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Movement-Evoked Pain, Physical Function, and Perceived Stress: An Observational Study of Racial Differences in Aging non-Hispanic Blacks and non-Hispanic Whites with Knee Osteoarthritis

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Abstract

Background: Knee osteoarthritis (OA) is a pervasive musculoskeletal condition, often exacerbated by movement-evoked pain (MEP). Despite established research demonstrating significant racial differences in OA pain, few studies have investigated ethnic/racial group differences in MEP and lower extremity function and their association with psychosocial factors, such as perceived stress. Therefore, the primary aims were: (1) to identify ethnic/racial group

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differences in persons with or at risk for knee OA pain based on MEP, physical performance, and perceived stress measures, and (2) to determine if perceived stress explains the relationship between MEP and function in non-Hispanic Blacks (NHBs) and non-Hispanic Whites (NHWs).

Methods: A total of 162 NHB and NHW community-dwelling older adults (50–78 years of age) were included in this analysis from the Understanding Pain and Limitations in Osteoarthritic Disease (UPLOAD) cross-sectional cohort study. Demographic, anthropometric, pain and functional parameters were assessed using a battery of validated instruments. Descriptive statistics, parametric, and multivariate analyses were conducted to determine ethnic/racial differences in perceived stress, MEP, and function.

Results: Our results support the hypothesis that among persons with knee OA pain, NHBs have significantly greater MEP and lower functional level, despite similar levels of perceived stress. However, perceived stress was more strongly related to MEP in NHB compared to NHWs. Differences in function were limited to walking speed, where NHWs demonstrated faster gait speed.

Conclusions: Our cross-sectional study demonstrated important ethnic/racial differences in MEP and function. Also, perceived stress had a stronger effect on MEP in NHBs, suggesting that perceived stress may more strongly influence pain with physical movement among NHB adults. MEP may be a clinically important pain outcome to measure in persons with OA, and these data warrant future research on the impact of stress on pain and functional outcomes in older adults, particularly in NHBs.

Keywords

pain; osteoarthritis; movement; function; stress; ethnicity/race

1. Introduction

Chronic pain is a global public health problem. Indeed, twelve of the most-disabling chronic conditions are associated with chronic pain (GBD 2016 Disease and Injury Incidence and Prevalence Collaborators, 2017). Among these, osteoarthritis (OA) causes musculoskeletal pain that is often initiated or exacerbated by movement, which leads to significant limitations in physical function, participation in daily activities, and mobility (Cruz-Almeida, Rosso, et al., 2017; Cruz-Almeida, Cardoso, et al., 2017; March et al., 2014). While pain-related function is a strong predictor of current and future disability in older adults, especially older non-Hispanic Blacks (NHBs) (Walker et al., 2016a; Smith et al., 2016; Zakoscielna & Parmelee, 2013), movement-evoked pain (MEP) may be a stronger predictor of musculoskeletal disability than pain at rest or general pain (Mankovsky-Arnold et al., 2014).

MEP refers to pain that is triggered or exacerbated by active or passive movement and that is clearly differentiated by the person from their background ongoing spontaneous pain (Corbett et al., 2019). MEP is a unique construct (vs. pain-at-rest) to study in individuals with hip and knee OA, including those who subsequently undergo joint replacement, given its relationship to functional status and recovery outcomes (Sayers et al., 2016). Despite several examples of direct measurement of pain brought on by movement, typical

approaches to pain assessment fail to specifically measure MEP and do not distinguish between chronic pain experienced at rest and with movement (He, Grant, Holden, & Gilron, 2017; Corbett et al., 2019; Butera, Fox, & George, 2016). This is problematic because increasing research suggests that MEP can be not only mechanistically distinct from rest pain (i.e., spontaneous pain) (He et al., 2017; Mankovsky-Arnold, Wideman, Larivière, & Sullivan, 2014), but is also likely one of the primary drivers of impaired mobility, particularly in older populations.

While MEP has been understudied in general, the extent to which MEP differs across ethnic/racially diverse older adults has not been investigated. Standard pain measures have revealed greater pain and disability among NHB adults with OA and other pain conditions compared to their non-Hispanic white (NHW) counterparts (Vina et al., 2018; Janevic et al., 2017). We recently found that higher MEP was significantly associated with poorer lower extremity functional performance (e.g., gait speed) in both NHBs and NHWs with or at risk for knee OA, with more NHBs having severe MEP (Cruz-Almeida, Cardoso et al., 2017). Taylor and colleagues (2018) did not find racial differences in the relationship between slow gait speed and pain in older adults and concluded that the underlying factors for this finding are more intrinsic to disparate environmental conditions rather than a function of ethnic/race itself. While numerous factors, such as pain catastrophizing, negative/positive affect, social demographics and perceived control, are recognized as contributing to ethnic/racial differences in OA-related pain (Cruz-Almeida, Cardoso, et al., 2017; Bartley et al., 2019; Cardoso et al., 2018), emerging evidence suggest that psychosocial stress (e.g., perceived stress) represents another important risk factor contributing to increased pain and disability in older adults with or at risk for knee OA (Sibille et al., 2018; Vaughn, Terry, Bartley, Schaefer, & Fillingim, 2018).

