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Dispositional traits help explain individual differences in relationships between a radiographic knee osteoarthritis measure, pain, and physical function

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Abstract

Background: The concordance between radiograph-derived Kellgren–Lawrence (KL) scores for knee osteoarthritis (KOA) and experimental and clinical pain and KOA-related physical function is conflicting.

Objectives: We investigate whether the inclusion of dispositional traits reduces variability between KOA radiographic findings, experimental pain, clinical pain, and function in individuals with knee pain.

Design: This study is a cross-sectional, secondary analysis of data collected from the UPLOAD-II study.

Methods: Adults aged 45–85 years with and without knee pain were enrolled. Data collected included sociodemographics, knee radiographs, experimental pain, clinical pain and function, and trait affect. Vulnerable and protective dispositional traits were classified from combined positive and negative trait affect measures. KL scores were determined from the knee radiographs. Unadjusted and adjusted (age, sex, comorbidities, and body mass index) regression analyses were completed with SAS version 9.4 (Cary, NC, USA).

Results: The study included 218 individuals with a mean age of 58 years, 63.6% women, and 48.2% non-Hispanic black adults. Dispositional traits were associated with the experimental pain measures. No association between radiographic KOA and experimental pain was observed. In a combined and adjusted analysis, dispositional traits were predictive of knee punctate pain temporal summation ($p = 0.0382$). Both dispositional traits and radiographic KOA scores independently and combined were predictive of Graded Chronic Pain Scale pain and function, and Western Ontario and McMaster University pain and function ($ps \leqslant 0.01$). Improvements in R^2 were noted across all models with the inclusion of dispositional traits.

Conclusion: Consideration of dispositional traits reduces the variability between radiographic KOA and pain and function. Non-pathological and associated pain-related psychological factors and dispositional traits might serve as parsimonious proxy tools to improve clinical assessments.

Registration: N/A.

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Plain language summary

Dispositional traits help explain individual differences in relationships between a radiographic knee osteoarthritis measure, pain, and physical function

Significance

- The concordance between radiographic knee osteoarthritis and experimental and clinical pain is conflicting.
- Dispositional traits comprise the infrastructure from which an individual interprets and interacts with the environment and are predictive of sensory sensitivity, response to stress, psychopathology, and behavior.
- Consideration of dispositional traits improves the congruence between knee osteoarthritis Kellgren-Lawrence scores, experimental pain, and clinical pain.

Keywords: dispositional traits, function, Kellgren–Lawrence scores, knee osteoarthritis, pain

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Introduction

Knee osteoarthritis (KOA) is a common progressive joint disease characterized by pain and disability.[1] Radiographs are used to assess KOA severity. Kellgren–Lawrence (KL) scores are a common diagnostic classification system for evaluating grades of KOA with 0 showing no evidence of KOA to 4 indicating severe KOA.[2] Relationships between experimental and clinical pain and KOA radiographic classification based on KL scores are mixed. Individuals with KOA show heightened sensitivity compared to non-KOA controls on measures of experimental pain testing; however, across the different grades of KOA, the differences in sensitivity are less apparent.[3–5] Some research indicates that experimental pain sensitivity is more associated with clinical pain.[3,6] Findings between radiographic KOA and clinical pain are also mixed with several studies indicating no relationship and others showing significant relationships.[7–11] With approximately 30% of individuals with severe KOA being asymptomatic, the ability to identify the factors contributing to individual differences in pain and function would be a significant clinical benefit.[12]

Numerous psychological factors are associated with pain and function including anxiety, depression, catastrophizing, and fear avoidance. Less frequently considered are dispositional traits also known as temperament or personality traits which are neurobiological based and are associated with stress sensitivity and contribute toward cognitive, emotional, sensory, and behavioral functioning.[13–15] Dispositional traits exist across species and have been extensively studied in animal and clinical models.[13,16–20] Initial considerations of dispositional traits were described as early as 400 BC. Hippocrates is widely recognized for his identification of the four humors and their association with health and emotional functioning.[21] Broadly investigated, numerous psychological theories and models have been developed around related constructs.[19,21–24] Preclinical and animal studies have provided further validating evidence for the underlying genetic and predisposing nature of dispositional traits.[16–18,25]

