Daily Stress and Mood and Their Association With Pain, Health-Care Use, and School Activity in Adolescents With Sickle Cell Disease

Karen M. Gil,1 PhD, James W. Carson,1 PhD, Laura S. Porter,1 PhD, Jawana Ready,1 PhD, Cecelia Valrée,1 BA, Rupa Redding-Lallinger,1 MD, and Charles Daeschner,2 MD

1University of North Carolina–Chapel Hill and 2East Carolina University

Objective To determine the extent to which daily stress and mood are associated with pain, health-care use, and school activity in adolescents with sickle cell disease (SCD).

Method Adolescents with SCD (n = 37; aged 13 to 17 years) completed daily diaries assessing pain, stress, mood, activity, and health-care use for up to 6 months. Multilevel modeling was used to analyze the data. Results Daily increases in stress and negative mood were associated with increases in same-day pain, health-care use, and reductions in school and social activity. Increases in positive mood were associated with decreases in pain, less health-care use, and more activity participation. Notably, pain was predictive of higher stress and lower positive mood on subsequent days. Conclusion Pain in adolescents with SCD is stressful and may lead to alterations in mood states. Understanding the way in which these variables relate to health-care use and activity may lead to improved pain management approaches.

Key words sickle cell disease, diary, pain, adolescents

Recurrence pain from sickle cell disease (SCD) can be a significant and disabling problem (Ballas, 1998). Recurrent pain can result in frequent and costly health-care contacts and school or work absences, and may lead to depression and other emotional problems, social isolation, and poor quality of life (Brown, Doepke, & Kaslow, 1993; Midence & Elander, 1994). Moreover, research findings indicate that patients with frequent painful episodes and frequent health-care use have the highest mortality rate (Platt et al., 1991).

The onset of pain in SCD is usually unpredictable. Dehydration, infection, physical overexertion, and exposure to cold weather have been commonly implicated as precipitants of vascular occlusion. However, the empirical evidence to date suggests that most pain episodes are not preceded by an obvious precipitating factor (Ballas, 1998).

Psychological stress has been implicated as a precipitating or exacerbating factor in the course of a number of chronic illnesses, such as coronary heart disease (Fontana, Kerns, Rosenberg, & Colonese, 1989), pediatric rheumatoid arthritis (von Weiss et al., 2002), and childhood diabetes (Brand, Johnson, & Johnson, 1986). More recently, the critical influence of daily fluctuations in stress on pain and other indices of disease expression has been recognized. For example, stress has been associated with daily fluctuations in pain in patients with fibromyalgia and rheumatoid arthritis (Affleck, Tennen, Urrows, & Higgins, 1994; Stone, Broderick, Porter, & Kael, 1997). In children, researchers have shown that increases in daily stress are significantly related to reports of fatigue and stiffness in children with rheumatic disease (Schanberg et al., 2000) and to somatic symptoms in children with recurrent abdominal pain (Walker, Garber, Smith, Van Slyke, & Claar, 2001).

Although psychological stress has been implicated in the onset of painful episodes in SCD, the earlier studies that supported this relationship relied on retrospective and descriptive methods with very small samples (Leavell & Ford, 1983; Nadel & Portadin, 1977), which make the findings less compelling. However, findings from two recent studies provide more convincing support for the hypothesized relationship between stress and pain in individuals with SCD. In a study of 52 adults, Porter et al. (1998) found that higher levels of daily stress as mea-
The purpose of the present study was to analyze daily patterns of pain, stress, and mood in adolescents with SCD over several months. Specifically, we hypothesized that increased daily stress and negative mood measured prospectively by daily diaries would be associated with higher daily pain on the same day and on subsequent days. On the other hand, we hypothesized that increased positive mood would be associated with lower daily pain on the same day and on subsequent days. In addition, we hypothesized that pain as well as increased daily stress and negative mood on pain days would be associated with greater decreases in school activity and greater health-care utilization. Alternatively, increased positive mood on pain days would be associated with less activity reduction and fewer health-care contacts.