Living with a chronic pain condition like OA is stressful and can place further physiological and psychological burden on the body ultimately leading to accelerated aging and disability, especially in vulnerable older adult populations such as NHBs (Anton et al., 2015; Sibille et al., 2012). Stress has been identified as one of the top 10 determinants of health disparities and has been linked to coronary vascular disease, obesity, diabetes, autoimmune disorders, and chronic pain (Djuric et al., 2010; Abdallah & Geha, 2017). Stressors more frequently experienced by ethnic/racial minority groups, including socioeconomic disadvantage and racial discrimination, have been associated with health status and health behaviors (Ahmed, Mohammed, & Williams, 2007; Jackson, Knight, & Rafferty, 2010) including Black American women with OA (Walker Taylor et al., 2018). Of particular interest is perceived stress, defined as an individual's perception or feelings about the degree to which one's life is appraised as stressful over a given time period (Cohen et al., 1983). Chronic psychosocial and perceived stress may contribute to greater musculoskeletal pain (Tsuboi et al., 2017), experimental pain sensitivity (Mechlin et al., 2005; Gordon, Johnson Nau, Mechlin, & Girdler, 2017), and disability in chronic rheumatological conditions (Sumner et al., 2019). High perceived stress has been associated with heightened pain intensity and interference with normal household and work activities in older adults (White et al., 2014), and stress may contribute to previously documented racial/ethnic groups differences in OA pain (Vaughn et al., 2018). Indeed, recent research suggests that not only do NHBs with or at risk for OA have higher levels of clinical and experimentally-induced pain, functional

limitations, and perceived stress than do NHWs, but also that high perceived stress predicts higher MEP and lower function in older NHBs (Sibille et al., 2018; Booker et al., 2018).

Despite abundant evidence indicating that pain impacts physical function, there remains considerable knowledge gaps regarding MEP in ethnically/racially diverse older adults with or at risk for OA, and the contributions of stress thereto. To our knowledge, no studies to date have directly examined potential ethnic/racial differences in the association between perceived life stress and experimental measures of MEP and performance-based physical function among older NHBs and NHWs with knee OA. Therefore, the primary objectives of the present study were: (1) to identify ethnic/race group differences in persons with knee OA pain specific to MEP, physical performance, and perceived stress measures, and (2) to determine if perceived stress explains the relationship between MEP and function in NHBs and NHWs. We hypothesized that: 1): NHBs will demonstrate significantly higher MEP, lower physical function performance, and higher perceived stress in comparison to NHWs; and 2) Perceived stress will be a significant psychosocial factor that explains the relationship between higher MEP and lower function in NHBs, but not NHWs.

2. Materials and Methods

Reporting in this article follows the recommendations of the Strengthening the Reporting of Observational studies in Epidemiology (STROBE) guidelines (Vandenbrouke et al., 2014).

2.1. Design.

This is a secondary data analysis of a prospective observational cohort study including older adults with knee pain who participated in the community-based study Understanding Pain and Limitations in Osteoarthritic Disease (UPLOAD) at the University of Florida (UF) and the University of Alabama at Birmingham (UAB). The parent study's purpose is to identify the biopsychosocial factors that underlie ethnic differences in pain and functional limitations in adults with or at risk for symptomatic knee OA. Institutional Review Boards at the UF and UAB approved the study.

2.2. Participants.

The UPLOAD study enrolled individuals between 45 and 85 years of age, who identified themselves as either non-Hispanic Black/African American or non-Hispanic White/ Caucasian or European. Participants reported unilateral or bilateral knee pain and screened positive for clinical knee OA, which has a high sensitivity and specificity for radiographically confirmed symptomatic knee OA (Altman et al., 1986; Roux et al., 2008). Given widespread variability in definitions of OA (Kraus et al., 2015), we adopted this approach to be as inclusive as possible in recruitment and enroll a cohort with a broad range of OA characteristics, from very early signs to more advanced disease. The goal of the study was to recruit individuals with or at risk of knee OA and follow prospectively to understand factors associated with disease progression, clinical pain, and functional limitations.

Additional details of the screening and inclusion/exclusion criteria are reported in several published articles (Cardoso et al., 2016; Cruz-Almeida, Cardoso et al., 2017). Briefly, exclusion criteria were applied to reduce the presence of medical conditions that could

confound symptomatic knee OA-related outcomes or preclude successful completion of the protocol including: systemic rheumatic disease/condition, surgery to the index knee, uncontrolled hypertension (>150/95), loss of peripheral sensation, neurological disorders, cardiovascular or peripheral arterial disease, serious psychiatric disorder resulting in recent hospitalization (within the past 12 months), diminished cognitive function, and pregnancy due to unknown risk to the fetus. As shown in Figure 1, a total of 126 NHBs and 156 NHWs were enrolled. For the analysis reported in this paper, we selected individuals who were 50 years of age and older, resulting in a final sample size of 83 NHBs and 79 NHWs. We selected individuals 50 and older to (1) capture individuals entering "later life" to better understand the impact of aging on MEP and function, and (2) include individuals meeting one of the clinical criteria for knee OA (i.e. age 50 and older, Altman et al., 1986).

2.3. Procedures.

Upon arriving at the clinical laboratory, participants provided informed consent and completed a series of baseline questionnaires that assessed demographics, health and pain history, and perceived stress. Next, a physical exam of the knees and hands assessed for current pain, bony enlargement, and crepitus. The knee reported by the participant as most painful was designated as the index knee. In addition, posterior-anterior and lateral radiographs of the index knee were obtained, and study rheumatologists read the radiographs to provide a Kellgren-Lawrence (KL) score, which ranges from 0 (no joint changes) to 4 (severe joint changes) (Kellgren & Lawrence, 1957). The visit concluded by conducting physical performance (gait and balance tests) and lower extremity strength tests.

