

The relationship between pain and eating among overweight and obese individuals with osteoarthritis: An ecological momentary study

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KW Choi, TJ Somers, MA Babyak, KJ Sikkema, JA Blumenthal, FJ Keefe. The relationship between pain and eating among overweight and obese individuals with osteoarthritis: An ecological momentary study. *Pain Res Manag* 2014;19(6):e159-e163.

BACKGROUND: Osteoarthritis (OA) patients who are overweight or obese report higher levels of pain compared with their normal-weight OA counterparts. Evidence suggests that overweight or obese OA patients also experience pain relief from eating foods high in calories, fat or sugar. Eating to alleviate pain may be problematic because it can lead to additional weight gain, which may contribute to heightened pain.

OBJECTIVES: To investigate the relationship between pain and food intake using ecological momentary assessments in a sample of 71 overweight and obese OA patients.

METHODS: Participants completed two consecutive days of diary entries in which they recorded their levels of pain, mood and food intake throughout the day. Data were analyzed using generalized estimating equations that modelled pain as a predictor of calorie, fat and sugar intake. All models were adjusted for sex, body mass index, negative mood, time and treatment history.

RESULTS: Pain significantly predicted calorie ($Z=2.57$; $P=0.01$) and fat intake ($Z=1.99$; $P=0.05$).

CONCLUSIONS: Using ecological momentary assessments as a novel approach, the present study provides preliminary data supporting a relationship between pain and food intake among overweight and obese OA patients. Continued advances in our understanding of the relationship between pain and eating behaviour may help to optimize intervention strategies for these patients.

Key Words: BMI; Eating; Ecological momentary assessments (EMA); Obesity; Osteoarthritis; Pain; Weight

Osteoarthritis (OA) is a prevalent degenerative joint disorder, affecting >31 million North Americans (1,2) and >150 million individuals worldwide (3). One of the defining features of OA is debilitating pain (4). OA patients who are overweight (body mass index [BMI] 25 kg/m² to 29 kg/m²) or obese (BMI ≥30 kg/m²) are more likely to experience elevated levels of pain compared with normal-weight OA patients (5-8) due, in part, to greater strain on weight-bearing joints (9). Weight loss is known to be an effective measure to decrease pain and improve function in overweight or obese patients with OA (10-14). However, some overweight and obese OA patients may find that pain interferes with their ability to manage their weight (15,16), although reasons for this are not well understood.

Evidence suggests that consuming certain foods, particularly substances high in calories, fat and sugar, can provide pain relief (17-25). The consumption of foods high in calories, fat or sugar has been shown

Le lien entre la douleur et l'alimentation chez les personnes qui font de l'arthrose et qui font de l'embonpoint ou sont obèses : une étude écologique momentanée

HISTORIQUE : Les patients qui font de l'arthrose et qui font de l'embonpoint ou sont obèses déclarent un niveau de douleur plus important que leurs homologues qui font de l'arthrose et dont le poids est normal. D'après les données probantes, les patients qui font de l'arthrose et qui font de l'embonpoint ou sont obèses voient leur douleur soulagée par la consommation d'aliments riches en calories, en matières grasses ou en sucre. Il peut être problématique de manger pour soulager la douleur, car cette habitude peut favoriser la prise de poids, ce qui peut contribuer à accroître la douleur.

OBJECTIFS : Explorer le lien entre la douleur et la consommation d'aliments au moyen d'évaluations écologiques momentanées auprès d'un échantillon de 71 patients qui font de l'arthrose et qui sont obèses ou font de l'embonpoint.

MÉTHODOLOGIE : Pendant deux jours consécutifs, les participants ont inscrit dans un journal leur niveau de douleur, leur humeur et leur consommation d'aliments tout au long de la journée. Les chercheurs ont analysé les données au moyen d'équations d'estimation généralisées faisant appel à un modèle de douleur comme prédicteur de consommation de calories, de matières grasses et de sucre. Tous les modèles ont été rajustés compte tenu du sexe, de l'indice de masse corporelle, de l'humeur négative, du moment et des antécédents thérapeutiques.

