box instead of a street address. The distribution of the excluded patients was random on all variables. The dataset included 211 unique Census tracts: 103 (49%) with

only one patient per tract and 108 (51%) with more than one patient per tract: 55 tracts with 2 patients, 29 tracts with 3 patients, and 24 tracts with ≥4 patients (mean = 2, range 1–9).

Neighborhood characteristics differed considerably between the most and least disadvantaged neighborhoods as measured by SDI. For example, compared to the least disadvantaged neighborhoods, the most disadvantaged neighborhoods had more minority population (91.6% vs 6.7%), more poverty (38.5% vs 3.3%), more unemployment (8.4% vs 2.0%), more households without a vehicle (29.1% vs 1.7%), more cost-burdened households (35.6% vs 8.8%), and more households receiving public assistance or food stamps (29.9% vs 2.1%).

## Characteristics of the sample by adherence status

The characteristics of the final sample ($N = 415$), overall and by adherence status, are described in Table 2. The patient population, mean age 66.1 years (SD 9.3), was 56% male and 70% White; 11% were current smokers. In terms of adherence to PR, 26% had low adherence, 23% were moderately adherent, and 51% highly adherent.

As seen in Table 2, there were no significant differences between adherence groups in terms of age, sex, race, living arrangements, BMI, smoking pack-years, physician-diagnosed depression, or distance to the PR clinic. However, the three adherence groups differed significantly in baseline functional capacity (6MWD), co-morbidities, smoking status, and number of prescribed PR sessions. They also differed in neighborhood characteristics, specifically % households receiving public assistance or food stamps, % households in poverty, % cost-burdened households, % minority population, and % disabled population. The unadjusted mean SDI scores stratified by adherence levels showed that high adherers experienced the lowest socioeconomic disadvantage (4.2, SD 2.9) while moderate adherers experienced the highest (5.2, SD 3.0),$p < 0.01$ (Table 2).

## Multivariate statistics

In a multiple multinomial logistic regression of individual characteristics (Table 3, Model 1), compared with high adherers, low adherers were more likely to be current smokers (RRR 2.98, $p < 0.01$) and have lower functional capacity as measured by 6MWD (RRR 0.30, $p < 0.01$ and RRR 0.17, $p < 0.001$ for 150– 249 m and ≥250 m, respectively; reference category < 150 m). Moderate adherers did not differ from high adherers in terms of individual characteristics. After adding neighborhood characteristics (Table 3, Model 2), all differences between low and high adherers were preserved with minimal changes in effect size, while moderate adherers were more likely than high adherers to experience socioeconomic disadvantage as measured by the SDI (RRR 1.16, $p < 0.01$). In both models, year of PR was positively associated with low adherence (RRR 1.07 and 1.08, respectively; $p < 0.05$ for both).

The best fitted model of individual and neighborhood characteristics adjusted for clustering into Census tracts is presented in Table 4. By this predictive model, White race doubled and current smoking tripled the relative risk of low vs high adherence ($p < 0.05$ and $p < 0.01$, respectively), while each increase in 6MWD category decreased the risk of low adherence by 72% and 84%, respectively ($p < 0.001$ for both). Year of PR was associated with a 10%

increased risk for low adherence ($p < 0.001$) relative to high adherence. Each decile increase in the neighborhood SDI increased the risk of moderate vs high adherence by 14% ($p < 0.01$). Thus, the highest socioeconomic disadvantage was associated with a 140% risk of moderate vs high adherence compared to the lowest socioeconomic disadvantage.

## Discussion

We identified social determinants of adherence to PR by enhancing a clinical database with neighborhood-level socioeconomic measures obtained from the U.S. Census. Findings showed that, relative to high adherence, low adherence was correlated with low adherence as correlated with low functional capacity, current smoking, and White race, while moderate adherence was correlated with socioeconomic disadvantage. The distinction is important because it highlights different pathways to suboptimal adherence and calls for intervention approaches that are tailored to specific types of nonadherence. For example, while adherence-promoting strategies for patients with limited functional capacity may include home-based or inpatient PR, strategies targeting socioeconomically disadvantaged patients may additionally include interventions that address cost- or stress-related barriers.

