The daily impact of pain from metastatic breast cancer on spousal relationships: A dyadic electronic diary study

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1. Introduction

Women with metastatic breast cancer (MBC) experience significant pain [15]. Although pain management in MBC is a significant quality of life (QOL) concern, complete pain relief is rare [53]. This is disconcerting because unrelieved pain increases the risk for mood disturbance [44,52] and can inhibit immune function, facilitating the progression of metastatic disease [37].

Patients who are in pain often turn to their spouses or intimate partners to provide physical and emotional support. [26,27]. The spousal relationship is also an important coping resource in MBC [2,20]. However, like patients, partners are profoundly affected by cancer and its symptoms [18]. Over time, the coordination of care and social support may become challenging and wear on couples’ relationships. Researchers have called for greater partner involvement in pain management programs at the end-of-life [27]. For such programs to be effective, a greater understanding of the links between pain, mood, and relationship functioning is needed.

Although we know that pain, mood, and relationship functioning are related [44,52], it is unclear how they are related. For example, chronic pain patients who report better functioning relationships experience less distress and less severe pain [36,41]; however, among cancer patients, pain has been associated with decrements in relationship functioning [10,17]. One possibility is that patients become distressed when they are in pain and this causes them to negatively evaluate their relationships and perceive lower levels of social support [49]. Another possibility is that partners, who often overestimate patients’ pain [8], can become overwhelmed by the patient’s pain and distress, and this can undermine their provision of support [7,13]. Patients’ pain and distress may also be perceived by patients and partners as disruptive; interfering with the quality of time they spend together. Prospective studies that include patients and partners and consider both of their perspectives could clarify these associations.

Most of our knowledge of pain, mood, and relationship functioning has come from global retrospective measures. Conclusions
are thus limited because pain and mood vary considerably both within and across days [28] and research documents biases in our ability to accurately recall past events [42]. “Daily process” methods like paper-and-pencil diaries minimize retroprojection errors by capturing phenomena in real-time [6]. However, individuals sometimes fail to complete diaries as instructed and fake responses by forward- or back-filling entries [46]. In contrast, electronic diaries (EDs) administered on handheld computers often involve repeated assessments over short durations, have signals to prompt participants, and provide time and date stamps for completion [47]. Using EDs to conduct intensive longitudinal studies can yield new information about temporal associations and help to establish causal linkages in an effort to better understand how pain and depressive symptomatology co-occur [51]. Our previous work has shown that EDs are well-accepted by breast cancer patients [1]; however, studies have yet to use this technology to model how the support process unfolds in real-time in couples’ daily lives. By assessing the unique effects of patient and partner pain appraisals on mood and relationship functioning, researchers can develop a better understanding of how pain affects relationships in MBC and identify targets for future couple-focused interventions aimed at this vulnerable and under-researched population.

2. Method

2.1. Procedure

Patients were identified based on a review of medical charts and asked to participate during their routine clinic visits. Female patients were eligible if they: (1) were starting treatment for MBC; (2) had a physician-rated Eastern Cooperative Oncology Group (ECOG) performance status score ≤2 (i.e., ambulatory and capable of all self-care but unable to perform any work activities); (3) rated their average pain as being 1 or higher (0 = no pain and 10 = worst pain imaginable) on the Brief Pain Inventory [BPI; [11]]; (4) were fluent in English; and, (5) had a male partner (spouse or significant other) with whom they lived for at least 1 year.

Research staff approached 94 female MBC patients and their male partners. Of these, 59 (62.8%) couples agreed to participate. Reasons for refusal were: (1) the patient and/or partner were not interested (57.1%); (2) the patient and/or partner thought that carrying the ED would be burdensome and/or conflict with their work responsibilities (20%); (3) the patient and/or partner did not think they would have time to answer repeated assessments (20%); and (4) the patient and/or partner thought that the study was not relevant to them (2.9%). Comparisons were made between patients who refused and those who agreed to participate based on available data for age, ECOG performance status, race, average pain (BPI) at time of recruitment, and primary metastatic site. Significant differences were found for age (t(51) = −3.98, p = 0.001) and pain (t(82) = 5.55, p = 0.001). Specifically, patients who agreed to participate were younger (M = 49.38, SD = 10.76) than those who refused (M = 58.11, SD = 9.30), and patients who agreed to participate had higher ratings of pain (M = 4.41, SD = 3.01) than those who refused (M = 1.12, SD = 0.43).

Patients and partners were each provided their own password-protected ED. The diaries were programmable Palm Tungsten E or E2 computers (32 MB RAM) weighing 4.7 oz and powered by rechargeable lithium ion batteries. Unlike the Tungsten E2’s which used non-volatile flash memory, complete data loss occurred if the Tungsten E batteries were not recharged daily. Handheld computer dimensions were approximately 4.5 × 3.1 × 0.5 in. Participants used a stylus to touch fixed-response options in answer to questions presented in a fixed order on a 2.4-in. transflective liquid crystal color display (resolution, 320 × 320 pixels). Couples were trained to use the EDs and received follow-up telephone calls within 3 days of taking them home. Despite this, participants sometimes forgot to charge their ED batteries each night, resulting in data loss. Consequently, usable ED data were obtained from both members of the couple in only 45 of 59 cases (76%). In nine cases, the partner forgot to recharge the battery, but the patient did not, resulting in our retrieving data only from the patient. In three cases, the patient forgot to recharge the battery but the partner did not, resulting in our retrieving data only from the partner. In two cases, both members of the couple failed to recharge the battery resulting in complete data loss. All the data that were retrieved were included in the analyses, resulting in a final sample size of 54 patients and 48 partners.