RÉSULTATS : La douleur était un prédicteur important de consommation de calories ($Z=2,57$, $P=0,01$) et de matières grasses ($Z=1,99$, $P=0,05$).

CONCLUSIONS : Au moyen d'une démarche novatrice d'évaluations écologiques momentanées, la présente étude fournit des données préliminaires qui appuient un lien entre la douleur et la consommation d'aliments chez les patients qui font de l'arthrose et qui sont obèses ou font de l'embonpoint. Notre compréhension croissante du lien entre la douleur et les comportements liés à l'alimentation pourrait contribuer à optimiser les stratégies interventionnelles auprès de ces patients.

to modulate various internal experiences including negative mood (26-28) and psychological stress (29,30). Notably, experimental studies from animal and human models have shown that these foods can also lead to pain relief (17-25), possibly by modulating the endogenous opioid system (31,32) and reducing activation of brain regions associated with pain (19). There is additional evidence suggesting that overweight and obese individuals may be especially susceptible to eating to attain such physiological effects (33,34). Given that consuming foods high in calories, fat and sugar can be experienced as a potent source of pain relief, it is possible that some overweight or obese OA patients turn to greater intake of such foods when they experience pain. In turn, this type of eating could lead to additional weight gain, ultimately resulting in greater pain and disability for these overweight or obese OA patients. However, to our knowledge, this clinically relevant behaviour has not yet been investigated in this population.

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Moreover, the magnitude of the relationship between pain and food intake has not been quantified outside of experimental contexts.

In the current study, we sought to examine the relationship between pain and food intake in a sample of overweight and obese patients with OA using ecological momentary assessments (EMAs) (35). EMAs involve repeated observations of an individual's experiences and behaviours as they occur in the normal daily environment (36), and offer a suitable naturalistic method to track how pain and food intake may fluctuate in tandem throughout the day in this population. We hypothesized that momentary levels of pain experienced by individual OA patients would account for variations in eating behaviour, such that higher levels of pain would be associated with greater intake of calories, fat and sugar throughout the day.

METHODS

Participants

Participants were recruited from a larger intervention trial investigating the separate and combined effects of two behavioural interventions for overweight or obese patients with knee osteoarthritis (37). All eligible patients were >18 years of age, with BMIs ≥ 25 kg/m², had no other major medical morbidities and met the American College of Rheumatology criteria for OA, with radiographic screening to confirm the presence of OA in one or both knees (for complete inclusion/exclusion criteria, refer to Somers et al [37]). On completion of the intervention trial, letters were sent to 131 individuals about participating in the present diary study. Seventy-five individuals were enrolled in the diary study. Among those who declined participation, the most frequently cited reasons included being too busy, lack of interest, being lost to contact and having moved out of state. Of those enrolled, four did not complete any assessments. Thus, data from 71 individuals were available for the present diary study.

Design

Following informed consent, participants completed a baseline assessment in which their height and weight were recorded, and self-reported demographic information was collected. After being educated on EMA rationale and methodology, they were given an electronic beeper and pocket-sized structured paper diary (consisting of two daily booklets) to take home with them. They were trained by a data technician regarding the use of the paper diary system and electronic beeper, and practiced completing sample diary entries. For food intake records, they also received a comprehensive packet of information about estimating standard portion sizes and were encouraged to include food labels and to write down as much information as possible about what they ate and/or drank without specifically weighing intake or calculating calorie amounts.

Participants were scheduled to complete the diary component within one week of their baseline assessment. This component consisted of two consecutive days at their convenience in which participants completed diary entries throughout the day. Individual entries were designed to take no longer than 2 min to complete, and were made on both a random and event-dependent basis. First, entries regarding pain and mood were completed at random intervals in response to the electronic beeper. The beeper was programmed to signal the participants randomly two to three times every hour between 06:00 and 24:00 (excluding sleep hours). Second, entries were self-initiated by participants whenever they were consuming any meal, snack or drink. These event-dependent entries included food records in addition to the usual pain and mood ratings. Participants were instructed to complete their diary entries immediately on being signalled by the beeper or at the time of eating, and to log the exact time of entry. If they were unable to enter the data at the time, they were asked to do so at the next possible opportunity.

