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Daily pain variations among patients with hand, hip, and knee osteoarthritis

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Summary

Objective: This study examined within-day osteoarthritis (OA)-related pain patterns and associated patient characteristics.

Methods: Participants with physician diagnoses and self-reported symptoms of hand ($N=40$), hip ($N=32$), and knee ($N=85$) OA recorded pain using a handheld computer on one weekday and one weekend day, with ratings beginning immediately after waking, then approximately every 2 h following. Pain was rated on a sliding visual analog scale with hidden coding of 1–100. Multivariable linear mixed models examined associations of patient demographic characteristics, enrollment site (Durham VA Medical Center vs Duke University Medical Center), joint site, body mass index, and pain medication use with within-day pain range (maximum minus minimum pain rating) and area under the curve (AUC) of pain ratings, which incorporates the magnitude of all pain measurements.

Results: Pain patterns differed substantially across individuals. The sample means of the average, maximum, and minimum weekday pain scores were 35.3, 54.4, and 17.9, respectively. The mean pain range was 36.4, and the mean pain AUC was 564.3 (possible range: 16–1600). Pain scores were similar on weekends. In multivariable mixed models, both knee and hip OA were associated with a greater within-day pain range than hand OA. Only VA enrollment site was associated with a significantly greater pain AUC.

Conclusion: There is substantial within-day range in OA-related pain. Both pain range and overall within-day magnitude vary according to patient characteristics. Patients' records of within-day pain patterns could be used in clinical encounters to tailor recommendations for the timing of medication use and behavioral strategies.
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Key words: Osteoarthritis, Pain, Hand, Hip, Knee.

Introduction

While there has been long-standing interest in daily pain patterns in the context of rheumatological disorders, this area of research has primarily focused on rheumatoid arthritis[1–8]. In contrast, few studies have reported within-day pain patterns among patients with osteoarthritis (OA)[9–13]. This is likely because OA symptoms are generally considered less dynamic, other than changes with activity and rest[14]. However, prior studies suggest there are clinically meaningful within-day changes in pain levels among patients with OA. For example, in one study of 21 patients with hand OA, pain ratings over a 24 h period varied an average of 42 points on a scale of 0–100[11]. Because pain is a primary outcome in OA, both in clinical and research settings, it is important to develop our understanding of within-day OA-related pain patterns, variability, and associated factors.

The objective of this study was to examine daily pain patterns, using handheld computer-based diaries, among individuals with hand, hip, and knee OA. These analyses add to the current literature regarding within-day OA-related pain in three ways. First, these analyses involved two clinically relevant pain-related variables that have not been included in prior studies: the range of pain scores reported within a day and the area under the curve (AUC) of pain ratings, which can be viewed as the overall "burden" or magnitude of pain experienced during the day. Second, these analyses compare within-day pain ratings according to joint site, which has not been reported in previous studies. Third, analyses also examined associations of other patient clinical and demographic factors with within-day OA-related pain. This provides information on patient groups who may be at increased risk for greater overall pain levels within a day, as well as greater fluctuations in pain, which can impact ability to perform daily activities.

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Methods

PARTICIPANTS AND RECRUITMENT

Participants were patients of the Durham VA Medical Center (VAMC) and Duke University Medical Center. Enrollment at Duke was limited to patients of physicians in one primary care clinic; the remaining recruitment methods were similar between the two sites. Using electronic medical records, we identified patients with an ICD-9 code for OA (715) in the hand, hip, or knee, as well as a physician diagnosis of OA based on radiographic evidence. These patients were mailed introductory letters and called by a study team member to assess eligibility and interest in participation. To be eligible, patients were required to self-report having OA-related symptoms (pain, aching, stiffness, or swelling in or around a joint) on most days of at least 1

month of the prior year. Exclusion criteria included: new analgesic or anti-inflammatory medications (within the past 10 days), rheumatoid arthritis, and significant vision or hearing problems.