Patients reported on their own pain and mood 6 times a day for 14 consecutive days (84 total assessments). They also reported on their perceptions of relationship functioning (interference and social support) once in the evening for each of 14 consecutive days. Participants reported on the patient’s pain, their own mood, and their perceptions of relationship functioning with the same frequency and at relatively the same time as patients. To keep the length of the assessment day and the intervals between assessments consistent across participants, diaries were programmed to prompt assessments by generating alarms between 9:00 am and 9:00 pm. A stratified-random sampling scheme was used to ensure that moments sampled within blocks were random and that the entire waking day was covered. The minimum time between assessments was 30 min. The morning assessment was randomly scheduled between 9:00 am and 10:00 am (Time 1). Four daytime assessments followed; one occurred between 10:30 am and 12:30 pm (Time 2), two occurred between 1:00 pm and 5:00 pm (Time 3 and Time 4), and one occurred between 5:30 pm and 7:30 pm (Time 5). A final evening assessment occurred between 8:00 pm and 9:00 pm (Time 6). The alarm schedule for the patient’s ED was randomly generated at the time of recruitment. To ensure that patients and partners would report on the same phenomena and to decrease the likelihood that they would discuss their responses while completing assessments, the partner’s ED was programmed to generate alarms within a 15 min window around the patient’s scheduled assessments. Depending on the type of assessment (morning, daytime, or evening), the time needed for completion was 2–5 min. Patients and partners received gift cards (up to $80 each) based on the percentage of assessments they completed. Overall, patients completed an average of 69.78% (SD = 21.93%) and spouses completed an average of 67.23% (SD = 23.53%) of assessments. No significant differences were found between patients and partners with regard to the number of assessments completed (t(100) = 0.57, p = 0.75). There were also no significant differences between patients who completed less than or more than the average number of assessments for morning pain (t(714) = −1.27, p = 0.20); however, those who completed fewer assessments reported receiving less physical (t(578) = −3.96, p = 0.001) and emotional support (t(578) = −2.69, p = 0.007) from their partners.

2.2. Measures

ED studies often involve intensive assessment schedules, making reactivity, reduced adherence, and participant burden major concerns [14]. Because ED measures need to be as brief and engaging as possible, researchers often truncate existing measures or create single-item measures. Since no published studies have used electronic diaries to assess the associations between pain, mood, and relationship functioning, the validity of such brief measures has not been evaluated. However, some have argued that the use of single-item or brief measures is appropriate when the construct

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2.2.1. Pain

Severity. At each assessment, patients and partners rated the patient’s pain at that moment on an 11-point Likert-type scale from 0 (no pain) to 10 (worst pain imaginable) using a single-item from the Brief Pain Inventory (BPI) [16]. Because we were interested in examining temporal associations, our focus was on patient and partner reports of the patient’s morning pain.

Medication use and pain relief. At each assessment, patients were asked if they had taken any medication to relieve their pain since the previous assessment (yes/no) using a single-item adapted from BPI. If they responded “yes”, two follow-up questions were asked – “What type of medication did you take (prescription or over-the-counter medication)?” and “How much relief has the medicine provided?” (adapted from the BPI [16]). Response options were on an 11-point Likert-type scale from 0 (no relief) to 10 (total relief).

2.2.2. Mood

At each assessment, patients and partners rated the intensity of their own mood on a 5-point Likert-type scale ranging from 1 (not at all) to 5 (extremely) using 8 adjectives based on the circumplex model of affect [40]. This model postulates that the structure of affect is characterized as an ordering of affective states around the circumference of a circle that consists of two sets of bipolar orthogonal dimensions. The first set comprises moods with a perceived arousal (i.e., aroused vs. unaroused) or valence evaluation (i.e., pleasant vs. unpleasant) component. The second set involves combinations of these components [50]. The 8 mood adjectives used in this study (see Fig. 1) were taken from the original list of mood adjectives identified by Larsen and Diener [32] and chosen on the basis of our previous ED research in breast cancer that showed that a short mood measure comprised of one adjective representing each of the 8 poles of the mood circumplex could perform comparably to longer mood measures [1].

2.2.3. Relationship functioning

At the end of each day (i.e., evening assessment) relationship functioning was assessed by asking patients and partners to rate how much cancer interfered with their relationship that day and the amount of social support (emotional and physical) that was provided and received.

Relationship interference. Both patients and partners rated their agreement with the statement, “My/My partner’s cancer interfered with the quality of time we spent together today,” on a Likert-type scale ranging from 1 (not at all) to 4 (very much). This item was used as a measure of “relationship functioning” because marital studies suggest that individuals’ perceptions of the quality of time they spend with their partners as a couple is related to their marital satisfaction [23].

Received emotional and physical support. Patients rated their agreement with the statements, “Today my partner was attentive to my emotional needs,” and “Today my partner was attentive to my physical needs,” on a Likert-type scale ranging from 1 (not at all) to 4 (very much).

Provided emotional and physical support. Partners rated their agreement with the statements, “Today I was attentive to my partner’s emotional needs,” and “Today I was attentive to my partner’s physical needs,” on a Likert-type scale ranging from 1 (not at all) to 4 (very much).

2.3. Data analysis strategy

Our primary goal was to understand how relationship functioning is affected by MBC pain. Thus, in an effort to develop a process

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Fig. 1. The mood circumplex model and mood adjectives used in the current study.
model of how pain might affect relationship functioning over the course of a typical day we focused on temporal associations. We expected that patient and partner reports of greater patient pain in the morning would be associated with more negative mood throughout the day, and this in turn would result in both patients and partners reporting poorer relationship functioning in the evening (i.e., patients and partners would report greater interference with the quality of time they spent together that day, patients would report receiving less physical and emotional support from their partners, and partners would report providing less physical and emotional support to patients). A reciprocal model whereby ineffective partner support could cause patients to experience greater negative affect and in turn report higher levels of pain is also plausible; however, pain was chosen as the focal predictor in this study because a growing number of studies from both the cancer and chronic pain literatures suggest that depression is a consequence of pain [19,21].

