Brief Report: Using Actigraphy to Compare Physical Activity Levels in Adolescents with Chronic Pain and Healthy Adolescents

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Objectives  This study compared activity levels of adolescents with chronic pain and healthy adolescents, and investigated relations between actigraphy and subjective measures of activity limitations and depression.  

Methods  Forty adolescents (n = 20 with chronic pain, n = 20 otherwise healthy; 12–17 years; 72.5% females) participated. Adolescents completed questionnaires regarding pain, activity limitations, and depression. Activity levels were assessed for 7 days using the Actiwatch 64/C213 device, yielding mean and peak activity levels, and time spent in moderate and sedentary activity.  

Results  Physical activity was lower in adolescents with chronic pain than in healthy peers. Adolescents with chronic pain reported significantly higher levels of activity limitations and depression. Age and gender were related to activity. Higher activity was inversely correlated with pain frequency and depression. Peak activity was also significantly inversely related to self-reported pain intensity and activity limitations.  

Conclusions  Actigraphy may be useful for examining physical activity outcomes in adolescents with chronic pain.

Key words  actigraphy; activity limitations; chronic pain; pediatric; physical activity.

Introduction

Chronic or recurrent pain can affect many domains of children’s normal daily life activities. Many adolescents with chronic pain report significant limitations in activity participation, including school attendance and sports or exercise participation (Kashikar-Zuck, Goldschneider, Powers, Vaught, & Hershey, 2001). Increased participation in physical activities is also a focus of most multidisciplinary treatment programs (Eccleston, Malleson, Clinch, Connell, & Sourbut, 2003). It is critical that research on pediatric chronic pain incorporate measurement of functional outcomes related to pain, rather than focusing on pain alone. This will help to develop theoretical models of pain-related disability (Palermo, 2000), and is an important step in preventing development of chronic pain and related disability in adulthood.

Previous studies have largely examined functional outcomes via subjective questionnaire measures, a number of which have been used successfully (Eccleston, Jordan, & Crombez, 2006). Children and adolescents with chronic pain demonstrate functional impairment on self-report measures such as the Functional Disability Inventory (Walker & Greene, 1991) and the Child Activity Limitations Interview (CALI) (Palermo, Witherspoon, Valenzuela, & Drotar, 2004). However, self-report measures are subject to response shift and reporter bias, and provide only adolescent’s subjective perspective on their difficulty functioning, rather than capturing physical activity levels during normal activities. Objective measures of activity may complement self-report measures and increase our understanding of pain and disability. A few studies in pediatric chronic pain have included laboratory-based objective measures of physical functioning, including a timed 10 m walk (Eccleston et al., 2003), peak oxygen consumption measurements during exercise (Singh-Grewal, Wright, Bar-Or, & Feldman, 2006), and grip strength and extension force (Wessel et al., 1999). While these objective measures are useful, laboratory measures are limited in that they do not capture routine functioning, and are subject to social desirability and related factors that may impact performance. Additional objective measures of physical function, such as actigraphy, have the benefit of capturing activity during normal daily routines and may improve our ability to measure functioning and treatment effects in this population.
Physical activity is an important part of daily functioning and is of clinical relevance for children with chronic pain, who report less participation in usual physical activities. Actigraphy allows for objective, unobtrusive measurement of activity levels over extended periods in the home and during normal activities. The technology uses a small watch-like device to continuously monitor movement. Actigraphy has been used widely to study sleep/wake patterns, but also provides useful information about activity levels during waking hours. Recent studies have demonstrated the utility of actigraphy in research with adults with chronic pain. Adults with chronic low back pain and fibromyalgia demonstrate lower levels of activity measured via actigraphy than controls (Korszun et al., 2002; Spenkelink, Hutten, Hermens, & Greitemann, 2002). Adolescents with chronic pain are likely to have similar reductions in physical activity, and the purpose of this study is to use actigraphy as an objective means of examining activity patterns in this population.

To our knowledge, no previous research has examined activity levels measured by actigraphy in adolescents with chronic pain. There is also a significant gap in the literature regarding how actigraphy measures relate to subjective measures of activity limitations in adolescents. In this preliminary study, we compare activity levels of adolescents with chronic pain and healthy adolescents using actigraphy and subjective measures of activity limitations. Based on previous research showing functional impairment in this population, we hypothesize that both subjective and objective measures of activity will be impaired in adolescents with chronic pain. We also investigate relations between actigraphic measures of activity levels and subjective measures of activity limitations, pain, and depression, with the hypothesis that activity would be lower with higher levels of pain and depressive symptoms.

**Method**

This study was approved by the Institutional Review Board at the academic medical center where the study was conducted. Written informed consent was obtained from parents and guardians, and written assent was obtained from adolescents for participation in this study.