2.4. Measures

2.4.1. Perceived Stress.—The Perceived Stress Scale is a 10-item global measure of an individual's perception of psychosocial stress during the past month (Cohen, Kamarck, & Mermelstein, 1983). Each item is rated on a 5-point scale ranging from never (0) to very often (4). Positively worded items are reverse scored, and the ratings are summed, with higher scores indicating more perceived stress. Total scores range from 0–40 and for our analysis, perceived stress scores were modeled as a continuous variable.

2.4.2. Physical Function.—The Short Physical Performance Battery (SPPB) consists of three measures of lower-extremity mobility function: three increasingly difficult standing balance tasks (side-by-side, semi-tandem, and tandem stance), 4-meter normal walking speed, and timed repeated chair stand (i.e., ability and time to rise from a chair safely 5 times) (Guralnik et al., 1995). The SPPB has been validated and used widely in older adults, including middle-aged adults ages 50–64 (Miller, Wolinksy, Andresen, Malmstrom, & Miller, 2008; Deshpande, Metter, Guralnik, Bandinelli, & Ferrucci, 2013), with various chronic conditions including chronic pain (Eggermont et al., 2014; Fowler-Brown et al., 2013). Participant performance on each of these three movements is scored from 0 (worst performance) to 4 (best performance), and a total score is calculated for a possible maximum score of 12; thus, 0= worst performance to 12= best performance. Lower scores indicate greater functional limitation and scores are analyzed as a continuous variable.

2.4.3. Movement-evoked pain.—For the purposes of this study, we used two approaches to measure MEP. First, we examined the intensity of pain during weight-bearing lower extremity movements that rely heavily on the flexion of the knee as measured by the SPPB. Participants were asked for a numeric pain rating after each movement using a numerical rating scale from 0 (no pain) to 100 (the most intense pain imaginable).

Second, MEP was measured by having participants rate the intensity of pain during maximal isometric strength testing of the knee extensor muscles. This measure of bilateral (index knee and non-index knee) lower extremity strength was assessed by having the participant extend the leg with maximum force while a handheld dynamometer (Lafayette Hand-Held Dynamometer: Model 01165, Lafayette Instruments, Inc., Lafayette, IN) was placed just above the ankle to resist the participant's movement. The tests were performed three times on each leg while the participant was in a sitting position with knee extended 75° from the horizontal position. The three pain ratings were averaged for each knee.

2.4.4. Pain and Function.—The Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) is a reliable and well-validated self-report measure of knee and hip OA symptoms and function within the immediate past 48 hours (Bellamy et al., 1988; Collins et al., 2011). The WOMAC has three subscales: pain during passive and active activities, stiffness, and impairments in physical function. Scores for the five pain items are summed for a possible score of 0–20 and higher scores indicate worse pain. The WOMAC pain subscale was included in the models to control for the effects of "self-reported" OA pain distinct from measuring movement-evoked pain during the performance of the tasks.

2.4.5. Sample Characteristics.—Ethnicity and race were based on responses to the following questions: (1) are you Hispanic or Latino? (Yes or No), and (2) what is your race or origin: Asian or Asian American; Black or African American; White, Caucasian, or European; American Indian or Alaska Native; Native Hawaiian or Other Pacific Islander; and Some Other Race or Origin? Additional demographic and baseline anthropometric data, including age, gender, education level, past and current medical history, height, weight, and body mass index were assessed and reviewed for accuracy by a study-designated advanced practice nurse.

2.5. Analysis.

Ethnic/race differences in demographic characteristics and study variables were examined using chi-square (x^2) for dichotomous variables and ANOVA for continuous variables. A composite proxy of SES was computed by averaging the z-scores of our measures of education and income, where higher education and higher income categories reflect higher SES status. Mean intensity ratings for MEP were generated for NHBs and NHWs. ANCOVAs determined differences in measures of perceived stress, MEP, and function. In order to examine the influence of ethnic/race group, perceived stress and their interaction on MEP and function, two sets of analyses are presented. First, crude unadjusted models were performed, followed by fully adjusted models, which included covariates of SES index, age, KL-score on the index knee, BMI, study site (UF & UAB), and WOMAC scores to adjust for the chronicity of ongoing OA pain. Statistical significance was considered at $p < .05$.

3. Results

3.1. Participant Characteristics.

A total of 162 participants (83 NHBs, 79 NHWs) were included in the analyses (Table 1). Our study sample was mostly female (61.1%) and recruited from the UF location (63.6%). There were significant ethnic/race group differences in age and SES. NHBs were younger, more economically and educationally disadvantaged, and less likely to be married compared to NHWs.

3.2. Ethnic/Racial Differences in MEP, Function, and Perceived Stress.

There were significant racial/ethnic differences in all measures of MEP in both the crude unadjusted and fully adjusted models (Table 2), such that NHBs reported greater MEP than NHWs. In addition, NHBs were more likely to report the maximum intensity of pain (pain intensity = 100) for MEP, while more NHWs were likely to report no MEP (pain intensity = 0). In general, both groups demonstrated moderate functional performance on the SPPB, but NHBs showed significantly lower overall function (p= 0.01) and walking speed (p <0.01). Balance and chair standing performance were similar across ethnic/race groups. Perceived stress did not differ across groups.

