

Ambulatory Monitoring of Physical Activity and Symptoms in Fibromyalgia and Chronic Fatigue Syndrome

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Objective. Fibromyalgia (FM) and chronic fatigue syndrome (CFS) are associated with substantial physical disability. Determinants of self-reported physical disability are poorly understood. This investigation uses objective ambulatory activity monitoring to compare patients with FM and/or CFS with controls, and examines associations of ambulatory activity levels with both physical function and symptoms during activities of daily life.

Methods. Patients with FM and/or CFS ($n = 38$, mean \pm SD age 41.5 ± 8.2 years, 74% women) completed a 5-day program of ambulatory monitoring of physical activity and symptoms (pain, fatigue, and distress) and results were compared with those in age-matched controls ($n = 27$, mean \pm SD age 38.0 ± 8.6 years, 44% women). Activity levels were assessed continuously, ambulatory symptoms were determined using electronically time-stamped recordings at 5 time points during each day, and physical function was measured with the 36-item Short Form health survey at the end of the 5-day monitoring period.

Results. Patients had significantly lower peak activity levels than controls (mean \pm SEM $8,654 \pm 527$ versus $12,913 \pm 1,462$ units; $P = 0.003$) and spent less

time in high-level activities when compared with controls ($P = 0.001$). In contrast, patients had similar average activity levels as those of controls (mean \pm SEM $1,525 \pm 63$ versus $1,602 \pm 89$; $P = 0.47$). Among patients, low activity levels were associated with worse self-reported physical function over the preceding month. Activity levels were inversely related to concurrent ambulatory pain ($P = 0.031$) and fatigue ($P < 0.001$). Pain and fatigue were associated with reduced subsequent ambulatory activity levels, whereas activity levels were not predictive of subsequent symptoms.

Conclusion. Patients with FM and/or CFS engaged in less high-intensity physical activities than that recorded for sedentary control subjects. This reduced peak activity was correlated with measures of poor physical function. The observed associations may be relevant to the design of behavioral activation programs, because activity levels appear to be contingent on, rather than predictive of, symptoms.

Fibromyalgia (FM) is characterized by diffuse pain and tenderness (1,2). Individuals who meet the criteria for FM (2) typically experience secondary symptoms including fatigue, sleep disturbances, and cognitive dysfunction (1–5). Because of the substantial overlap in clinical presentation and biologic correlates of the primary and secondary FM symptoms (6), many individuals with FM will also fulfill the criteria for chronic fatigue syndrome (CFS) (7,8), particularly in tertiary care centers (1).

Physical disabilities are common in individuals with FM and CFS, with self-reported functional limitations that are ~ 2 SD below the mean value for physical function in the general population (9,10). Lower physical activity levels may contribute to the onset and severity of symptoms (11–14), and exercise interventions result in symptom improvement in both FM and CFS (13,15–18). Causes of poor self-reported functional sta-

The opinions and assertions expressed herein are those of the authors and are not to be construed as reflecting the views of the Uniformed Services University of the Health Sciences or the United States Department of Defense.

Supported in part by the Department of Army (grant DAMD17-00-2-0018).

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Submitted for publication February 9, 2004; accepted in revised form October 6, 2004.

tus are not well understood. Symptom status and psychosocial factors are partially predictive of self-reported physical function (10,19,20).

Most research examining determinants of physical function in FM/CFS is based on methods that may have inherent biases, because both symptoms and physical function have been recorded using retrospective, self-reported data. When asked to retrospectively report symptoms, individuals do not accurately integrate all their experiences over a given period of time; instead, there is a tendency to report peak symptoms and most recent symptoms (21). Moreover, individuals modify retrospective symptom reports on the basis of their symptoms and moods at the time of survey completion (22). To minimize this retrospective bias, the present study uses continuous, automated activity monitoring and repeated symptom assessments throughout the day.

Compliance and accuracy of the timing of symptom reports can be validated using an electronic storage device (21,22–26). These “real-time” symptoms can be crosstabulated with objective measures of physical activity obtained during the same periods of time. This method enables improved investigation of cause–effect relationships between activity levels and symptoms during activities of daily life. Little is known about these causal pathways in FM/CFS. For example, patients with FM frequently report that their symptoms worsen after high levels of activity, and that they are unable to perform activities because of symptoms. The longitudinal design of the electronic method permits evaluation of the short-term (within 30 minutes) relationship between activity and symptoms as well as the long-term association of aggregated daily activity levels and nocturnal restlessness with composite symptom measures (4,23,27). In the present study, we tested the hypotheses that FM/CFS is associated with reduced levels of daily activity and increased indices of disturbed sleep, and that high levels of activity are followed by increased symptoms.

