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Association of Poverty Income Ratio with Physical Functioning
in a Cohort of Patients with Systemic Lupus Erythematosus

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By

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B.S.
University of Georgia
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Abstract

Association of Poverty Income Ratio with Physical Functioning
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By Courtney Elizabeth Hoge

Background: Lower socioeconomic status (SES) is associated with poor physical functioning in systemic lupus erythematosus (SLE) patients; however, previous studies have not used poverty income ratio (PIR) as a proxy for SES in this population. Additionally, multi-component functional assessments are a novel approach in SLE. Thus, we examined the association of poverty income ratio (PIR) with self-reported physical functioning in a cohort of SLE patients and examined whether this association was similar for self-reported physical functioning and a set of complementary measures of physical functioning.

Methods: We used cross-sectional data on 744 participants from the ongoing Georgians Organized Against Lupus (GOAL) cohort, and secondary analyses used data on 56 participants from a GOAL-ancillary pilot study. Primary analyses utilized multivariable linear regression to estimate the association between PIR (categorized as <1.00, 1.00-1.99, 2.00-3.99, and ≥4.00) and physical functioning (PF; scaled subscore from Short Form-12 survey). Secondary analyses summarized complementary measures of physical functioning as means or percentages by PIR (categorized as <1.00, 1.00-1.99, and ≥2.00).

Results: Overall, the mean age of participants was 48.0 years; 6.7% were male; 80.9% were black; and 37.5%, 21.0%, 29.6% and 12.0% had PIRs of <1.00, 1.00-1.99, 2.00-3.99, and ≥4.00, respectively. The overall mean PF score was 45.8 (36.2, 40.7, 55.5, and 61.2 for PIRs of <1.00, 1.00-1.99, 2.00-3.99, and ≥4.00, respectively). With adjustment, higher PIRs (<1.00, 2.00-3.99, and ≥4.00, respectively vs. 1.00-1.99) remained associated (β (95% CI)) with higher PF scores (-6.0 (-12.8 to 0.8), 10.9 (3.3 to 18.6), and 16.2 (6.4 to 26.0)). In secondary analyses, increased PIR was associated with better physical functioning, in that participants with higher PIRs, on average, had higher scores for measures of physical performance, were less likely to report difficulty with activities of daily living, and had fewer falls in the prior year.

Conclusion: Our results show that higher SES is associated with improved physical functioning across multiple domains, warranting further research into multi-component functional assessments to develop individual treatment plans and potentially improve disparities in outcomes.

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Background

Systemic lupus erythematosus (SLE) is an autoimmune disease characterized by widespread inflammation and multisystem involvement. Survival and life expectancy among patients with SLE have increased over the past few decades as a result of improvements in diagnosis and treatment, shifting the burden of disease management from treating disease-specific manifestations to preventing and treating chronic complications.[1,2] From the patient's perspective, individuals with SLE have to effectively manage and control SLE symptoms and flares, as well as various comorbid conditions.[2] SLE can have an extensive impact on physical, social, and psychological aspects of patient health; thus, patient-reported outcomes have emerged as an important aspect of SLE that should be investigated.[1-3]

In addition to the heterogeneity in manifestations and severity, SLE is also known for its racial and socioeconomic disparities in outcomes.[1,2] Ethnic minorities tend to develop SLE earlier than white populations and often have a greater number of comorbidities, higher disease activity, greater disease damage, and higher mortality.[1] Black patients with SLE have been reported to have a higher prevalence of end-stage renal disease, cardiovascular disease, and multi-organ damage in comparison to white patients.[1,2] Among ethnic minorities, low socioeconomic status (SES) and education are risk factors for worse outcomes, potentially making disease management difficult, as effectively managing multiple health conditions often requires skills that are related to higher SES and education.[2,4] Lower SES among SLE patients has been associated with greater disease damage, worse disease activity, and greater risk for incident depression or worse

depressive symptomatology;[5-8] however, measuring SES directly is difficult and potentially unrealistic. Education and occupation are often used as surrogates for SES, because income is less frequently collected.[4] Studying differences in outcomes by SES in SLE populations is important to better understand this disease, improve treatments, and potentially reduce disparities.

Given the multitude of pervasive symptoms and an unpredictable disease course, SLE often results in work loss,[9,10] activity limitations,[11] and reduced quality of life. Health-related quality-of-life (HRQOL), or the aspects of life that are affected by health or functional status, is consistently reduced in SLE patients[3] for physical, mental, social, and emotional components.[12] In addition to pain and fatigue, other factors that are associated with lower HRQOL in SLE patients include stress, cognitive impairment, and depression.[13-16] Lower HRQOL may be associated with increased disease-related damage and activity; however, these associations are not consistent across studies or time.[17-19] Additionally, low SES, measured as educational attainment and as individual or neighborhood income level, has been associated with lower HRQOL.[6,8,20] Though studies consistently report lower HRQOL in most domains for patients with SLE, both disease-related and non-disease-related factors associated with HRQOL are widely varying and reflect complexities that are involved in examining HRQOL.

SLE patients frequently have muscle weakness, high levels of fatigue, and low rates of physical activity,[21-23] potentially resulting in reduced physical functioning, an important component of HRQOL.[24] Andrews *et al.*[23] indicated that among SLE patients, reduced

lower extremity muscle strength, but not muscle mass, was associated with increased physical disability on the 36-item Short Form Health Survey (SF-36). Meanwhile, Piga *et al.*[25] showed that SLE patients with musculoskeletal manifestations (*i.e.*, arthritis) had greater impairment of HRQOL, as measured by the SF-36, in comparison to similar patients without musculoskeletal manifestations. Though Boström *et al.*[26] demonstrated that there was no association between aerobic capacity and overall disease activity or organ damage in SLE patients, there was a moderately strong association between aerobic capacity and self-reported physical functioning. While each of these elements may be individually associated with poor health outcomes, a comprehensive, patient-centered approach that considers the sum of these factors as contributing to the risk of poor outcomes is imperative for improved treatment.