During the two days, participants were contacted by a researcher who could troubleshoot technical difficulties and answer any questions. Participants were also instructed to mail back each day's booklet the following morning, and were contacted for follow-up if any diary information was unclear. They were paid \$15 for each completed daily booklet and an additional \$10 for complete recording. All procedures were approved by the university Institutional Review Board.

Measures

Baseline: Height and weight: Weight was measured to the nearest 0.1 kg using a balance scale. Height was measured to the nearest 1 cm. BMI was calculated by dividing weight (kg) by height (m²).

Diary: Pain: Participants rated the intensity of their current pain at each diary entry point using a numerical rating scale ranging from 0 to 10, with 0 being 'no pain' and 10 being 'worst pain' at that moment. The numerical rating scale is commonly used in pain research (38) and has been found to be a sensitive, reliable and valid measure of subjective pain intensity (39) with demonstrated clinical relevance (40).

Negative mood: Participants rated their negative mood at each diary entry point using single Likert-type items in which they were asked to rate each of three adjectives – angry, nervous and sad – on a scale of 0 to 3, with 0 being 'very much unlike this' and 3 being 'very much like this'. Others have used similar methods of measuring negative mood (41-43); reliability in the current sample was acceptable (Cronbach's alpha = 0.62). A negative mood score was formed from the summed composite of these items, with potential values ranging from 0 to 9.

Food intake: Participants recorded any intake of food, beverages and/or dietary supplements, and were specifically instructed to include all details such as brand names, preparation methods and amount consumed. Participants were also encouraged to return food labels with their completed diary. The food intake records were analyzed by a nutritionist trained in calculating energy density, fat and sugar content of food records using the ESHA Food Processor SQL nutrition program (ESHA Research, USA). This software program has been used for dietary assessment in various health research studies (44,45), and features a comprehensive database of 32,000 foods compiled from 1300 scientific sources of nutrition information. For the analyses presented in the present study, overall calories (in kilojoules) were extracted, as well as the corresponding macronutrient levels of fat and sugar (both in grams). Overall caloric intake was investigated as a marker of overeating. In addition, the present study focused on fat and sugar because previous literature has connected the consumption of these substances with pain relief (17-23).

Data processing and analyses

Criteria for inclusion in statistical analyses were: if the participant made at least 20 full entries per day over both days of recording; and if corresponding nutritional data were available. Full entries consisted of time of day, pain rating, mood ratings and food intake records if a meal/snack was indicated. According to these criteria, 54 of 71 participants had sufficiently complete diary data across both days. These participants made an average of 33 diary entries per day, yielding a total of 3264 data points for analysis. χ^2 and *t* test analyses were used to examine any differences in the 54 individuals who completed the study compared with the 17 who did not. Differences were examined for sex, age, education, marital status and previous intervention condition. The only difference that emerged was that individuals with incomplete diary data had higher BMI levels compared with those with complete diary data (mean for noncompleters = 36.9, mean for completers = 32.6; $t[69]=2.73$; $P=0.003$). All further analyses only include the 54 participants with complete data.

Generalized estimating equations (GEEs) (46) were used to account for within-subject dependence between observations and to accurately estimate SEs by allowing participants to serve as their own control. First, simple bivariate models were run to test the concurrent relationship between momentary pain and calories, fat or sugar. Three corresponding GEE models were subsequently tested by including a set of a priori variables as covariates. These covariates – sex, BMI, negative mood, time and previous intervention condition – were included as potential confounders due to their associations with both pain and food intake in previous literature (5,47-53). The models were defined using the following equations:

$$\text{Calories} = \text{pain} + \text{sex} + \text{BMI} + \text{negative mood} + \text{time} + \text{previous intervention condition}$$

$$\text{Fat} = \text{pain} + \text{sex} + \text{BMI} + \text{negative mood} + \text{time} + \text{previous intervention condition}$$