Socioeconomic disadvantage as a risk factor for adherence to PR is underinvestigated, although it has been acknowledged in the context of adherence to COPD medications (35–38). Our analysis showed that socioeconomic disadvantage is an important correlate of adherence to PR. Similar results have been reported for cardiac rehabilitation, with patients of lower socioeconomic status and current smokers attending three times fewer sessions than patients without such risk factors (39). In our study, patient characteristics predictive of lowest adherence to PR were White race, smoking, and low baseline functional capacity, which may be indicative of health-related barriers to following the exercise regimen. In contrast, patients having moderate adherence were characterized by socioeconomic disadvantage. These findings indicate that in the absence of health-related limitations that drive low adherence, the main barrier to PR is of socioeconomic nature.

Socioeconomically disadvantaged individuals face a variety of chronic stressors in daily living, which trigger unhealthy behaviors (13–16) that help regulate mood (14, 40). The coping functions of such behaviors make them particularly salient and limit the ability of patients to adopt health-beneficial but challenging regimens (15, 41). Future research should test approaches to mitigate the negative impact of socioeconomic disadvantage on adherence to PR. For example, there is evidence that perceived sense of control acts as a buffer against the effect of socioeconomic disadvantage (42). Several studies have reported success in increasing adherence by using positive affect/self-affirmation (43), mindfulness-based stress reduction (44), and financial literacy interventions to reduce financial stress (45).

Traditionally, the adherence behavior has been viewed as a behavioral problem of the patient (46), and adherence-promoting strategies have focused on individual patient psychology, with little consideration of the socio-environmental context in which the patient is situated (47, 48). Meta-analyses show limited success of this approach to behavioral change (49–51), indicating a need for shift toward social factors that impact patients' ability to follow medical recommendations. Understanding adherence to PR as an interaction between the patient and

his or her social environment could produce a more effective framework for achieving better adherence (52, 53).

The majority of research on adherence to PR has focused on completion of prescribed sessions, dichotomizing patients into completers and non-completers (4, 19, 54, 55). In contrast, we coded adherence rates in three categories – low, moderate, and high – on the basis of a calculated ratio of attended-to-prescribed sessions (<35%, 35–85%, and >85%). We chose this approach after preliminary analysis which showed that non-completers are not a homogenous group in terms of clinical and socioeconomic characteristics, and that discerning a degree of non-completion can reveal different non-adherence typologies. The results confirmed this preliminary observation. The adherence rate of 51%, based on attending at least 85% of prescribed sessions, is consistent with previous reports (3–5).

To our knowledge, this is the first study to investigate social determinants of adherence to PR in patients with COPD. The paucity of such research is partially explained by the lack of socioeconomic data in clinical registries and medical records. Despite an increased scientific interest in the role of socio-environmental factors for health, clinical registries rarely include sufficient socioeconomic data. In this study, we overcame this limitation by using area-level socioeconomic data aggregated to Census tracts, proxy for neighborhoods. Although individual- and area-level measures of wealth, income, education, and occupation are closely associated (26), they are not perfectly correlated, especially for racial/ethnic minorities. Ideally, neighborhood-level social indicators should be used together with, rather than in place of, individual-level indicators, as they provide complementary information on social context and living circumstances. This study shows that neighborhood-level data can be used to assess risk of nonadherence to PR. However, it also highlights the need for expanding health records with socioeconomic and spatial data, which is relevant for clinical decision-making.

Systematic reviews have established that socioeconomic disadvantage negatively impacts COPD outcomes, including morbidity and mortality (56), and results in health disparities (57). Possible mechanisms of that correlation include environmental exposures, occupational risk factors, and smoking, all of which are socially stratified. This study highlights adherence to PR as another potential contributor to COPD disparities by social class, suggesting that for COPD patients in relatively good health, the main barriers to high adherence may be of socioeconomic nature.