Physical functioning is commonly studied among SLE patients, as functional limitations due to the disease are widespread. Previous studies frequently rely on self-reported physical functioning,[8,10,11] and while perceived physical functioning is important in addressing HRQOL, objective measures of physical functioning have not been as readily studied in SLE populations.[27] Measures of physical functioning in older adults, such as instrumental activities of daily living (IADLs) and basic activities of daily living (BADLs), history of falls, gait speed, and chair stands,[28] are predictors of worse mortality and health outcomes.[29] Multi-component functional assessments are infrequent in SLE populations, and to our knowledge, this approach has not been utilized for examining disparities in functioning by SES.

Previous studies examining HRQOL and SES have shown that lower SES is associated with worse physical functioning among non-diseased populations.[30] Jolly *et al.*[8] showed that both higher educational attainment and zip-code based annual household income >$35,000 per year were associated with better physical functioning among SLE patients. In a Polish cohort of SLE patients, greater years of education and improved social conditions, which was subjectively assessed using the individuals' residing location, type of building in which they lived, and whether they had access to running water or central heating, was associated with improved physical functioning,[20] when measured using the SF-36. Trupin *et al.*[6] showed that lower individual SES (*i.e.*, educational attainment, annual household income, and at or below 125% of the federal poverty threshold) was associated with greater disease activity, poorer physical functioning, and greater depressive symptomatology, while the association between neighborhood-level SES and these outcomes were weaker. While previous studies have examined the association of SES with physical functioning using educational attainment, zip-code based income, and indicators of income above vs. below the federal poverty threshold, studies have not used income-to-poverty ratio, commonly known as the poverty income ratio (PIR), with more than two categories. Education and especially zip-code-based annual income are limited in the information they portray as proxies for SES, because the sole purpose of zip codes is for postal services, and education may not account for SES differences due to non-modifiable factors (*i.e.*, race or gender). The PIR, which is the official poverty measure of the U.S. Census,[31] not only reflects individual SES but accounts for family size, resulting in an estimate that provides a more accurate picture of an individual's poverty experience.

As previously stated, literature regarding the association between SES and physical functioning is fairly substantial, but to our knowledge, the operational use of PIR to measure SES and its association with physical functioning has not been extensively examined in an SLE population. Studies examining physical functioning in SLE patients frequently utilize self-reported measures,[6,8,20] but do not employ multi-component assessments of functioning, such as those applied in populations of older adults. Additionally, multi-component measures of physical functioning, and how these outcomes differ by SES, have not been extensively studied in SLE populations. Greater understanding of the association of SES (*i.e.*, PIR) with physical functioning, using both perceived and objective measures, may help target interventions and therapies for SLE patients in hopes of ameliorating disparities in outcomes.

Examining the relationship between SES and physical functioning in SLE patients may better inform recommended care for SLE patients. Studies of SES and health outcomes in patients with SLE are diverse; however, previous studies of HRQOL have targeted predominately white populations,[6-8] despite black individuals having a greater susceptibility for worse SLE-related outcomes.[1,2] Therefore, investigating this association in a cohort with better representation of black individuals is needed to advance our understanding of the role of sociodemographic factors in health-related quality of life. Using cross-sectional data from the Georgians Organized Against Lupus (GOAL) cohort, an ongoing, large cohort predominantly comprised of black participants, as well as the Approaches to Positive, Patient-centered Experiences of Aging in Lupus (APPEAL) ancillary pilot study, we examined the association between SES and self-reported

physical functioning. In secondary analyses among the subset of GOAL cohort that participated in APPEAL, we also examined whether this association was similar between self-reported physical functioning and a comprehensive set of other measures related to physical functioning, including objective measures of physical performance.

Methods

Study Populations and Data Sources

For primary analyses, we used data from the ongoing GOAL cohort study, which encompasses a large, population-based sample of patients with SLE from metropolitan Atlanta, Georgia. Recruitment and data collection methods have been previously published.[32] Briefly, participants of GOAL were primarily recruited from the existing Georgia Lupus Registry, a population-based registry funded by the Centers for Disease Control and Prevention, which aimed to estimate the incidence and prevalence of SLE in metropolitan Atlanta.[33] Additionally, patients not included in the registry but who were receiving SLE treatment at Emory University, Grady Memorial Hospital (a large safety-net hospital in Atlanta), or from community rheumatologists in metropolitan Atlanta at the time of recruitment were recruited to enrich the cohort. All participants were recruited by mail, by telephone, or in person, with subsequent assessments performed annually since Wave 1 (baseline; September 2011-September 2012). A total of 850 participants who were aged ≥18 years with a documented diagnosis of SLE (≥4 revised American College of Rheumatology (ACR) criteria[34] or 3 ACR criteria with a final diagnosis of SLE by a board-certified rheumatologist) were included in Wave 1.