TABLE 1
Sample demographics

Variable	Total n	n (%)	Mean \pm SD
Age, years	54		62.7 \pm 9.3
Body mass index, kg/m ²	54		32.6 \pm 4.8
Female sex	49	41 (83.7)	
Race	53		
Caucasian		34 (64.2)	
African-American/other		19 (35.8)	
Married	48	28 (58.3)	
Annual family income \geq 20,000 USD	48	41 (85.5)	
Education	50		
Less than high school		1 (2.0)	
High school degree		5 (10.0)	
Some college		7 (14.0)	
College degree		22 (44.0)	
Graduate degree		15 (30.0)	

$$\text{Sugar} = \text{pain} + \text{sex} + \text{BMI} + \text{negative mood} + \text{time} + \text{previous intervention condition}$$

in which sex, BMI and previous intervention condition were between-person baseline variables, while pain, negative mood and time were within-person diary variables. For statistical interpretation, the continuous time variable was recoded into a six-level categorical variable reflecting the standard intervals in which the average participant may be expected to consume a meal: midnight to 06:00; 06:00 to 09:00 (breakfast period); 09:00 to 11:00; 11:00 to 14:00 (lunch period); 14:00 to 17:00 pm; 17:00 to 20:00 pm (dinner period); and 20:00 to 24:00. All GEE models were run using SAS Genmod (SAS Inc, USA), with the correlational structure set as unstructured.

RESULTS

Description of sample

The participants (Table 1) were mostly female ($n=49$ [83.7%]) and their ages ranged from 42 to 80 years (mean [\pm SD] 62.68 \pm 9.32 years). Their mean BMI was 32.6 \pm 4.8 kg/m² and 69% were classified as obese. The self-reported racial/ethnic composition was 64.2% Caucasian and 35.8% African American/other, and the majority ($n=50$ [74%]) held at least a college or graduate degree. Participants in the present diary study had previously been randomly assigned in the larger intervention trial to the following groups: pain coping skills training (18.5%); behavioural weight management (33.3%); a combination of these two interventions (27.8%); or standard care (20.4%).

The mean (\pm SD) daily diary level of pain was 2 \pm 1.65 (range 0 to 8) and the average negative mood rating was 1 \pm 1.23 (range 0 to 5). The mean total calorie intake per day was 1992 \pm 599 calories (range 656 to 3941 calories), with an average total of 103 g fat and 86 g sugar consumed.

Principal findings

The primary research hypothesis was that momentary levels of pain would be associated with food intake, as defined by calorie, fat and sugar intake. According to the first GEE model, after adjusting for sex, BMI, negative mood, time and previous intervention condition, pain was a significant predictor of calorie intake ($Z=2.57$; $P=0.01$). This suggests that when patients reported higher levels of pain, they also reported eating more calories. Specifically, the model coefficients indicated that for every unit increase in pain rating, there may be an expected increase of 4.25 calories. Sex ($P=0.007$) and negative mood ($P=0.01$) were also significant predictors of calorie intake, such that being male was related to greater calorie intake, as were lower momentary levels of negative mood. Calories consumed were also significantly higher for the breakfast, lunch and dinner periods ($P<0.01$).

In the next model, examining fat intake as the outcome and adjusted for sex, BMI, negative mood, time and previous intervention condition, pain was a significant predictor ($Z=1.99$; $P=0.05$), suggesting that patients experiencing higher levels of momentary pain also consumed more fat. In this model, sex ($P<0.001$) and negative mood ($P=0.03$) significantly predicted fat intake in the same direction as previously, such that being male and lower levels of negative mood were predictive of greater calorie intake. BMI was also a significant predictor ($P=0.03$) of fat intake, in that higher BMI was related to greater intake from moment to moment. Fat intake was also significantly elevated for the lunch and dinner periods ($P<0.001$).

In the final model with sugar intake as the outcome, and adjusted for sex, BMI, negative mood, time and previous intervention condition, pain was not found to be a significant predictor ($Z=1.574$; $P=0.12$). Negative mood ($P=0.01$) was a significant predictor of sugar intake, such that lower levels of negative mood were predictive of greater sugar intake. Sugar intake was also significantly elevated during the breakfast period ($P=0.04$).

