

Research Article

# Cross-Sectional Examination of Musculoskeletal Pain and Physical Function in a Racially and Socioeconomically Diverse Sample of Adults

Angie L. Sardina, PhD,<sup>1,\*</sup> Alyssa A. Gamaldo, PhD,<sup>2,3</sup> Ross Andel, PhD,<sup>4,5</sup> Shanthi Johnson, PhD,<sup>6</sup> Tamara A. Baker, PhD,<sup>7</sup> Roland J. Thorpe, PhD,<sup>8</sup> Cathy McEvoy, PhD,<sup>4</sup> Michele K. Evans, MD,<sup>2</sup> and Alan B. Zonderman, PhD<sup>2</sup>

<sup>1</sup>Department of Recreation Therapy, College of Health and Human Services, University of North Carolina Wilmington. <sup>2</sup>Laboratory of Epidemiology & Population Sciences, National Institute on Aging, National Institute on Aging, Biomedical Research Center, Baltimore, Maryland. <sup>3</sup>Human Development and Family Studies, Penn State University, University Park, Pennsylvania. <sup>4</sup>University of South Florida, College of Behavioral and Community Sciences, School of Aging Studies, Tampa. <sup>5</sup>Department of Neurology, Memory Clinic, 2nd Faculty of Medicine, Charles University and Motol University Hospital, Prague, Czech Republic. <sup>6</sup>Faculty of Kinesiology and Health Studies, Saskatchewan Population Health and Evaluation Research Unit, University of Regina, Canada. <sup>7</sup>Department of Psychiatry, School of Medicine, The University of North Carolina at Chapel Hill. <sup>8</sup>Hopkins Center for Health Disparities Solutions, Bloomberg School of Public Health, Johns Hopkins University, Baltimore, Maryland.

\*Address correspondence to: Angie L. Sardina, PhD, Department of Recreation Therapy, College of Health and Human Services, University of North Carolina Wilmington, 601 S. College Road, Wilmington, NC 28403-5685. E-mail: [sardinaa@uncw.edu](mailto:sardinaa@uncw.edu)

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## Abstract

**Background:** Musculoskeletal pain alters physiological function, which may be evidenced as early as middle age. Previous research has concluded that middle-aged adults are a high-risk group for musculoskeletal pain and report functional limitations similar to older adults. However, few studies have examined the relationships between musculoskeletal pain and physical function, using objective performance measures in a sample of racially and socioeconomically diverse adults. Thus, this study examined musculoskeletal pain in relation to physical function in middle-aged (30–64 years) White and Black adults and investigated whether the relationship varied by sociodemographic characteristics.

**Methods:** This cross-sectional examination incorporated data from the Healthy Aging in Neighborhoods of Diversity across the Life-Span Study. Participants ( $n = 875$ ) completed measures of musculoskeletal pain and objective measures of physical performance (ie, lower and upper body strength, balance, and gait abnormalities). Physical performance measures were standardized to derive a global measure of physical function as the dependent variable.

**Results:** Approximately, 59% of participants identified at least 1 pain sites ( $n = 518$ ). Multivariable regression analyses identified significant relationships between greater musculoskeletal pain and poorer physical function ( $\beta = -0.07$ ,  $p = .031$ ), in mid midlife ( $\beta = -0.04$ ,  $p = .041$ ; age 40–54) and late midlife ( $\beta = -0.05$ ,  $p = .027$ ; age 55–64).

**Conclusions:** This study observed that musculoskeletal pain was associated with poorer physical function within a diverse group of middle-aged adults. Future research should longitudinally explore whether chronic musculoskeletal pain identified at younger ages is associated with greater risk for functional limitation and dependence in later life.

**Keywords:** Health disparities, Minority aging, Physical performance, Socioeconomic status

Musculoskeletal pain is associated with greater levels of disability (1,2) and threatens functional independence across numerous age groups. Existing literature is largely focused on musculoskeletal pain and poorer physical function in older adult populations, despite some evidence of midlife musculoskeletal pain and similar reports in physical impairments (3,4). Older individuals tend to express more musculoskeletal pain (5) of greater intensity (6), whereas middle-aged individuals tend to express more musculoskeletal pain locations of unidentifiable causes and are considered a high-risk group for developing chronic pain (7). Rustøen et al. (4) identified pain as a chronic and persistent problem for middle-aged adults; and Covinsky et al. (3) concluded that middle-aged individuals who express musculoskeletal pain are reporting functional impairments similar to those typically observed in older adult samples. As such, more research is needed that explores the relationship between musculoskeletal pain and physical function in young adulthood to midlife.

While much of the literature has primarily focused on subjective measures of physical function (3,8–11), the World Health Organization's International Classification of Functioning (WHO's ICF) has emphasized the importance of conducting comprehensive objective measures to assess the extent to which functional impairments exist for those with a specific condition (12,13). Subjective reports of activity limitations are meaningful to understanding perceived health and function; however, they may not provide a comprehensive picture regarding the level or extent of functional impairment among those in early to midlife who experience musculoskeletal pain.