PATIENTS AND METHODS

Patient selection. Patients ($n = 38$, mean \pm SD age 41.5 ± 8.2 years, 74% women) were recruited through local newspaper and clinic advertisements. Inclusion criteria were the presence of the American College of Rheumatology diagnostic criteria for FM ($n = 29$) (2) and/or the criteria for CFS ($n = 9$) as defined by Fukuda et al (6). Consistent with prior observations (1), CFS often coincided with FM (21 [72%] of the 29 patients with FM, group concordance 55%) (Table 1).

Table 1. Characteristics of the study populations*

| | Controls ($n = 27$) | Patients ($n = 38$) | <i>P</i> |
|------------------------------|--------------------------|--------------------------|----------|
| Age, mean \pm SD years | 38.0 ± 8.6 | 41.5 ± 8.2 | 0.11 |
| Sex, no. (%) | | | |
| Male | 15 (56) | 10 (26) | 0.017 |
| Female | 12 (44) | 28 (74) | |
| Race, no. (%) | | | |
| African American | 8 (30) | 8 (21) | 0.19 |
| Caucasian | 11 (41) | 24 (63) | |
| Other | 8 (30) | 6 (16) | |
| Height, mean \pm SD meters | 1.79 ± 0.11 | 1.66 ± 0.13 | 0.009 |
| Weight, mean \pm SD kg | 77.2 ± 15.8 | 72.7 ± 12.8 | 0.33 |
| Diagnosis, no. (%) | | | |
| Fibromyalgia + CFS | – | 21 (55) | – |
| Fibromyalgia only | – | 8 (27) | – |
| CFS only | – | 9 (24) | – |

* CFS = chronic fatigue syndrome.

Exclusion criteria were 1) severe physical impairment precluding ambulatory physical exercise (e.g., bilateral amputation, complete blindness); 2) medical conditions known to cause FM or CFS symptoms, including obesity (body mass index >30 kg/m²), autoimmune/inflammatory diseases, cardiopulmonary disorders, chronic asthma, uncontrolled endocrine or allergic disorders (e.g., hypothyroidism, diabetes, allergic rhinitis), or malignancy; 3) current psychiatric disorders of schizophrenia, major depression with suicidal ideation, or substance abuse within 2 years; and 4) medication usage other than as-needed analgesics. Age-matched healthy, sedentary control volunteers ($n = 27$, mean \pm SD age 38.0 ± 8.6 years, 44% women) were enrolled using the same exclusion criteria. To avoid confounding by high levels of routine exercise, controls were enrolled by excluding individuals who were participating in regular exercise programs.

Ambulatory activity assessments. Ambulatory physical activity levels were assessed using an actigraph accelerometer (Actiscore; Mini-Mitter, Bend, OR). The actigraph is a wristwatch-sized ($37 \times 29 \times 9$ mm), light-weight (17 gm) device that has been validated previously (28,29). Actigraphs contain a piezo-electric sensor that generates a voltage when the device undergoes a change in acceleration. The actigraph is most sensitive to movement perpendicular to the device. Actigraphs were placed on the wrist and, consequently, are most sensitive to the natural movements of the arm but adequately assess whole-body movements (28,30). The signal is amplified and digitized by the on-board circuit at 31.25-msec intervals, and stored in memory as activity counts. The device has a sensitivity of <0.01 G-force, and there is a linear relationship between activity counts and G-force (1 G-force = 251 counts; 100 G-force = 3,133 counts). Care was taken for proper placement of the actigraph by using a standardized mounting and positioning protocol (28).

Activity counts were recorded continuously and summed over 5-minute epochs. Peak and average activity levels were assessed across the 5-day observation period, with exclusion of missing data resulting from temporary removal of the actigraph.

Peak activity levels were defined as the highest level of activity in a 5-minute period during 1) the entire 5-day

Table 2. Comparison of physical activity levels in patients with fibromyalgia/chronic fatigue syndrome versus controls*

| | Controls | Patients | <i>P</i> |
|---|----------------|-------------|----------|
| Peak activity level, units | 12,913 ± 1,462 | 8,654 ± 527 | 0.003 |
| Average daily activity level, units | 1,602 ± 89 | 1,525 ± 63 | 0.47 |
| Time spent in specific activity levels, % | | | |
| High | 1.3 ± 0.3 | 0.2 ± 0.1 | 0.011† |
| Moderate | 14.8 ± 1.5 | 13.6 ± 1.4 | |
| Low | 38.7 ± 1.6 | 42.8 ± 1.2 | |
| Very low | 45.8 ± 2.8 | 43.9 ± 2.0 | |

* Except where indicated otherwise, values are the mean ± SEM (not adjusted for sex and age).