For secondary analyses, we used data from the APPEAL ancillary pilot study. Recruitment and data collection methods have been described previously;[27] however, methods are briefly summarized here. Participants of GOAL were eligible for APPEAL if the following inclusion criteria were met: black or white race; ability to speak English;

sufficient hearing and vision to undergo study testing; and ability to travel to an in-person visit for study testing.[27]

We used a cross-sectional design to describe the association of PIR with physical functioning, which were reported via questionnaire during a single wave of GOAL (Wave 5; June 2016 – July 2017). Likewise, a cross-sectional design was used to examine the association of PIR with complementary measures of physical functioning (*i.e.*, objective physical performance, reported activities of daily living, and falls history), which were measured during APPEAL study visits (October 2016 – April 2017). There was a total of 814 adult participants in Wave 5 of GOAL and 60 adult participants in APPEAL. For primary analyses, participants were excluded if they were missing either question comprising the physical functioning summary score (n=14), PIR (n=45), or any other covariates (n=70), leaving 744 participants in the final models. For analyses of complementary measures of physical functioning in APPEAL, participants were excluded if they were missing information on PIR (n=4), yielding a sample of 56 participants. The Emory University Institutional Review Board approved GOAL and APPEAL study protocols, and all participants in GOAL and APPEAL provided informed consent.

Study Variables

Poverty Income Ratio (PIR)

Self-reported PIR was estimated as the ratio of a household income, as reported by the participant, to their appropriate poverty threshold for household size,[35] as defined by the United States Census Bureau. PIR, which was grouped into categories of <1.00, 1.00-

1.99, 2.00-3.99, and ≥4.00 for primary analyses, served as the exposure of interest to estimate the association of different levels of PIR with physical functioning. When examining the association of PIR with complementary measures of physical functioning among the n=56 included in these analyses, PIR was collapsed into categories of <1.00 (household income below the poverty threshold), 1.00-1.99, and ≥2.00 (household income more than twice the poverty threshold) to maximize study power.

Physical Functioning (PF)

Self-reported physical functioning (PF), the primary outcome of interest, was ascertained from the self-administered Short Form-12 questionnaire (SF-12), which is a 12-item version of the SF-36 that is validated[36] and recommended for use in SLE.[12] The PF subscore was calculated from responses to two items of the SF-12: "Does your health now limit you in moderate activities, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf?" and "Does your health now limit you in climbing several flights of stairs?", with possible responses for both items of "yes, limited a lot," "yes, limited a little," and "no, not limited at all." The subscore was scaled 0-100, where higher scores represent better functioning.[37] In sensitivity analyses, PF was also dichotomized as limited a lot vs. not limited a lot for each question that comprised the scaled PF subscore.

Complementary Measures of PF in APPEAL

Physical Performance

Physical performance was assessed using the Short Physical Performance Battery (SPPB).[29] The SPPB assessed balance (ability to hold standing poses in different foot

positions), gait speed (fastest of two 4-meter walks at regular pace), and lower body strength (time taken to complete five chair stands without using arms), which were scored 0-4 (higher scores indicating better levels of physical performance). The physical performance score was the sum of these three individual scores (range 0-12).[29]

Activities of Daily Living

Instrumental activities of daily living (IADLs; *e.g.*, food preparation and housework)[38] and basic activities of daily living (BADLs; *e.g.*, bathing and dressing)[39] were self-reported, yielding scores that were dichotomized as the ability to perform the activity independently or with minimal assistance vs. inability to perform the activity without assistance.

Falls

Participants were asked if they had fallen in the past year and how many falls they had had in the past year.

Other Variables

All other variables were obtained via the Wave 5 GOAL questionnaires. SLE-related organ damage was assessed using the Brief Index of Lupus Damage (BILD) score (range, 0-30), where higher scores indicate greater levels of damage.[40] Depressive symptomatology was assessed via the nine-item Patient Health Questionnaire (PHQ-9; range 0-27), where higher scores indicate more severe depression symptomatology.[41] Current SLE activity was assessed using the Systemic Lupus Activity Questionnaire

(SLAQ) (range, 0-44), with higher scores indicating greater SLE-related disease activity.[42] Age at SLE onset, sex, race, ethnicity, years of education, work status, marital status, and whether receiving social support were self-reported by participants. Disease duration was calculated as the difference in age at survey and age at SLE onset.

Statistical Analysis

Participant characteristics of GOAL were summarized overall and by PIR category using χ^2, Fisher's exact, analysis of variance, or non-parametric equality of medians tests, as appropriate. For the association between PIR and PF, slopes (βs) and 95% CIs were estimated with multivariable linear regression models. Adjustment for age, race, sex, education, marital status, and disease duration, which were considered a priori confounders, was performed. Because SLE-related organ damage (BILD), depression (PHQ-9), and SLE-related disease activity (SLAQ) were considered potential confounders or mediators, separate adjustment for each of these factors was performed using the fully-adjusted multivariable model. Race and current work status were also considered effect modifiers; thus, multivariable models were further stratified by these covariates. Sensitivity analyses of the association between PIR and PF were performed using multivariable logistic regression models for each question comprising the PF subscore to estimate odds ratios (ORs) and 95% CIs. Sensitivity analyses utilized an identical modeling strategy for linear regression models; however, these sensitivity analyses did not address effect modification by race or current work status.

Complementary measures of physical performance were summarized overall and by PIR category. Scores for physical performance and self-reported functioning were reported as

means or percentages, as appropriate. Comparisons of scores across PIR categories were tested via Fisher's exact or non-parametric equality-of-means tests, as appropriate. All analyses were conducted using SAS v. 9.4 (Cary, NC), and the threshold for statistical significant was set at α=0.05.

Results

Characteristics of the SLE Cohort

Table 1 shows that 37.5%, 21.0%, 29.6% and 12.0% of GOAL participants included in our study had PIRs <1.00, 1.00-1.99, 2.00-3.99, and ≥4.00, respectively. The overall mean age was 48.0 years, with mean ages of 44.3 years, 50.4 years, 48.9 years, and 53.1 years for PIRs of <1.00, 1.00-1.99, 2.00-3.99, and ≥4.00, respectively. Overall, 6.7% of the participants were male, and there were no differences in sex by PIR category. Participants with a higher PIR were more likely to be white and married and were also more likely to report having higher educational attainment and to not be receiving social support in the form of disability payment (Table 1).