DAILY DIARY MEASURES

Handheld computers were used for daily pain data collection because prior studies have shown that compliance and completion rates are better with these devices compared with paper diaries[15,16]. Participants were given a handheld computer (Axim X30 Pocket PC Running Window Mobile 2003 Second Edition; Dell Inc., Round Rock, TX) and asked to complete pain diaries on two separate days. We chose to administer the pain diary on 2 days, rather than a longer period of time, because of feasibility concerns. Specifically, prior studies had not used handheld computers for multiple daily pain measures among samples of primarily older adults, who likely have little or no experience with these devices. Because some evidence indicates pain severity differs on weekends than weekdays[9], all participants were asked to complete diaries on one weekday and one weekend day. If participants had OA-related pain in more than one hand, hip, or knee joint, they were instructed to indicate which joint was the most painful and asked to base all diary ratings on that joint, without consideration of pain at other locations. The handheld computer program reminded participants to rate their pain in this index joint.

On each day of recording, participants were asked to rate their pain level immediately after waking, then approximately every 2 h ($\pm$10 min to avoid expectation effects). Participants were required to complete at least seven pain ratings to have a valid pain diary completion day. An audible alarm prompted pain recordings, and the alarm could be suspended for up to 15 min if participants were not able to immediately complete the pain recording. If a participant did not respond to the alarm within the 15 min period, that pain rating was skipped. Pain was recorded on a sliding visual analog scale (VAS) with anchors of ''no pain'' and ''worst pain''. Although numbers were not visible to participants, data from the VAS were stored on a scale of 1−100. Participants were also asked to record each time they took prescription or non-prescription pain medication for their OA symptoms.

PARTICIPANT CHARACTERISTICS

We examined whether the following participant characteristics were associated with pain variables: enrollment site (Duke vs Durham VAMC), joint site for which pain ratings were recorded (hand, hip or knee), age, race (white vs non-white), education level (high school graduation or less education vs any education beyond high school), working status (working full or part time vs not currently working for wages), marital status (currently married vs not) body mass index (BMI; calculated from self-reported height and weight), and pain medication use during the diary day. These variables were selected on the basis of prior OA and pain-related research[17–23]. Specifically, these variables have been associated with general chronic pain severity (i.e., age, race, education level, marital status) and/or OA-specific pain severity (i.e., use of VA health care, joint site, race, education level, work status, BMI, medication use) in some prior studies. All of these variables except for medication use (which was collected on the handheld computer) were collected during the baseline interview.

STATISTICAL ANALYSES

Because some individuals who consented to participate in the study did not complete any valid days of pain diary entry, we first compared demographic and clinical characteristics of participants who did and did not complete at least one pain diary day; chi-square tests and *t*-tests were used to examine categorical and continuous variables, respectively.

For each pain diary, we calculated the average of all pain ratings, maximum pain rating, minimum pain rating, range of pain ratings (defined as the maximum rating minus the minimum rating) and AUC of pain ratings. The curve for the AUC calculation is represented by the series of pain measurements for each study participant from the initial pain measurement time (hour 0) through the measurement at hour 16. Depending on the length of the wake period of a participant and if any ratings were skipped, the number of possible pain ratings is somewhat variable (range: 7−10). We also conducted sensitivity analyses including only measurements through hour 14, since a large proportion participants did not complete an hour 16 rating; results of these analyses were not different from those including hour 16. If any pain measurement was missing in the interval due to being skipped or the individual having retired for the day, we carried the previous observation forward. Individual pain AUCs were calculated using the trapezoidal rule[24].

To account for repeated measurements within subjects (weekday and weekend), a linear mixed model[25] with random intercepts was fit to examine the relationships of pain range and pain AUC with the following *a priori* selected variables: weekend day status, enrollment site, joint site, age, race, education, working status, marital status, BMI, and any pain medication use (yes vs no) during the diary day. We first fit simple mixed models to examine bivariate associations of each variable with pain range and AUC. Next, we fit a multivariable model including all *a priori* selected variables, in order to examine associations of each variable with pain range and AUC while accounting for other variables that may be associated with pain[17–21]. As a check for potential collinearity in the multivariable models, we examined correlations among explanatory variables. Correlations ranged in magnitude from 0.01 to 0.45. The highest correlation was between age and working status, which is expected given that many older individuals in this study were retired. Other diagnostic assessments (variance inflation factors, pairwise or variable correlations, parameter and standard error interpretation) also indicated no problems with multicollinearity[26]. However, because gender was highly correlated with study enrollment site, it was not included in these analyses. All analyses were conducted using SAS version 9.1 (SAS Institute, Cary, NC), and statistical significance was evaluated at the $P < 0.05$ level.