To accomplish the aims of the study, we utilized the daily diary method. Daily diary methods have individuals track closely, as they happen under naturalistic conditions, fluctuations in stress, mood, and pain. Diaries provide useful information on patterns of pain and symptoms and may be more accurate than hospital records about the duration, frequency, and severity of illness events and health contacts (e.g., Norman, McFarlane, Streiner, & Neale, 1982). Diaries may be especially useful in understanding patterns of SCD pain, since individuals with SCD often report mild to moderate pain that is managed at home and not reported to health-care providers (Gil et al., 2000; Shapiro, Dinges, Orne, Ohene-Fremong, & Orne, 1990). Moreover, diaries provide a more accurate recording of particularly the temporal sequences of events, and thus provide advantages when analyzing the links between stress, mood, and pain. Although the use of home diaries to assess pain and other symptoms in SCD is not a new method, prior studies that have included diaries to examine pain in individuals with SCD have been primarily descriptive studies of pain course and response (Fuggle, Shand, Gill, & Davies, 1996; Gil et al., 2000; Gill, Shand, Fuggle, Dugan, & Davies, 1997; Shapiro et al., 1990, 1995). In contrast, the present study utilized daily diary methods to investigate the temporal link between daily stress and moods and daily pain and pain response. Furthermore, we incorporated the use of powerful, multilevel statistical analyses to perform a more careful examination of the temporal sequencing of within-person variables (Schwartz & Stone, 1998; West & Hepworth, 1991).

Method

Participants and Setting

Participants were recruited from the University of North Carolina (UNC) and the East Carolina University sickle cell clinics. Patients were screened by their primary physician to determine participant phenotype and whether there were any medical contraindications for participation (e.g., neurological impairment). There are three major types of SCD: sickle cell anemia, or homozygous SS; hemoglobin SC disease; and sickle beta thalassemia syn-
dromes. Phenotype was determined for participants using standard laboratory methods including hemoglobin electrophoresis. The sample was 37 adolescents (24 girls, 13 boys) in the age range of 13 to 17 (M = 14.8, SD = 1.4). Twenty-eight had sickle cell anemia, 6 had hemoglobin SC disease, and 3 had sickle beta thalassemia syndromes.

**General Procedures**

Institutional review boards (IRB) at UNC–Chapel Hill and East Carolina University approved the study protocols. Informed consent was obtained from participants and their caregivers according to IRB procedures. During an initial evaluation, adolescents completed questionnaires assessing baseline stress and psychological distress. After the initial evaluation, participants entered the diary phase of the study for up to 6 months.

**Daily Diary of Pain, Health-Care Use, Activity, Stress, and Mood**

The daily diary was a simple form that adolescents completed each day. It was modeled after the diary used in our prior study of adults (Porter et al., 2000). Adolescents were trained in how to complete the diary by an investigator in person who helped them to complete sample diaries. Each adolescent was given a folder with personalized training materials to refer to, including definitions for common SCD complications. Adolescents were given daily prompts to complete the diaries by a programmable wristwatch and were provided with stamped addressed envelopes in which to return diaries on a weekly basis. Weekly telephone contact was maintained to reinforce diary completion and to answer any questions.

**Sickle Cell Disease Pain, Other Pain, and Health-Care Use**

The first section of the diary asked about SCD pain and health-care use. These questions were modified from the Structured Pain Interview and Daily Self-Monitoring Record developed by Gil (1994). Participants were asked if they had SCD pain today that was located anywhere in the body and that had no known cause other than SCD. They then rated their average pain level for the day on a 100 mm visual analogue scale (VAS). A *pain day* was defined for the analyses as any day on which the child reported “yes” to the question “Are you having an episode of sickle cell pain today?” Adolescents were also asked to indicate pain duration, whether they called or visited their doctor, went to the emergency room (ER), were admitted to the hospital, or took prescription medication. Reliability and validity of the items have been reported in studies of children and adolescents with SCD (e.g., Gil et al., 1991, 1993, 2000). The items were found to have satisfactory test-retest reliability and adequate interrater reliability. Positive correlations were found between health-care use data obtained from this self-report format and documented health-care contacts recorded in the medical record.

For this study, adolescents were also asked whether they experienced any pain other than SCD pain, such as headache or menstrual pain for girls. First, they responded to the question “Did you experience other pain today unrelated to SCD?” If “yes,” the adolescent was asked to describe the nature of the pain and then rate the average *other pain* level for the day on a 100 mm VAS similar to the one described above.