3.3. Relationship between Perceived Stress and MEP and Function

Separate general linear models were conducted to examine the association of perceived stress and ethnicity/race with MEP (Table 3) and function (Table 4). Overall, there was not a significant main effect for the association of perceived stress with any measure of MEP; although, walking pain approached statistical significance (p= 0.06). However, significant interactions between perceived stress and ethnicity/race emerged for most measures of MEP, even after controlling for demographics and WOMAC. This significant interaction was observed for balance pain [$F_{(1, 143)}$ = 87.6, p= 0.006)], walking pain ($F_{(1,144)}$ = 7.71, p= 0.006)], and marginally for chair stand pain [$F_{(1, 137)}$= 7.40, p= 0.007)] and index knee strength pain [$F_{(1, 145)}$ = 3.10, p= 0.08]. As shown in Figure 2, the steeper slope is evidence that perceived stress is more strongly related to MEP in NHBs than NHWs.

There was a significant main effect of perceived stress for total functional performance [$F_{(1, 145)}$ = 7.94, p= 0.006] and walking speed (p= 0.03). There was a trend toward significance for chair stand function (p=0.08). In contrast to MEP, there were no interaction effects for perceived stress and race for any of the physical function performance measures.

4. Discussion

4.1. Significance of Results

This is the first study to explore how perceived stress differentially impacts non-Hispanic Blacks and non-Hispanic Whites in the context of MEP and function. Our findings are novel in demonstrating that (1) NHBs experience greater MEP, and perceived stress was more strongly related to MEP in NHBs compared to NHWs, and (2) perceived stress was significantly associated with physical function performance across both racial/ethnic groups.

Although the average intensity of MEP was relatively low for both groups, NHBs reported significantly greater intensity of MEP (i.e., twice as intense pain ratings) compared to NHWs. Furthermore, not only do NHBs report greater MEP but fewer NHBs report zero pain intensity as compared to NHW, suggesting that MEP is experienced by a greater proportion of NHBs. Notably, these differences in MEP remained significant even after controlling for background pain as measured by the WOMAC pain scores. These findings support our first hypothesis that NHBs would demonstrate greater MEP. The question becomes "why do NHBs have more MEP?" Research has consistently found that NHBs report increased sensitivity to laboratory pain stimuli (Rahim-Williams et al., 2012; Kim et al., 2017; Bell et al., 2018), and similar findings have emerged among individuals with or at risk for knee OA (Cruz-Almeida, Cardoso, et al., 2017). Like laboratory-induced pain, MEP represents a form of evoked pain due to internal mechanical stimuli induced by movement. Hence, if NHBs exhibit a pain modulatory profile characterized by increased pain facilitation and decreased inhibition, this could explain their greater pain in response to movement-evoked stimuli. More severe joint damage could also contribute to greater MEP among NHBs, as some previous work has reported more severe radiographic OA among NHBs (Braga et al., 2009; Nelson et al., 2011), in which case movement may actually generate a more intense nociceptive stimulus in the joint, thereby inducing greater pain. However, KL scores did not differ significantly between ethnic/race groups in this study, and MEP was greater in the NHB group even after controlling for KL scores.

There were no group differences in levels of perceived stress, but the association of perceived stress with MEP was moderated by race/ethnicity. Specifically, higher perceived stress was more strongly associated with greater MEP during balance, walking, and chair stand tasks among NHBs but not among NHWs. The reasons for this pattern of results are not completely clear; however, it is conceivable that stress may be associated with biological and/or psychosocial responses that differentially influence MEP among NHBs versus NHWs. For example, Gordon and colleagues (2017) demonstrated similar chronic stress exposure and acute stress reactivity among NHBs and NHWs; however, stress reactivity was protective against pain in NHWs but not NHBs. Similarly, Herbert and colleagues (2017) found that pain intensity was negatively associated with a biological measure of stress (cortisol) in NHWs, but not in NHBs. Some have even suggested that epigenetic alterations in the stress response receptor gene (NR3C1) and immune cytokine genes, which are associated with chronic pain and chronic stress, may notably contribute to the differential modulation of chronic pain by ethnicity/race, leaving Black Americans more vulnerable to severe and disabling pain (Aroke et al., 2019).

Our findings of similar magnitude of stress are consistent with previous literature showing no significant ethnic/racial differences (Cohen & Williamson, 1988; Kim et al., 2009), while other studies have shown significantly greater perceived stress in NHWs (Carson et al., 2018; O'Neal et al., 2015). There are several potential explanations for the lack of ethnic/race group differences in perceived stress. One, models were adjusted for socioeconomic and demographic factors that could in fact mediate the relationship between perceived stress and ethnicity/race. Second, differences in stress appraisal and coping factors may obscure or balance out any potential differences in perceived stress. Third, the presence of chronic knee pain may represent a persistent stressor that equalizes perceived stress in both ethnic groups.

While the magnitude of perceived stress did not differ across racial/ethnic groups, the nature of the underlying exposures to stress (e.g. nature of exposure, life interference, duration, timing) likely does differ, which may explain differential associations between stress and MEP. For example, NHBs experience far greater levels of discrimination, and this type of stress has been associated with increased pain in prior work (Goodin et al., 2013). Hence, it may be the nature or the duration of stressors rather than their perceived magnitude that contributes to greater MEP.