Results

A total of 942 recruitment letters were mailed to potential participants at Duke University Medical Center and the Durham VAMC. A total of 189 individuals (20%) consented to participate and completed a baseline visit (Fig. 1). Among those who declined to participate, the most common reasons were ''not interested'' (43%) and being too busy (16%); 25% of those who declined did not provide a specific reason. Among the 189 individuals who consented to participate, 157 (83%) completed at least one valid pain diary day and are included in these analyses (Fig. 1). Those who did not complete pain diaries were significantly older (mean ages: 66.4 years vs 61.7 years, $P = 0.025$), had a higher proportion of non-whites (62.5% vs 39.4%, $P = 0.019$), and had a lower proportion of participants with education beyond high school (62.5% vs 86.6%, $P = 0.002$). Of the 157 who completed pain diaries, 128 (82%) had both weekend and weekday entries, nine (6%) had a weekend entry only, and 20 (13%) had a weekday entry only.

Demographic and clinical characteristics of participants who completed at least one pain diary day are presented in Table I. The most commonly affected joint was the knee, followed by the hand and the hip. A total of 108 participants (69%) reported having pain in another hand, hip, or knee joint, in addition to the joint for which they reported pain in this study. The most common pain medication types participants reported using on at least one diary day were: non-steroidal anti-inflammatory drugs (31%), acetaminophen (15%), and opioid analgesics (10%). There were

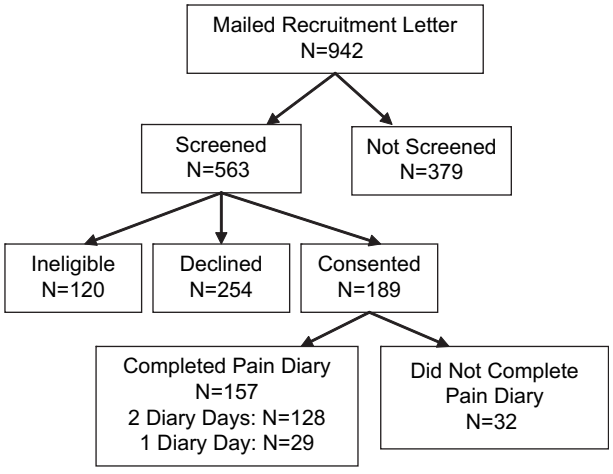

Fig. 1. Study recruitment and enrollment numbers.

Table I
Characteristics of study sample – total and by study site

	Overall, $N = 157$*	Duke participants ($N = 99$), n (%)*	Durham VAMC participants ($N = 58$), n (%)*
Pain logs completed			
Both weekend and weekday	128 (82)	85 (86)	43 (74)
Weekend or weekday only	29 (18)	14 (14)	15 (26)
Joint with most pain			
Right hip	19 (12)	11 (11)	8 (14)
Left hip	13 (8)	11 (11)	2 (3)
Right knee	48 (31)	26 (26)	22 (38)
Left knee	37 (24)	18 (18)	19 (33)
Right hand	26 (17)	19 (19)	7 (12)
Left hand	14 (9)	14 (14)	0 (0)
Mean age (SD)	61.7 (10.6)	62.9 (10.8)	59.6 (10.0)
Gender			
Male	76 (48)	25 (25)	51 (88)
Female	81 (52)	74 (75)	7 (12)
Race			
White	94 (61)	66 (67)	28 (49)
Non-white	61 (39)	32 (33)	29 (51)
Highest level of education			
High school graduate or less	21 (13)	15 (15)	6 (10)
Education beyond high school	136 (87)	84 (85)	52 (90)
Work status			
Work full time or part time	66 (42)	49 (49)	17 (29)
Not working for wages	91 (58)	50 (51)	41 (71)
Marital status			
Currently married/living as married	95 (61)	62 (63)	33 (57)
Divorced/separated/widowed or never married	62 (39)	37 (37)	25 (43)
Mean BMI (SD)	31.3 (7.4)	31.5 (7.7)	31.0 (6.9)
Pain medication use during diary day			
Weekday†	70 (47%)	40 (42%)	30 (58%)
Weekend day‡	63 (46%)	38 (43%)	25 (51%)

*Values are n (%) unless otherwise indicated. Percentages and means calculated omit missing responses from denominator (BMI has 2 missing responses, race has 2 missing responses).