Prior research has predominately focused on psychological pathologies in investigations of predictors of experimental and clinical pain. However, a strong body of evidence has been established in preclinical and clinical studies demonstrating the predictive utility of the non-pathological dispositional traits.[13,18,24] Although temperament is comprised of cognitive, sensory, physiological, and affective components, we and others have found a simple measure of trait affect significantly relevant.[26–32] Consistent with numerous models, Affect Balance Style (ABS) is a measure of combined levels of positive and negative trait affect.[27,33] We have shown ABS is associated with clinical pain, experimental pain, and pain-related psychological factors (e.g. somatic sensitivity, anxiety, catastrophizing, depression) in individuals with and without chronic pain.[26,27,29,33] In

addition, aligning with preclinical models, we reported that the healthy and low ABS indicate more 'protective' traits compared to the more 'vulnerable traits' of the depressive and reactive ABS.[29] Dispositional traits may help inform clinical practice by accounting for some of the observed individual differences in radiographic KOA, pain, and function.

The purpose of the study was to investigate relationships between dispositional traits and radiographic KOA as measured by KL scores across measures of (1) experimental pain, (2) clinical pain and functioning, and whether the inclusion of dispositional traits with radiographic KOA scores improves the relationships with (1) experimental pain and (2) clinical pain and physical function. We hypothesized the relationships between radiographic KOA and experimental pain, clinical pain, and physical function would be limited. With consideration of dispositional traits, the variance accounted for in the study models would increase. Furthermore, in individuals with similar radiographic KOA classifications, those with vulnerable dispositional traits will report greater experimental and clinical pain and functional limitations compared to those with protective dispositional traits.

Methods

Participants

Adults between 45 and 85 years of age with and without chronic knee pain who self-identified as either non-Hispanic black (NHB) or non-Hispanic white (NHW) were recruited and enrolled at the University of Florida and the University of Alabama at Birmingham between August 2015 and May 2017.[34] Community advertisements and clinic referrals were the primary forms of recruitment. Exclusion criteria for the UPLOAD-2 study included: (1) cognitive impairment; (2) use of opioids on a daily basis; (3) hospitalization for a psychiatric illness in the preceding year; (4) a history of acute myocardial infarction, heart failure, or uncontrolled hypertension (BP > 150/95 mm Hg); (5) prosthetic knee replacements or other clinically significant surgery to the affected knee; (6) peripheral neuropathy; and/or (7) systemic diseases including rheumatoid arthritis, systemic lupus erythematosus, or fibromyalgia. This study was conducted in accordance with the Declaration of Helsinki. The UPLOAD-2 study was approved by the University of Florida Institution Review Board (IRB approval number 201400209) on 6 June 2014 and the University of Alabama at Birmingham Institution Review Board (IRB approval number 40915002) on 11 November 2014. All participants provided verbal and written informed consent prior to study participation. The current study consisted of data collected as part of the UPLOAD-2 study specific to participants with radiographic-derived KOA KL scores based on American College of Rheumatology criteria and a completed Positive and Negative Affect Schedule (PANAS).[35] This manuscript follows the STROBE checklist reporting guidelines.[36] An abstract of this data was presented at the United States Association for the Study of Pain conference in Cincinnati, Ohio in May 2022. Data are not publicly available but can be requested from the corresponding author. The current investigation is a cross-sectional analysis. The measures described are limited to those relevant to the identified research questions.

Procedures

Participants completed a health assessment and experimental pain testing session. Data collected included information specific to sociodemographics, health status, pain history, health outcomes, experimental pain testing, and knee radiographs. Questionnaires were completed and experimental pain testing was conducted specific to the index knee which was defined as the most painful knee for participants reporting knee pain and a randomized knee for the no knee pain comparison group. Participant questionnaires were reviewed for completeness to reduce bias.

Measures

Sociodemographic and health status

Baseline characteristics and health-related outcomes. Sociodemographic characteristics included age, sex, ethnicity/race, highest education completed, income range, and insurance status. Participants completed a health assessment and health history questionnaire including the report of current comorbidities including high blood pressure, heart disease, cancer, diabetes, asthma/breathing problems, kidney disease, thyroid problems, stroke, seizure, chronic pain, neurological disorder, depression, other mental health condition or other health problem. Height and weight were measured and body mass index (BMI) was calculated.