Follow-up analyses: practical significance

To probe the practical significance of pain levels on food intake, follow-up analyses were conducted for calories and fat, which were significant predictors in earlier analyses. Cutoffs were established, in which momentary pain ratings between 0 and 2 were classified as low pain, ratings between 3 and 6 as moderate pain, and ratings >7 as high pain.

T tests comparing high pain to low pain moments across participants indicated that moments in which pain ratings were high differed significantly from moments in which pain ratings were low, in terms of calories eaten ($P=0.04$). Specifically, 52 more calories were eaten, on average, during a given moment of high pain compared with low pain (112 kJ and 60 kJ, respectively). Similarly, momentary fat intake also differed significantly between high- and low-pain moments ($P=0.02$). Specifically, participants ate more than twice the amount of fat, on average, during a given moment of high pain compared with low pain (5.4 g and 2.4 g, respectively).

There was a similar but non-significant trend when comparing calorie intake in high-pain moments to moderate-pain moments (112 kJ and 69 kJ eaten on average, respectively). However, fat intake was significantly higher in high-pain moments compared with moderate-pain moments (5.4 g and 2.7 g on average, respectively; $P=0.05$).

Comparing moments in which pain ratings were moderate versus low, more calories were eaten on average during moderate-pain moments than in low-pain moments (69 kJ and 60 kJ, respectively) although this difference was not statistically significant. Similar to calorie intake, there was a trend toward more fat eaten in moderate pain moments than in low pain moments (2.7 g and 2.4 g, respectively), although this was also not significant.

DISCUSSION

Using an ecological momentary approach, the present study provides novel data supporting a relationship between momentary pain levels and food intake among overweight or obese patients with OA. Our results suggest that patients eat when they experience elevated pain, potentially as a strategy to cope with pain. This behaviour is likely to be counterproductive because it may ultimately result in increased weight, pain and disability. Although previous work has shown that food intake, particularly foods with high caloric content, can produce pain relief (17-23), the present study is the first to quantitatively establish a relationship between higher levels of pain and increased eating in a patient population with persistent pain.

Interestingly, we found that when overweight and obese OA patients reported higher levels of pain, they also reported eating a greater number of calories. This is particularly noteworthy because our analyses adjusted for the potential confounders of sex, BMI, negative mood, time and previous intervention condition. Using a similar model, we also found that patients reported a significant relationship between higher levels of pain and increased fat intake. These observed relationships between pain and both calorie and fat intake extend a recent qualitative study

using narrative accounts (54) in which overweight individuals with pain reported a desire to consume greater quantities of rich and calorically dense foods when experiencing pain. To our knowledge, our study was the first to begin using quantitative data to explore this relationship. The results contextualize how overweight and obese OA patients may find weight management particularly difficult due to a tendency to eat foods high in calories and fat when experiencing pain. This merits further investigation because foods high in calories or fat may underlie inflammatory and metabolic processes involved in both obesity (55) and pain (56) among OA patients.

We found that levels of negative mood were inversely related to food intake, which suggests that, in moments when patients reported increased negative mood, they were also reporting lower food intake. This was somewhat surprising given literature that suggests that food intake increases during negative mood states (51,57). One possible reason for this finding is that our study is one of the first to examine the relationship between negative mood and food intake while statistically adjusting for pain, and other demographic and medical variables. Previous work has not examined these types of variables simultaneously. Another reason could be related to the brief negative mood scale used in the present study. While we worked to keep the daily diary assessments as least burdensome as possible for the participants, we acknowledge that future research may consider using a more robust measure of negative affect. Finally, it is also possible that participants experienced increased negative mood at times they were not eating, and while they ate their negative mood actually decreased. However, our analyses examined only concurrent relationships between variables, limiting potential inferences about directionality. Future studies are needed to further explore the respective influences of mood and pain on food intake, and to clarify these temporal relationships by carefully examining mood and pain before, during and after food intake.