Outpatient PR is typically prescribed to patients residing within a reasonable commuting distance to an outpatient PR clinic. Driving distance of >36 miles compared to <6 miles has been reported as a risk factor for adherence (58). In this study, the outpatient PR clinic was located in the City of Birmingham, Alabama, where proximity to the city is correlated with socioeconomic disadvantage. The lack of association between driving distance and adherence in this analysis is in line with the finding that socioeconomic disadvantage is a risk factor for adherence.

Finally, it should be noted that the analysis spanned 17 years, and later year of entry in the PR program was a risk factor for low adherence, most likely reflecting changes in patient

characteristics due to program modifications. Specifically, in the initial years of the program, COPD patients were usually referred by a pulmonologist after careful selection in order to maximize the likelihood of PR completion. In later years, referrals to the program increased in number, included more smokers and patients with co-morbidities, and were eventually made automatic at the time of hospital discharge through the implementation of a standard COPD order set. For example, before 2005, 10% of participants were current smokers, compared to 14% after 2005. Similarly, in the first year of the program, patients had an average of 1.1 co-morbidities (SD 1.1), while in the last year they had 3.7 co-morbidities (SD 1.6); the proportion of patients with physician-diagnosed depression increased four-fold. Such changes in patient characteristics have most likely contributed to lower adherence rates over time.

### Limitations

This study has several limitations. First, its cross-sectional design limits the ability to make causal inferences about the observed relationships between socioeconomic disadvantage and decreased adherence. The study is also limited to COPD patients in a single outpatient PR clinic and may not be representative of all COPD patients. Third, our data featured a sparsely populated cluster structure that ruled out multilevel modeling. Instead, we accounted for clustering on Census tracts by adjusting for standard errors and the variance-covariance matrix of estimates.

In this analysis, we used physician-reported measure of depression. As depression, an important determinant of COPD outcomes, tends to be clinically underdiagnosed (59,60), results may have underestimated the true impact of depression on adherence to prescribed PR.

Finally, neighborhood socioeconomic measures, although reasonably correlated with individual-level measures, are not a perfect substitute for individual socioeconomic data. To the extent possible, future adherence studies should collect patient-level socioeconomic indicators.

## Conclusions

Socioeconomic disadvantage and health status impact patients' ability to attend PR over extended periods of time. While smoking and low functional capacity are predictors of low adherence, socioeconomic disadvantage is a predictor of moderate adherence. Interventions to improve adherence to PR should be tailored to the specific pathways leading to suboptimal adherence.

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## Table 1

Orthogonal VARIMAX rotated factor patterns and loadings of neighborhood variables.

| | Variable | Factor loading |
|---|---|---|
| 1 | % Adults age 25+ without high-school diploma | |
| 2 | % Adults age 25+ with college degree | |
| 3 | Median household income | |
| 4 | % Households with interest, dividend, or rental income | |
| 5 | Median value of owner-occupied housing | |
| 6 | % Households on public assistance or food stamps | 0.7385 |
| 7 | % Households in poverty | 0.8534 |
| 8 | % Cost-burdened households (housing >30% income) | 0.6083 |
| 9 | Civilian unemployment rate, % | 0.5110 |
| 10 | % Households without vehicles | 0.8745 |
| 11 | Mean number of household vehicles | |
| 12 | % Minority population | 0.7107 |
| 13 | % Disabled population | |
| 14 | % Households with seniors (age 65+) living alone | |
| 15 | % Single-parent households with children | |

*Note:* Blanks represent factor loading < 0.5.