† Main effect for group differences on log-transformed ratios (Wilks' lambda = 0.834, F[3,61] = 4.057). Component analysis of log-transformed ratios yielded significant differences (*P* < 0.01) for % time spent in high-level activity only (see text for details).

observation period (Table 2), and 2) within each of the specific episodes throughout the day. Specific episodes were defined as morning (first hour after waking up), mid-morning (1 hour postawakening until lunch), afternoon (between lunch and 3:00–4:00 PM), and evening (between 3:00–4:00 PM until 30 minutes before going to bed) (Figure 1). Each episode (e.g., morning) was composed of multiple 5-minute segments, in which each of these segments consisted of a cumulative count of activity units. For each patient, we examined the epoch with the highest value to determine peak activity level. Peak activity levels were not averaged across days, but absolute peak values irrespective of the day of observation are reported in Table 2 and Figure 1.

Average activity levels were calculated using parallel procedures 1) over the entire 5-day observation period (Table 2), and 2) within each of the 4 specific episodes throughout the day (morning, mid-morning, afternoon, and evening). Average values across all 5-minute epochs within each episode (e.g., morning) were calculated, and those averages were subsequently averaged over the 5-day period. For example, for the 60-minute morning episode (from waking up until 1 hour postawakening), a total of twelve 5-minute epochs were examined; the peak activity level was the highest value among the twelve 5-minute epochs on 1 of the 5 observation days, and the average activity for that episode was calculated as the average over the 12 values, which was then averaged over the 5-day observation period.

In addition, registrations were made of the duration (as a percentage of time spent) in high-level activities (>8,000 units/5 minutes; e.g., running, gardening), moderate-level activities (>3,000–8,000 units/5 minutes; e.g., effortful walking), low-level activities (1,000–3,000 units/5 minutes; e.g., office work, minimal physical activity), and very-low activity levels (<1,000 units/5 minutes; e.g., sitting still, lying down). The percentage of time spent in high-level activities was used as an additional measure to avoid potential biases resulting from chance observations resulting from a (very high) single 5-minute period.

Assessment of ambulatory sleep parameters. To document differences between patients and controls in sleep

parameters, we assessed the duration of sleep, restlessness during sleep, and sleep efficiency. Wake-up time and sleep time were based on patients' self reports and were validated using actigraphy data. Based on prior validation studies, patients were deemed awake when activity exceeded 50% of the average daytime activity level and asleep when activity levels reached 50% below patients' average nocturnal level. Average nocturnal activity levels were assessed for each night and averaged across the 4 nights of observation. The sleep fragmentation index was also used as a second, actigraph software-based indicator of restless sleep, calculated as follows: (% 1-minute intervals of movement during sleep + % 1-minute intervals of immobility) divided by total 1-minute immobility intervals (Mini-Mitter). Sleep latency was defined as the time between going to bed and actual sleep start, which was determined as the first 10-minute span of immobility (<40 counts per minute). Sleep efficiency, used as a measure of sleep quality, was defined as follows: (time in bed spent asleep divided by total time in bed) multiplied by 100 (Mini-Mitter).

Ambulatory symptom assessments. *Symptom ratings.* Patients and controls rated symptom severity at 5 time points during the day over a consecutive 5-day period. Self-reports of pain, fatigue, and stress levels were made on a 10-point scale, with higher scores indicating more symptoms. We have used similar strategies for ambulatory symptom assessments in patients with cardiac disease (31). Real-time assessments of symptoms are superior to retrospective symptom reports in many clinical settings because such evaluations are not influenced by recall biases (25). Symptom ratings were made using the actigraph keypad to improve compliance and allow for validation of accurate time of entry (22,26). Patients were instructed to complete symptom reports at 5 time points: 1) upon awakening prior to getting out of bed, 2) 1 hour after waking up, 3) before lunch, 4) late afternoon between 3:00 and 4:00 PM, and 5) 30 minutes before going to bed. To optimize compliance of symptom monitoring during daily activities, the actigraphs prompted patients with 3 alerts that were preset based on usual wake-up time (1 hour post-, 5 hours post-, and 9 hours postawakening). The first and last entries were not accompanied by an alert in order to minimize interference with patients' usual sleep-wake patterns.