**School and Other Activities**

To assess daily activity, adolescents were asked whether, on that day, they (1) stayed home from school, (2) participated in extracurricular or after-school activities, and (3) completed household chores. There is considerable variability among SCD children in their ability to continue school activity during painful episodes (e.g., Shapiro et al., 1995). Children often miss school and withdraw from peer activities due to SCD pain, and prior research has shown that activity reduction is an important measure of response to chronic pain conditions (e.g., Gil et al., 2000; Walters & Williamson, 1999).

**Stress**

The second section contained an assessment of daily stress based upon the approach used by Stone and colleagues (Stone & Neale, 1982, 1984; Stone et al., 1997) and similar to that used in our prior research with adults (Porter et al., 2000). As part of the initial diary completion training session, adolescents were given a list of daily stressors. However, rather than complete the checklist each day, they were asked to use it as a guide for the range of potential stressors. Each day, they were asked to rate the perceived level of overall stress of the day on a 100 mm VAS anchored at *not at all stressful* and *as stressful as I can imagine*. They were asked to describe what situations they were dealing with that day, to identify the most stressful situation, and to select one of six categories that best described it: school, family, boyfriend/girlfriend, other friends or other relationships, sickle cell disease, or other.

**Mood**

The final section of the diary consisted of the daily mood scale developed by Diener and Emmons (Diener &
Emmons, 1985; Emmons & Diener, 1985). The mood scale assessed two dimensions of affect—positive affect (PA) and negative affect (NA)—by asking participants to rate the degree to which they felt various mood states that sampled these two overall domains of affect (PA = happy, enjoyment/fun, joyful, pleased; NA = depressed/blue, unhappy, angry/hostile, frustrated, worried/anxious). Adolescents rated each mood each day on a 6-point scale from not at all to extremely. Composite scores for PA and NA were obtained using the procedures described in Diener and Emmons; that is, the sum score of PA items was computed creating the positive mood variable and the sum score for the NA items was computed creating the negative mood variable. This mood scale has shown adequate reliability and validity in daily diary studies with college students (Diener & Emmons, 1985; Emmons & Diener, 1985) as well as utility in examining the relationships between stress, pain, and mood in participants with pain (Stone et al., 1997). To examine the internal consistency of the scale with the adolescents in this study, we calculated alpha coefficients and found that reliability for each mood scale was high (alpha for PA = .92 and for NA = .88).

**Enhancing Compliance With Diary Completion**

In addition to keeping the diary brief and simple to complete, several other strategies were in place to facilitate diary completion. First, adolescents were provided with wristwatches that were preprogrammed to signal them by a beep once at the end of each day as a reminder to complete the diary. Second, adolescents received monetary incentives—$0.50 per day for each completed diary with a bonus at the end of the week of $1.50 if all diaries for that week were completed. Adolescents were given one stamped addressed envelope for each week and asked to return the diaries by mail. Third, participants were contacted by telephone once per week to provide social reinforcement and encouragement for them to complete and mail in their diaries. The telephone interviewer was trained to conduct a standard protocol. First, the interviewer reported on the completeness of the diaries (e.g., “We have received your diaries from last week”). Second, the interviewer answered any questions related to the recording procedures, such as how to mark the VAS. Questions related to the disease or its management were directed to appropriate personnel.

**Baseline Evaluation of Stress and Psychological Adjustment**

The main purpose for the initial evaluation was to compare diary data on stress and psychological status to commonly used and standardized questionnaires in order to verify the reliability and validity of these diary measures.

**Daily Hassles**

The Adolescent Daily Hassles Scale (Seidman et al., 1995) was used as a baseline measure of daily hassles. This is a 28-item scale examining daily hassles in areas including family, peers, school, neighborhood, and resources. Adolescents rate each stressor on a 4-point rating scale (not a hassle/hasn’t happened in the past month to a very big hassle). The daily hassles’ cumulative severity score is the sum of the ratings. The Adolescent Daily Hassles Scale is part of a comprehensive inventory, the Adolescent Microsystems Scale, which examines social support, neighborhood cohesion, and involvement in activities with families and friends and at school (Seidman et al., 1995). This baseline measure of daily hassles was selected for inclusion in the present study since the Adolescent Microsystems Scale was normed on a large sample of 998 African American, Latino, and white adolescents. The coefficient alpha for the 28-item measure was .89 (Seidman et al., 1995).