Descriptive statistics were calculated for each of the major study variables and paired t-tests were conducted to determine whether mean scores differed for patients and partners (see Table 1). Due to the nested and interdependent nature of these data, multilevel modeling analyses were conducted [6,33]. Such models can handle missing data and maximize the utility of existing data [29]. This is particularly important given the intensive repeated measures daily diary design that we employed. Since our previous work in breast cancer showed that daily pain reports co-vary with moods containing an arousal and/or an evaluation component [1] and because we wanted to see how different moods affected relationship functioning, we examined average ratings of each of the 8 moods (aggregated across the 4 daytime assessments) as putative mediators of the link between morning pain ratings and evening reports of relationship functioning. The variables that are part of the proposed mediation system were all at the lower level (i.e., level-1), so we conducted multilevel mediation analyses at the within-subjects level [5,30] also known as 1→ 1 mediation [31]. Below we first describe a multilevel mediation modeling approach as applied to the individual patient. We then extend this model to the dyadic context by incorporating both patient and partner momentary reports of the patient’s morning pain as well as patient and partner evening reports of relationship functioning (i.e., cancer interference and provided/received emotional support).

**Table 1. Correlations, descriptive findings, and results of analyses regressing daytime mood on morning pain, controlling for morning mood.**

<table>
<thead>
<tr>
<th>Patients</th>
<th>Partners</th>
<th>Mean ± SD and paired t-tests</th>
<th>Correlations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mood</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Active</td>
<td>.17</td>
<td>.06</td>
<td>.02</td>
</tr>
<tr>
<td>Quiet</td>
<td>.24</td>
<td>.12</td>
<td>.12</td>
</tr>
<tr>
<td>Happy</td>
<td>.24</td>
<td>.12</td>
<td>.12</td>
</tr>
<tr>
<td>Tired</td>
<td>.24</td>
<td>.12</td>
<td>.12</td>
</tr>
<tr>
<td>Peppy</td>
<td>.24</td>
<td>.12</td>
<td>.12</td>
</tr>
<tr>
<td>Glum</td>
<td>.24</td>
<td>.12</td>
<td>.12</td>
</tr>
<tr>
<td>Cancer Interference</td>
<td>.24</td>
<td>.12</td>
<td>.12</td>
</tr>
<tr>
<td>Physical Support</td>
<td>.24</td>
<td>.12</td>
<td>.12</td>
</tr>
<tr>
<td>Emotional Support</td>
<td>.24</td>
<td>.12</td>
<td>.12</td>
</tr>
</tbody>
</table>

**Note:** ICCs = Intra-class correlations for repeated measurements taken over time. *p < 0.05. **p < 0.01.

**Fig. 2** depicts a comparison of single-level mediation (top panel) to multilevel (i.e., within-subjects) mediation (bottom panel). In a trivariate single-level system, path a represents the link between the predictor X (morning pain) and the mediator M (daytime mood), path b represents the link between X and the outcome Y (evening relationship functioning), and path c represents any remaining link between X and Y after controlling for M. In single-level mediation models, the total effect (labeled c but not depicted in Fig. 2) is equivalent to a + b + c, where a + b represents the indirect or mediated effect and c represents the direct effect. The classic demonstration of statistical mediation articulated by Baron and Kenny [4] suggests the following steps: (1) estimate the link between X and Y (i.e., c); (2) estimate the link between X and M (i.e., a); (3) demonstrate that M is related to Y while holding X constant (i.e., b); and, (4) show that the remaining direct effect (i.e., c) is not statistically different from zero (indicating full mediation) or is significantly decreased compared to c (indicating partial mediation). Because the Baron and Kenny [4] causal steps approach has low statistical power for detecting mediated effects [35], we followed more current recommendations for demonstrating mediation that focus on the higher power direct test of the indirect effect, a + b [34].

Whereas paths a, b, and c in single-level mediation are assumed to be constant effects across all persons j, multilevel mediation
allows for the possibility that each of these effects may vary from person to person, as represented in bottom panel of Fig. 2 by the circled random effects of the a, b, and c fixed effect path coefficients. Specifically, instead of there being a single estimated a path (e.g., patient morning pain → patient daytime peppy affect) estimated in one model and a single estimated b path (e.g., patient daytime peppy affect → patient evening reports of cancer interference) estimated in a separate model, multilevel mediation simultaneously estimates both of these effects in the same model and allows for a distribution of a and b path effects across patients. When applied to lower-level multilevel data, the mediated effect is $a \times b + cov(a_i, b_j)$, where the latter term refers to the covariance between the a and b random effects [5]. Because the a and b paths can have corresponding random effects, the calculation and inferential test of the indirect or mediated effect are different than what is detailed by Baron and Kenny [4] and must account for the covariance of the a and b random effects. Thus, in the context of lower-level multilevel mediation with significant a and b random effects, the total effect (c) is no longer mathematically equivalent to the sum of $a \times b + c$ as is the case in classic mediation. Further details can be found in Bauer et al. [5] and Kenny et al. [30]. Nevertheless, in our findings, random effects for the a and b paths were never both substantial enough to be estimated; thus, mediated effects could be reduced to a test of the product of the a and b paths.

Because mediation invokes a mechanism reflecting a causal chain of events over time, an ideal design would measure X earlier in time from M and measure M earlier in time from Y [22]. We made use of such a design by using morning, daytime, and evening within-day assessments. Where possible, we further controlled for the previous time levels of outcomes [12]. For example, to conduct a more stringent test of the effects of morning pain ratings on daytime mood, we controlled for the effects of morning mood. As Table 2 shows, when we did this, only the associations between morning pain and daytime active, tired, and peppy mood remained significant. Given this, subsequent analyses focused exclusively on these 3 daytime moods as putative mediators between morning pain and evening relationship functioning outcomes.