†Denominator for percent calculation is the number of subjects who completed weekday pain logs ($n = 148$ overall, $n = 96$ for Duke site, and $n = 52$ for VA site).

‡Denominator for percent calculation is the number of subjects who completed weekend pain logs ($n = 137$ overall, $n = 88$ Duke for site, and $n = 49$ for VA site).

differences in participant characteristics between the two study sites with respect to gender, race, work status, and joint site.

Table II displays the average, maximum, and minimum pain scores, as well as pain ranges and AUC measurements, according to weekday/weekend status and joint site. Pain ratings on weekends were similar but slightly lower than weekdays. Overall, pain ratings generally reflect mild to moderate pain levels[27]. Because pain ratings were very similar on weekdays and weekends, we report descriptive data according to joint site for weekdays only (Table II). Participants who reported on hand pain had lower average, maximum, and minimum pain scores, as well as lower pain ranges and pain AUCs compared to those who reported on hip or knee pain. Pain ratings and ranges for hip and knee were similar. The average pain AUC was largest for knee pain.

Figure 2 is a composite plot showing the mean pain ratings at 2 h intervals after waking, for weekdays and weekends separately. Because daily pain patterns were very similar for hand, hip, and knee OA, we have combined all joints in this plot. Due to limited number of observations, pain ratings for 18 h after initial pain recording are not included in the plot. This plot shows a decrease in mean pain between the first rating (immediately after waking) and the second rating (2 h later), both on weekdays and weekends. There is an increase in pain between the second and third pain ratings, which is more pronounced on weekdays than weekends. On weekdays, mean pain ratings were similar from the third through sixth ratings (4–10 h after waking), then declined over the next three ratings. On weekends, mean pain ratings continued to increase from the third to fourth pain ratings (4–6 h after waking), then gradually declined for the remainder of the day. Figure 3 shows examples of daily pain plots from individual participants, with individual pain AUC values provided for each of the plots. These examples highlight the array of different within-day pain patterns that were observed.

In unadjusted linear mixed models, the following were associated with significantly greater pain range (Table III): higher BMI, knee and hip joint involvement (compared to hand involvement), and use of pain medications during that day; older age and white race were associated with

Table II
Pain ratings according to weekend/weekday and joint site

	Average pain rating (mean (SD*))	Maximum pain rating (mean (SD))	Minimum pain rating (mean (SD))	Pain range† (mean (SD))	AUC‡ (mean (SD))
Weekday ($N = 148$)	35.3 (23.0)	54.4 (27.9)	17.9 (19.1)	36.4 (21.5)	564.3 (365.3)
Weekend ($N = 137$)	33.4 (21.8)	52.4 (26.4)	17.6 (18.6)	34.8 (20.7)	532.1 (354.2)
Hand§ ($N = 39$)	26.5 (22.0)	42.3 (28.9)	13.3 (18.2)	28.9 (21.1)	423.7 (351.7)
Hip§ ($N = 28$)	36.4 (22.7)	59.1 (27.7)	17.6 (19.6)	41.5 (23.0)	575.2 (359.2)
Knee§ ($N = 81$)	39.2 (22.6)	58.5 (26.1)	20.3 (19.1)	38.3 (20.4)	628.3 (359.2)

Note: All pain ratings were on a scale of 1–100.
*SD = Standard Deviation.
†Pain range is defined as the maximum pain rating minus the minimum pain rating for the day.
‡AUC = Area under the curve of pain measurements: possible range of 16–1600.
§Ratings for each joint site are from weekday diaries.

significantly lower pain range. In the adjusted mixed model, the only factor that remained statistically significantly associated with pain range was joint site, with both hip and knee involvement being associated with greater pain range than hand involvement ($P = 0.044$). The intra-class correlation (ICC) coefficient for pain range was 0.64, indicating that 64% of the variability in pain range was between subjects. This indicates a high correlation between weekend and weekday pain range within individuals[28].