In terms of function, our observed differences in performance were driven primarily by slower walking speed in NHBs versus NHWs. This is consistent with epidemiological studies that demonstrate that older NHBs and Hispanics experience significantly greater arthritis-attributable physical limitations and disability as compared to NHWs and other ethnic/racial groups (Barbour, Helmick, Boring, & Brady, 2017; Vaughn et al., 2018). Perceived stress was significantly associated with overall functional performance, walking speed, and chair stand completion time; however, this relationship was not race-dependent in our study.

Jordan and colleagues' (1998) asked, "are ethnic or cultural differences in the psychosocial determinants of… arthritis pain…worthy of study?" (p. 81). Our findings demonstrate the need to understand how psychosocial factors, such as perceived stress, contribute to MEP in NHBs specifically. This calls for a scientific paradigm shift for more *within-group* research to fully explicate the unique contextual relationship of perceived stress and pain. What is unclear is the causal relationship between stress and MEP: does greater MEP increase psychological and physical stress or vice versa? Direction of causation notwithstanding, perceived stress remains an important factor to measure, and attenuate, given its association with multiple pain-related outcomes such as function (Booker et al., 2018), pain interference (White et al., 2014), sleep disturbances (Eslami, Zimmerman, Grewal, Katz, & Lipton, 2016), and cellular aging (Sibille, et al., 2012). Individuals with more severe MEP and worse functional performance also demonstrate significantly greater depressive symptoms, higher use of active and passive coping strategies, and more catastrophizing, pain hypervigilance and negative affect (Cruz-Almeida, Cardoso, et al., 2017). Differences in MEP and perceived stress are clinically meaningful and should be further elucidated through clinical and research efforts.

4.2. Clinical Applications and Research Implications.

Measurement obscurity has greatly hampered our recognition and response to MEP. Nonetheless, our findings indicate the importance of measuring MEP in addition to spontaneous and rest pain in clinical and research settings in individuals with musculoskeletal conditions. Understanding MEP in the context of function provides new insight on the adverse effects of movement (Cruz-Almeida, Cardoso, et al., 2017; Corbett, et al, 2019). Particularly, studying how movement produces or exacerbates knee pain may lend greater interpretive value for common outcomes of OA, such as decreased physical activity and avoidance of activity. Further, given the relationship with function, MEP (i.e., objective measurement rather than self-report) may also represent an important patient-reported outcome measure (PROM) to be considered in initiatives such as IMMPACT (Dworkin et

al., 2005), Patient-Reported Outcomes Measurement Information System (PROMIS®, Cook et al., 2016), and Analgesic, Anesthetic, and Addiction Clinical Trial Translations, Innovations, Opportunities, and Networks (ACTTION; Fillingim et al., 2014), especially when studying chronic conditions of aging such as OA. In managing knee OA, MEP may be an important target to treat through behavioral modification to sustain optimal joint and muscle function. Future mechanism-based research is needed to accurately phenotype MEP in older individuals with OA.

Even with low perceived arthritis-related stress, NHBs with functional limitations still experience high life stressors compared to NHWs (McIlvane, Baker, & Mingo, 2008). Thus, to fully comprehend ethnic/race group differences in pain-related outcomes, research is needed to address psychosocial sources of perceived and actual stress, such as discrimination and socioeconomic/financial stress, given the differential effects across the ethnic/race groups (Baker, Buchanan, & Corson, 2008; Burgess et al., 2009; Dugan et al., 2018; Herbert et al., 2017; Walker Taylor et al., 2018). Providers must also be more attentive to social and environmental conditions as key aspects in application of the biopsychosocial model of pain and disability (Fillingim, 2017). More comprehensive measurement of stress may reveal specific environmental exposures or life events, and cognitive-affective responses thereto, that explain the stronger association of stress with MEP and function in NHBs. Meints and Edwards (2018) present an array of stress-related psychological factors to consider when interpreting chronic pain outcomes, especially since NHBs engage in more negative pain coping, such as catastrophizing, that are associated with poor pain outcomes (Meints, Miller, & Hirsch, 2017). This might inform positive coping interventions designed to reduce perceived stress and MEP in groups of people at high-risk. The current study contributes to the literature by investigating mechanisms that have previously been underappreciated and may highlight potentially important opportunities to intervene on psychosocial and environmental distress through stress management.

4.3. Strengths and Limitations

We acknowledge strengths and limitations in our study. One strength of this study involves multiple performance-based techniques to measure MEP, a more objective method to assess current pain rather than recalled pain. As previously noted, there is presently no standardized method to clinically (re)produce and measure MEP giving rise to potential measurement error. Subsequently, our primary measure of clinical MEP (i.e., SPPB) requires further validation and the lab-based measurement of MEP may not be representative of the most painful movement-based activities. More dynamic tests of MEP are needed to distinguish MEP during passive and active flexion/extension of the knee. Nonetheless, significant ethnic/race differences in MEP intensity were observed. Specifically, two parameters of MEP, walking pain and balance pain, show indication that the SPPB can accurately distinguish movement and mobility activities associated with more/less pain. While the SPPB is valid and reliable for use in older adults and in chronic pain populations, its reliability in younger adults (50–64 years) and across ethnic groups is limited which may introduce age-related physical performance bias; and is therefore a limitation in our study. Given the heterogeneity of our sample inclusion age, physical performance could differ by

age group; however, we were unable to examine possible cohort differences due to unequal distribution across age groups and subsequent insufficient power for statistical analyses.