Additionally, existing literature generally supports the relationship between musculoskeletal pain and physical function across the life course (3,14–16); however, the relationships between these constructs may be subject to individual differences (14,17,18). The ICF posits that functioning results from interactions between health conditions/function and personal factors (eg, age, sex, race, and socioeconomic status [SES]). Despite greater reports of musculoskeletal pain and poorer physical function among minorities, previous research examining this topic has typically considered personal factors as confounders within the analyses, rather than exploring how the relationship between musculoskeletal pain and physical function may vary by these personal factors (19–21). However, there is an increasing demand within health disparities and minority health research to shift from this methodological approach and focus more on the moderational influence of these personal factors when exploring correlates/determinants of health (22). Specifically, there is a paucity of research that assesses moderation of musculoskeletal pain and physical function by sociodemographic characteristics, particularly race and SES (1,23). However, disentangling how race and SES affect the association between musculoskeletal pain and physical function is imperative to further our understanding of who may be at greatest risk of impairment when experiencing musculoskeletal pain.

Specifically, a high percentage of minority populations (eg, Blacks (24) and those of lower SES (25,26)) are at the greatest risk of experiencing musculoskeletal pain that results in impairment, activity limitations, and participation restrictions (27–29). Given minority subgroups, particularly Blacks, are more likely than Whites to have lower levels of SES (eg, low education, risk for poverty, and low income), it is difficult to determine whether health outcomes vary strictly by race, strictly by SES, or by a combination of race and SES (20). Specifically, minority-aging scholars have further suggested the social disadvantage often experienced by members of the Black community (eg, racism) may increase the likelihood of experiencing or

exacerbate health disparities (30). On the other hand, LaVeist et al. (19), Clay et al. (31), and Taylor et al. (32) concluded that when accounting for measures of SES (eg, years of education), racial disparities in health and function (eg, chronic conditions, grip strength, and gait speed) are often reduced or eliminated. Such that individuals, regardless of race, will experience similar health outcomes when residing in the same contexts. However, there is limited research that has explored, in sufficient detail, the dynamic and complex relationships that exist between sociodemographic characteristics (eg, race and SES) and pain as it relates to objective physical function among younger to middle-aged Black and White adults who are socioeconomically diverse.

To build upon previous research, the aims of this study were to (a) examine the relationship between musculoskeletal pain and global physical function (ie, a global measure of objective performance measures based upon upper and lower body strength, balance, and gait abnormalities) and (b) explore whether sociodemographic characteristics (eg, age, sex, race, and various measures of SES) moderate any observed relationships between musculoskeletal pain and physical function, in a socioeconomically diverse sample of community-dwelling Black and White adults.

## Method

### Participants

Cross-sectional data were utilized from the Healthy Aging in Neighborhoods of Diversity across the Life Span (HANDLS) study, a 20-year longitudinal study examining the influences of race and SES over time on health outcomes (33). HANDLS participants in this article were community-dwelling, socioeconomically diverse Blacks and Whites, initially aged 30–64 ( $n = 875$ ), with valid measures of musculoskeletal pain, health status, and physical function. HANDLS recruited participants from 13 predetermined groups of contiguous census tracts located within Baltimore, MD. HANDLS used an area probability strategy to recruit a representative sample of Black and White adults aged 30–64 in Baltimore city (33). Interviews were conducted in participants' homes, as well as within Medical Research Vehicles parked within participants' neighborhoods. HANDLS was approved by the Institutional Review Board at the National Institute of Environmental Sciences at the National Institutes of Health. All participants provided written informed consent. To test the study aims, the current study utilized cross-sectional data from Wave 1, which was collected over approximately 4½ years (2004–2009).

### Measures

**Musculoskeletal pain.** A physician or nurse practitioner collected participants' experiences with musculoskeletal pain during a structured interview, in which participants indicated whether they had experienced pain in the neck, low back, muscles, and/or joints within the 12 months before data collection. Hand pain was derived from the following question: "Is pain or arthritis in the hands worse recently?" Responses were summed (range 0–5) and then categorized into 3 groups: (a) no pain sites, (b) single pain site, or (c) 2 or more pain sites due to unequal distribution. These groupings are consistent with previous research (34,35).

**Objective measures of physical function.** Physical function was assessed by objective, performance-based measures of upper and lower body strength (ie, grip strength and chair stands) and balance (ie,

side-by-side, semi-tandem, and tandem stand; scores across each performance measure are available in [Supplementary Table 1](#).

**Upper body strength.** Right- and left-handed grip strength were measured using a Jamar Hydraulic Hand Dynamometer (Model No. 5030J 1 Sammons Preston Rolyan, Bolingbrook, IL), in which the maximum kilograms of force were recorded. Two trials were conducted across each hand and the average of the 2 hands was calculated, which is consistent with previous research (36).

**Lower body strength.** Times to complete 5- and 10-chair stands (seconds) were used as indicators of lower body strength. To identify meaningful differences and reduce ceiling effects in performance earlier in the life course, chair stand measures were modified by increasing the completion number from 5 to 10 for the study (33). The split time for 5-chair stands and total time to complete 10-chair stands were recorded separately during testing (37).