In unadjusted linear mixed models, the following were significantly associated with greater pain AUC (Table IV): VA enrollment site, higher BMI, and knee involvement (compared with hand involvement); older age and white race were associated with significantly smaller pain AUC. In the adjusted mixed model, only VA enrollment site was significantly associated with significantly greater pain AUC. The ICC coefficient for AUC was 0.88 indicating that 88% of the variability in AUC was between subjects. This indicates a high correlation between weekend and weekday pain AUC within individuals.

Discussion

This study is one of few to describe within-day pain patterns among patients with OA. Overall, participants reported a substantial range of pain scores within a day, with a mean range of about 35 points between maximum and minimum ratings (on a scale of 1–100). This study adds to the growing literature showing there are important variations in OA-related pain that occur within months[29], weeks[9,30], and even days[11,12,31]. A composite plot of all participants' daily pain ratings (Fig. 2) showed a pattern consistent with what is generally considered a typical clinical picture of OA. Pain scores decreased between the first and second ratings, reflecting a decline in initial morning symptoms that is considered to be common among patients with OA[14,32]. Following this decline, pain ratings increased again, possibly reflecting a response to typical daily activity patterns. Pain levels then declined in the evening, likely in response to decreased activity. Another study of patients with knee OA showed a similar pattern of increasing pain during the morning and early afternoon, with declining pain during the evening[13].

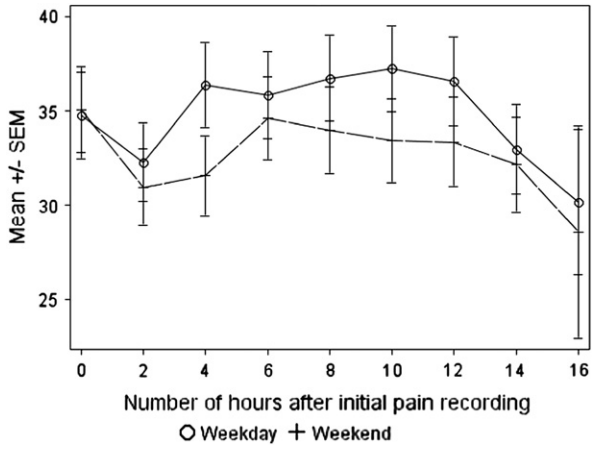

Fig. 2. Composite plot of mean pain ratings.

While the patterns of daily pain among participants as a whole reflect the main tenets of OA-related pain, there were substantial differences in these patterns across individuals (Fig. 3). This highlights the importance of understanding the daily pain patterns of individual patients as a part of clinical care for OA. The timing of patients' use of medications and behavioral strategies can be tailored to account for individual pain patterns and may result in more optimal pain control. For example, if a patient has a consistent period of peak pain in the mid-afternoon, pain medication could be taken just prior to this time point. As another example, patients can be instructed to exercise during periods in which pain is typically at a low point.

We also observed differences in daily pain ratings according to joint site. While pain ratings were relatively similar among participants with hip and knee OA, hand OA was associated with both lower pain severity and range. Hand OA is generally considered to be less painful than hip or knee OA, but differences in within-day pain ranges have not been previously reported. The smaller pain range in hand OA may be related to the lack of weight-bearing loads that are sustained by both the hip and knee throughout the day.

This study also separately examined daily pain on weekdays vs weekends. One previous study of 20 patients with knee OA found that pain ratings were higher on weekends than weekdays[9]. However, we did not observe substantial differences in pain ratings on weekends and weekdays, though pain ratings were slightly lower on weekends. The overall patterns of daily pain ratings were also similar on weekdays and weekends (as shown in Fig. 2), except for a few minor but interesting departures. Specifically, mean weekend pain ratings increased more slowly after the second observation (2 h after waking), started to decline earlier in the day, and did not reach the initial waking pain rating at any other point in the day. These differences could be related to a lower level of activity on weekends. Further examination of the association of physical activity level with