## Table 2

Characteristics of study participants ($N$ = 415): overall and by adherence status.

| Variables | Overall | Adherence | | |
|---|---|---|---|---|
| | | Low (<35%) 106 (25.5) | Moderate (35–85%) 98 (23.6) | High (>85%) 211 (50.8) |
| ***INDIVIDUAL*** | | | | |
| Age, years (range 41–87) | 66.1 (9.3) | 66.3 (9.6) | 64.6 (9.4) | 66.7 (9.0) |
| Sex | | | | |
| Male | 233 (56.1) | 63 (59.4) | 46 (46.9) | 124 (58.8) |
| Female | 182 (43.9) | 43 (40.6) | 52 (53.1) | 87(412) |
| Race | | | | |
| White | 290 (69.9) | 79 (74.5) | 62 (63.3) | 149 (70.6) |
| Non-White | 125 (30.1) | 27 (25.5) | 36 (36.7) | 62 (29.4) |
| Lives alone | 53 (12.8) | 12 (11.3) | 13 (13.3) | 28 (13.3) |
| BMI, kg/m$^2$ (range 14.2–80.7) | 28.6 (8.5) | 28.4 (82) | 29.5 (9.4) | 28.2 (82) |
| **Co-morbidities (range 0–9)**[a] * | 2.7 (1.9) | 3.0 (1.9) | 2.7 (2.0) | 2.5 (1.8) |
| **6MWD, m**[a] *** | 267.4 (117.0) | 227.0 (121.8) | 270.8 (123.4) | 286.1 (106.5) |
| <150 | 69 (16.6) | 32 (30.2) | 17 (17.4) | 20 (9.5) |
| 150–249 | 110 (265) | 29 (27.4) | 24 (24.5) | 57 (27.0) |
| ≥250 | 236 (56.9) | 45 (19.1) | 57 (68.2) | 134 (635) |
| **Current smoking**[a] ** | | | | |
| Yes | 46(11.1) | 19 (17.9) | 13 (13.3) | 14 (6.6) |
| No | 369 (88.9) | 87 (82.1) | 85 (86.7) | 197 (93.4) |
| Smoking pack-years | 46.8 (42.5) | 51.3(49.0) | 48.8 (54.0) | 43.5 (31.5) |
| Depression | 89 (21.5) | 28 (26.4) | 24 (24.5) | 37 (17.5) |
| **Prescribed sessions**[a,b] * | | | | |
| ≤20 | 107 (25.8) | 23 (21.7) | 20 (20.4) | 64 (30.3) |
| 21–30 | 230 (55.4) | 57 (53.8) | 57 (582) | 116 (55.0) |
| >30 | 78 (18.8) | 26 (24.5) | 21(21.4) | 31 (14.7) |
| Distance from home, miles (range 0.7–183) | 18.2 (21.1) | 18.9 (16.1) | 17.5 (26.3) | 18.2 (20.7) |
| ***NEIGHBORHOOD*** | | | | |
| % College degree | 27.2 (20.7) | 25.8 (19.6) | 30.5 (22.7) | 26.3 (202) |
| % No high school diploma | 16.3 (10.5) | 16.7 (10.2) | 15.0 (10.8) | 16.7 (10.4) |
| Median household income, $ | 46,748.1 (22,261.7) | 46,9615 (22,239.8) | 46,824.7 (24,825.6) | 46,605.3 (21,094.6) |
| % Households with interest, dividend, or rental income | 25.5 (16.5) | 23.3 (14.4) | 24.4 (17.8) | 27.1 (16.8) |
| Civilian unemployment rate, % | 45 (3.5) | 4.8 (3.5) | 4.7 (3.3) | 4.2 (3.6) |
| % Households without vehicle | 8.1 (9.4) | 8.5 (10.8) | 9.4 (9.8) | 7.4 (8.2) |
| Mean number of household vehicles | 1.8 (0.4) | 1.8 (0.4) | 1.8 (0.4) | 1.8 (0.4) |
| Median value of owner-occupied housing, $ | 138,194.0 (88,611.9) | 138,7415 (79,17359) | 148,136.7 (104,997.9) | 133,300.9 (84,752.2) |