Data reported are cross-sectional preventing causal inferences. Lastly, our models had limited predictors, and there are likely other factors that may further explain these racial/ethnic differences. Specifically, factors that contribute disproportionately to increased stress among NHBs include lower socioeconomic status (greater unemployment, lower income, and lower education level, unsafe neighborhoods), racial discrimination, higher chronic disease burden, and reduced access to healthcare (Poleshuck & Green, 2008; Vaughn et al., 2018). Therefore, future studies should critically examine the effect of 'race, place, and income base' to disentangle the stress exposures that contribute to greater MEP. Despite these limitations, our study provides new insights into racial differences in MEP, function, and perceived stress.

5. Conclusions

Movement-evoked pain is a significant aspect of the chronic pain experience in aging adults with or at risk for knee OA. In particular, our findings show that NHBs experience more MEP compared to NHWs. Perceived stress is an interesting and meaningful psychological mechanism contributing to the relationship between ethnic/race and MEP during physical performance tasks. In conclusion, these results suggest that future research on the association between ethnicity/race, MEP, and function requires more careful attention to identifying precise factors that explain differences in symptomatic knee OA.

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Highlights

- Older non-Hispanic Blacks (NHBs) report nearly twice as much MEP as compared to their older non-Hispanic White (NHWs) peers.
- Perceived stress was not significantly different by race, yet the association between perceived stress and MEP was stronger in NHBs compared to NHWs.
- Higher perceived stress is negatively associated with physical performance.
- Additional intraracial and interracial group research is needed to fully explicate the unique contextual relationship of perceived stress, pain, and function.

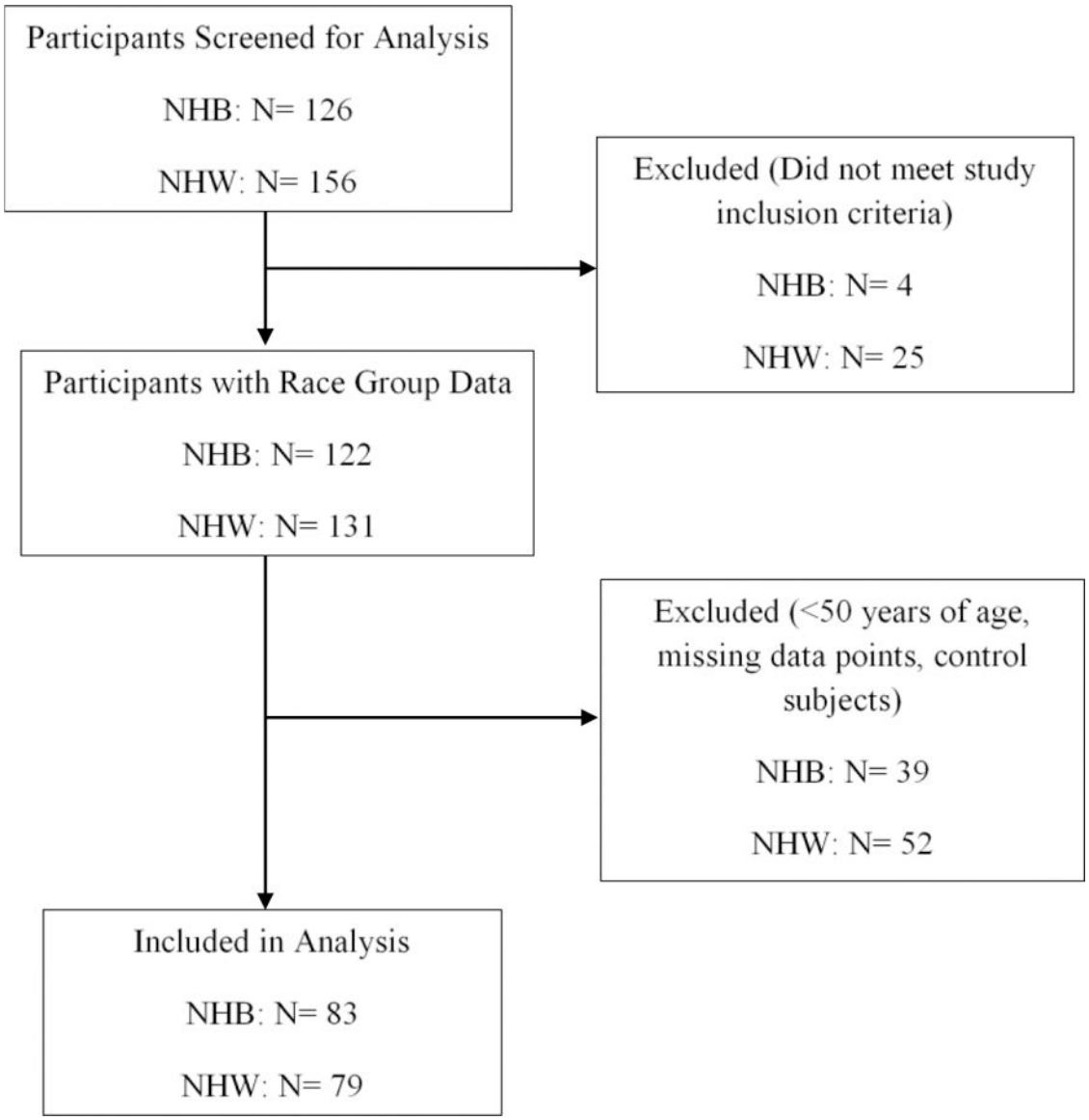
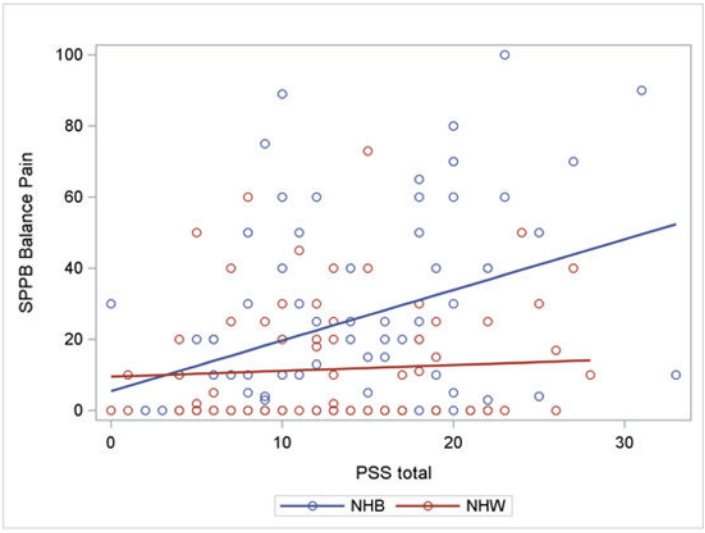