The mean age at the onset of SLE for all included participants was 32.5 years, while the mean ages at the onset of SLE for PIRs of <1.00, 1.00-1.99, 2.00-3.99, and ≥4.00 were 30.1, 34.3, 32.6, and 35.1 years, respectively. The mean years of disease duration at the time of the survey differed by PIR category, such that participants with a higher PIR were more likely to have longer disease duration (Table 1). The median overall BILD score was 3.0, and there were no differences in BILD scores by PIR. PHQ-9 and SLAQ scores significantly differed by PIR, in that participants with a lower PIR were more likely to have higher depressive symptoms and disease activity scores (Table 1).

Association of PIR with Self-Reported PF in GOAL

The mean scaled PF scores for included GOAL participants with PIRs of <1.00, 1.00-1.99, 2.00-3.99, ≥4.00 were 36.2, 40.7, 55.5, and 61.2, respectively (Table 2). When

adjusting for age, sex, and race, participants with a PIR <1.00 had a PF score that was, on average, 7.0 points lower than participants with a PIR of 1.00-1.99, while participants with a PIR of 2.00-3.99 had a mean PF score that was 13.1 points higher and participants with a PIR ≥4.00 had a mean PF score that was 20.6 points higher than participants with a PIR of 1.00-1.99. Further adjustment for education, marital status, and disease duration did not substantially change these results (Table 2). After multivariable adjustment and adjusting for BILD, PHQ-9, and SLAQ scores individually, differences in PF scores by PIR were reduced; adjustment for SLAQ scores reduced differences in PF scores the most (Table 2).

Stratified Association of PIR with Self-Reported PF in GOAL

Stratifying by current work status indicated that increased PF scores were associated with increasing PIR for employed and unemployed participants; however, tests for effect modification by work status were not statistically significant (Table 3). Among participants who were black, participants with a PIR <1.00 had a PF score that was, on average, 6.4 points lower, participants with a PIR of 2.00-3.99 had a mean PF score that was 10.5 points higher, and participants with a PIR ≥4.00 had a mean PF score that was 17.4 points higher when comparing to participants with a PIR of 1.00-1.99, adjusting for age, sex, education, marital status and disease duration. A similar association was seen among non-black participants, and results for effect modification by race were not statistically significant (Table 3).

Sensitivity Analyses

Sensitivity analyses in which the two SF-12 questions comprising the scaled PF score were dichotomized (Table 4) revealed comparable results to primary analyses. In comparison to participants with a PIR of 1.00-1.99, participants with a PIR <1.00 had 26% increased likelihood of reporting that their health limited moderate activities, while participants with a PIR of 2.00-3.99 had 51% reduced corresponding likelihood and participants with a PIR ≥4.00 had 64% reduced corresponding likelihood. Adjustment for age, sex, race, education, marital status, and disease duration did not considerably change these results. Likewise, individual adjustment of BILD, PHQ-9, and SLAQ scores with multivariable adjustment did not substantially change the association (Table 4). Participants with a PIR <1.00 were 30% more likely to report their health limiting their ability to climb several flights of stairs in comparison to those with a PIR of 1.00-1.99, whereas those with a PIR of 2.00-3.99 were 54% less likely and those with a PIR ≥4.00 were 61% less likely to report limited ability to climb stairs. Further multivariable adjustment did not substantially change the association of PIR with individuals' health limiting their ability to climb several flights of stairs. Additional adjustment for BILD, PHQ-9, and SLAQ scores separately gave similar estimates, but adjusting for SLAQ reduced differences in estimates closer to the null (Table 4).

Complementary PF Measures in APPEAL

The mean PF score for the APPEAL participants included in our study was 38.0, while mean PF scores for participants with PIRs of <1.00, 1.00-1.99, and ≥2.00 were 32.3, 22.5, and 60.0, respectively (Table 5). The overall mean balance score was 3.6, while the

overall mean gait speed score was 3.4; however, neither balance nor gait speed scores statistically significantly differed by PIR category. The mean lower body strength scores for PIRs of <1.00, 1.00-1.99, and ≥2.00 were 1.6, 1.4, and 2.7, respectively. For PIRs of <1.00, 1.00-1.99, and ≥2.00, the mean overall physical performance scores were 8.4, 8.2, and 10.2, respectively. Overall, 35.7% of participants reported difficulty with food preparation, 14.3% reported difficulty with housework, 41.1% reported difficulty with shopping, and 12.5% reported difficulty with transportation; yet, the only IADL that statistically significantly differed by PIR was transportation, where 22.6% of participants with a PIR <1.00 reported difficulty with transportation and 0.0% of participants with PIRs of 1.00-1.99 and ≥2.00 reported difficulty with transportation. Overall, 19.6% of APPEAL participants included in our study reported difficulty with incontinence, which was the only BADL that statistically significantly differed by PIR: 25.8% of participants with a PIR <1.00 reported difficulty with incontinence, 30.0% of participants with a PIR of 1.00-1.99 reported difficulty with incontinence, and 0.0% of participants with a PIR ≥2.00 reported difficulty with incontinence. The mean number of falls that participants reported in the year previous to the study was 2.1. Falls were less frequently reported among those with a PIR >2.00 (26.7% vs. 48.4% and 70.0% for PIRs <1.00 and 1.00-1.99, respectively) although the difference was not statistically significant (Table 5).