In addition to the non-independence due to assessments within individuals, we also had to account for the non-independence due to individuals (i.e., patients and partners) being from the same couple. One way to address this would be to designate one person (e.g., the patient) as the target and to model how that individual’s pain reports affect his or her own and his or her partner’s relationship outcomes. Although this is a reasonable approach, our goals were to maximize the use of the data we collected from both partners and to model the mutual influence process that is potentially occurring in the couple by examining how each person’s daily perceptions of the patient’s pain can affect his or her own and his or her partner’s relationship outcomes. To accomplish this, we examined the unique aspects of each individual’s pain reports while controlling for the report of his or her partner, setting what was common to both partners aside in our mediation analyses. Stated differently, if one views what is common to both patients’ and partners’ reports as the degree to which they overlap or agree regarding the severity of the patient’s pain, then our analysis modeled the effects of each person’s pain experience that was not also being experienced by his or her partner. Indeed, studies in the chronic pain literature have shown that couples who report larger differences in patient disability ratings experience greater global distress than those who report smaller differences [8]. We wanted to determine whether the unique aspects of patient and partner pain ratings serve a similar role in terms of their contribution to the within-day variability in relationship outcomes in the context of advanced cancer.

Fig. 3 depicts a dyadic model whereby daytime patient mood mediates the link between patient and spouse morning ratings of pain and patient and spouse evening ratings of relationship functioning. Note, we focused on patient daytime mood as the focal mediator in our analyses because there was a degree of predictive overlap between patient and partner mood ratings. Unlike the sole mediation effect depicted in Fig. 2, the dyadic model in Fig. 3 can test four possible indirect effects. For example, the first possible indirect effect, $a_1 \times b_1$, represents the mediating effect of patient daytime mood on the association between patient ratings of morning pain and patient evening ratings of relationship functioning. The second possible indirect effect, $a_2 \times b_2$, represents the mediating effect of patient daytime mood on the association between partner ratings of the patient’s morning pain and patient evening ratings of relationship functioning. The third possible indirect effect, $a_1 \times b_2$, represents the mediating effect of patient daytime mood on the association between partner ratings morning pain and partner evening ratings of relationship functioning. Finally,
the fourth possible indirect effect, $a_2 + b_2$, represents the mediating effect of patient daytime mood on the association between patient ratings of morning pain and partner evening ratings of relationship functioning. Admittedly this dyadic approach to mediation is more complex than examining the effects of only one person’s pain reports on both partner’s outcomes; however, it may also provide a more valid portrait of the overall impact of pain on couple functioning because it considers both partner’s perspectives, acknowledges that patients and partners may not always agree about the patient’s pain, and allows for the possibility that the level of disagreement between patients and partners (operationalized here as the unique, non-overlapping component of their pain reports) may play a significant role in affecting relationship functioning.

the fourth possible indirect effect, $a_2 / C_3 b_2$, represents the mediating effect of patient daytime mood on the association between partner rating of patient morning pain on partner evening rating of cancer interference; $a_2 / C_3 b_2$, represents the mediating effect of partner rating of patient morning pain on partner evening rating of cancer interference; $a_2 / C_3 b_2$, represents the mediating effect of patient daytime mood for the association between partner ratings of patient morning pain and partner evening ratings of cancer interference; $a_2 / C_3 b_2$, represents the mediating effect of patient daytime mood on the association between partner ratings of patient morning pain and partner evening ratings of cancer interference. $a_2 / C_3 b_2$, represents the mediating effect of patient daytime mood on the association between partner ratings of patient morning pain and partner evening ratings of cancer interference.

**p ≤ 0.06.**  
*p ≤ 0.05.**  
*p ≤ 0.01.**  
**p ≤ 0.005.**

**Fig. 3.** Dyadic multilevel mediation model of the pain → mood → relationship functioning process. Note: Direct paths from patient rating of patient pain to partner rating of relationship functioning ($C_j$) and partner rating of patient pain to patient rating of relationship functioning ($C_j$) were estimated but not depicted for ease of visualization.

### Table 2

Results of dyadic multilevel analyses showing patient daytime mood as a mediator of the link between patient and partner reports of the patient’s morning pain and their evening reports of cancer interference with the quality of time spent together.

<table>
<thead>
<tr>
<th>Effect</th>
<th>Tired mood Estimate</th>
<th>SE</th>
<th>Z</th>
<th>PME (%)</th>
<th>Peppy mood Estimate</th>
<th>SE</th>
<th>Z</th>
<th>PME (%)</th>
<th>Active mood Estimate</th>
<th>SE</th>
<th>Z</th>
<th>PME (%)</th>
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<tbody>
<tr>
<td>$a_1$</td>
<td>0.059***</td>
<td>0.011</td>
<td>5.215</td>
<td>-0.060**</td>
<td>0.019</td>
<td>-3.164</td>
<td>-0.077**</td>
<td>0.016</td>
<td>-4.721</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$b_1$</td>
<td>0.164***</td>
<td>0.054</td>
<td>3.431</td>
<td>-0.172***</td>
<td>0.053</td>
<td>-3.230</td>
<td>-0.117**</td>
<td>0.056</td>
<td>-2.077</td>
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<tr>
<td>$c_1$</td>
<td>0.106***</td>
<td>0.026</td>
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<td>0.106</td>
<td>0.032</td>
<td>3.318</td>
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<tr>
<td>$a_2$</td>
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<td>0.011</td>
<td>5.215</td>
<td>-0.060**</td>
<td>0.019</td>
<td>-3.164</td>
<td>-0.077**</td>
<td>0.016</td>
<td>-4.721</td>
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<tr>
<td>$b_2$</td>
<td>0.184***</td>
<td>0.054</td>
<td>3.431</td>
<td>-0.172***</td>
<td>0.053</td>
<td>-3.230</td>
<td>-0.117**</td>
<td>0.056</td>
<td>-2.077</td>
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</tr>
<tr>
<td>$c_2$</td>
<td>-0.001</td>
<td>0.025</td>
<td>-0.036</td>
<td>-0.001</td>
<td>0.026</td>
<td>-0.027</td>
<td>-0.004</td>
<td>0.026</td>
<td>-0.159</td>
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<tr>
<td>$c_3$</td>
<td>0.106***</td>
<td>0.022</td>
<td>4.780</td>
<td>0.087***</td>
<td>0.020</td>
<td>4.444</td>
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<td>0.019</td>
<td>4.956</td>
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<tr>
<td>$c_4$</td>
<td>0.042***</td>
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<td>1.924</td>
<td>0.037</td>
<td>0.029</td>
<td>1.260</td>
<td>0.037</td>
<td>0.024</td>
<td>1.519</td>
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</tr>
</tbody>
</table>