**Psychological Distress**

Symptoms of psychological distress were assessed in adolescents using the Symptom Checklist-90–Revised (SCL-90–R; Derogatis, 1983). The SCL-90–R measures psychological distress along nine dimensions: somatization, obsessive compulsive, interpersonal sensitivity, depression, anxiety, hostility, phobic anxiety, paranoid ideation, psychotism, and other dimensions of distress. The Global Severity Index (GSI) was used as the summary score of psychological distress.

**Data Management and Analyses**

Data were entered into Excel Spreadsheets for transport into SAS for Windows. The Windows applications of SAS have the specialized statistical procedures (e.g., PROC MIXED) necessary for analyzing multilevel data sets with repeated measures. All data were double entered and compared to eliminate any errors in data entry.

**Testing the Study Hypotheses**

In order to perform the main analyses of the daily diary data, we used multilevel models for analyzing temporal data as outlined by Schwartz and Stone (1998) and West and Hepworth (1991). These statistical methods accommodate the complexities of temporal data sets that involve two components: sampling at the level of the person (between-person factors) and sampling of the day-to-day
changes in the within-person factors. Such multilevel models offer a number of advantages that we were able to exploit, including (1) their ability to examine the impact of within-person factors such as stress and mood on fluctuations in dependent variables (e.g., pain), (2) methods for handling unequal numbers of observations for participants, which is typically the case in daily diary studies, (3) statistical strategies to control for missing data and serial dependency that preclude any need to supply values for missed assessments (i.e., a continuous-time autoregressive error structure; see Schwartz & Stone, 1998), and (4) correction strategies for the possible influence of relationships between outcome variables and other within-person factors through the employment of person-centered versions for each within-person predictor, resulting in estimated effects that are entirely free from all between-person variance (Schwartz & Stone, 1998). Another advantage of multilevel analyses is that the unit of analysis is observations, in this case days, rather than persons (Schwartz & Stone, 1998). Thus, as is the case in many longitudinal design studies, the overall number of participants might seem small, but the sample size can be offset by the number of observations per participant. The use of multilevel modeling to analyze the diary data provided adequate statistical power to detect significant effects, since in the present study over 4,000 repeated observations were used in the analyses.

All multilevel model analyses were generated using PROC MIXED in SAS (SAS Institute, 1997). Binomial models were applied where appropriate (i.e., health-care use and activity outcomes). As recommended by Schwartz and Stone (1998), to ensure that coefficients for within-person predictors remained unbiased, each model included the aggregated person-means corresponding to within-person diary predictors as control variables (e.g., individuals’ mean as well as day-to-day levels of SCD pain). However, because results corresponding to these control variables were not central to our hypotheses, only results for within-person associations are reported herein.

Results
Diary Completion and Descriptive Diary Information
The 37 adolescents completed a total of 4,012 days out of a possible 5,276 days, representing a completion rate of 76%. On average, adolescents completed 108 diary days (range 20–197 days). Analyses of variance and regression analyses were conducted to examine associations between rates of diary completion and age, gender, and disease severity variables. A significant relationship was demonstrated for age, indicating that younger adolescents were more likely to complete their diaries, $F(1, 35) = 4.04, p = 0.05$.

Adolescents reported a mean pain rating of 40.8 (range = 6–86) and mean pain duration of 16.4 hours (range = 0.4–75 hours) on pain days. On pain days, adolescents reported a mean stress rating of 21.5 (SD = 22.8) compared with a mean of 10.5 (SD = 14.3) on nonpain days. Positive mood was lower (10.3 vs. 13.5) and negative mood higher (6.1 vs. 3.6) on pain and nonpain days, respectively.