Clinical and radiographic criteria

Posterior–anterior and lateral radiographs of the knee were taken of the participant's index knee. Posterior–anterior view radiographs were obtained using a Synaflexer with the X-ray beam centered on the joint line at a 10° caudal angulation. Lateral radiographs were obtained with the knee flexed at 40°. An experienced rheumatologist at the University of Florida, blinded to the knee group and participant characteristics, evaluated all radiographs for both study sites using the KL classification system (score range 0–4).[37]

Experimental pain measures

Pressure pain threshold. Pressure pain threshold was assessed at the medial ($n=217$) and lateral ($n=216$) knee, using a handheld AlgoMed, Medoc digital pressure algometer. The pressure was increased at a constant rate of 30 kPa/s until the participant indicated the first sensation of pain, pain threshold. Pressure pain threshold testing was repeated three times at each site and the average at each site was used for analysis. The maximum pressure of the knee was 500 kPa. The order of testing sites was randomized.

Punctate pain temporal summation. Punctate stimuli were delivered with a calibrated 300*g* nylon monofilament on the index knee. First, a single stimulation was provided and then participants were asked whether the stimulation was painful and if so to provide a pain rating from 0 to 100. Then a series of 10 stimulations were given and participants were again asked if the stimulation was painful and if so to provide a pain rating from 0 to 100. This procedure was repeated twice. The average of the series stimulation was subtracted from the average of the single stimulation as a measure of punctate pain temporal summation and used for analysis ($n=218$).

Clinical pain measures

Graded Chronic Pain Scale. The GCPS was used to assess the severity of knee pain and its impact on activities ($n=216$). The measure is scored using two sub-scales, characteristic pain intensity (CPI) (0–100 score) and disability score (0–100 score) over a 6-month period. The higher the score, the higher the pain intensity and greater physical disability. The GCPS has demonstrated good internal consistency in prior research ($\alpha=0.74$).[38]

Western Ontario and McMaster Universities Arthritis Index. The WOMAC was used to assess knee pain, function, and stiffness over the past 48 h.[39] The three subscales, pain (0–20 score), stiffness (0–8 score), and function (0–68 score), sum for a total WOMAC score (0–96 score) with higher scores indicating worse pain, stiffness, and functional limitations. The WOMAC pain ($n=217$) and function ($n=218$) were used in analyses. The WOMAC has demonstrated good internal consistency ($\alpha=0.84$–0.95) across several previous studies.[40,41]

Total pain sites. Participants were asked to select from a list of pain sites if they experienced pain '*more days than not over the past three months*'. Bilateral body sites included hands, arms, shoulders, neck, head/face, chest, stomach, upper back, lower back, knees, legs (other than knees), or feet/ankles (0–24 sites). A greater number of pain sites is associated with worse health outcomes with three or more pain sites considered as widespread pain.[42,43]

Dispositional traits

The PANAS is comprised of 10 positive and 10 negative words that reflect emotions and feelings.[44] Participants indicate on a five-point Likert scale how they feel 'in general' to each word from 1 = 'very slightly or not at all' to 5 = 'extremely'. Scores range from 10 to 50 for both positive (PA) and negative (NA) affect, with higher scores indicating higher levels. The PANAS has a very good internal reliability with Cronbach alpha coefficient scores ranging from 0.86 to 0.90 for the PA scale and 0.84 to 0.87 for the NA scale.[45]

Affect Balance Style (ABS) is determined based on published adult normative means for trait PANAS.[33] Although categorizing relationships between two independent continuous variables is not a recommended statistical approach, a review of foundational literature indicates the approach aligns with the conceptual models of several temperament theorists. The four group/quadrant classification of ABS styles is consistent with well-established lines of investigation that extend from Eysenck's Personality Inventory,[46] to Watson, Clark, and Tellegen – the developers of the PANAS,[33] and persist in more current conceptual circumplex models of affect.[19] The ABS groups were defined as follows: healthy ABS = high PA >35 and low NA ≤ 18.1; low ABS = low

PA⩽35 low NA⩽18.1; reactive ABS=high PA>35 high NA>18.1, and depressive ABS=low positive PA⩽35 and high NA>18.[27,33] Protective and vulnerable dispositional traits were then categorized such that those individuals with healthy or low ABS were identified as having more protective traits and those individuals with reactive or depressive ABS were identified as having more vulnerable traits.[29] The two dispositional trait groups were used in study analyses (0=protective, 1=vulnerable) ($n=218$).