Discussion

In this cross-sectional study of a cohort of patients with SLE, we examined the association of PIR with physical functioning. On average, participants with higher PIRs had higher PF scores. However, differences in PF scores by PIR category were greatest among participants with the highest income relative to poverty level, compared to those at the poverty level; whereas those with income below the poverty level had similar scores to those with income at the poverty level. This association was generally robust to adjustment for potential confounders, but less robust to adjustment for SLE-related damage, depression, or SLE-related activity. Additionally, among the pilot participants, those with higher PIRs, on average, had higher scores for measures of physical performance. Other complementary measures of physical functioning indicated better functioning with higher PIRs, with higher PIR being associated with fewer participants reporting difficulties with IADLs and BADLs and reporting fewer falls, although not all associations were statistically significant in this small subset. Overall, we found that higher PIR was associated with better physical functioning and performance across multiple domains.

The overall mean PF score for GOAL was 45.8, while the overall mean PF score for APPEAL was 38.0, indicating that participants of APPEAL had worse physical functioning than GOAL, which is the overall cohort from which APPEAL participants were selected. However, associations of complementary measures of physical functioning with PIR in the APPEAL pilot, on average, reflected similar associations observed in the overall GOAL, that higher PIR was associated with better PF scores. Although PIRs of

2.00-3.99 and ≥4.00 were collapsed into a single category for APPEAL, the lowest and highest PIR categories of APPEAL had similar scores to the lowest and highest PIR categories of GOAL (36.2 and 61.2 vs. 32.3 and 60.0). Differences in physical performance scores, on average, were larger with higher PIR. Of the IADLs, a greater proportion of individuals with lower PIRs reported difficulties with food preparation, housework, laundry, shopping, and transportation. Statistically significant differences in the proportion of individuals reporting difficulties with domains of IADLs by PIR category were only observed for transportation, for which nearly a quarter of those with income below the poverty level reported difficulties, but no respondents in higher categories reported these difficulties. Other IADL domains showed similar patterns even though they were not statistically significant. Likewise, for BADLs, a greater proportion of participants with lower PIRs reported difficulties with bathing, dressing, incontinence, and toileting; yet, statistically significant differences in the proportion of individuals reporting difficulties with BADLs between PIR categories were only observed for incontinence, which was only reported among those at (30%) or below (26%) the poverty level. Though history of falls did not statistically significantly differ by PIR, the mean number of falls in the prior year was lower in higher PIR categories.

Because our method of determining PF scores[37] is not validated across studies of HRQOL, it is unknown whether the estimated differences reflect clinically important differences in physical functioning. However, using the statistical definition of a minimally important difference in PF scores as half a standard deviation of the PF score[43] from the overall GOAL cohort (=18.0 points), we found that the range of mean

unadjusted physical functioning scores was 36.2-61.2, indicating a minimally important difference in PF scores across all PIR categories by this definition, although pairwise differences in mean unadjusted PF scores between adjacent PIR categories were not meaningful.

Regardless of PIR category, PF scores in this cohort and ancillary pilot study were fairly low, as both studies had overall PF scores that were well below the mean of the healthy population in which the SF-12 was developed (50.0).[44,45] Studies investigating predictors of physical functioning also show lower PF scores for individuals with SLE.[46] To our knowledge, previous studies of HRQOL that examined physical functioning and SES have neither used PIR nor a categorization of a similar measure (*i.e.*, a measure that accounts for income relative to family size) with more than 2 categories. Trupin *et al.*[6] showed that increased income was associated with higher PF scores from the SF-36, which is consistent with the results seen in our study, while Kulczycka *et al.*[20] showed a significant correlation between level of education and PF score. Likewise, higher income as a dichotomous exposure has been associated with higher PF scores.[8] Previous studies examining the association of SES with HRQOL report relatively similar results.

In the ancillary pilot study, substantial levels of impairment in physical performance and self-reported functioning were found, irrespective of PIR category. For many domains, increasing PIR was associated with less impairment; however, we also found slightly greater impairment among participants with a PIR between 1.00-1.99 than those with a PIR of <1.00 for balance, lower body strength, and overall physical performance scores.

Regardless of PIR, physical performance in this SLE cohort was comparable to, and sometimes lower than, that in the older (≥70 years) adult population, in which the test was developed.[29] In a population-based sample of older adults born before 1947 in the United States, both educational attainment and occupational attainment were significantly associated with improved physical performance.[47] More specifically, adults who had more sources of income had faster gait speed,[47] which corresponds to the similar association of increased gait speed scores with higher PIRs found in our study.

Our study has limitations not noted above that are worth mentioning. First, this study is cross-sectional, which limits causal inference, and the lack of long-term follow-up data means that we do not know individual trajectories in PIR or physical functioning over time. Exclusions due to missing data, especially with regards to PIR, may have led to selection bias, as individuals uncomfortable reporting this information may be different than those that did; however, missingness was not substantial in the primary analyses (<10%). Selection bias due to missingness in secondary analyses using APPEAL data is also possible, even though missingness was also <10%. Because PF scores were determined using two questions from the SF-12 survey, the measure may not adequately represent physical functioning, and misclassification may have occurred. Misclassification of other covariates is possible, such as disease activity being underestimated because SLAQ does not account for renal disease, which is a strong predictor of disease activity.[19] Additionally, participants indicated feeling the same or better than usual on the day of the APPEAL study visit, which may have led to underreporting of poor functioning[27] (*i.e.*, misclassification). Functioning may fluctuate

over time with SLE activity, so a single measure of physical functioning in GOAL or the measures of functioning performed on the day of assessment in APPEAL may not accurately portray participants' functioning. As with all observational studies, it is possible that we have not accounted for unknown confounders, and thus have residual confounding. With regards to APPEAL, a substantial limitation of our study was due to the small sample size, as analyses were inadequately powered to adjust for factors that influence or confound functioning, such as age, sex, and race. Lastly, generalizability of the results beyond metropolitan Atlanta may be limited, because the cohort is a population-based sample reflecting the demographics of this specific area.