During the study period, 43% ($n = 16$) of the adolescents had a sickle cell–related health-care contact. An analysis of type of contact indicated that 16% ($n = 6$) of the adolescents went to the ER, 19% ($n = 7$) were hospitalized, 32% ($n = 12$) visited their physician, and 32% ($n = 12$) made a telephone call to a health-care professional. Some adolescents had multiple contacts on the same day. Of the 31 participants who experienced pain during the study period (range 1–52 days), on average they went to the ER on 4% of pain days, they were in the hospital on 4% of pain days, they visited their physician on 6% of pain days, and they called their physician or other health-care professional on 3% of pain days. For 81% of the pain days, there were no health-care contacts. Adolescents reported using analgesic medication on 26% of pain days, and narcotic medication on 19% of pain days. Regarding activity, they stayed home from school on 13% of pain days and eliminated extracurricular activities on 10% of pain days and household chores on 18% of pain days. Thus, for a large proportion of days when adolescents had pain, they managed pain on their own without a health-care contact.

Comparison of Stress and Mood Diary Data With Baseline Summary Measures
The correlation of cumulative severity scores from the Adolescent Daily Hassle Scale to the overall mean daily stress level from the diaries was $r(37) = .39, p < .05$. The correlation of the GSI from the SCL-90-R to overall negative mood from the diaries was $r(33) = .43, p < .05$; and to overall positive mood from the diaries, $r(33) = -.36, p < .05$. Since the time frame referenced for the summary measures (the prior week for the SCL-90-R and the prior one-month period for the baseline hassle scale) was different from that of the diary (that day), these modest yet significant correlations suggest relationships between diary variables with summary measures that are in the expected directions.
Same-Day Stress and Mood and Their Association With SCD Pain Ratings

Multilevel random effects models were used in order to examine the association between daily stress, mood, and reports of SCD pain levels. These models indicated that on a day-to-day basis, increases in stress were significantly associated with increases in pain ($t = 10.07$, $p < .0001$). Multilevel random effects models were also used to examine the association between daily mood and ratings of pain. Increases in negative mood were significantly related to increases in pain ($t = 8.55$, $p < .0001$), while increases in positive mood were associated with decreases in pain ($t = -10.09$, $p < .0001$; see Table I). In all of these same-day models, other pain significantly interacted with stress and mood such that the combination of higher stress and higher other pain was associated with increases in SCD pain, and the combination of higher levels of negative mood and higher other pain was associated with increases in SCD pain. Positive mood had an inverse relation such that the combination of high positive mood and lower other pain was associated with lower levels of SCD pain. When stress and negative and positive mood were entered in a single simultaneous equation, stress ($t = 7.23$, $p < .0001$) and positive mood ($t = -5.99$, $p < .0001$) continued to show independent associations with pain, while the association between negative mood and pain was no longer significant.

Table I. Summary of Multilevel Random Effects Analyses of Associations Between Stress and Mood and Pain

<table>
<thead>
<tr>
<th></th>
<th>Same-Day SCD Pain</th>
<th></th>
<th>Next-Day SCD Pain</th>
<th></th>
<th>SCD Pain 2 Days Later</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$B$</td>
<td>$t$</td>
<td>$B$</td>
<td>$t$</td>
<td>$B$</td>
<td>$t$</td>
</tr>
<tr>
<td>Stress</td>
<td>0.12</td>
<td>$10.07^{a}$</td>
<td>N</td>
<td>NS</td>
<td>N</td>
<td>NS</td>
</tr>
<tr>
<td>Other pain</td>
<td>0.04</td>
<td>$2.84^{a}$</td>
<td>N</td>
<td>NS</td>
<td>N</td>
<td>NS</td>
</tr>
<tr>
<td>Stress $\times$ Other Pain</td>
<td>0.01</td>
<td>$4.50^{a}$</td>
<td>N</td>
<td>NS</td>
<td>N</td>
<td>NS</td>
</tr>
<tr>
<td>Negative Mood</td>
<td>0.36</td>
<td>$8.55^{a}$</td>
<td>N</td>
<td>NS</td>
<td>N</td>
<td>NS</td>
</tr>
<tr>
<td>Other pain</td>
<td>0.07</td>
<td>$4.84^{a}$</td>
<td>N</td>
<td>NS</td>
<td>N</td>
<td>NS</td>
</tr>
<tr>
<td>Negative Mood $\times$ Other Pain</td>
<td>0.005</td>
<td>$2.23^{a}$</td>
<td>N</td>
<td>NS</td>
<td>N</td>
<td>NS</td>
</tr>
<tr>
<td>Positive Mood</td>
<td>$-0.40$</td>
<td>$-10.09^{a}$</td>
<td>$0.12$</td>
<td>$3.11^{b}$</td>
<td>N</td>
<td>NS</td>
</tr>
<tr>
<td>Other pain</td>
<td>0.06</td>
<td>$3.95^{a}$</td>
<td>N</td>
<td>NS</td>
<td>N</td>
<td>NS</td>
</tr>
<tr>
<td>Positive Mood $\times$ Other Pain</td>
<td>0.006</td>
<td>$-2.67^{a}$</td>
<td>N</td>
<td>NS</td>
<td>N</td>
<td>NS</td>
</tr>
</tbody>
</table>