**Balance.** Balance was measured using the side-by-side, semi-tandem, and full-tandem stand test (38). Participants were required to maintain balance without assistance for a given period (ie, side-by-side stand was held for 10 s and semi-tandem and tandem stand were held for 30 s), and the time balance was lost was noted. [Supplementary Table 2](#) displays the timing and scoring of the balance tasks, which are consistent with prior research (38,39). Scores across each balance test were summed to derive a composite measure of balance, in which higher scores represented better balance.

**Gait.** Any observed abnormalities in gait (ie, “senile,” “Parkinsonian,” “spastic,” and/or “other” types of gait disturbances) were coded as “abnormal” by a trained physician. Participants who did not display any of the aforementioned gait disturbances were coded as “normal” (33). Gait abnormalities were used as a proxy for impaired mobility.

### Moderators

**Sociodemographic variables.** Age at baseline was grouped to distinguish “young midlife” (0; age 30–39), “mid midlife” (1; age 40–54), and “late midlife” age (2; age 55–64). Sex represented “males” and “females.” Race was coded as “White” or “Black.” To assess SES, measures of education quantity and quality, as well as poverty status, were included. Education was continuous and reflected the total years of education attained (range 0–21 years). Because education quantity may not necessarily reflect education quality, and quality of education has been uniquely associated with health outcomes (40), we measured reading literacy, a proxy of education quality, using the Wide Range Achievement Test, Third Edition (WRAT-III (41)). Total WRAT-III scores were used and ranged from “low reading literacy” (0) to “high reading literacy” (42). Poverty status was determined by household poverty guidelines published by the U.S. Department of Health and Human Services (43) and was defined as “below poverty status” (reported income at or below 125% of the poverty level) or “above poverty status” (reported income more than 125% of the poverty level (33)).

**Covariates.** Number and type of health conditions were obtained from medical history interviews, in which participants were asked to indicate “yes” or “no” if a health provider ever diagnosed them with the following health conditions: (a) fracture, (b) hypertension, (c)

hyperthyroidism and (d) hypothyroidism, (e) stroke, (f) asthma, (g) diabetes, (h) sleep apnea, (i) osteoarthritis, (j) rheumatoid arthritis, and/or (k) gout. Health conditions consisted of 2 composite variables. First, a sum score was calculated for musculoskeletal-related conditions (ie, fracture, osteoarthritis, rheumatoid arthritis, and gout; total range 0–4), based upon the number of “yes” responses indicated. Similarly, a sum score was calculated for all other medical conditions (ie, hypertension, stroke, asthma, diabetes, sleep apnea, and hyper- and hypothyroidism; total range 0–7), based upon the number of “yes” responses indicated. Due to unequal distribution, both health variables were collapsed to the following: none (0), one (1), or at least 2 (2). Incorporation of 2 composite variables of health conditions aimed to differentiate the relationships between types of health conditions as each may have unique implications on musculoskeletal pain and/or physical function. Body mass index was calculated as weight (kg) divided by height (m<sup>2</sup>) and remained continuous within the analyses.

The Center for Epidemiologic Studies-Depression (CES-D) scale was used to examine depressive symptomology of the sample (44). The CES-D is a 20-item scale that examined depressive symptoms, mood, and affect over the past week (range = 0–60). Higher total scores reflected greater depressive symptomology. The CES-D was analyzed separately as it is representative of psychological health.

### Statistical Analyses

To examine the relationship between musculoskeletal pain and global physical function in a sample of community-dwelling adults, 6 physical function tasks (ie, right grip strength, left grip strength, times to complete 5- and 10-chair stands, balance scores, and gait) were converted into z-scores and averaged to comprise a measure of global physical function, which is consistent with previous studies (45,46). The use of a physical function composite measure may reduce limitations that arise by examining a singular or numerous physical measures. Specifically, this composite measure promotes the ability to examine overall functional status or system performance of the individual assessed (45,47,48). For this particular composite, higher scores on the global physical function variable indicated better performance across measures.

Only participants with complete sociodemographic, musculoskeletal pain, health, and physical function data were included within the analyses. Using only complete data in these studies may lead to bias; however, multiple imputation may produce similar biases, especially if data are not missing at random, as is the case here, or when the percentage of missing data across variables is large (49,50). Pearson (for continuous and dichotomous variables) and spearman (for ordinal variables) correlations were initially conducted to examine the relationships among musculoskeletal pain and global physical function. One-way analysis of variance was conducted to explore group differences of variables significantly associated with global physical function. Following these analyses, 2 multivariable linear regression models were conducted separately for musculoskeletal pain and physical function. Multivariable linear regression models were utilized given the models had one continuous outcome (global or physical function score) and multiple categorical and continuous predictors (51). Model 1 tested the association between musculoskeletal pain and global physical function after adjusting for sociodemographic variables (ie, age group, sex, race, years of education, WRAT-III scores, and poverty status). Model 2 additionally controlled for health-related factors (eg, musculoskeletal conditions, other medical conditions, body mass index,

and CES-D). To examine whether the association between pain and physical function was moderated by sociodemographic characteristics, Model 3 tested 2-way interactions between musculoskeletal pain and sociodemographic predictors using multivariable linear regression. Model 1 was used to minimize the number of predictors included in Model 3.