**Participants**

Inclusion criteria for all participants required that they were 12–18 years of age, had no serious chronic medical conditions or developmental disabilities, and were literate in English. Participants with chronic pain were recruited from a multidisciplinary pediatric chronic pain clinic via a letter or in person during a clinic visit. Healthy adolescents were recruited through postings advertising the study in the local metropolitan area. Inclusion criteria for the pain group required that they were currently receiving care from the pain clinic, and had pain present for at least 3 months that was occurring ≥3 days/week and was at least moderate in intensity. Participants in the healthy group were matched in age (within 6 months) and sex to a subject in the pain group. Fifty-two eligible subjects were contacted. The majority (86%) consented to participate in the study. Subjects who did not enroll in the study were either not interested or too busy to participate. Two participants with chronic pain and two healthy participants were not included in the final analysis due to missing data and one participant with chronic pain was not included due to failure to consistently wear the actigraph, thus the final sample of 40 subjects was slightly imbalanced in gender matching between groups.

Adolescents with chronic pain (n = 20) were predominately females (75%) and Caucasians (93%) with a mean age of 15.05 (SD = 1.39). On average, they had pain for ≥6 months and had moderate to severe usual pain intensity. Primary pain locations included: head and neck (n = 7), shoulder (n = 2), abdomen (n = 2), back (n = 2), and extremities (n = 7). Healthy adolescents (n = 20) were predominately females (70%) and Caucasians (85%), with a mean age of 14.65 (SD = 1.98). Interested participants were screened by a member of the research team.

**Procedures**

After the initial screening and enrollment, adolescents completed questionnaire measures of activity limitations, fatigue, pain, and depressive symptoms, and sustained actigraphy monitoring for 7 consecutive days. Study materials were given to participants during a routine outpatient visit or were mailed or delivered via a home visit. All participants were instructed to wear the waterproof Actiwatch 24 hr per day during the 7-day period. Participants were instructed to complete questionnaires independently at home at any convenient time during the week that they wore the Actiwatch. Actiwatches and questionnaires were returned by mail in postage paid envelopes. Participants were compensated for their time with gift cards to local stores.

**Measures**

**Demographics**

Parents completed a demographic questionnaire. Variables assessed included annual household income, adolescent age, gender, ethnicity, and racial background.
Pain Perception
Adolescents completed a pain questionnaire to quantify their pain frequency and intensity during the previous 3 months. Pain frequency was determined using a 6-point Likert scale ranging from “less than once a month,” (1), to “daily,” (6). Usual pain intensity was measured using a 11-point numerical rating scale ranging from “no pain,” (0), to “worst pain possible,” a score of 10 (Peterson & Palermo, 2004).

Daytime Activity Levels
Activity levels were assessed via ambulatory actigraphy using the Actiwatch 64 device (Mini Mitter Company; Bend, OR, USA). This small lightweight unit worn on the non-dominant wrist provides continuous monitoring of the subject’s activity levels. Movement is sensed by an omni-directional mercury switch that is open when there is no movement and closed when movement above a set threshold is detected. Each time the switch closes, an activity count is generated. Counts were stored on the device in 1 min epochs. Data were extracted using Mini Mitter’s Actiware version 5.0 software.

In addition to the duration of daytime wake periods, four activity scores were obtained from actigraphy data. Mean activity level was calculated as the mean number of activity counts per 1 min epoch during each daytime wake period. Peak activity level was calculated as the highest number of activity counts achieved in a single 1 min epoch per daytime wake period. Moderate activity was calculated as the number of 1 min epochs per day reaching activity counts ≥1500 (as per Riddoch et al., 2004). Sedentary activity was calculated as the number of 1 min epochs per day with activity counts ≤40 (medium rest threshold for Actiware 5.0 software). Days per week with ≥30 min of moderate activity was also calculated. All scores were averaged across 7 consecutive days. Actigraphy has been used to measure physical activity in a number of pediatric populations including overweight, and the Actiwatch 64 has been validated with observation and pedometer readings (Puyau, Adolph, Vohra, & Butte, 2002). The Actiwatch does not provide feedback to patients about their activity levels.

Subjective Activity Limitations
Adolescent subjective report of activity limitations was assessed using a self-report version of the CALI. This 21-item instrument assesses children’s perceived difficulty in completing typical daily activities due to pain. Higher scores indicate greater perceived functional impairment. The CALI has excellent internal consistency, moderate test–retest and cross-informant reliability, and is responsive to changes in children’s pain symptoms (Palermo et al., 2004).