Despite these limitations, our study has several strengths. The relatively large sample size of GOAL limits random error, thereby improving precision. A population-based sample of patients with SLE with adequate representation of black individuals yields an accurate portrayal of HRQOL in a diverse cohort, which is particularly important, as black individuals with SLE are at the greatest risk of poor SLE outcomes. Sensitivity analyses showing that the association between PIR and PF remained after dichotomizing the outcome reduces concerns about whether the measurement of PF scores was too crude or does not represent a comprehensive picture of functioning. Lastly, the use of multi-domain functional assessments is relatively novel in SLE populations, providing new insight that allows for developing individual treatment plans and improving disparities in outcomes.

In conclusion, multi-domain assessments of functioning are a fairly new approach to measuring outcomes in SLE populations. Our study contributes to the body of literature by further exploring disparities in outcomes among SLE patients. Given these results, future directions would include multi-domain assessments in the larger GOAL cohort, as well as investigating trajectories in both SES and functioning, and how these two are associated. Thus, our study highlights the usefulness of a multi-domain approach to establish patient-centered strategies for improvement of functioning, which may be used to improve the burden of SLE and reduce disparities in outcomes.

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Tables

Table 1. Characteristics of SLE patients participating in the Georgians Organized Against Lupus cohort (June 2016 - July 2017) overall and categorized by poverty income ratio

Characteristic	Overall (n=744)	Poverty income ratio[a] <1.00 (n=279)	1.00-1.99 (n=156)	2.00-3.99 (n=220)	≥4.00 (n=89)	p Value[b]
Sociodemographic						
Mean (SD) age at survey	48.0 (13.6)	44.3 (13.9)	50.4 (13.4)	48.9 (13.0)	53.1 (12.0)	<0.001
Sex, no. (%)						
Male	50 (6.7)	16 (5.7)	12 (7.7)	17 (7.7)	5 (5.6)	0.75
Female	694 (93.3)	263 (94.3)	144 (92.3)	203 (92.3)	84 (94.4)	
Race, no. (%)						
Black	602 (80.9)	257 (92.1)	138 (88.5)	154 (70.0)	53 (59.6)	
White	117 (15.7)	16 (5.7)	13 (8.3)	55 (25.0)	33 (37.1)	<0.001
Other	25 (3.4)	6 (2.2)	5 (3.2)	11 (5.0)	3 (3.4)	
Ethnicity, no. (%)[c]						
Hispanic	30 (4.1)	10 (3.6)	5 (3.2)	11 (5.0)	4 (4.5)	0.81
Non-Hispanic	709 (95.5)	266 (96.4)	150 (96.7)	208 (95.0)	85 (95.5)	
Mean (SD) years of education	14.6 (3.0)	13.1 (2.3)	13.8 (2.4)	16.1 (2.9)	17.4 (2.9)	<0.001
Currently employed, no. (%)						
No	449 (60.4)	212 (76.0)	103 (66.0)	104 (47.3)	30 (33.7)	<0.001
Yes	295 (39.7)	67 (24.0)	53 (34.0)	116 (52.7)	59 (66.3)	
Currently married/partner, no. (%)						
No	504 (67.7)	247 (88.5)	125 (80.1)	92 (41.8)	40 (44.9)	<0.001
Yes	240 (32.3)	32 (11.5)	31 (19.9)	128 (58.2)	49 (55.1)	
Currently receiving social support, no. (%)[d]						
No	410 (56.2)	117 (42.4)	71 (47.3)	148 (68.5)	74 (84.1)	<0.001
Yes	320 (43.8)	159 (57.6)	79 (52.7)	68 (31.5)	14 (15.9)	
Clinical						
Mean (SD) age at diagnosis, years	32.5 (12.0)	30.1 (11.3)	34.3 (12.4)	32.6 (12.0)	35.1 (12.3)	<0.01
Mean (SD) disease duration, years	15.4 (10.0)	13.7 (9.9)	16.1 (10.8)	16.2 (9.5)	18.0 (9.6)	<0.001

Table 1. Characteristics of SLE patients participating in the Georgians Organized Against Lupus cohort (June 2016 - July 2017) overall and categorized by poverty income ratio

		Poverty income ratio[a]				
Characteristic	**Overall (n=744)**	**<1.00 (n=279)**	**1.00-1.99 (n=156)**	**2.00-3.99 (n=220)**	**≥4.00 (n=89)**	**p Value[b]**
Median (IQR) BILD score	3.0 (1.0-4.0)	3.0 (1.0-5.0)	3.0 (1.0-4.0)	2.0 (1.0-4.0)	2.0 (1.0-3.0)	0.17
Median (IQR) PHQ-9 score	6.0 (2.0-11.0)	8.0 (4.0-12.0)	7.0 (3.0-12.0)	5.0 (2.0-9.0)	3.0 (2.0-8.0)	<0.001
Median (IQR) SLAQ score	15.0 (9.0-22.0)	18.0 (12.0-24.0)	16.0 (9.5-22.0)	11.0 (7.0-18.0)	10.0 (7.0-15.0)	<0.001