For significant 2-way interactions identified, simple slopes analyses (52) were estimated to examine the association between musculoskeletal pain and global physical function across the levels of musculoskeletal pain and sociodemographic variables.

Independent variables and covariates were centered at the mean to assist with the interpretation of the findings. Multivariable linear regression results were reported using standardized coefficients to facilitate comparisons among tests with different metrics. Statistical significance was set at two-tailed,  $p < .05$ . All statistical analyses were conducted using the SAS statistical software package 9.2 (Cary, NC).

### Results

Of the 2361 participants in the HANDLS sample with available data, 1468 were missing sociodemographic, health, pain, or physical function data and were excluded from the study's analyses using listwise deletion. Participants who were excluded from the study's analyses ( $n = 1486$ ) were compared to those who were included to identify any significant differences between the 2 groups in sociodemographic characteristics.

Chi-square tests of independence for categorical variables and independent samples  $t$  tests for noncategorical variables were conducted to examine differences in sociodemographic characteristics (ie, age group, sex, race, years of education, WRAT-III scores, and poverty status) between those excluded and those included from analyses. Those excluded from analyses were significantly more likely to be younger (age group = 30–39; 25.2%;  $\chi^2 (2) = 13.33, p = .001$ ), male (47.0%;  $\chi^2 (1) = 7.74, p = .005$ ), below poverty status (47.2%;  $\chi^2 (1) = 4.23, p = .039$ ), and reported significantly less years

of education ( $M = 11.82, SD = 2.78; t (2263) = -3.03, p = .003$ ) than those who were included. There were no significant differences observed between those excluded and included on race,  $\chi^2 (1) = 2.89, p = .089$  or WRAT-III scores,  $t (1731) = -0.61, p = .544$ .

The final sample with valid data across all sociodemographic, health, pain, and physical function data ( $n = 875$ ) was predominantly middle-aged ( $M = 48.5, SD = 8.90$ ), female, Black, indicated an average of high school education, obtained an approximate WRAT-III score of 42, and were considered above poverty status (57.1%; see Table 1 for participant characteristics). Approximately 36% of the sample reported 1 musculoskeletal pain site ( $n = 312$ ) and nearly 24% indicated 2 or more musculoskeletal pain sites ( $n = 206$ ). Individuals who reported musculoskeletal pain were more likely to be older in age ( $p < .001$ ), female ( $p = .010$ ), and experience comorbidities ( $p < .001$ ; Table 2).

Overall, global physical function was evenly distributed across the sample ( $M = -0.00, SD = 0.44$ , range of scores =  $-1.37$  to  $+1.29$ ). Those who were older ( $p = .009$ ) tended to demonstrate poorer physical function (see Table 2 for correlation coefficients). A subsequent 1-way analysis of variance identified a statistically significant difference between age groups and physical function scores,  $F (2, 872) = 3.89, p = .021$ . Tukey's post hoc testing revealed that those in late midlife demonstrated significantly worse global physical function than those in young midlife (95% CI =  $-0.210, -0.005$ ) and mid midlife (95% CI =  $-0.162, -0.001$ ; see Table 3 for global physical function scores across subgroups). There was no statistically significant difference between those in young midlife and those in mid midlife on global physical function scores (95% CI =  $-0.721, 0.408$ ). Individuals who reported a higher number of comorbid medical conditions ( $p = .026$ ) tended to demonstrate poorer physical function. Significant relationships were also identified between musculoskeletal pain groups and global physical function ( $p = .003$ ), which suggested that those with more musculoskeletal pain were more likely to demonstrate worse global physical function. A subsequent analysis of variance was conducted to examine differences between musculoskeletal pain groups on physical function. A significant difference

**Table 1.** Sociodemographic, Health, and Pain Characteristics of the Final Sample ( $N = 875$ )

Variables	<i>n</i> (%)	Range	<i>M</i> ( <i>SD</i> )
Sociodemographic characteristics			
Age groups (years)			
30–39 (young midlife)	166 (18.97)	—	—
40–54 (mid midlife)	447 (51.09)	—	—
55–64 (late midlife)	262 (29.94)	—	—
Sex (female)	515 (58.86)	—	—
Race (Black)	453 (51.77)	—	—
Education	—	1 to 21	12.19 (2.91)
Poverty status (below poverty status)	375 (42.86)	—	—
WRAT-III (score)	—	11 to 57	41.88 (8.05)
Health characteristics			
Musculoskeletal-related health conditions ( $\geq 1$ )	396 (45.26)	—	—
Other health conditions ( $\geq 1$ )	485 (55.42)	—	—
CES-D (score)	—	0 to 59	16.55 (11.89)
Body mass index (kg/m <sup>2</sup> )	—	15.82 to 57.94	29.95 (7.72)
Musculoskeletal pain			
No pain	357 (40.80)	—	—
One pain site	312 (35.66)	—	—
Two or more pain sites	206 (23.54)	—	—
Physical function	—	-1.37 to +1.29	-0.00 (0.44)

Note: CES-D = Centers for Epidemiological Studies-Depression scale; SD = standard deviation; WRAT-III = Wide Range Achievement Test (Third Edition).