The present study had several limitations. First, as mentioned previously, our analyses were correlational in nature and did not allow for causal inferences. Follow-up studies could build on the current study's findings to explore potential causal mechanisms (eg, through experimental methods, longitudinal designs and/or cognitive interviewing). Second, participants in the present study were volunteers recruited from a completed intervention trial, which raises issues regarding sample representativeness and intervention effects. However, we adjusted all analyses for previous intervention condition and no significant relationships were found. Future work should extend the current findings by investigating the relationships between pain and eating among overweight and obese OA patients who are naive to behavioural treatments for pain and/or weight management.

Next, levels of food intake were self-reported by all participants and may have been influenced by social desirability bias or problems with recording. We had to exclude >20% (17 of 71) of the participants due to incomplete diary data. These noncompleters were not significantly different from those included in the analyses, except in terms of BMI. It is possible that heavier individuals experienced a greater degree of struggle or shame with eating behaviour and, therefore, were less likely to follow through with consistent self-monitoring. Also, reporting food intake may itself influence eating behaviour (58). Future work should consider methods of collecting data on food intake that do not require conscious monitoring (eg, blood sugar monitors). In addition, participants were allowed to choose their two-day recording window, which could have introduced variability based on eating patterns on weekdays versus weekends. Future studies could consider assigning participants to one weekday and one weekend (eg, Friday and Saturday), or following participants over more days of food recording.

Finally, in our follow-up analyses, we found that >50 additional calories were eaten on average during moments of high pain versus low pain. Given the persistent moments of high pain experienced during the day by an individual, this has the potential to accumulate to several hundred extra calories consumed per day, an amount that is clinically relevant for weight gain (59) and deserves further research in this population. At the same time, our main analyses initially showed a relatively modest effect

in terms of the number of additional calories consumed while in greater pain (59). Our study was the first to take a naturalistic approach to examine the relationship between pain and eating in participants' everyday environment, which may partially explain the modest relationships found. However, it also represents the first attempt to quantify the magnitude of this potential association and, therefore, would be bolstered by future efforts to both replicate and extend this finding.

Despite the limitations, the present study has important methodological features that should be highlighted. First, we sampled a clinical population of overweight and obese patients with radiographically confirmed knee OA. Second, we extracted detailed nutrition content from participants' food intake records using an established software program. Third, we used EMAs and multilevel modelling, which are particularly advantageous for exploring the relationships between pain and eating throughout the day. EMAs reduce the retrospective biases inherent in dietary recall (60), allowing more accurate estimation of food intake in relation to momentary pain. In addition, EMAs yield naturalistic, ecologically valid data (36) that complement previous experimental studies investigating food intake and pain relief.

Our study suggests that overweight and obese OA patients may find it challenging to resist eating when experiencing high levels of pain, a tendency likely to contribute to excess weight and paradoxically perpetuate OA pain. This raises implications for clinical care – specifically, the importance of teaching overweight or obese OA patients not only to manage their weight, but also to develop a repertoire of strategies other than eating to cope with their pain. A recent intervention trial involving these patients (37) found that combining both treatment approaches – ie, weight management and pain coping skills training – produced synergistic improvements in pain and weight outcomes. Overweight and obese OA patients in this trial who received both pain and weight management interventions had better outcomes, in terms of both pain and weight, than patients who received either treatment alone or standard care. Future interventions specifically targeting eating as a coping behaviour may prove particularly effective for this population.

CONCLUSION

We have presented innovative data supporting a relationship between momentary pain, and calorie and fat intake among overweight or obese patients with OA. These findings point toward a complex cycle in which OA pain, food intake and obesity may be mutually reinforced through eating in the presence of pain. Further research investigating eating behaviour as a factor in the maintenance of both pain and obesity will continue to gain relevance as the numbers of individuals with OA and OA-associated comorbidities, including obesity, continue to rise.

ACKNOWLEDGEMENTS: The authors thank Maggie Rogers for study database support and Michael Coggins for help with diary data entry.

FUNDING: This study was supported by the National Institutes of Health Grant P01 AR50245.

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