[a]Ratio of household income to appropriate poverty threshold for household size, as defined by the United States Census Bureau (lower poverty income ratio indicates greater poverty)
[b]By χ^2, Fisher's exact, analysis of variance, or non-parametric equality-of-medians test, as appropriate
[c]Missing data, n=739
[d]Missing data, n=730
BILD: Brief Index of Lupus Damage, PHQ-9: nine-item Patient Health Questionnaire, SLAQ: Systemic Lupus Activity Questionnaire: higher scores indicate more of the domain measured with these instruments
SLE: systemic lupus erythematosus

Table 2. Association between poverty income ratio and self-reported physical functioning among participants with SLE in the Georgians Organized Against Lupus cohort[a]

	Poverty income ratio[b]			
Outcome	**<1.00**	**1.00 - 1.99**	**2.00 - 3.99**	**≥4 .00**
Mean (SD) physical functioning score[c]	36.20 (34.16)	40.71 (35.38)	55.45 (34.85)	61.24 (34.75)
Difference in physical functioning score[c] (95% CI)				
Unadjusted	-4.50 (-11.31, 2.30)	1.00 (ref.)	14.75 (7.62, 21.88)	20.53 (11.48, 29.58)
Age, sex, and race adjusted	-7.02 (-13.79, -0.25)	1.00 (ref.)	13.09 (6.00, 20.17)	20.62 (11.54, 29.69)
Multivariable-adjusted[d]	-6.02 (-12.81, 0.76)	1.00 (ref.)	10.90 (3.25, 18.55)	16.21 (6.39, 26.03)
Multivariable + BILD score	-4.13 (-10.80, 2.55)	1.00 (ref.)	10.91 (3.42, 18.39)	13.47 (3.82, 23.13)
Multivariable + PHQ-9 score	-4.92 (-11.22, 1.38)	1.00 (ref.)	7.99 (0.87, 15.11)	12.34 (3.21, 21.48)
Multivariable + SLAQ score	-2.56 (-8.82, 3.69)	1.00 (ref.)	6.51 (-0.55, 13.57)	9.17 (0.08, 18.25)

[a]Analysis of complete data (n=744)

[b]Ratio of household income to appropriate poverty threshold for household size, as defined by the United States Census Bureau (lower poverty income ratio indicates greater poverty)

[c]Scaled score of physical functioning (PF) subscore from twelve-item Short-Form Health Survey (SF-12), 0-100 (higher scores indicate better physical functioning)

[d]Adjusted for age, sex, race (black vs. not black), education, marital status (married vs. not married), and disease duration

BILD: Brief Index of Lupus Damage, PHQ-9: nine-item Patient Health Questionnaire, SLAQ: Systemic Lupus Activity Questionnaire: higher scores indicate more of the domain measured with these instruments

SLE: systemic lupus erythematosus

Table 3. Association between poverty income ratio and self-reported physical functioning by race and work status among participants with SLE in the Georgians Organized Against Lupus cohort

		Difference in physical functioning score[a] (95% CI) by poverty income ratio[b]			
Stratified covariate	**n (%)**	**<1.00**	**1.00 - 1.99**	**2.00 - 3.99**	**≥4 .00**
Current work status[c]	725				
Employed	295 (40.7)	-12.94 (-24.53, -1.34)	1.00 (ref.)	3.59 (-7.45, 14.64)	2.99 (-9.97, 15.95)
Unemployed[d]	161 (22.2)	3.31 (-11.93, 18.56)	1.00 (ref.)	11.90 (-3.94, 27.55)	21.48 (2.05, 40.92)
p-Values for interaction		*0.13*	*ref.*	*0.83*	*0.27*
Disabled	269 (37.1)	0.02 (-9.15, 9.19)	1.00 (ref.)	1.44 (-11.26, 14.14)	-13.65 (-45.89, 18.60)
p-Values for interaction		*0.06*	*ref.*	*0.43*	*0.15*
Race[c]	744				
Black	602 (80.9)	-6.39 (-13.52, 0.75)	1.00 (ref)	10.47 (2.05, 18.88)	17.43 (5.91, 28.95)
Not black	142 (19.1)	-6.00 (-26.02, 14.02)	1.00 (ref)	11.32 (-6.33, 28.97)	13.11 (-6.44, 32.67)
p-Values for interaction		*0.62*	*ref.*	*0.38*	*0.85*

[a]Scaled score of physical functioning (PF) subscore from twelve-item Short-Form Health Survey (SF-12), 0-100 (higher scores indicate better physical functioning)
[b]Ratio of household income to appropriate poverty threshold for household size, as defined by the United States Census Bureau (lower poverty income ratio indicates greater poverty)
[c]Adjusted for age, sex, race (black vs. not black), education, marital status (married vs. not married), and disease duration
[d]Includes retired, homemaker, and student populations
SLE: systemic lupus erythematosus

Table 4. Association between poverty income ratio and low vs. high physical functioning among participants with SLE in the Georgians Organized Against Lupus cohort[a]: sensitivity analysis