Statistical analysis

Data were assessed for distributional form using visual inspection (histograms, boxplots) and normality was tested using the Shapiro–Wilk test. Missing variables were minimal ($n=2$) and treated as missing. To test the research hypotheses of this paper, simple and multiple linear regression models were constructed. To assess the distributional assumptions of the regression models (normality of residuals, homogeneity of variance for residuals), residuals plots and normal probability plots were examined. We did not observe patterns within these graphs that would indicate a violation of the assumptions. Sample size calculations were completed for the parent study. Given this study is a secondary data analysis with a fixed sample size of 218, we have estimated and presented the effect sizes that would achieve 90% power (probability of being declared significant) for a sample size of 218 using a Type I error of 0.05. Additional explanatory variables included in all adjusted analyses were age, sex (ref=male), total number of comorbidities, and BMI. Participant characteristics are presented as descriptives.

To address question 1, investigate relationships between experimental pain, KL scores, and dispositional traits. Regression analyses were conducted for each outcome measure: pressure pain threshold at the medial knee, pressure pain threshold at the lateral knee, and punctate pain temporal summation as follows – Model 1: dispositional traits only, Model 2: KL scores only, Model 3: combined KL score and dispositional traits, Model 4: KL score, dispositional traits, and additional explanatory variables.

To address question 2, investigate relationships between clinical pain and functional measures, KL scores, and dispositional traits. Regression analyses were completed for each outcome measure GCPS CPI, WOMAC Pain, GCPS Interference, and WOMAC Function as follows – Model 1: dispositional traits only, Model 2: KL scores only, Model 3: combined KL score and dispositional traits, Model 4: KL score, dispositional traits, and additional explanatory variables.

Statistical analyses were completed using SAS version 9.4 (Cary, NC, USA). All statistical tests were conducted using a Type I error of 0.05.

Results

Descriptives

A total of 218 participants were included in the analysis. Participants were 57.4 ± 7.7 years of age, predominately female (65.1%) with 46.8% self-reporting as NHB (Table 1). There were no sex differences in dispositional traits or radiographic KOA as measured by KL scores. The NHB participants differed on socioenvironmental factors compared to NHW participants. NHB participants were younger, had less education, had lower income, and had a greater number of comorbidities compared to the NHW participants. Ethnicity/race is a self-reported construct where proportions of representation can be reported. However, as our ethnic/race groups do not match on relevant sociodemographic factors and the inclusion of covariates does not balance out group differences, and only a subgroup of each ethnic/race group is represented, a generalizable sample was not obtained.[47] The term sociodemographic groups rather than ethnic/race groups is a more accurate description and will be used for the group variable in the Results and Discussion.

Comparisons were also completed within each of the dispositional trait groups, for example, for protective traits, the healthy and low ABS groups were compared, and for vulnerable traits the reactive and depressive ABS groups were compared specific to age, sex, number of pain sites, BMI, experimental and clinical pain, and functional measures. No significant differences were observed.

Relationships between dispositional traits, radiographic KOA, and experimental pain

Dispositional traits were significantly associated with medial ($b=-57.0$, $p=0.0047$) and lateral ($b=-60.2$, $p=0.0065$) pressure pain threshold

Table 1. Baseline characteristics of participants.

Variable	Total sample ($n=218$)
Sociodemographic status	
Age, $M \pm SD$	57.4 ± 7.7
Gender, *N* (%)	
Male	76 (34.9)
Female	142 (65.1)
Sociodemographic groups, *N* (%)	
NHB	102 (46.8)
NHW	116 (53.2)
Site, *N* (%)	
University of Florida	136 (62.4)
Univeristy Alabama at Birmingham	82 (37.6)
Education, *N* (%)	
High school or less	127 (58.3)
Higher education	91 (41.7)
Income, *N* (%)	
$0–29,999	109 (50.0)
$30,000–79,999	70 (32.1)
$80,000+	36 (16.5)
Not reported	3 (1.4)
Clinical characteristics	
BMI, $M \pm SD$	31.4 ± 7.5
No. comorbidities (0–14), *N* (%)	
0	70 (32.1)
1–2	118 (54.1)
3+	30 (13.8)
KL scores, *N* (%)	
0–1	150 (68.8)
2–4	68 (31.2)

BMI, body mass index; KL, Kellgren–Lawrence; M, mean; NHB, non-Hispanic black; NHW, non-Hispanic white; SD, standard deviation.

and punctate temporal summation ($b=6.1$, $p=0.0288$) with the vulnerable traits group showing greater pain sensitivity (Table 2A, Model 1). Radiographic KOA was not associated with experimental pain (Table 2A, Model 2). In a regression analysis with KL score and dispositional traits, only dispositional traits were significantly associated with medial ($b=-56.5$, $p=0.0050$) and lateral ($b=-59.1$, $p=0.0074$) pressure pain threshold (Table 2A, Model 3). Inclusion of dispositional traits accounted for an additional 3% of the variance compared to KL scores alone.