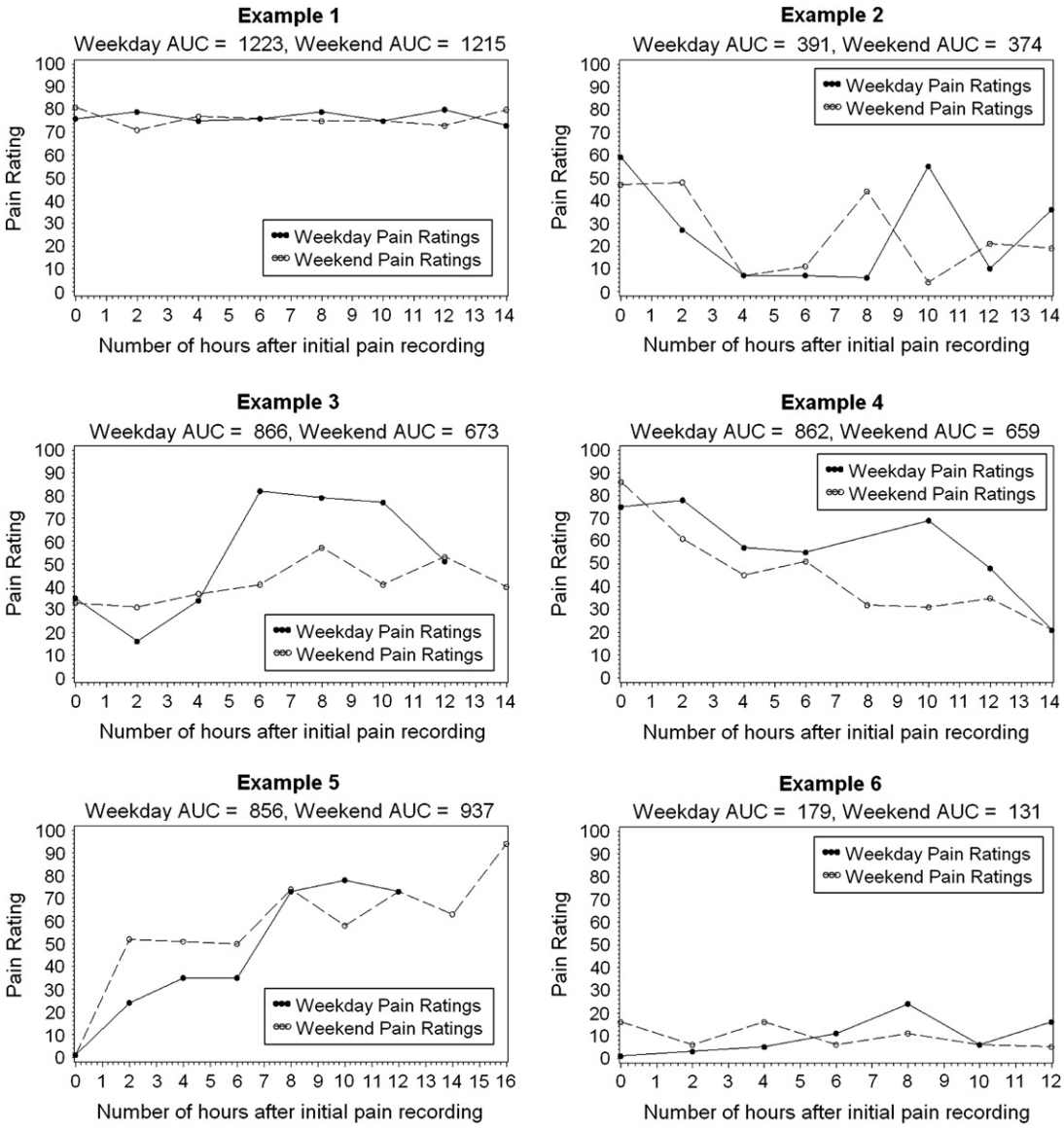

Fig. 3. Examples of pain daily pain plots from individual participants.

within-day OA pain patterns is an important area for additional research.

In an adjusted analysis, the only factor associated with pain range was joint site. As noted above, pain ranges are likely smaller in the hand because it is not subject to the same variations in mechanical loads as the weight-bearing joints. Although not statistically significant, estimates of pain range for non-whites were larger than for whites. While the clinical relevance of this difference is not clear, additional study of possible racial differences in pain range, as well as underlying factors, would be useful.