**Morning mood** 0.274*** 0.026 10.660 0.371*** 0.043 8.611 0.256*** 0.038 6.690

**Daytime mood**

**Evening mood**

Note: Estimates with same letter subscript were constrained to be equal based on comparison of model BIC statistics. PME = Proportion of mediated effect; $a_1$ = effect of patient ratings of morning pain on patient daytime mood; $b_1$ = effect of patient daytime ratings of mood on patient evening rating of cancer interference; $c_1$ = direct effect of patient rating of morning pain on patient evening rating of cancer interference; $a_2$ = effect of partner ratings of patient morning pain on patient daytime mood (controlling for patient morning mood); $b_2$ = effect of patient daytime ratings of mood on partner evening ratings of cancer interference; $c_2$ = direct effect of partner rating of patient morning pain on partner evening rating of cancer interference; $a_3$ = effect of partner rating of patient morning pain on patient evening ratings of cancer interference; $a_4 + b_4$ = the mediating effect of patient daytime mood for the association between patient rating of morning pain and patient evening ratings of cancer interference; $a_5 + b_5$ = the mediating effect of patient daytime mood for the association between partner ratings of patient morning pain and partner evening ratings of cancer interference; $a_6 + b_6$ = the mediating effect of patient daytime mood on the association between partner ratings of patient morning pain and partner evening ratings of cancer interference.

$^1$ p ≤ 0.06.  
$p ≤ 0.05.**  
$p ≤ 0.01.***  
$p ≤ 0.005.$
There were models where paths $a_1$ and $a_2$ (representing the effects of patient and spouse morning ratings on daytime patient affect) and paths $b_1$ and $b_2$ (representing the effects of patient daytime ratings of affect on evening patient-rated and spouse-rated relationship outcomes) were similar in size and constrained to be equal when the constrained model led to a smaller BIC (Bayesian Information Criterion) statistic. If the BIC for the constrained model is smaller than the unconstrained model, the constrained model becomes more parsimonious because it demonstrates better model fit. Finally, we examined whether demographic factors such as patient age, length of marriage, and time since diagnosis affected our associations of interest. The effects in the models presented below remained essentially unchanged after controlling for these variables, thus, we present the findings without these controls.

To provide some sense of the magnitude of the significant indirect effects from the multilevel mediation models, we calculated proportion of mediated effect (PME) statistics using the formula $\frac{a \times c}{a + b + c}$ where the numerator quantity represents the estimated mediated effect and the denominator quantity represents the total effect [34]. Note that each of the possible four indirect effects in each model has different direct effects (i.e., $c' \text{paths}$) and thus different total effect quantities. Moreover, in cases where there was inconsistent mediation (i.e., where the mediated effect had a different sign than the direct effect), we took the absolute value of the direct and indirect effects [34]. Thus PME values represent the proportion of the implied total effect of $(X \rightarrow Y)$ that is accounted for by the estimated mediated effect $(X \rightarrow M \rightarrow Y)$. Lastly, based on the suggestion of Raudenbush and Bryk [38], we considered the possibility that the predictors (as is the case for the outcomes) have both between-couple and within-couple variability. Although alternative analyses were conducted to control for these between-couple effects, these are not reported here because they did not change the statistical significance or pattern of the results described below.

3. Results

3.1. Sample characteristics

Patients were predominantly white (85%), well-educated (86% had at least 2 years of college study), and retired or unemployed (61%). All were married, with widespread variation in the length of time married ($M = 21.48$ years, $SD = 13.06$; range 1–55 years). Average age was 49.38 years, ($SD = 10.76$; range 30–73 years). Although all patients were beginning treatment for stage 4 (metastatic) disease at the time of study entry, disease stage at initial cancer diagnosis included stage 1 (13.56%), stage 2 (28.81%), stage 3 (15.25%), and stage 4 (42.37%). The average length of time since initial cancer diagnosis was 4.73 years ($SD = 4.5$; range 1 month to 19.3 years). Primary metastatic sites were: bone (56%), lung (22%), liver (10%), and brain (3%). With regard to treatment, 83% of patients were beginning chemotherapy, 15% hormonal therapy, and 2% radiation.

Partners’ average age was 51.32 years ($SD = 11.51$; range 32–78 years). The majority were white (88%), well-educated (86% had at least 2 years of college study) and employed full-time (60%). Forty of the 59 couples (67.5%) had annual incomes over $50,000/year and 25 couples (42%) had at least one child living with them at home.

3.2. Descriptive results

Table 1 shows Pearson correlations between each of the major study variables at each assessment for patients and partners as well as partial correlations between patients and partners for these variables. Table 1 also shows the means, SDs, and paired t-tests comparing means for patients and partners on the major study variables. Despite the fact that patients reported low average pain across assessments ($M = 2.45$, $SD = 2.23$), patients reported currently being in at least some pain ($BPI = 1$ or higher) on 59% of all assessments and being in significant pain ($BPI = 4$ or higher) on 19% of all assessments. Only 18% of those who reported currently experiencing pain had taken any form of pain medication since their previous assessment (i.e., prescription or over-the-counter medication). For those taking medication, the average pain relief rating was 6 ($SD = 2.96$) on a scale of 0 (no relief) to 10 (complete relief).