In combined and adjusted regression analyses including covariates age, sex, comorbidities, and BMI (Table 2A, Model 4), dispositional traits were significantly associated with punctate pain temporal summation ($b=6.8$, $p=0.0166$) while KL scores were not associated with any of the experimental pain measures. Female sex and higher BMI were associated with lower pressure pain threshold on both the medial and lateral knee. Female sex was also associated with greater punctate pain temporal summation.

Relationships between dispositional traits, radiographic KOA, and clinical pain and function

Dispositional traits were significantly associated with all measures of clinical pain (Table 2B, Model 1) with vulnerable traits related to worse pain and lower function. Radiographic KOA was also associated with all clinical pain and functional measures such that higher KOA was associated with worse pain and lower function (Table 2B, Model 2). In a regression analysis with KL score and dispositional traits, both KL scores and dispositional traits were associated with all clinical pain and functional measures ($ps<0.01$) (Table 2B, Model 3). Inclusion of dispositional traits accounted for an additional 6–10% of the variance compared to KL scores alone. Figure 1 is a residual plot of clinical pain and function measures by KL scores with a trend line for dispositional traits. Individuals with vulnerable traits reported greater clinical pain and interference on all clinical measures ($p<0.001$).

In adjusted regression analyses including age, sex, comorbidities, and BMI (Table 2B, Model 4), KL scores and dispositional traits were significantly associated with all clinical pain and functional measures ($ps<0.01$). A greater number of comorbidities was associated with all outcomes while higher age was associated with lower GCPS CPI, GCPS interference, and WOMAC pain.

Table 2. Multivariate-multiple regression models of dispositional traits and KL scores by experimental pain, clinical pain, and function.

	(A) Experimental pain						(B) Clinical pain							
	Pressure threshold medial knee		Pressure threshold lateral knee		Punctate temporal summation		GCPS CPI		GCPS interference		WOMAC pain		WOMAC function	
Variables	b(SE)	t	b(SE)	t	b(SE)	t	b(SE)	t	b(SE)	t	b(SE)	t	b(SE)	t
Model 1														
DT	−57.0(20.0)**	−2.7	−60.2(21.9)**	−2.8	6.0(2.8)*	2.2	18.5(4.1)***	4.5	19.6(5.0)***	3.9	3.8(0.7)***	5.1	12.2(2.5)***	4.9
R^2	0.0296		0.0295		0.0246		0.0790		0.0680		0.1159		0.1080	
Model 2														
KL score	−3.8(7.1)	−0.5	−6.8(7.7)	−0.9	−0.7(0.7)	−1.0	5.5(1.3)***	4.3	6.7(1.5)***	4.4	0.9(0.2)***	4.1	3.9(0.8)***	5.2
R^2	0.0015		0.0041		0.0037		0.0763		0.0820		0.0723		0.1213	
ΔR^2	−0.0146		−0.0254		−0.0209		−0.0027		0.0140		−0.0436		0.0133	
Model 3														
KL	−3.0(6.8)	−0.4	−5.8(7.5)	−0.8	−0.8(0.7)	−1.1	5.3(1.2)***	4.4	6.4(1.5)***	4.4	0.8(0.2)***	4.3	3.8(0.7)***	5.4
DT	−56.5(19.9)**	−2.8	−59.1(21.9)**	−2.7	6.2(2.8)	2.2	17.7(3.9)***	4.5	18.6(4.8)**	3.9	3.7(0.7)***	5.1	11.6(2.3)***	5.1
R^2	0.0305		0.0324		0.0293		0.1482		0.1473		0.1795		0.2184	
ΔR^2	0.0290		0.0283		0.0256		0.0719		0.0653		0.1072		0.0971	
Model 4														
KL score	4.0(7.0)	0.6	−0.3(7.8)	0.0	−0.7(0.8)	−0.9	5.1(1.3)***	4.1	5.4(1.4)**	3.7	0.7(0.2)**	3.2	2.9(0.7)***	4.2
DT	−33.1(20.3)	−1.6	−41.5(23.3)	−1.8	6.8(2.8)*	2.4	11.3(3.9)**	2.9	12.2(4.7)**	2.6	2.7(0.7)**	3.8	8.9(2.3)**	3.9
Age	0.8(1.4)	0.6	0.8(1.4)	0.6	0.1(0.1)	1.0	−0.9(0.2)***	−3.9	−0.7(0.3)**	−2.7	−0.1(0.0)*	−2.6	−0.2(0.1)	−1.9
Sex	−91.8(20.3)***	−4.5	−47.2(21.9)*	−2.2	4.9(2.2)*	2.2	−8.0(3.7)	−2.2	−7.6(4.0)	−1.9	−1.2(0.6)	−1.9	−4.3(2.1)*	−2.1
Comorbidities	−11.6(7.4)	−1.6	−6.0(9.8)	−0.6	0.9(0.9)	1.0	5.6(1.4)***	4.0	8.0(1.5)***	5.2	1.1(0.2)***	4.7	3.7(0.7)***	5.1
BMI	−3.9(1.3)**	−2.9	−3.3(1.6)*	−2.1	−0.2(0.2)	−1.2	0.1(0.3)	0.2	0.3(0.3)	0.8	0.1(0.1)	1.4	0.3(0.2)	1.6
R^2	0.2065		0.0976		0.0606		0.2527		0.2608		0.2941		0.3279	
ΔR^2	0.1760		0.0652		0.0313		0.1045		0.1135		0.1146		0.1095	