This study also examined associations of participant characteristics with the AUC of pain ratings. The pain AUC reflects the total ''pain burden'' or magnitude of pain experienced by participants during the day. In the adjusted analysis, the only factor significantly associated with pain AUC was study enrollment site. Specifically, those enrolled at the Durham VAMC had a greater pain AUC than those enrolled at Duke University Medical Center. Prior research has also shown that VA health care users with arthritis have more severe symptoms than both non-veterans and veterans who do not receive care within the VA health care system[18]. The reasons for more severe arthritis symptoms among VA health care users are not entirely clear, though these patients tend to have overall poorer health status than the general population and also are more likely to have military-related orthopedic injuries that could lead to more severe OA[33–35].

Another contribution of this study was the assessment of the feasibility of using handheld computers to capture within-day pain data among patients with OA. Most previous studies using handheld computer diaries were completed among younger adults, who likely have more experience with these types of devices[15,16,36–38]. Overall this study showed this is a viable method of pain data collection among patients with OA, but there are some caveats. Although we purposefully developed a very simple program for pain recording, 17% of participants did not complete any daily pain diaries. Furthermore, older participants and those with lower education levels were less likely to

Table III
Associations of participant characteristics with pain range: results of linear mixed models

	Unadjusted model results					Adjusted model results				
	Estimate	Standard error	Lower 95% CL*	Upper 95% CL	*P*-value	Estimate	Standard error	Lower 95% CL	Upper 95% CL	*P*-value
Weekend day	−1.7	1.5	−4.6	1.3	0.2689	−2.0	1.5	−4.9	1.0	0.1926
VA enrollment site	2.8	3.3	−3.6	9.2	0.3859	−0.7	3.5	−7.7	6.3	0.8428
Age	−0.3	0.1	−0.6	−0.1	0.0201	−0.045	0.2	−0.4	0.3	0.8032
White race	−11.1	3.1	−17.3	−5.0	0.0005	−6.6	3.5	−13.5	0.4	0.0636
BMI	0.7	0.2	0.2	1.1	0.0020	0.3	0.2	−0.1	0.8	0.1403
Joint site†					0.0014					0.0444
Hip	14.0	4.5	5.1	22.8	0.0022	10.4	4.6	1.3	19.5	0.0252
Knee	12.1	3.6	5.0	19.3	0.0010	8.6	3.9	0.8	16.3	0.0317
Education beyond high school	−3.9	4.6	−12.9	5.2	0.4026	−3.0	4.7	−12.2	6.3	0.5275
Working full or part time	1.7	3.2	−4.6	7.9	0.6011	−0.1	3.7	−7.4	7.1	0.9697
Married/living as married	−0.3	3.2	−6.7	6.0	0.9186	−1.3	3.2	−7.6	5.0	0.6779
Pain medication use	7.2	2.4	2.5	11.9	0.0028	4.8	2.5	−0.1	9.7	0.0551

279 out of 285 observations used in adjusted mixed model, ICC = 0.64. Six observations were deleted due to missing data.
*CL = Confidence Limits.
†Referent category: hand.

complete any daily pain diaries. However, pain diary completion did not differ according to race. The most common reason diaries were not completed was that participants had difficulty operating the handheld computer or did not keep the batteries charged as instructed. Another option for collecting pain dairy data is to utilize a simpler form of an electronic diary, which may result in higher completion rates. However, simpler devices may restrict the type of data being collected. For example, a recent study used an Actiwatch accelerometer (Mini-Mitter, Bend, OR) for collecting pain data among patients with OA, but this device is limited to numeric data entry[10]. The choice of electronic device and programming methods should be made with consideration of both the data needed and the patient population involved.