**Table 2.** Correlation Coefficients Between Sociodemographic, Health, Pain, and Physical Function

	1	2	3	4	5	6	7	8	9	10	11	12
1. Age groups	—											
2. Sex	-0.01	—										
3. Race	0.03	0.01	—									
4. Education	-0.03	0.05	0.01	—								
5. WRAT-III	-0.09*	0.03	-0.26***	0.44***	—							
6. Poverty status	0.04	-0.01	-0.21***	0.25***	0.25***	—						
7. Musculoskeletal conditions	0.02	-0.14***	-0.07*	-0.06	-0.04	-0.08*	—					
8. Other health conditions	0.34***	0.11**	0.10**	-0.03	-0.03	-0.05	0.03	—				
9. CES-D	-0.05	-0.03	0.04	-0.02	-0.07*	-0.07*	0.02	-0.04	—			
10. BMI	-0.03	-0.05	-0.04	-0.02	-0.03	0.06	0.13***	-0.01	-0.03	—		
11. Musculoskeletal pain	0.15***	0.09**	-0.03	0.02	0.02	-0.02	0.01	0.19***	-0.00	0.02	—	
12. Physical function <sup>†</sup>	-0.09**	-0.04	0.03	-0.02	-0.04	0.06	0.05	-0.07*	-0.01	-0.01	-0.10**	—

Note: BMI = body mass index; CES-D = Centers for Epidemiological Studies-Depression scale; WRAT-III = Wide Range Achievement Test (Third Edition).

<sup>†</sup>Physical function comprised the average of the z-scores of the 6 physical function tasks (ie, right grip strength, left grip strength, times to complete 5- and 10-chair stands, balance, and gait abnormalities).

\* $p < .05$ , \*\* $p < .01$ , \*\*\* $p < .001$ .

between musculoskeletal pain groups and physical function scores was observed,  $F(2, 872) = 4.59$ ,  $p = .010$ . Tukey's post hoc testing revealed that participants with 2 or more pain sites demonstrated significantly worse global physical function scores than those in young midlife (95% CI = -0.207, -0.026). No significant difference was observed between those in late midlife and mid midlife (95% CI = -0.169, 0.017). Race ( $p = .386$ ), sex ( $p = .193$ ), poverty status ( $p = .084$ ), education ( $p = .600$ ), WRAT-III ( $p = .19$ ), body mass index ( $p = .688$ ), and CES-D ( $p = .714$ ) were nonsignificantly associated with global physical function scores.

### Adjusted relationships between musculoskeletal pain and physical function

Greater musculoskeletal pain was significantly associated with poorer physical function, even after adjusting for all sociodemographic ( $p = .021$ ; Model 1) and health ( $p = .031$ ; Model 2) characteristics (see Table 4 for standardized coefficients for all models).

A significant 2-way interaction was observed between musculoskeletal pain and age group ( $p = .040$ ; 95% CI = -0.009, -0.000). Estimated simple slopes identified that more musculoskeletal pain was significantly associated with worse physical function, particularly for "mid midlife" (age 40–54;  $\beta = -0.04$ ,  $p = .041$ ) and "late midlife" adults (age 55–64;  $\beta = -0.05$ ,  $p = .027$ ; Model 3; Figure 1). Simple slopes were trending toward, but did not reach, statistical significance for "young midlife" (age 30–39) adults within these analyses ( $\beta = -0.04$ ,  $p = .064$ ). No significant 2-way interactions were observed between musculoskeletal pain and race ( $p = .076$ ), musculoskeletal pain and sex ( $p = .578$ ), musculoskeletal pain and WRAT-III ( $p = .463$ ), musculoskeletal pain and education ( $p = .097$ ), or musculoskeletal pain and poverty status ( $p = .983$ ). We explored for potential model saturation by conducting multiple multivariable linear regressions. Specifically, we conducted models where interactions were explored individually. However, we did not see any significant changes (eg, changes in the significance of the pain  $\times$  age interactions).

**Table 3.** Performance on Physical Function Measures Across Moderator Subgroups

Moderator Subgroups	Global Function Scores		
	<i>n</i>	<i>M (SD)/n (%)</i>	Range
Age groups (years)			
30–39 (young midlife)	166	0.05 (0.39)	-1.11 to +1.01
40–54 (mid midlife)	447	0.02 (0.45)	-1.37 to +1.20
55–64 (late midlife)	262	-0.06 (0.45)	-1.28 to +1.29
Sex			
Male	360	0.03 (0.44)	-1.37 to +1.29
Female	515	-0.02 (0.44)	-1.28 to +1.08
Race			
Black	453	0.01 (0.44)	-1.37 to +1.08
White	422	-0.01 (0.45)	-1.27 to +1.29
Poverty status			
Below poverty status	375	-0.03 (0.47)	-1.37 to +1.08
Above poverty status	500	0.02 (0.41)	-1.26 to +1.29

Note: Six physical function tasks (ie, right grip strength, left grip strength, times to complete 5- and 10-chair stands, balance scores, and gait) were converted into z-scores and averaged to comprise a measure of global physical function.