*$p < 0.05$. **$p < 0.01$. ***$p < 0.0001$.
BMI, body mass index; CPI, characteristic pain intensity; DT, dispositional traits (1 = protective and 2 = vulnerable); GCPS, graded chronic pain scale; KL score, Kellgren and Lawrence score; WOMAC, Western Ontario and McMaster University.

Male sex was associated with greater GCPS CPI and greater WOMAC function.

Discussion

Our study investigated the relationships between experimental pain, clinical pain, physical functioning, and radiographic KOA measured by dispositional traits and KL scores. Dispositional traits were associated with all experimental pain, clinical pain, and functional measures. Radiographic KOA was not associated with experimental pain but was associated with all clinical pain and functional measures. As hypothesized, inclusion of dispositional traits in models with radiographic KOA, variability was reduced and all models were strengthened. Dispositional traits help to explain some of the observed individual differences between radiographic KOA, experimental pain, clinical pain, and physical function. Dispositional traits are non-pathological, neurobiological-based, and are associated with pain-related psychological measures. As such, a brief measure of dispositional traits may serve as a clinical tool to improve the assessment and treatment planning process for individuals with chronic pain.

Relationships between dispositional traits, radiographic KOA, and experimental pain

Relationships between experimental pain measures and dispositional traits were indicated. In general, as anticipated, individuals with vulnerable dispositional traits had lower pressure pain thresholds and greater punctate pain temporal summation compared to individuals with protective dispositional traits. In adjusted analyses, only punctate pain temporal summation was associated with dispositional traits. One factor that may contribute to a limited indication of relationships between dispositional traits and experimental pain is a brief pain stimuli exposure period. Our previous investigation of ABS in healthy subjects indicated associations were limited to the ischemic measure, which is a prolonged painful stimulus.[33]

Contrary to previous research, we found no significant relationships between KL scores and the experimental pain measures. Both pressure pain threshold and punctate pain temporal summation have been associated with KOA.[3] There is some evidence to suggest that radiographic evaluations of KOA such as KL scores may mis-estimate disease severity.[48,49] Our study sample was comprised of individuals who reported knee pain in the prior month with over 68% not meeting radiographic KOA criteria (KL score $\geq$2). In addition, the sample sizes were small for those individuals with a KL score of 2 or greater. Previous research indicated greater KL scores were associated with pressure pain threshold likely related to mechanical hyperalgesia of the knee.[50] Given that a majority of our participants did not have KL scores of 3 or 4, the small representation of individuals meeting KOA criteria may explain the lack of relationship. Importantly, the inclusion of dispositional traits increased the variance accounted for in all the experimental pain models.