Depressive Symptoms
Because depressive symptoms have been shown to relate to activity levels, the major depressive disorder subscale from the Revised Child Anxiety and Depression Scale (RCADS) was used to assess adolescent subjective report of depressive symptoms. Scores are based on gender and grade, and good internal consistency (α = .76) and validity have been demonstrated (Chorpita, Yim, Moffitt, Umemoto, & Francis, 2000).

Statistical Analysis
Analyses were conducted using SPSS v15.0. Group differences were tested via independent samples t-tests, and bivariate correlations and ANOVAs were used to explore relations among actigraphic activity level variables and demographic and self-report measures.

Results
Analyses indicated no significant differences in age, sex, ethnicity, or racial background between adolescents with chronic pain and otherwise healthy adolescents. Adolescents in the two groups had similar duration of daytime wake periods (about 15 hr). Significant differences were found between groups on all activity scores, with adolescents with chronic pain engaging in lower mean and peak levels of activity than healthy peers, and spending less time per day in moderate or vigorous activity and more time in sedentary activity. Healthy adolescents achieved ≥30 min of moderate to vigorous activity about 3 days per week, compared to 1.6 days per week achieved by adolescents with chronic pain. Similar to existing literature, adolescents with chronic pain reported significantly higher levels of activity limitations and depression compared to healthy peers. All effect sizes were moderate to large (Table I). Statistical power to detect group differences on actigraphy variables with α of .05 and two-tailed tests ranged from 79.9% to 99.9%.

Within the entire sample, peak activity level was inversely correlated with self-report of activity limitations on the CALI (r = −.40, p = .01), while other actigraphy scores were not significantly related to CALI scores. Similar to previous research, age was inversely correlated with activity level such that older adolescents engaged in less moderate activity (r = −.49, p = .001), and showed lower mean and peak activity levels (r = −.33 and r = −.32, respectively, both p = .04). Higher levels of activity were associated with less frequent pain (r’s range
from \( r = -.45 \) to \( -.66 \), \( p \)-values <.01). Greater mean (\( r = -.31, p = .05 \)) and peak (\( r = -.45, p = .003 \)) activity were also associated with lower intensity pain. Higher activity levels (\( r \)'s range from \( -.36 \) to \( -.39 \), \( p \)-values <.02) and lower sedentary activity (\( r = .33, p = .04 \)) were associated with fewer depressive symptoms, as measured by the RCADS. Correlations were also repeated within the chronic pain group. While some coefficients were in the moderate range (.3 –.4) none reached significance.

In a two-factor ANOVA (group and gender) predicting peak activity levels, study group predicted activity and also interacted with gender to predict activity, with healthy males demonstrating higher peak activity than females, and males with chronic pain showing lower activity than females with chronic pain (Figure 1). The pattern shown with peak activity level is similar to findings observed with mean activity level and time spent in moderate activity.

### Discussion

The purpose of this study was to use actigraphy as a method of assessing physical activity patterns in adolescents with chronic pain. Adolescents with chronic pain evidenced lower objective activity levels and more self-reported activity limitations in comparison to healthy adolescents. Healthy adolescents demonstrated mean physical activity levels similar to those reported in healthy European adolescents (Riddoch et al., 2004). While adolescents with chronic pain engaged in less moderate to vigorous physical activity than healthy adolescents, neither group met the national minimum guidelines of 30 min per day. Age and gender were also related to physical activity, as has been demonstrated in previous work (Riddoch et al., 2004). Males with chronic pain demonstrated more impairment in peak activity than females. Because boys are typically more active than girls (Riddoch et al., 2004), this result was surprising. However, withdrawal from vigorous physical activities may be an important area to explore in future research examining gender differences in functional impairment. Results from this study provide strong initial support for the feasibility and validity of actigraphy as an objective measure of activity levels in this population. Some differences were found between activity scores. Peak activity levels were associated with all subjective measures.

### Table 1. Comparing Measures of Pain, Functioning, and Physical Activity in Adolescents with Chronic Pain and Healthy Adolescents