### Discussion

The purposes of this study were to examine the relationship between musculoskeletal pain and global physical function and explore whether sociodemographic characteristics moderate any observed relationships between musculoskeletal pain and physical function. We found that individuals who reported more musculoskeletal pain had significantly worse physical function, which appears to be evident at the age of 40. Approximately 59% of a middle-aged sample of urban-dwelling Whites and Blacks indicated 1 or more musculoskeletal pain site/s, which is consistent with large epidemiological studies that have identified musculoskeletal pain prevalence rates ranging from 14% to 64% across the United States (25,26,53).

**Table 4.** Multivariable Linear Regression Models to Examine the Relationship Between Musculoskeletal Pain and Physical Function

Variables	Global Physical Function								
	Model 1 <sup>†</sup>			Model 2 <sup>‡</sup>			Model 3 <sup>§</sup>		
	Unstandardized Beta (SE)	β	95% CI	Unstandardized Beta (SE)	β	95% CI	Unstandardized Beta (SE)	β	95% CI
Musculoskeletal pain	-0.04 (0.02)*	-0.08	-0.083, -0.007	-0.04 (0.02)*	-0.07	-0.080, -0.003	-0.04 (0.02)*	-0.07	-0.077, -0.001
Age group	-0.05 (0.02)*	-0.09	-0.098, -0.012	-0.05 (0.02)*	-0.08	-0.010, -0.006	-0.06 (0.02)*	-0.09	-0.100, -0.014
Sex	-0.04 (0.03)	-0.04	-0.095, 0.024	-0.03 (0.03)	-0.03	-0.088, 0.033	-0.04 (0.03)	-0.04	-0.097, 0.022
Race	0.02 (0.03)	0.02	-0.043, 0.079	0.02 (0.03)	0.03	-0.037, 0.086	0.02 (0.03)	0.02	-0.045, 0.078
Education	-0.00 (0.00)	-0.01	-0.013, 0.001	-0.00 (0.01)	-0.01	-0.013, 0.010	-0.00 (0.01)	-0.01	-0.014, 0.009
WRAT-III	-0.00 (0.00)	-0.06	-0.007, 0.000	-0.00 (0.00)	-0.06	-0.007, 0.000	-0.00 (0.00)	-0.06	-0.008, 0.001
Poverty status	0.07 (0.03)*	0.08	0.010, 0.136	0.08 (0.03)*	0.09	0.015, 0.142	0.07 (0.03)*	0.08	0.012, 0.137
Pain × Age group							-0.00 (0.00)*	-0.07	-0.009, -0.000
Pain × Sex							-0.02 (0.04)	-0.02	-0.099, 0.055
Pain × Race							-0.07 (0.04)	-0.06	-0.151, 0.007
Pain × Poverty status							0.03 (0.04)	0.00	-0.079, 0.081
Pain × Education							0.01 (0.01)	0.06	-0.002, 0.027
Pain × WRAT-III							-0.00 (0.00)	-0.03	-0.008, 0.003
Total adjusted R <sup>2</sup>		0.02			0.02			0.02	
Adjusted R <sup>2</sup> change					0.00			0.00	

Notes: SE = standard error; WRAT-III = Wide Range Achievement Test (Third Edition); β = standardized beta. The table includes all main effects for Models 1, 2, and 3, but only incorporates 2-way interactions from significant main effects. N = 875.

<sup>†</sup>Model 1 adjusted for sociodemographic characteristics (ie, age, sex, race, years of education, WRAT-III total score, and poverty status).

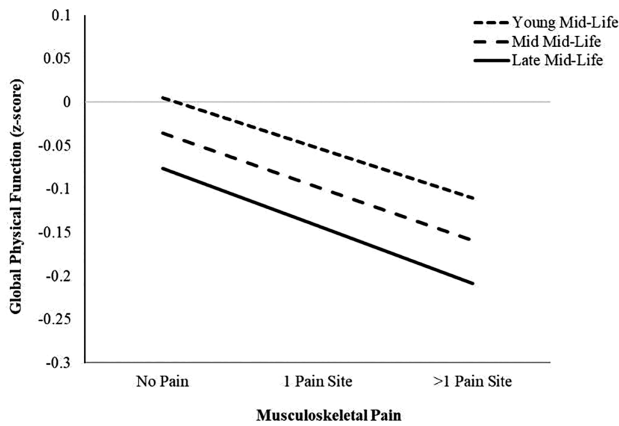
<sup>‡</sup>Model 2 adjusted for sociodemographic characteristics and health characteristics (ie, musculoskeletal-related medical conditions, other medical conditions, depressive symptoms, and body mass index).

<sup>§</sup>Model 3 adjusted for all sociodemographic characteristics (ie, age, sex, race, years of education, WRAT-III total score, and poverty status).

\*p < .05, \*\*p < .01, \*\*\*p < .001.