There are some limitations to this study. First this study involved patients with OA who participated in a study involving electronic pain data collection (17% of those originally identified from medical records), and this sample may not be generalizable to all patients with OA. It is possible that patients with only mild pain or very stable pain were less likely to participate in a study that involved pain recording (though some patients with mild and/or stable pain were represented; Fig. 3). It is also possible that participants with less confidence in using an electronic diary were less likely to participate. Second, patients who did vs did not complete pain diaries differed in some demographic characteristics, and they may also differ according to other unmeasured characteristics. This could also affect generalizability of the results. Third, while we required participants to have documentation of a physician diagnosis of OA (based on radiographic evidence) in the medical record, these diagnoses were made in the clinical context and therefore not according to one specific set of radiographic criteria (i.e., Kellgren and Lawrence). Fourth, we found that study enrollment site and gender were strongly correlated as few females were enrolled at the VA ($n = 8$); therefore, we did not include gender in our analyses. Therefore we were not able to examine gender differences in daily pain patterns. Fifth, while we documented pain medication use, participants were not characterized regarding other therapies that may have affected pain levels (i.e., physical therapy, recent joint injections). Sixth, many participants were currently using analgesic or anti-inflammatory drugs, which may have resulted in conservative estimates of pain levels. Seventh, this study involved only 2 days of diary measurement. Some research on a more general group of

Table IV
Associations of participant characteristics with AUC of pain ratings: results of linear mixed models

	Unadjusted model results					Adjusted model results				
	Estimate	Standard error	Lower 95% CL*	Upper 95% CL	*P*-value	Estimate	Standard error	Lower 95% CL	Upper 95% CL	*P*-value
Weekend day	−20.1	14.7	−49.2	9.0	0.1742	−19.8	14.6	−48.7	9.2	0.1789
VA enrollment site	256.4	55.2	147.4	365.5	<0.0001	211.5	62.0	89.0	334.0	0.0008
Age	−6.2	2.6	−11.4	−1.0	0.0196	−4.3	3.2	−10.6	2.1	0.1846
White race	−121.0	58.0	−235.6	−6.4	0.0386	5.3	61.8	−116.9	127.5	0.9315
BMI	8.1	3.8	0.5	15.7	0.0362	5.1	4.1	−3.1	13.2	0.2196
Joint site†					0.0136					0.2277
Hip	152.4	82.4	−10.5	315.2	0.0665	80.3	80.5	−78.9	239.4	0.3207
Knee	196.8	66.5	65.5	328.1	0.0036	120.3	69.6	−17.3	257.8	0.0861
Education beyond high school	−149.2	82.6	−312.3	13.9	0.0727	−160.2	82.4	−323.0	2.6	0.0537
Working full or part time	−75.8	57.2	−188.7	37.2	0.1870	−82.5	65.0	−210.9	46.0	0.2064
Married/living as married	43.0	58.0	−71.5	157.6	0.4593	38.8	56.1	−72.1	149.7	0.4899
Pain medication use	33.8	29.6	−24.6	92.2	0.2548	9.7	29.7	−48.8	68.2	0.7443

279 out of 285 observations used in adjusted mixed model, ICC = 0.88. Six observations were deleted due to missing data.
*CL = Confidence Limits.
†Referent category: hand.

patients with chronic pain indicated that at least 4 days of pain diary measurement may be more desirable for obtaining a representative picture of patients' pain[39]. Therefore it would be optimal for future studies to incorporate a greater number of pain diary days.

In summary, this study showed that overall, patients with hand, hip, and knee OA reported substantial within-day range in pain levels. There were also considerable inter-individual differences in pain patterns. These results have implications for both clinical practice and research methodology. From a clinical perspective, assessing individual patients' patterns of OA-related pain can help with recommendations for timing of medication use or other treatments. In terms of research methods, results suggest the time of day at which pain is assessed may affect participants' responses, particularly since current pain levels can affect patients' pain recall[40,41]. The use of pain diaries as outcome measures can overcome this problem and provide a rich source of pain-related data. When it is not feasible to collect within-day pain diaries, studies should attempt to assess longitudinal or pre–post treatment pain measures at the same time of day, and/or ask participants to report their highest and lowest pain levels (in addition to average pain). Future research on within-day pain patterns should examine associations with psychological and behavioral factors.

Conflict of interest

None of the authors have any conflicts of interest to disclose regarding this manuscript, including employment, consultancies, stock ownership, honoraria, paid expert testimony, patient applications, or grants/funding.

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