	OR (95% CI) for physical functioning score[b] by poverty income ratio[c]			
Model	**<1.00**	**1.00 - 1.99**	**2.00 - 3.99**	**≥4 .00**
Health limits moderate activities				
Unadjusted	1.26 (0.84, 1.90)	1.00 (ref.)	0.49 (0.30, 0.78)	0.36 (0.19, 0.70)
Age, sex, and race adjusted	1.48 (0.97, 2.26)	1.00 (ref.)	0.51 (0.32, 0.83)	0.35 (0.18, 0.68)
Multivariable-adjusted[d]	1.46 (0.95, 2.25)	1.00 (ref.)	0.49 (0.29, 0.83)	0.36 (0.17, 0.75)
Multivariable + BILD score	1.34 (0.87, 2.08)	1.00 (ref.)	0.48 (0.28, 0.82)	0.42 (0.20, 0.87)
Multivariable + PHQ-9 score	1.45 (0.92, 2.27)	1.00 (ref.)	0.54 (0.31, 0.94)	0.41 (0.20, 0.88)
Multivariable + SLAQ score	1.28 (0.82, 2.02)	1.00 (ref.)	0.58 (0.34, 1.01)	0.50 (0.23, 1.07)
Health limits climbing several flights of stairs				
Unadjusted	1.30 (0.87, 1.92)	1.00 (ref.)	0.46 (0.30, 0.71)	0.39 (0.22, 0.70)
Age, sex, and race adjusted	1.46 (0.98, 2.20)	1.00 (ref.)	0.48 (0.31, 0.75)	0.38 (0.21, 0.70)
Multivariable-adjusted[d]	1.38 (0.91, 2.08)	1.00 (ref.)	0.57 (0.36, 0.93)	0.51 (0.27, 0.96)
Multivariable + BILD score	1.25 (0.82, 1.89)	1.00 (ref.)	0.57 (0.35, 0.92)	0.59 (0.31, 1.13)
Multivariable + PHQ-9 score	1.35 (0.88, 2.08)	1.00 (ref.)	0.64 (0.39, 1.06)	0.59 (0.30, 1.16)
Multivariable + SLAQ score	1.20 (0.78, 1.85)	1.00 (ref.)	0.67 (0.41, 1.11)	0.69 (0.35, 1.34)

[a]Analysis of complete data (n=744)
[b]Dichotomized two questions comprising physical functioning (PF) subscore from twelve-item Short-Form Health Survey (SF-12): limited a lot vs. not limited a lot
[c]Ratio of household income to appropriate poverty threshold for household size, as defined by the United States Census Bureau (lower poverty income ratio indicates greater poverty)
[d]Adjusted for age, sex, race (black vs. not black), education, marital status (married vs. not married), and disease duration
BILD: Brief Index of Lupus Damage, PHQ-9: nine-item Patient Health Questionnaire, SLAQ: Systemic Lupus Activity Questionnaire: higher scores indicate more of the domain measured with these instruments
SLE: systemic lupus erythematosus

Table 5. Physical performance and self-reported function overall and categorized by poverty income ratio of SLE participants in the APPEAL ancillary pilot study (October 2016 - April 2017)

		Poverty income ratio[a]			
Measure	**Overall (n=56)**	**<1.00 (n=31)**	**1.00-1.99 (n=10)**	**≥2.00 (n=15)**	**p Value[b]**
Physical functioning					
Mean (SD) physical functioning score[c]	37.95 (34.37)	32.26 (33.04)	22.50 (21.89)	60.00 (35.10)	0.02
Physical performance[d]					
Mean (SD) balance score[e]	3.64 (0.86)	3.67 (0.94)	3.50 (0.85)	3.67 (0.72)	0.53
Mean (SD) gait speed score[e]	3.36 (1.07)	3.13 (1.26)	3.30 (0.95)	3.87 (0.35)	0.13
Mean (SD) lower body strength score[e]	1.84 (1.36)	1.58 (1.34)	1.40 (1.08)	2.67 (1.29)	0.02
Mean (SD) overall physical performance score[f]	8.84 (2.61)	8.39 (2.92)	8.20 (1.99)	10.20 (1.82)	0.04
Instrumental activities of daily living					
No. (%) reporting difficulty with:					
Food preparation	20 (35.7)	12 (38.7)	5 (50.0)	3 (20.0)	0.31
Housework	8 (14.3)	6 (19.4)	2 (20.0)	0 (0.0)	0.17
Laundry	2 (3.6)	2 (6.5)	0 (0.0)	0 (0.0)	0.11
Managing finances	2 (3.6)	1 (3.2)	1 (10.0)	0 (0.0)	0.21
Managing medications	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	-
Shopping	23 (41.1)	12 (38.7)	6 (60.0)	5 (33.3)	0.23
Transportation	7 (12.5)	7 (22.6)	0 (0.0)	0 (0.0)	0.04
Using telephone	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	-
Basic activities of daily living					
No. (%) reporting difficulty with:					
Bathing	8 (14.3)	5 (16.1)	2 (20.0)	1 (6.7)	0.67
Dressing	8 (14.3)	5 (16.1)	2 (20.0)	1 (6.7)	0.67
Feeding self	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	-
Incontinence	11 (19.6)	8 (25.8)	3 (30.0)	0 (0.0)	<0.01
Toileting	1 (1.8)	1 (3.2)	0 (0.0)	0 (0.0)	1.00
Transferring	5 (8.9)	2 (6.5)	3 (30.0)	0 (0.0)	0.05
Falls					
No. (%) with falls in prior year	26 (46.4)	15 (48.4)	7 (70.0)	4 (26.7)	0.10
Mean (SD) number of falls in prior year	2.08 (0.84)	2.13 (0.74)	2.14 (1.07)	1.75 (0.96)	0.70

Table 5. Physical performance and self-reported function overall and categorized by poverty income ratio of SLE participants in the APPEAL ancillary pilot study (October 2016 - April 2017)

[a]Ratio of household income to appropriate poverty threshold for household size, as defined by the United States Census Bureau (lower poverty income ratio indicates greater poverty)
[b]By Fisher's exact or non-parametric equality-of-means test, as appropriate
[c]Scaled score of physical functioning (PF) subscore from twelve-item Short-Form Health Survey (SF-12), 0-100
[d]Assessed via the Short Physical Performance Battery (SPPB)
[e]Scaled, 0-4
[f]Scaled, 0-12
Higher scores reflect better functioning for all scales; SLE: systemic lupus erythematosus