NS = not significant.

$p < .05$.

$p < .01$.

$p < .001$.

$p < .0001$.

Lagged Associations Between Stress, Mood, and SCD Pain Ratings

In order to investigate whether stress and mood temporally preceded pain, we conducted exploratory analyses investigating the association between stress and pain ratings and between mood and pain ratings on the 2 immediately preceding days. Stress ($B = 0.03$, $t = 4.85$, $p < .0001$), and mood ($B = 0.03$, $t = 3.83$, $p < .0001$) were significantly related to increases in pain ratings on the 2 immediately preceding days. Increases in stress ($B = 0.05$, $t = 7.53$, $p < .0001$) and decreases in positive mood ($B = 0.02$, $t = 3.76$, $p < .0001$) were also significantly associated with increases in SCD pain ratings on the 2 immediately preceding days. These findings suggest that stress and mood may temporally precede increases in SCD pain ratings, providing further support for the role of stress and mood in the experience of SCD pain.
subsequent days, that is, on pain for the next day and for 2 days later. Most of these analyses were not significant or not in the expected direction. In other words, there was no evidence that higher levels of stress and negative mood predicted pain on the next 2 days, or that positive mood was protective.

**Reverse Relationships**

One issue that we are aware of is that the pain itself is stressful and may lead to alterations in mood states. Thus, pain on one day may lead to stress or negative mood on subsequent days. This possibility was tested by examining the relationship between daily pain and subsequent stress and mood using similar procedures as described above. Table III summarizes the results of these analyses. In all these models, SCD pain and other pain were significant predictors. SCD pain and other pain predicted higher levels of stress and lower levels of positive mood on the subsequent 2 days. SCD pain did not predict negative mood on subsequent days.

**Discussion**

Daily stress and mood were associated with fluctuations in same-day SCD pain in the present study. Increases in stress and negative mood on a daily basis were associated with increases in same-day pain, whereas increases in positive mood were associated with decreases in same-day pain. The findings provide empirical support for common clinical observations that variations in stress and mood seem related to pain in SCD. The results are important in that this is the first study to examine daily fluctuations in stress, mood, and pain in a prospective diary design with SCD adolescents. Moreover, the results suggest that as in other childhood chronic illnesses (e.g., Schanberg et al., 2000; Walker et al., 2001), daily variation in stress and mood may be related to exacerbations in symptoms.

In the present study with adolescents, stress and mood did not predict fluctuations in SCD pain on subsequent days. Thus, the hypothesis related to the temporal precedence of stress and mood was not supported. To the contrary, the reverse model analyses lend support to the alternative hypothesis that adolescent SCD pain leads to

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**Table II. Summary of Multilevel Random Effects Analyses of Associations Between Activity and Health-Care Use and Stress and Mood**

<table>
<thead>
<tr>
<th></th>
<th>SCD Pain</th>
<th>Stress</th>
<th>Negative Mood</th>
<th>Positive Mood</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>B</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>t</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Same-Day Activity</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>School</td>
<td>0.04</td>
<td>11.43&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.02</td>
<td>4.92&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Extracurricular</td>
<td>0.06</td>
<td>15.48&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.01</td>
<td>3.49&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Chores at home</td>
<td>0.06</td>
<td>17.50&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.02</td>
<td>3.41&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Same-Day Health-Care Use</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Doctor calls</td>
<td>0.06</td>
<td>10.62&lt;sup&gt;a&lt;/sup&gt;</td>
<td>—</td>
<td>NS</td>
</tr>
<tr>
<td>Clinic visits</td>
<td>0.05</td>
<td>8.84&lt;sup&gt;a&lt;/sup&gt;</td>
<td>—</td>
<td>NS</td>
</tr>
<tr>
<td>ER visits</td>
<td>0.08</td>
<td>20.05&lt;sup&gt;a&lt;/sup&gt;</td>
<td>.01</td>
<td>2.85&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Hospitalizations</td>
<td>0.01</td>
<td>9.99&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-0.17</td>
<td>-6.63&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Prescription medications</td>
<td>0.08</td>
<td>17.59&lt;sup&gt;a&lt;/sup&gt;</td>
<td>—</td>
<td>NS</td>
</tr>
</tbody>
</table>