Much of the literature to date that explores the relationships between musculoskeletal pain and physical function have done so among older adult samples (1,34). However, some studies have found that middle-aged adults are a high-risk group for developing chronic pain (4) and are reporting similar levels of activity limitations typically identified among older age groups (3). Subjective measures of disability are widely used and well developed (54) and are capable of distinguishing across higher levels of individual function (55). Thus, research investigating the relationships between musculoskeletal pain and function at a younger age has commonly incorporated these subjective measures of activity limitations (3,9,56). However, subjective indices are designed to measure difficulty in performing specific tasks and may tend to correlate weakly with objective performance measures, which aim to assess performance or capacity (38,57). WHO's ICF model emphasizes the importance of complementing indicators, which may be traditionally focused on death and disease, to provide a richer understanding of health and functioning, rather than disability (13). Given this shift, objective measures may provide complementary information regarding the individual's level of function

(12,13). Though some research has included objective measures of physical functioning in midlife, particularly within HANDLS participants (36), objective measures of function are typically designed for older populations whose functional deficits may be more easily detectable (eg, examine time to complete 5-chair stands or standing balance tests of 10 s). As such, performance measures traditionally designed for older adults may not adequately detect subtle impairments in function earlier in the life course, as these individuals may demonstrate higher functional capacity and greater ability to compensate for losses (42). Hence, the findings of the current study seek to expand upon the existing literature by incorporating measures of function that were modified and of greater complexity (eg, increasing the number of chair stands from 5 to 10 s, time to maintain balance from 10 to 30 s) may detect subtle impairment evidenced in middle age. The use of an objective performance measure for those presenting with pain, especially when coupled with subjective indices of activity limitations, may elicit a more comprehensive understanding of the individual's level of impairment and the risk for experiencing activity limitations and/or participation restrictions (12).



**Figure 1.** Two-way interaction between musculoskeletal pain and age group in relation to global physical function. *Note:* Simple slopes estimated that musculoskeletal pain was significantly associated with poorer physical function across “mid midlife” adults (40–54 years of age) and “late midlife” adults (aged 55 and older).

Moreover, our findings identified a significant interaction between musculoskeletal pain and age groups, suggesting that individuals in mid midlife and late midlife are experiencing greater functional impairments when in pain. Hodges and Smeets (58) posited that individuals who experience pain may modify physiological functions (eg, redistribute load) to provide short-term relief, suggesting a degree of compensation for impairment. However, if the pain remains untreated and correct movement patterns go unrestored, it may exacerbate pain and progress to activity limitations and participation restrictions over time (59). Specifically, Ferrucci et al. (42) indicated that individuals in younger to middle adulthood might be capable of fully compensating for changes in function. However, with greater age may come a reduced ability to compensate, thereby functional impairments become more pronounced and easier to detect using objective measures of functional performance (eg, 5-second chair stand, and/or side-by-side, semi-tandem, or tandem stand). While we were unable to longitudinally explore this hypothesis, the objective performance measure included in this cross-sectional study detected differences in performance among those with musculoskeletal pain earlier in the life course, thus supporting the need for further exploration of potential longitudinal changes in the association between musculoskeletal pain and physical functioning with age.

Furthermore, future research should explore these associations using a global physical function score. Particularly, individually evaluating each performance indicator, while valuable information, presents challenges pertaining to progression/regression when describing functional status in a clinical setting to health care professionals (eg, physical therapists and physicians) (47). This may be particularly pertinent for those in middle-aged adults whose deficits across individual performance measures may be more subtle and masked by their ability to compensate. However, overall system performance, as considered in this global composite score, is particularly relevant to clinical professionals who seek to make comprehensive decisions regarding the description of changes in the functional status of the patient. As such, performance measures administered may be easier to interpret, promote effective comparison to healthy community-dwelling middle-aged adults, and holistically evaluate individual progress during treatment (47).

Furthermore, our findings are consistent with WHO’s ICF model, which posits that an individual’s level of function results from complex interactions between health and personal factors (eg, age) (12,13). Specifically, the ICF emphasizes the importance of considering physical, social, and economic barriers that exist within a particular environment that contributes to disability (12). Our study uniquely included racially and socioeconomically diverse participants who are typically underrepresented in the current literature. Previous research has identified that minorities (eg, Blacks), particularly individuals of lower SES, are at greater risk for experiencing pain (24). Specifically, Black adults are more likely to face unique life experiences (eg, prejudice and racism), which lead to or exacerbate health conditions and may differentially affect function (60,61). These experiences are associated with a high chronic level of stress that increases the likelihood of experiencing musculoskeletal pain (62). Furthermore, disparities related to SES, which may disproportionately affect Black adults, may constrain options related to effective pain management strategies (eg, cognitive behavioral therapy or physical-based therapies) and result in undertreatment of pain (63,64). Blacks and individuals of lower SES were also more likely to demonstrate poorer physical function (65), particularly if pain was present (14,15,24). Therefore, to better understand these constructs, we included a racially and socioeconomically diverse sample of Black and White adults in efforts to disentangle the complex relationships previously observed between sociodemographic characteristics (eg, race and SES) in relation to the experience of musculoskeletal pain and its association with physical function. While we did not observe significant associations of race with pain or physical function, poverty status served as a unique predictor after controlling for sociodemographic and health variables within the multivariable linear regression analyses.

Given the participants were recruited from neighborhoods with similar physical and social characteristics, it is possible that participants were exposed to similar adverse contextual factors that may promote pain and physical impairments regardless of their sociodemographic differences (19). For example, research by Taylor et al. (32) examined whether race differences existed between pain and slow gait speed. The researchers concluded that the relationship between pain and slow gait speed existed irrespective of race and may be attributed to unique life experiences (32). This underscores the importance of examining contextual factors in examining health disparities research. Another potential reason for the null findings might be sample selection bias, considering we only included participants with complete and valid data in the current study.