<table>
<thead>
<tr>
<th>Subjective measures:</th>
<th>Chronic pain (n = 20)</th>
<th>Healthy (n = 20)</th>
<th>( t )</th>
<th>( p )</th>
<th>( d )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pain frequency</strong></td>
<td>Mean (SD)</td>
<td>5.40 (1.05)</td>
<td>4.91–5.89</td>
<td>1.45 (0.94)</td>
<td>1.01–1.89</td>
</tr>
<tr>
<td><strong>Pain intensity</strong></td>
<td>Mean (SD)</td>
<td>6.60 (1.64)</td>
<td>5.83–7.37</td>
<td>2.35 (2.06)</td>
<td>1.39–3.31</td>
</tr>
<tr>
<td><strong>Activity limitations</strong></td>
<td>Mean (SD)</td>
<td>31.95 (17.74)</td>
<td>23.65–40.25</td>
<td>2.70 (4.34)</td>
<td>0.67–4.73</td>
</tr>
<tr>
<td><strong>Depression symptoms</strong></td>
<td>Mean (SD)</td>
<td>57.00 (12.78)</td>
<td>51.02–62.98</td>
<td>41.40 (9.94)</td>
<td>36.75–46.05</td>
</tr>
<tr>
<td><strong>Physical activity</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean duration of day</td>
<td>Mean (SD)</td>
<td>910 (50)</td>
<td>886–933</td>
<td>908 (48)</td>
<td>886–930</td>
</tr>
<tr>
<td>Mean activity level</td>
<td>Mean (SD)</td>
<td>415 (112)</td>
<td>363–468</td>
<td>515 (111)</td>
<td>463–567</td>
</tr>
<tr>
<td>Peak activity level</td>
<td>Mean (SD)</td>
<td>2430 (375)</td>
<td>2161–2699</td>
<td>3561 (921)</td>
<td>3130–3993</td>
</tr>
<tr>
<td>Moderate activity</td>
<td>Mean (SD)</td>
<td>20.21 (18.05)</td>
<td>11.76–28.66</td>
<td>39.45 (26.61)</td>
<td>26.99–51.90</td>
</tr>
<tr>
<td>Sedentary activity</td>
<td>Mean (SD)</td>
<td>65.16 (34.34)</td>
<td>49.09–81.23</td>
<td>42.26 (22.85)</td>
<td>31.57–52.96</td>
</tr>
<tr>
<td>Days/week achieving 30 min moderate activity</td>
<td>Mean (SD)</td>
<td>1.61 (1.90)</td>
<td>0.70–4.20</td>
<td>3.29 (2.80)</td>
<td>2.17–4.48</td>
</tr>
</tbody>
</table>

\( ^{a}\)T-scores.  
\( ^{b}\)Units are minutes.  
\( ^{c}\)Activity level units are counts per 1 min epoch.  
\( ^{d}\)Units are minutes per day.
This peak activity score indicates the most vigorous activity level achieved across 7 days. Consistently low peak activity scores are likely to indicate withdrawal from vigorous physical activities. Subjective measures, such as the CALI, may be more strongly related to peak activity level as they specifically assess difficulties participating in these types of activities.

Findings should be interpreted in light of several limitations. The sample size is small and requires replication with a larger sample, as a large number of analyses were conducted without adjusting for the increased probability of Type I error. Adolescents with chronic pain had a variety of pain problems, and different patterns of findings may have emerged with increased power to examine subgroup differences. A larger sample of adolescents with chronic pain may have allowed us to detect significant associations between actigraphy and self-report variables. Additionally, while actigraphy is an objective measure of movement, it is not able to detect the amount of exertion or energy expenditure associated with activity (Terrier, Aminian, & Schutz, 2001). Researchers interested in these variables might choose other physiological measures, such as peak oxygen consumption or consider using actigraph models that calculate energy expenditure such as the Actical® by Mini-Mitter. Actigraphy technology is relatively expensive, which may limit its clinical utility. It is currently used to assess sleep in clinical settings, but it remains to be seen whether it will become a cost-effective tool for physical activity assessment. As actigraphy technology is developed further, it may become feasible to incorporate feedback about activity levels into treatment programs.

Objective data about physical activity may inform measurement of treatment outcomes in children and adolescents with chronic pain. Future studies are needed with repeated measures of actigraphy to establish the stability of activity levels in adolescents with chronic pain and to further investigate associations between actigraphy and subjective report measures in this population. Research is also needed to examine weight and BMI as predictors of activity in the context of chronic pain. Future studies are also needed to investigate additional methods for analyzing daytime actigraphy data in adolescents with chronic pain, such as examining additional measures of variability and patterns between days via hierarchical linear modeling. One previous study has shown improvements in an objective measure of physical functioning following cognitive behavioral treatment in adolescents with chronic pain (Eccleston et al., 2003). Future work is needed to investigate whether actigraphy demonstrates positive changes in physical activity levels following treatment, or is predictive of future health outcomes among adolescents with chronic pain.

**Acknowledgments**

The authors would like to thank the children and families who participated in this research. This study was supported by K23MH01837 awarded to the senior author (T.M.P.) and by an N.L. Tartar Trust Fellowship awarded to the first author. We also acknowledge Janel Putnam and Jamie Armstrong who provided invaluable research assistance.

**Conflicts of interest:** None declared.

Received April 17, 2007; revisions received December 12, 2007; accepted December 2007

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