**NS** = not significant.

<sup>a</sup>p < .05.
<sup>b</sup>p < .01.
<sup>c</sup>p < .001.
<sup>d</sup>p < .0001.

**Table III. Summary of Multilevel Random Effects Analyses Predicting Stress and Mood from Pain (Reverse Models)**

<table>
<thead>
<tr>
<th></th>
<th>SCD Pain as a Predictor</th>
<th>Other Pain as a Predictor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>B</strong></td>
<td><strong>t</strong></td>
</tr>
<tr>
<td><strong>Next Day</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stress</td>
<td>0.18</td>
<td>7.64&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Negative Mood</td>
<td>—</td>
<td>NS</td>
</tr>
<tr>
<td>Positive Mood</td>
<td>-0.01</td>
<td>-2.17&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>2 Days Later</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stress</td>
<td>0.13</td>
<td>5.68&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Negative Mood</td>
<td>—</td>
<td>NS</td>
</tr>
<tr>
<td>Positive Mood</td>
<td>-0.02</td>
<td>-2.43&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

**NS** = not significant.

<sup>a</sup>p < .05.
<sup>b</sup>p < .01.
<sup>c</sup>p < .001.
<sup>d</sup>p < .0001.
increases in stress and changes in mood. Indeed, increases in SCD pain and other pain were predictive of both increases in stress and decreases in positive mood on the next day and 2 days later. Taken together, these results support speculations that pain or disease symptoms might be the initiating variable (e.g., Schanberg et al., 2000; Walker et al., 2001). It is also possible that there are bidirectional effects such that increases in pain lead to fluctuations in stress and mood, which in turn lead to escalating pain. For example, a child who wakes up with SCD pain may experience stress and reductions in positive mood because of needing to miss school or go to the doctor, or from the pain itself. Stress and mood changes may lead to more perceived pain in an escalating cycle. Even if these bidirectional effects are occurring on a daily basis, it appears that pain may be the more powerful variable initiating the cycle of subsequent changes.

Several issues or study limitations need to be considered when interpreting these results. First, as in other diary studies, there was a good deal of missing data and variability in the number of days completed by each adolescent in this study. Although the missing data were handled statistically through the use of multilevel models, it is possible that there were systematic influences to the pattern of missing data. Adolescents may have been less likely to complete diaries on days when they were experiencing high levels of pain. Indeed, in the present study, we found that pain was reported on only 8% of days, and the typical duration of pain was less than a day (about 16 hours). This pain rate is lower than reported in studies including parent report of child SCD pain (12% to 30% of days; Gil et al., 2000; Gill et al., 1997) and in prior studies of adults with SCD pain (67%; Porter et al., 2000). Future studies should attempt to assess the specific reasons for missing diary information in order to analyze for any systematic influences (Gil et al., 2000; Porter et al., 2000). This is especially important in that the failure to confirm the hypotheses related to the temporal precedence of stress and mood may have been influenced by the overall low rate of pain days. A second and related issue is that we used the day itself as the unit of analysis. It may be that stress and mood have more immediate effects on SCD pain, and thus our methods might have missed temporal effects that were present. Others have argued that more frequent recordings over the course of the day are needed to track the effects of events on disease symptoms (e.g., Walker et al., 2001). Future studies might ask adolescents to keep records at several points during the day such as morning, after school, and bedtime, in order to explore the possibility that there are more immediate effects of stress and mood changes on SCD pain. Finally, since the current study suggests that daily pain acts as an initiating factor in daily stress and mood fluctuations, future diary studies should include sleep variables such as sleep quality, since sleep may play a role in the pain-stress-mood cycle (Barbarin, 1999).