Fig. 1.
Flow Chart of Sample Enrollment

A.



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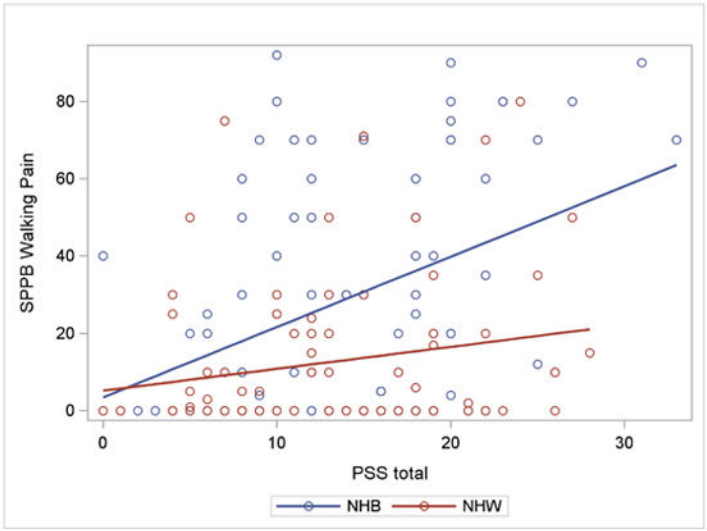

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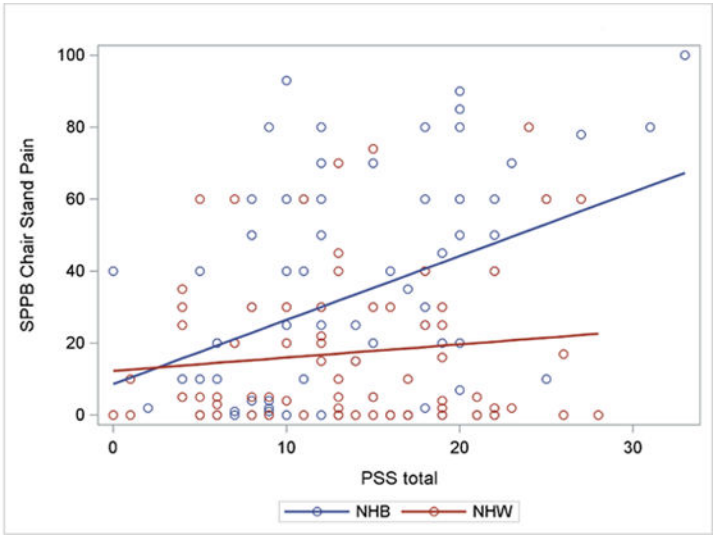

Fig. 2.

Linear Regression Slopes for Movement-evoked Pain for Perceived Stress*Race Interaction .

A. Balance Pain; **B**. Walking Pain; **C**. Chair Stand Pain

† Perceived Stress Score (PSS)

Table 1.

Demographic Characteristics of Study Sample

Characteristic	NHBs N= 83	NHWs N= 79	x^2 or F-value	*p*
Male (N, %)	36 (43.4)	27 (34.2)	1.44	0.23
Female (N, %)	47 (56.6)	52 (65.8)		
UF Site (N, %)	50 (60.24)	53 (67.1)	0.82	0.37
UAB Site (N, %)	33 (39.8)	26 (32.9)		
Age (M±SD)	58.04 ± 5.63	61.47 ± 7.63	10.69	**0.001**
SES Index	−0.26	0.28	16.69	**0.001**
KL Score (Index Knee)			7.98	0.09
0	25 (30.1)	19 (24.1)		
1	7 (8.4)	19 (24.1)		
2	17 (20.5)	13 (16.5)		
3	15 (18.1)	14 (17.78)		
4	18 (21.7)	12 (15.2)		
BMI (kg/m^2)	32.02 ± 6.92	31.00 ± 7.48	0.81	0.37
WOMAC	8.8 ± 3.89	6.29 ± 4.16	14.65	**0.0002**

Table 2.