Correlations between patient and partner mood were low, and in many cases, non-significant. Partners reported significantly more active, quiet, peppy, sad, and anxious mood than patients. Patients reported significantly more happy and tired mood than partners. Patient and partner reports of cancer interference with the relationship were significantly correlated; however, patients perceived greater interference than their partners. Interestingly, patients perceived that they received more physical and emotional support than their partners reported providing; however, this difference was only significant for physical support.

3.3. Dyadic multilevel mediation analyses: relationship interference

Table 2 summarizes the results from models testing whether patient daytime mood mediated the links between patient and partner morning ratings of patient pain and their evening ratings of cancer interference. Although each of the $a$ and $b$ paths across the 3 daytime moods (i.e., tired, peppy, and active) were statistically significant, none of the models revealed random effects for both the $a$ and $b$ paths simultaneously.

All four of the specific paths of the indirect effects were statistically significant for tired mood. Thus, both patient and partner ratings of greater patient pain in the morning were associated with greater patient tired affect during the day, which in turn was associated with both patients and partners reporting in the evening that cancer interfered with the quality of time they spent together that day.

For active mood and peppy mood, all four of the specific tests of the indirect effects were borderline significant ($p = 0.06$). Namely, both patient and partner ratings of greater patient pain in the morning were associated with less peppy and active mood during the day, which in turn was associated with both patients and partners reporting in the evening that cancer interfered with the quality of time they spent together that day.

Overall, in terms of the proportion of mediated effect (PME), patient aroused mood (more tired, less peppy, less active) accounted for 7–9% of the association between patient reports of morning pain and their evening reports of relationship interference. In contrast, patient aroused mood accounted for 68–92% of the association between partner reports of patient morning pain and their evening reports of relationship interference.

3.4. Dyadic multilevel mediation analyses: emotional social support

Table 3 summarizes the results from models testing whether patient daytime mood mediated the links between patient and partner morning ratings of patient pain and evening ratings of the emotional support that was received by the patient and provided by the partner.

Daytime tired affect emerged as a significant mediator in all four indirect effects linking morning pain and evening ratings of emotional support. Specifically, both patient and spouse ratings of greater patient pain in the morning were associated with...
patients reporting greater tired effect during the day; this in turn was associated with patients reporting in the evening that they received more emotional support and with partners reporting that they provided more emotional support.

For peppy mood, none of the indirect effects were significant. However, the $a_1$ and $a_2$ paths were significant, indicating that patient and partner ratings of greater patient pain in the morning were associated with less peppy patient mood during the day. For active mood, only two tests of the indirect effects ($a_1 + b_2$ and $a_2 + b_2$) were significant (see Table 3). Patient and partner reports of greater patient pain in the morning were associated with lower levels of patient active mood during the day; this in turn

Table 3

<table>
<thead>
<tr>
<th>Effect</th>
<th>Tired mood</th>
<th>Peppy mood</th>
<th>Active mood</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimate</td>
<td>SE</td>
<td>Z</td>
</tr>
<tr>
<td>$a_1$</td>
<td>0.057***</td>
<td>0.010</td>
<td>5.834</td>
</tr>
<tr>
<td>$b_1$</td>
<td>0.155***</td>
<td>0.053</td>
<td>2.913</td>
</tr>
<tr>
<td>$c_1'$</td>
<td>-0.044</td>
<td>0.029</td>
<td>-1.484</td>
</tr>
<tr>
<td>$a_2$</td>
<td>0.057***</td>
<td>0.010</td>
<td>5.834</td>
</tr>
<tr>
<td>$b_2$</td>
<td>0.155***</td>
<td>0.053</td>
<td>2.913</td>
</tr>
<tr>
<td>$c_2'$</td>
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<td>0.040</td>
<td>-0.897</td>
</tr>
<tr>
<td>$c_2'$</td>
<td>0.016</td>
<td>0.044</td>
<td>0.361</td>
</tr>
<tr>
<td>$c_2'$</td>
<td>-0.045</td>
<td>0.027</td>
<td>-1.672</td>
</tr>
</tbody>
</table>

Morning mood

<table>
<thead>
<tr>
<th>Estimate</th>
<th>SE</th>
<th>Z</th>
<th>PME (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a_1 + b_1$</td>
<td>0.009</td>
<td>0.003</td>
<td>2.520</td>
</tr>
<tr>
<td>$a_1 + b_2$</td>
<td>0.009</td>
<td>0.003</td>
<td>2.520</td>
</tr>
<tr>
<td>$a_2 + b_1$</td>
<td>0.009</td>
<td>0.003</td>
<td>2.520</td>
</tr>
<tr>
<td>$a_2 + b_2$</td>
<td>0.009</td>
<td>0.003</td>
<td>2.520</td>
</tr>
</tbody>
</table>

Note: Estimates with same letter subscript were constrained to be equal based on comparison of model BIC statistics. PME = Proportion of mediated effect; $a_1$ = effect of patient ratings of morning pain on patient daytime mood; $b_1$ = effect of patient daytime ratings of mood on patient evening ratings of received emotional support; $c_1'$ = direct effect of patient ratings of morning pain on patient evening ratings of provided emotional support; $c_1''$ = effect of patient ratings of morning pain on patient evening ratings of provided emotional support; $c_2'$ = effect of partner ratings of patient morning pain on partner evening ratings of provided emotional support; $c_2''$ = effect of partner ratings of patient morning pain on partner evening ratings of provided emotional support; $c_2''$ = effect of partner ratings of patient morning pain on partner evening ratings of provided emotional support; $c_2''$ = effect of partner ratings of patient morning pain on partner evening ratings of provided emotional support; $c_2''$ = effect of partner ratings of patient morning pain on partner evening ratings of provided emotional support; $c_2''$ = effect of partner ratings of patient morning pain on partner evening ratings of provided emotional support; $c_2''$ = effect of partner ratings of patient morning pain on partner evening ratings of provided emotional support; $c_2''$ = effect of partner ratings of patient morning pain on partner evening ratings of provided emotional support; $c_2''$ = effect of partner ratings of patient morning pain on partner evening ratings of provided emotional support; $c_2''$ = effect of partner ratings of patient morning pain on partner evening ratings of provided emotional support; 

$p < 0.06$.