Relationships between dispositional traits, radiographic KOA, and clinical pain and function

Dispositional traits were associated with clinical pain measures. The pattern of findings aligns with the heightened sensory sensitivity in individuals with vulnerable traits compared to those with protective traits.[31,33,51] Most striking is that a review of the means between the protective and vulnerable dispositional traits for GCPS CPI indicates an approximate average difference of 18.5 on a numerical rating scale of 0–100 between *the same KL scores, a recognized clinically significant difference*.[52] Our findings help explain what has been a perplexing clinical observation, significant individual differences in pain experiences within individuals with similar stages of radiographic KOA. The pain intensity report for individuals with a KL of 0 and vulnerable dispositional traits is similar to the pain intensity report of individuals with a KL score of 4 and protective dispositional traits.

Radiological KOA was also significantly associated will all clinical pain measures in unadjusted and adjusted analyses matching what was found in some previous studies.[7,8,50,53] As we had a significant proportion of participants reporting knee pain consistent with American College of Rheumatology criteria KL score of 0 and 1, the greater representation of individuals with no radiographic KOA may contribute to the observed relationships between KL scores and clinical pain compared to some of the prior publications that did not find a relationship.[54] Inclusion of dispositional traits improved the predictive modeling for all of the clinical pain measures, with overall models accounting for 25–33% of the variance in clinical pain experiences. In addition, as socioenvironmental factors are associated with a greater

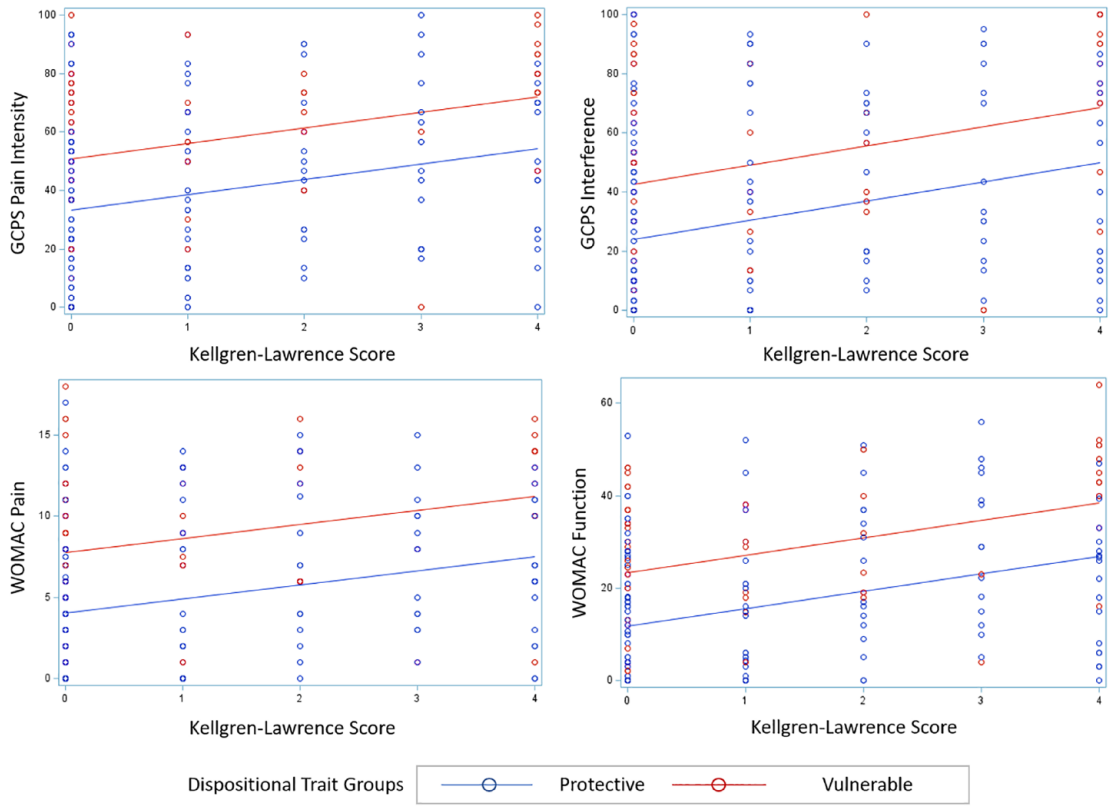

Figure 1. Clinical pain and function by Kellgren-Lawrence Scores with consideration for dispositional traits.

prevalence of arthritis, consideration of social-environmental factors may further inform findings regarding the relationships between radiographic KOA, dispositional traits, pain, and functioning.[49,55]

Strengths, limitations, and future directions

There are several strengths in the current investigation. First, the study includes a large sample of community-dwelling adults with a representation of NHB and NHW from differing socioenvironmental backgrounds. Second, all radiographs were read by a rheumatologist blinded to the participant characteristics (sex, age, sociodemographic group). Third, we included measures capturing both recent, that is, past 48 h (WOMAC), and within a 6-month timeframe (GCPS), to assess pain and function.