Average MEP, Function, and Perceived Stress in NHBs and NHWs

	NHB (N= 83)			NHW (N= 79)				
MEP	**Mean ± SD**	**Range**	**N (%) Reporting No MEP**	**Mean ± SD**	**Range**	**N (%) Reporting No MEP**	**Unadjusted *p***	**Adjusted *p***
Balance pain	25.44 ± 27.43	100	23 (28.40)	11.62 ± 16.81	73	42 (53.16)	**<0.01**	**<0.01**
Walking pain	29.05 ± 30.34	92	28 (34.15)	12.68 ± 19.83	80	40 (50.63)	**<0.01**	**0.03**
Chair stand pain	33.62 ± 29.71	100	14 (18.18)	17.57 ± 21.31	80	24 (31.17)	**<0.01**	**0.03**
Index knee strength pain	27.65 ± 27.58	100	7 (8.43)	12.73 ± 17.68	64	28 (35.44)	**<0.01**	**0.02**
Non-index knee strength pain	18.47 ± 23.32	100	21 (25.30)	9.64 ± 15.38	77	36 (45.57)	**<0.01**	0.22
Function	**Mean ± SD**		**Range**	**Mean ± SD**		**Range**	**Unadjusted *p***	**Adjusted *p***
Total Function Score	9.11 ± 1.82		33	9.70 ± 1.66		8	**<0.01**	0.08
Balance	3.69 ± 0.66		2	3.72 ± 0.70		3	0.69	0.90
Walking speed	3.55 ± 0.69		2	3.80 ± 0.54		3	**<0.01**	**0.05**
Chair stand	1.94 ± 1.34		4	2.18 ± 1.13		4	0.12	0.34
Perceived Stress	14.08 ± 6.65		33	13.31 ± 6.71		28	0.49	N/A

Table 3.

Coefficients for ANCOVA with MEP as Outcome (Adjusted Models)

	Balance Pain			Walking Pain			Chair Stand Pain		
Predictor	**SS**	**F**	***p***	**SS**	**F**	***p***	**SS**	**F**	***p***
Perceived stress	494.55	1.37	0.24	1521.38	3.59	0.06	740.99	1.69	0.20
Race	551.98	1.53	0.22	909.06	2.15	0.15	862.2	1.97	0.16
Perceived stress*race	2747.19	7.60	**0.006**	3264.68	7.71	**0.006**	3236.27	7.40	**0.007**
C_1 SES index	725.46	2.01	0.158	36.94	0.09	0.77	57.57	0.13	0.71
C_2 Age	173.89	0.48	0.49	228.52	0.54	0.46	442.66	1.01	0.32
C_3 KL score	451.35	1.25	0.27	1707.77	4.03	**0.05**	3922.67	8.97	**0.003**
C_4 BMI	70.06	0.19	0.66	432.84	1.02	0.31	1131.92	2.59	0.11
C_5 Study site	360.04	1	0.32	1306.72	3.09	**0.08**	13.95	0.03	0.86
C_6 WOMAC	13888.37	38.42	**<.0001**	17837	42.13	**<.0001**	18922.74	43.27	**<.0001**

	Index Knee Strength Pain			Non-Index Knee Strength Pain		
Predictor	**SS**	**F**	***p***	**SS**	**F**	***p***
Perceived stress	9.71	0.02	0.88	1137.53	3.52	0.06
Race	139.84	0.32	0.58	48.42	0.15	0.7
Perceived stress*race	1374.23	3.1	0.08	353.64	1.09	0.3
C_1 SES index	441.87	1	0.32	26.21	0.08	0.78
C_2 Age	59.4	0.13	0.71	514.38	1.59	0.21
C_3 KL score	47.25	0.11	0.74	258.59	0.8	0.37
C_4 BMI	664.48	1.5	0.22	211.21	0.65	0.42
C_5 Study site	1996.7	4.51	**0.04**	379.41	1.17	0.28
C_6 WOMAC	10239.43	23.12	**<.01**	8095.38	25.02	**<.01**

SES= socioeconomic status, BMI= body mass index, WOMAC= Western Ontario and McMaster Universities Osteoarthritis Index

Table 4.

Coefficients for ANCOVA with Function as Outcome (Fully Adjusted Models)

	Total Function			Balance			Walking Speed			Chair Stand		
Variables	**SS**	**F**	***p***	**SS**	**F**	***p***	**SS**	**F**	***p***	**SS**	**F**	***p***
Perceived stress	18.42	7.94	**0.006**	0.76	1.87	0.17	1.51	4.54	**0.03**	4.12	3.17	0.08
Race	1.62	0.7	0.41	0.005	0.01	0.91	0.03	0.1	0.75	0.92	0.7	0.4
Perceived stress*race	0.01	0	0.94	0.002	0	0.95	0.13	0.39	0.53	0.27	0.21	0.65
C_1 SES index	10.16	4.38	**0.04**	0.605	1.5	0.22	1.59	4.77	**0.03**	1.35	1.04	0.31
C_2 Age	14.65	6.31	0.01	2.734	6.77	**0.01**	1.07	3.21	0.07	1.25	0.96	0.33
C_3 KL score	1.61	0.69	0.41	0.046	0.11	0.74	0.39	1.17	0.28	0.003	0	0.96
C_4 BMI	17.51	7.54	**0.007**	3.36	8.31	**0.005**	0.03	0.09	0.77	6.76	5.19	**0.02**
C_5 Study site	20.54	8.85	**0.003**	2.45	6.05	**0.02**	2.01	6.04	**0.02**	18.36	14.09	**<0.01**
C_6 WOMAC	8.16	3.51	0.06	0.76	1.88	0.17	0.08	0.27	0.61	2.81	2.15	0.14