Retrospective self-reports of pain and fatigue. To examine the validity of the ambulatory symptom assessments, each patient's average and peak symptom ratings over the 5-day period were correlated with standard self-reported measures of perceived physical function and quality of life as determined on the Short-Form 36 (SF-36) health survey (32). The SF-36 was administered after completion of the 5-day ambulatory observation period and refers to symptoms experienced during the past month. Subscales of the SF-36 include physical functioning, social functioning, physical role, emotional role, mental health, vitality, bodily pain, and general health. The SF-36 is routinely used to evaluate the impact of medical conditions on patients' quality of life, with higher scores indicating better quality of life (i.e., less dysfunction). The purpose of cross-tabulating the SF-36 with ambulatory measures was to examine the correspondence between prospective ambulatory assessments of pain and fatigue with retrospective symptom reports based on the SF-36, and to examine whether physical activity levels were differentially predictive of prospective versus retrospective symptom reports.

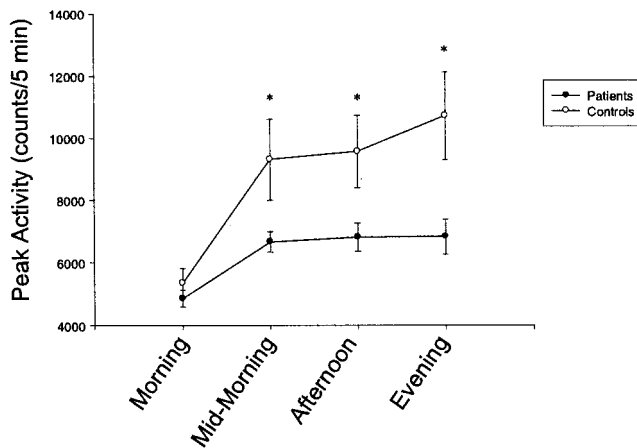


Figure 1. Diurnal variation in peak physical activity levels (counts per 5-minute [5 min] intervals), comparing patients with fibromyalgia/chronic fatigue syndrome ($n = 38$) with healthy sedentary controls ($n = 27$) during 4 phases of the day: 1) Morning (first hour after waking up), 2) Mid-Morning (1 hour postawakening until lunch), 3) Afternoon (between lunch and 3:00–4:00 PM), and 4) Evening (between 3:00–4:00 PM until 30 minutes before going to bed). All time segments were corrected for patients' individual wake-up times. Bars show the mean \pm SEM. * = $P < 0.05$ versus patients.

Statistical analysis. Average and peak activity levels were calculated throughout daytime episodes, and results are presented as the mean \pm SEM activity counts (in units per 5-minute epoch). Analysis of variance (ANOVA) was used to compare patients with controls. Because the groups were not matched for sex, analyses of covariance were conducted to adjust for potential effect modification related to sex. Differences in variability between groups were examined using Levene's test for equality of variance. Variances were not pooled across groups for t -test calculations if between-group variances were significantly different. To examine group differences in the percentage of time spent in various levels of activity, multivariate ANOVA was used to compare patients and controls on log-transformed ratios of percentages of time spent in each level of activity.

Symptom exacerbation and amelioration were evaluated by examining patients as their own controls. Mixed-effects modeling was used to examine relationships between activity levels and symptoms among patients, using day and time of observation as repeated measures and subject as the random factor. Lagged crosscorrelation coefficients were used to determine whether changes in activity levels preceded or followed changes in symptoms of pain and fatigue.

RESULTS

Patient characteristics. The characteristics of the patients and controls are presented in Table 1. Men displayed higher peak activity levels ($P = 0.014$) and higher nocturnal activity levels ($P = 0.05$) than did

women. After statistical adjustments for sex, none of the other demographic control measures were related to activity levels.

Daily activity levels in FM/CFS patients versus controls. Table 2 shows that patients had significantly lower peak activity levels compared with controls (mean \pm SEM 8,654 \pm 527 units versus 12,913 \pm 1,462 units; $P = 0.003$). Peak activity levels did not differ ($P = 0.78$) between patients with combined FM and CFS ($n = 21$; mean \pm SEM 8,744 \pm 712 units) and patients with either FM only ($n = 8$; 7,959 \pm 974 units) or CFS only ($n = 9$; 9,064 \pm 1,284 units). In contrast to the observed differences in peak activity, average physical activity levels did not differ between patients and controls (Table 2).