$p < 0.05$.

$p < 0.005$.

Table 4

<table>
<thead>
<tr>
<th>Effect</th>
<th>Tired mood</th>
<th>Peppy mood</th>
<th>Active mood</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimate</td>
<td>SE</td>
<td>Z</td>
</tr>
<tr>
<td>$a_1$</td>
<td>-0.063***</td>
<td>0.010</td>
<td>6.386</td>
</tr>
<tr>
<td>$b_1$</td>
<td>0.125**</td>
<td>0.052</td>
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</tr>
<tr>
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<td>-0.068</td>
</tr>
<tr>
<td>$a_2$</td>
<td>0.063***</td>
<td>0.010</td>
<td>6.386</td>
</tr>
<tr>
<td>$b_2$</td>
<td>0.125**</td>
<td>0.052</td>
<td>2.465</td>
</tr>
<tr>
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<td>-0.457</td>
</tr>
<tr>
<td>$c_2'$</td>
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</tr>
<tr>
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<td>0.027</td>
<td>-0.443</td>
</tr>
</tbody>
</table>

Morning mood

<table>
<thead>
<tr>
<th>Estimate</th>
<th>SE</th>
<th>Z</th>
<th>PME (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a_1 + b_1$</td>
<td>0.008</td>
<td>0.003</td>
<td>2.410</td>
</tr>
<tr>
<td>$a_1 + b_2$</td>
<td>0.008</td>
<td>0.003</td>
<td>2.410</td>
</tr>
<tr>
<td>$a_2 + b_1$</td>
<td>0.008</td>
<td>0.003</td>
<td>2.410</td>
</tr>
<tr>
<td>$a_2 + b_2$</td>
<td>0.008</td>
<td>0.003</td>
<td>2.410</td>
</tr>
</tbody>
</table>

Note: Estimates with same letter subscript were constrained to be equal based on comparison of model BIC statistics. PME = Proportion of mediated effect; $a_1$ = effect of patient ratings of morning pain on patient daytime mood; $b_1$ = effect of patient daytime ratings of mood on patient evening ratings of received physical support; $c_1'$ = direct effect of patient ratings of morning pain on patient evening ratings of received physical support; $c_1''$ = effect of patient ratings of morning pain on patient evening ratings of received physical support; $c_1''$ = effect of patient ratings of morning pain on patient evening ratings of provided physical support; $c_1''$ = effect of patient ratings of morning pain on patient evening ratings of provided physical support; $c_1''$ = effect of patient ratings of morning pain on patient evening ratings of provided physical support; $c_1''$ = effect of patient ratings of morning pain on patient evening ratings of provided physical support; $c_1''$ = effect of patient ratings of morning pain on patient evening ratings of provided physical support; 

$p < 0.06$.

$p < 0.05$.

$p < 0.005$.
was associated with partners reporting in the evening that they provided greater emotional support to the patient that day. PME calculations showed that patient tired mood accounted for 17% of the association between patient reports of morning pain and their evening reports of received emotional support from their partners. In contrast, patient tired and active mood accounted for 16–23% of the association between partner reports of patient morning pain and their evening reports of providing emotional support to the patient.

3.5. Dyadic multilevel mediation analyses: physical social support

Table 4 summarizes the results from models that tested whether patient daytime mood mediated the links between patient and partner morning ratings of patient pain and their evening ratings of the physical support that was provided by the partner and received by the patient.

Similar to the findings for emotional support, daytime tired affect emerged as a significant mediator in all four indirect effects linking patient and partner reports of patient morning pain with evening ratings of the physical support that was provided by the partner and received by the patient.

For peppy mood, the $a_1$ and $a_2$ paths were significant, meaning that patient and partner ratings of greater patient pain in the morning were associated with less patient peppy mood during the day. The $b_2$ path was also significant, meaning that when patients had greater peppy mood during the day their partners reported in the evening that they provided patients with less physical support that day.

For active mood, two tests of the indirect effects ($a_1 \times b_1$ and $a_2 \times b_2$) were significant. When patients and partners reported greater patient pain in the morning, patients reported lower levels of active mood during the day; this in turn was associated with partners reporting at bedtime that they provided greater physical support to the patient that day.

PME calculations showed that patient tired mood accounted for 82% of the association between patient reports of morning pain and their evening reports of received physical support from their partners. In contrast, patient aroused mood (more tired, less peppy, less active) accounted for 28–52% of the association between partner reports of patient morning pain and their evening reports of providing physical support to the patient.

4. Discussion

We found that greater patient pain in the morning was associated with lower levels of patient aroused mood (i.e., more tired, less peppy, less active) during the day (controlling for morning mood) and that moods with solely a valenced evaluation component (i.e., happy, sad) were not associated with patient pain. This finding is consistent with Turk et al. who found that patients with cancer-related pain had significantly higher levels of disability and inactivity than patients with non-cancer pain, even though their levels of pain severity were comparable [48]. Given the potentially life-threatening nature of their disease, women with MBC may be more likely to attribute their pain to disease progression, and this in turn may result in them conserving energy and reporting lower levels of aroused mood during the day.

Our findings extend previous research by identifying a causal chain of events linking pain, mood, and relationship outcomes among MBC patients and their partners. Couples reported greater relationship interference on days when patients experienced greater pain and tired mood; however, the pattern of association was slightly different for patients and partners. Patients’ morning pain was directly related to their evening reports of relationship interference and this association was further attenuated by their tired mood during the day. In contrast, partners’ reports of relationship interference were not directly related to their reports of patient pain. Rather, this association only occurred as an indirect effect through patient tired mood. Because patients directly experience pain, its presence alone may be sufficient for them to perceive an impact on their relationship. In contrast, partners may first need to observe the adverse effects of the patient’s pain condition on her mood in order to perceive the same impact. Although it remains unclear whether morning pain is more detrimental to emotional and relationship functioning than pain that occurs at other times of the day, our findings do suggest a “cascade effect” and that the effective management of morning pain should be a priority.