Some limitations warrant acknowledgment. First, the study is cross-sectional in design. Evaluating the prospective relationships between dispositional traits, radiographic KOA, experimental pain, clinical pain, and physical function would be highly informative. Second, 68.8% of our sample ($n = 150$) had KL scores < 2; thus, they did not meet the radiographic criteria for KOA. However, only 11% ($n = 23$) reported not having clinical pain or interference/disability. Thus, pain and functional limitations reported are possibly indicative of prodromal or clinical and not radiographic features of KOA or due to other causes.[35,49] In addition, as more than half of the participants did not meet KOA radiographic criteria, the generalizability of findings to a KOA population is limited. Third, Figure 1 represents a trend line as the sample size for the KL score stratified by dispositional traits. Our KL scores had limited sample sizes for KL 2–4 (with a total of $n = 68$) with KL 3 having the smallest sample size ($n = 16$). Fourth, although the PANAS questionnaire is a brief instrument that can be implemented in a clinical setting, it is limited to a focus on trait affect which is only one domain of dispositional trait functioning. Future investigations of a brief and more comprehensive measure of dispositional traits would be useful.[29] Fifth, arthritis prevalence is associated with socioenvironmental factors, future investigations

warrant consideration of these variables.[55] Finally, an adjustment in the statistical modeling approach might also be more informative.[56] The estimates from our regression models should be interpreted as the estimated effect of the variable upon the outcome after adjustment for the other predictors included in the models. In the likely event that another predictor exists that has not been included in our models, is correlated with the outcome of our model, and is correlated with a subset of the predictors in our model, then the estimates within our tables may be statistically biased.

Dispositional traits serve as the interpretative infrastructure between an animal or human's stress response system and the environment.[14,15,21,57,58] Rather than serving as an independent predictor, it is the combination of stress exposures with dispositional traits that increases or decreases health risks. Children and adults with vulnerable traits confronted by challenges without adaptive coping mechanisms are at greater risk for poor outcomes.[19,20,59–62] Importantly, preclinical and clinical models indicate that interventions can improve function, modifying predisposing dispositional vulnerabilities.[25,57,58] Importantly, dispositional traits are non-pathological, classifiable across all individuals, and highly associated with a list of commonly assessed pain-related psychological measures (depression, anxiety, catastrophizing, fear avoidance).[26,29,33] A measure of dispositional traits might serve as a parsimonious tool to improve pain-related assessments and might have utility in individualized treatment planning.

Conclusion

Poor concordance between radiographic KOA and patient reports of pain and functioning complicates treatment planning and creates challenges for clinicians and researchers. Consideration of dispositional traits improved the congruence between KOA measured by KL scores and pain and function in mid to older adults with or at risk for knee osteoarthritis. Findings indicate a consistent heightened sensitivity to pain in individuals with vulnerable traits compared to those with protective traits. Future research assessing whether the assessment of dispositional traits might serve as a tool to improve understanding of individual differences in pain-related experiences.

Declarations

Ethics approval and consent to participate

This study was conducted in accordance with the Declaration of Helsinki. The UPLOAD-2 study was approved by the University of Florida Institution Review Board (IRB approval number 201400209) on 6 June 2014 and the University of Alabama at Birmingham Institution Review Board (IRB approval number 40915002) on 11 November 2014. All participants provided verbal and written informed consent prior to any study procedures being conducted.

Consent for publication

Not applicable.

Author contributions

Angela M. Mickle: Data curation; Formal analysis; Validation; Writing – original draft.

Roland Staud: Conceptualization; Methodology; Supervision; Writing – review & editing.

Cynthia S. Garvan: Formal analysis; Writing – review & editing.

Daniel A. Kusko: Writing – review & editing.

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Kimberly T. Sibille: Conceptualization; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Supervision; Writing – original draft.

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Competing interests

The authors declare that there is no conflict of interest.

Availability of data and materials

Data are not publicly available but can be requested from the corresponding author.

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Supplemental material

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