| Variables | Overall | Adherence | | |
|---|---|---|---|---|
| | | Low (<35%) 106 (25.5) | Moderate (35–85%) 98 (23.6) | High (>85%) 211 (50.8) |
| % Seniors living alone | 9.9 (45) | 9.9 (4.3) | 10.1 (5.3) | 9.7 (4.3) |
| % Single parents with children | 19.0 (12.5) | 18.1 (14.6) | 19.2 (132) | 19.4(11.1) |
| **% Households with public assistance or food stamps** *b** | 10.1 (9.6) | 10.6 (9.4) | 11.7(11.0) | 9.2 (8.9) |
| **% Households in poverty** *b** | 14.2 (11.8) | 14.5 (11.9) | 16.4 (12.3) | 13.0(11.3) |
| % **Cost-burdened households** *b** | 18.1 (12.0) | 18.1 (14.9) | 20.2 (10.5) | 17.2 (10.9) |
| **% Minority population** *b*** | 375 (33.4) | 35.0 (31.2) | 45.7 (36.2) | 35.1 (32.7) |
| **% Disabled population***a,b*** | 8.4 (8.2) | 10.0 (8.4) | 9.5 (8.3) | 7.1 (8.0) |
| **SDI, deciles** *b*** | 45 (2.9) | 4.5 (2.8) | 5.2 (3.0) | 4.2 (2.9) |

*Notes:* Values are mean (SD) for continuous variables, N (%) for categorical variables.

*a*Low vs high adherence.

*b*Moderate vs high adherence.

Boldface indicates statistical significance of the difference between adherence categories

* $p < 0.05$,

** $p < 0.01$,

*** $p < 0.001$, two-tailed tests).

BMI, body mass index; 6MWD, 6-minute walking distance; SDI, socioeconomic disadvantage index.

## Table 3

Multiple multinomial logistic regression of adherence.

| | Model 1 (individual characteristics) | | Model 2 (individual + neighborhood characteristics) | |
|---|---|---|---|---|
| **Variables** | **RRR** | **[95% CI]** | **RRR** | **[95% CI]** |
| **Low Adherence**[a] | | | | |
| *Individual* | | | | |
| Age | 0.99 | 0.96–1.02 | 0.99 | 0.96–1.02 |
| Male | 1.14 | 0.65–1.99 | 1.14 | 0.68–1.92 |
| White | 1.50 | 0.81–2.76 | 1.91 | 0.95–3.87 |
| Lives alone | 0.92 | 0.42–2.01 | 0.90 | 0.41–1.96 |
| BMI, kg/m$^2$ | 0.99 | 0.96–1.03 | 0.99 | 0.96–1.03 |
| Co-morbidities | 1.08 | 0.92–1.26 | 1.09 | 0.93–1.27 |
| 6MWD, m[b] | | | | |
| 150–249 | **0.30**** | 0.14–0.64 | **0.29**** | 0.12–0.67 |
| ≥250 | **0.17***** | 0.08–0.35 | **0.16***** | 0.08–0.35 |
| Current smoking | **2.98**** | 1.34–6.63 | **2.78*** | 122–6.34 |
| Pack-years | 1.00 | 1.00–1.01 | 1.00 | 1.00–1.01 |
| Depression | 1.44 | 0.59–2.19 | 1.20 | 0.61–2.37 |
| Prescribed sessions[c] | | | | |
| 21–30 | 1.32 | 0.70–2.51 | 1.34 | 0.70–2.56 |
| >30 | 1.48 | 0.65–3.36 | 1.33 | 054–3.26 |
| Distance from home, mi. | 1.00 | 0.99–1.02 | 1.01 | 0.99–1.02 |
| Year | **1.07*** | 1.01–1.14 | **1.08*** | 1.02–1.15 |
| *Neighborhood* | | | | |
| SDI, deciles | — | — | 1.10 | 0.99–1.21 |
| **Moderate Adherence**[a] | | | | |
| *Individual* | | | | |
| Age | 0.98 | 0.95–1.01 | 0.98 | 0.95–1.01 |
| Male | 0.62 | 0.36–1.06 | 0.58 | 0.33–1.02 |
| White | 0.85 | 0.48–151 | 1.26 | 0.66–2.39 |
| Lives alone | 0.97 | 0.46–2.06 | 0.83 | 0.37–1.86 |
| BMI, kg/m$^2$ | 1.00 | 0.97–1.04 | 1.00 | 0.97–1.04 |
| Co-morbidities | 1.00 | 0.85–1.17 | 1.01 | 0.85–1.21 |
| 6MWD, m[b] | | | | |
| 150–249 | 0.51 | 0.22–1.18 | 0.50 | 021–1.18 |
| ≥250 | 0.48 | 0.22–1.03 | 0.47 | 021–1.06 |
| Current smoking | 1.70 | 0.73–3.97 | 1.48 | 059–3.73 |
| Pack-years | 1.01 | 1.00–1.01 | 1.01 | 1.00–1.01 |
| Depression | 1.02 | 0.53–1.97 | 1.06 | 054–2.07 |
| Prescribed sessions[c] | | | | |