Regarding activity level, there was an association of pain, stress, and mood with same-day reductions in school attendance, extracurricular activities, and completion of chores at home. Moreover, stress and negative mood were associated with decreases in activity, whereas positive mood even on pain days seemed to help children maintain school attendance and activity participation. Understanding the way pain and psychological factors relate to activity participation is important, since frequent school absences and underinvolvement in other activities may lead to poor academic progress and other social and emotional consequences, such as depression in children with chronic illnesses (e.g., Brown et al., 1993; Shapiro et al., 1995; Walters & Williamson, 1999). One potential issue to consider when interpreting the activity findings is that only adolescent self-report on the diary was used to determine activity reduction. We have some preliminary data that adolescents and parents generally agree on reports of activity reduction on daily diaries (Gil et al., 2000), and other studies have found that adolescent and parent ratings of activity restriction are highly correlated (Walters & Williamson, 1999). Yet future studies should include school records and other methods to corroborate adolescent reports of activity reduction.

Regarding same-day health-care use, pain was associated with telephone calls to doctors, clinic visits, hospitalizations, ER visits, and medication use. Fluctuations in stress and mood were associated with certain health-care contacts in adolescents (i.e., phone calls to doctors, clinic and ER visits), but not with hospitalizations or narcotic prescription use. Thus, stress and mood in adolescents may factor in health-care decisions for certain health-care contacts. However, SCD pain and perhaps unmeasured factors (e.g., parent stress and mood, health insurance) may be more important in predicting other aspects of health-care utilization.

The results of this study add support to the growing body of literature on the utility of daily diaries as a strategy for children to track pain and other disease symptoms on an ongoing basis under naturalistic conditions (Schanberg et al., 2000; Shapiro et al., 1995; Walker et al., 2001). Although completion rates were lower than with adults (86%; Porter et al., 2000), adolescents generally had relatively high completion rates (76%) even over...
an extended period of time. The comparison of diary information to the baseline measures suggests that the information gathered on diaries is reliable and valid. Moreover, the diary method allows for an analysis of the temporal sequencing of events (Stone & Neale, 1982; West & Hepworth, 1991). Thus, diaries may be useful in clinical practice in that they provide a rich source of temporal information with only minimal time needed for the child to complete the diary. When an adolescent is seen in clinic with pain, for example, the clinician might prescribe medication for it and at the same time instruct the adolescent to track the pain, his/her activity, and other relevant variables on a daily diary over the course of the next days or weeks. Then, at a follow-up visit, the clinician could evaluate the intensity and duration of pain and its impact on daily functioning, and thereby evaluate the response to the medication. In a similar way, clinicians might incorporate diaries in the evaluation of psychosocial interventions. Previously, we have shown that diaries can be useful in analyzing the day-to-day impact of a coping-skills practice on adjustment variables such as school absence and health-care use (Gil et al., 2001).

The results of this study have potential implications for the clinical management of pain in adolescents with SCD. Pain in children is often undertreated. In light of the finding that pain precedes stress and mood changes and is associated with activity reduction, clinicians might consider treating SCD pain more aggressively to preserve involvement in school and social activity and minimize the impact on daily mood. To achieve optimal pain management in adolescents with SCD, interventions might need to integrate psychological and disease management approaches (i.e., instructions on effective medication and health-care use strategies) with standard pharmacologic management, since a comprehensive pain control protocol might have larger and broader effects. Stress and mood management components may be important enhancements to cognitive-behavioral pain management programs for children with SCD (Gil et al., 1997, 2001). Improved interventions might actually help patients prevent pain, manage pain more effectively at home, utilize health care more efficiently, and otherwise improve the quality of their lives.

In conclusion, future studies are needed to extend this research to younger children with SCD, as there is limited research looking at pain, stress, or mood variables in children less than 7 years of age (Fuggle et al., 1996; Gil et al., 2000). By doing so, researchers will be able to study the developmental progression of the impact of these variables from childhood to adulthood, which could be beneficial in identifying appropriate points of intervention. Moreover, future studies are needed to evaluate the role of sleep, coping strategies, and other relevant variables in daily pain.

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Fontana, A. F., Kerns, R. D., Rosenberg, R. L., &