Similar to the findings for relationship interference, we found that while partners significantly over-estimated patients’ pain, partner pain ratings were not significantly associated with their provision of physical or emotional support to the patient. Rather, partners were more likely to provide support in response to patient positive daytime mood. Although these findings are consistent with studies from the support mobilization literature showing that the level of distress experienced by the support recipient is an important predictor of receiving support [24], it is noteworthy that the moods that mediated associations between morning pain and evening reports of provided/received support either had an arousal (i.e., active mood) or an arousal plus an evaluation component (i.e., tired and peppy moods). In the context of a chronic illness such as cancer, the partner may expect the patient to adjust to living with a certain degree of pain and may thus provide support only when he sees that pain is adversely affecting the patient’s activity level or is making her less active and sad. Perhaps when the patient’s pain condition is not severe enough to affect her daily activity and sadness is not clearly communicated, the partner does not know that there is a problem that requires him to act by providing support.

Patients reported receiving more physical and emotional support than their partners reported providing; however, patient mood accounted for a larger percentage of the association between pain and partner’s provision of social support than it did for patients’ receipt of social support. It is possible that patients and partners had different definitions of support. However, we found that patients received more support and partners provided more support in response to greater patient pain and negative mood. This finding differs from previous studies in early stage breast cancer that have suggested that patient distress can erode partner support over time [7]. In the context of the greater pain and symptom burden associated with MBC, it is possible that patient expression of negative mood may indeed have had the expected effect of mobilizing greater partner support [9]. However, all our participants were initiating treatment for MBC and we only followed them for 2 weeks, so it is equally possible that spousal support is mobilized in periods of acute stress but can erode over longer periods of time (e.g., after treatment). It is also noteworthy that mood accounted for a larger percentage of the association between pain and the provision/receipt of physical support than it did for emotional support for both patients and their partners. One possibility is that patients may find it easier to request physical support when they are in pain and partners may find it easier to respond to patient pain and distress by providing such support, particularly when they themselves may be experiencing distress.

Finally, even though partners may have been doing the “right thing” by responding supportively to the patient’s pain and mood, both patients and partners reported greater relationship interference when the patient was in more pain. As MBC and pain progress and the patient moves toward end-of-life, couples’ relationships and interactions may become increasingly clouded by the cancer experience. Our previous work has shown that couples who are aware of the relationship implications of advanced cancer and
who strive to maintain or enhance their relationships while coping with cancer experience better psychosocial adjustment [3]. Pain programs may thus benefit from including a component that teaches couples how to continue to relate as loving partners as opposed to relating as patient and caregiver.

4.1. Limitations and strengths

This study had some limitations. First, patients reported moderate pain at enrollment (M = 4.41); but their average daily pain was much lower (M = 2.45). Although EDs may yield different information from that obtained by retrospective measures [45], it is noteworthy that patients took medication 18% of the times they were in pain. This may have affected associations between variables. Nonetheless, the low daily pain levels that were reported provide a conservative test of our hypothesis and suggest that regardless of severity, the daily variability in pain influences both mood and relationship functioning. Second, the moderate rates of adherence with the ED assessments (68%) may have been because patients were initiating treatment for MBC, had increased demands on their time and were experiencing pain and cancer-related symptom burden. The fact that alarms were generated during a fixed time each day (9:00 am to 9:00 pm) may also have affected adherence; participants sometimes slept early/woke up late and missed assessments. Another issue is that participants were relatively young (M = 49.38); the median age for a breast cancer diagnosis is 61 years [25]. Older patients may have declined because they were uncomfortable with the computerized assessments.

Despite collecting repeated measures, our sample size of couples was small and the validity of the brief relationship functioning measures has not been established. These factors may have contributed to our finding a number of “trends” (p < 0.06), particularly for the indirect effects of peppy and active mood. However, this is the first study to use EDs to identify within-day processes linking pain to relationship outcomes; since the trends were in the same direction as the significant effects, they can provide direction for future work [39] and suggest that pain may influence relationship functioning in MBC through its effects on patients’ aroused mood. Finally, 1/3 of eligible couples refused to participate. Patients who participated had higher levels of pain, were predominately Caucasian, and well-educated. Other variables may have differentiated these groups. Thus, caution must be exercised in generalizing beyond the sample enrolled in this study.

This study also had a number of strengths. We examined a stage of cancer that has received very little attention in the QOL literature, despite the fact that women with MBC experience significant pain and are living longer with their disease. This is one of the few studies to examine the effects of cancer pain from both partners’ perspectives. Indeed, the dyadic data analysis technique we employed allowed us to: (1) account for the non-independence of patients’ and partners’ responses; (2) consider the effects of patient and partner ratings of patient pain on patient and partner outcomes, and (3) examine the effects of pain and mood on the provision and receipt of social support. Finally, this study is unique in its use of EDs to measure associations between pain, mood, and relationship functioning in a way that is not possible with typical paper-and-pencil designs.

We found that mood mediated the effects of patient pain on couples’ relationship functioning by influencing patient and partner perceptions of relationship interference, the partners’ provision of physical and emotional support, and the patient’s receipt of that support. Thus, while biomedical intervention may be effective in alleviating some of the nociceptive aspects of pain, such modalities may not be sufficient. More research is needed to investigate how psychological factors and couple-focused interventions can be integrated with biomedical therapy to provide optimal therapeutic effects. Such treatment is likely to improve the QOL of both MBC patients and their partners and help them cope with this distressing and life-threatening disease.

Conflict of interest statement

The authors do not have any conflicts of interest to declare.

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