| | Model 1 (individual characteristics) | | Model 2 (individual + neighborhood characteristics) | |
|---|---|---|---|---|
| **Variables** | **RRR** | **[95% CI]** | **RRR** | **[95% CI]** |
| 21–30 | 1.67 | 0.89–3.15 | 1.71 | 0.91–320 |
| >30 | 1.87 | 0.82–4.28 | 1.83 | 0.82–4.12 |
| Distance from home, mi. | 1.00 | 0.99–1.01 | 1.00 | 0.99–1.02 |
| Year | 1.04 | 0.99–1.10 | 1.05 | 0.99–1.12 |
| *Neighborhood* | | | | |
| SDI, deciles | — | — | **1.16** ** | 1.04–129 |

Notes:

[a] Reference category = High adherence.

[b] Reference category <150.

[c] Reference category ≤20.

Boldface indicates statistical significance:

* $p < 0.05$,

** $p < 0.01$,

*** $p < 0.001$, two-tailed tests.

BMI, body mass index; 6MWD, 6-minute walking distance; SDI, socioeconomic disadvantage index; RRR, relative risk ratio.

**Table 4**

Individual and neighborhood predictors of adherence.

| Variables | RRR | 95% CI |
|---|---|---|
| **Low Adherence (reference High Adherence)** | | |
| *Individual* | | |
| Age | 0.98 | 0.96–1.01 |
| Male | 1.32 | 0.81–2.13 |
| White | **2.03** * | 1.04–3.95 |
| 6MWD, m (base <150) | | |
| 150–249 | **0.28** *** | 0.12–0.64 |
| ≥250 | **0.16** *** | 0.07–0.34 |
| Current smoking | **3.11** ** | 1.42–6.81 |
| Prescribed sessions (base ≤20) | | |
| 21–30 | 1.28 | 0.70–2.36 |
| >30 | 1.32 | 0.55–3.16 |
| Year | **1.10** *** | 1.04–1.16 |
| *Neighborhood* | | |
| SDI, deciles | 1.08 | 0.98–1.19 |
| **Moderate Adherence (reference High Adherence)** | | |
| *Individual* | | |
| Age | 0.98 | 0.95–1.01 |
| Male | 0.72 | 0.44–1.17 |
| White | 1.33 | 0.71–2.49 |
| 6MWD, m (base <150) | | |
| 150–249 | 0.48 | 0.21–1.10 |
| ≤250 | 0.46 | 0.21–1.02 |
| Current smoking | 1.79 | 0.74–4.32 |
| Prescribed sessions (base ≥20) | | |
| 21–30 | 1.56 | 0.84–2.90 |
| >30 | 1.72 | 0.78–3.79 |
| Year | 1.06 | 1.00–1.12 |
| *Neighborhood* | | |
| SDI, deciles | **1.14** ** | 1.03–126 |

*Notes:* Boldface indicates statistical significance:

* $p < 0.05$,

** $p < 0.01$,

*** $p < 0.001$, two-tailed tests.

6MWD, 6-minute walking distance; SDI, socioeconomic disadvantage index; RRR, relative risk ratio.