This study is one of the first to examine the relationships between musculoskeletal pain using a global measure of physical function across participants who are typically underrepresented in the literature (eg, Blacks and/or adults of lower SES (33)). The individual performance measures included accounted for potentially higher functional abilities across a younger sample who may possess greater compensatory abilities (42). This is an important contribution to the literature, given overall disability and self-reported functional limitations are more often utilized across younger age groups (3), yet may not correlate well with objective indices (38,57).

Additionally, this study expands the body of knowledge regarding the relationships between pain variables and physical function evidenced earlier in the life course. Although we were unable to

explore longitudinal relationships due to these cross-sectional data, we were able to demonstrate that physical deficits may be evidenced in physical performance measures, particularly among individuals who report musculoskeletal pain.

### Limitations

Although HANDLS is a longitudinal study, the data analyzed were collected from Wave 1 and are thereby cross-sectional. While Baltimore is similar to other mid-sized urban cities in the United States (33), the results may not be generalizable to participants who reside outside of Baltimore, particularly to Blacks and Whites who are living in nonurban settings (eg, suburban or rural areas). Furthermore, to continue to understand the extent of these relationships between musculoskeletal pain and physical function, longitudinal investigations are necessary. Furthermore, no statistically significant effect moderation was noted for race, despite the similarity in coefficient when compared with age. It is possible that the findings may be due to a lack of precision versus no association. However, it is more likely indicative of a lack of association, given the HANDLS study's factorial design that crosses age by race. Compared with other studies, which likely were relatively unbalanced and in which race and SES were confounded, HANDLS has roughly similar sample sizes in its underlying sampling design (age by sex by race by poverty status).

The measure of musculoskeletal pain does not provide an indication of the level of frequency, intensity, or duration of pain. Furthermore, descriptions of the pain were not available, which may be pertinent to distinguishing whether the pain experienced is musculoskeletal or neuropathic. Additionally, information pertaining to pharmacological management of pain (eg, opioid use) was not available within the data. Future studies should incorporate more comprehensive musculoskeletal pain measures and account for prescription and over-the-counter pain management approaches, to further our understanding of the relationships between musculoskeletal pain and physical function. Furthermore, the composite outcome measure has not been validated and requires additional testing in future studies. Additionally, many participants were excluded from analyses due to missing data suggesting selection bias. Those who were excluded were more likely to be younger, below poverty status, with fewer years of education.

### Conclusions

Musculoskeletal pain is significantly associated with poorer physical function in middle-aged adults. As such, performance measures may be used to detect deficits in physical capabilities among those who report musculoskeletal pain at younger ages. These findings suggest that longitudinal exploration is needed to identify whether chronic musculoskeletal pain identified at younger ages is associated with greater risk for functional limitation and dependence in later life. Overall, greater attention should be given to understanding musculoskeletal pain and their relationships to physical function in young adulthood to promote earlier intervention and functional independence over time.

### Supplementary Material

Supplementary data are available at *The Journals of Gerontology, Series A: Biological Sciences and Medical Sciences* online.

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### Conflict of Interest

None declared.

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## Supplemental Table 1

### *Performance on Physical Function Measures*

<b>Functional Measures</b>	<b>Global Function Scores</b>	
	<i>M(SD)/n(%)</i>	range
Left Grip Strength (kg)	33.99 (12.84)	0-70
Right Grip Strength (kg)	33.27 (12.03)	0-66
5-Chair Stands (seconds)	14.77 (6.63)	0-42.90
10-Chair Stands (seconds)	29.47 (13.50)	0-71.50
Balance (score)	8.41 (1.94)	0-9
Gait (abnormal)	48 (5.49)	0-1

*Note:* Grip strength=maximum kilograms of force across two trials, average of two trials were calculated (higher score=better strength); chair stands reflect the amount of seconds to complete 5 and 10 chair stands (higher score=poorer time); balance is reflected as a score based on performance on side-by-side, semi-tandem, and tandem stand tests (see Supplemental Table 1), with higher score reflective of better balance); and gait reflects abnormalities observed by the clinician (normal vs abnormal).

Supplemental Table 2

*Balance Measures and Scoring Procedures*

Measure	Task	Time	Scoring
Side-by-Side Stand	Stand with feet together	10 seconds	0 = <9.9 seconds or unable 1 = 10 seconds
Semi-Tandem Stand	Stand with the side of the heel of one foot touching large toe of the other foot	30 seconds	0 = unable 1 = 1-9.9 seconds 2 = 10-19.9 seconds 3 = 20-29.9 seconds 4 = 30 seconds
Tandem Stand	Stand heel-to-toe with feet together	30 seconds	0 = unable 1 = 1-9.9 seconds 2 = 10-19.9 seconds 3 = 20-29.9 seconds 4 = 30 seconds

*Note:* Participants were coded based on the length of time in which they were able to maintain their balance. A sum score was calculated for the side-by-side (1=pass/0=fail), semi-tandem, and tandem stands possible range=0-9; higher score = better. (9, 28)