As shown in Figure 1, peak activity levels displayed diurnal fluctuations ($P < 0.001$), and patients had lower activity levels throughout the day compared with controls (P between groups = 0.005; P for interaction = 0.020), except during the first hour upon awakening. Diurnal activity fluctuation did not vary across the 5 days of observation. Individual differences in peak activity levels were larger among controls than among patients, as indicated by significantly larger variability of peak activity among controls compared with patients ($P < 0.05$) (Figure 1).

Patients spent significantly less time in high-level activities compared with controls (mean \pm SEM 0.2 \pm 0.1% versus 1.3 \pm 0.3%; $P = 0.001$). Statistical log-transformed ratio analysis of the 4 levels of activity examined simultaneously confirmed that patients spent significantly less time in high-level activities (overall $P = 0.011$).

Statistical adjustment for sex and age did not alter these results. Patients still had lower peak activity levels (adjusted mean 8,989 \pm 901 units in patients versus 12,443 \pm 1,078 units in controls; $P = 0.020$) and spent less time in high-level activities (0.3 \pm 0.2% versus 1.2 \pm 0.2% in controls; $P = 0.007$).

Sleep efficiency. Patients had longer mean sleep latency time (an indicator of disturbed sleep) than did controls (mean \pm SEM 20.0 \pm 22.9 minutes versus 10.8 \pm 13.6 minutes; $P = 0.051$). No differences were found in total duration of sleep. After statistical adjustment for sex and age, patients displayed more activity during sleep ($P = 0.050$), less sleep efficiency ($P = 0.076$), longer sleep latency ($P = 0.049$), and a nonsignificantly elevated sleep fragmentation index ($P = 0.17$) as compared with controls (Table 3).

Table 3. Nocturnal sleep characteristics in patients with fibromyalgia/chronic fatigue syndrome and controls*

| | Controls | Patients | <i>P</i> |
|----------------------------------|--------------|--------------|----------|
| Sleep duration, minutes | 438.1 ± 16.1 | 425.8 ± 12.6 | 0.560 |
| Average nocturnal activity level | 84.6 ± 17.6 | 130.1 ± 13.5 | 0.050 |
| Sleep fragmentation index | 12.0 ± 1.9 | 15.5 ± 1.5 | 0.170 |
| Sleep latency, minutes | 9.6 ± 4.3 | 20.7 ± 3.3 | 0.049 |
| Sleep efficiency level | 86.8 ± 1.8 | 82.6 ± 1.4 | 0.076 |

* Except where indicated otherwise, values are the mean ± SEM (sex- and age-adjusted). See Patients and Methods for details of sleep characteristics.

Ambulatory activities and symptoms of patients in relation to self-reported function. Ambulatory peak activity levels had a positive correlation with better self-reported physical function as determined by higher SF-36 scores (physical role $r = 0.45$, physical function $r = 0.30$; both $P < 0.05$), but there was no significant association between peak activity levels and self-reported pain ($r = 0.21$, $P = 0.22$) or general health ($r = 0.22$, $P = 0.35$). Associations between average activity levels and self-reported physical function were in the same direction, but were statistically nonsignificant ($P > 0.1$).

Ambulatory symptom reports were significantly correlated with retrospective self-reported SF-36 measures of physical function, and these displayed satisfactory divergent validity. Specifically, average pain reports during ambulatory monitoring were associated with SF-36–reported pain ($r = -0.60$, $P < 0.001$) and physical function ($r = -0.47$, $P = 0.004$), but not with physical role or general health. Negative correlation coefficients were in the expected direction, reflecting that higher SF-36 values, indicative of less dysfunction, are associated with fewer ambulatory symptoms. Ambulatory fatigue measures were not related to indices of health on self-report ($P > 0.10$). Ambulatory distress was associated with the SF-36 emotional role subscale scores ($r = -0.31$, $P = 0.04$) but not with other self-reported measures. Analyses of peak symptoms during ambulatory monitoring revealed similar results, with lower correlation coefficients for the associations.

Activity levels of patients in relation to ambulatory symptoms. Figure 2 shows that average and peak symptoms (pain, fatigue, and distress) were consistently elevated among patients versus controls throughout the day ($P < 0.01$). We examined whether short-term associations existed between activity levels and subsequent symptoms (in the range of 30–0 minutes prior to symptom assessment, using 5-minute segments). Averaged activity levels over the 30-minute period prior to symp-

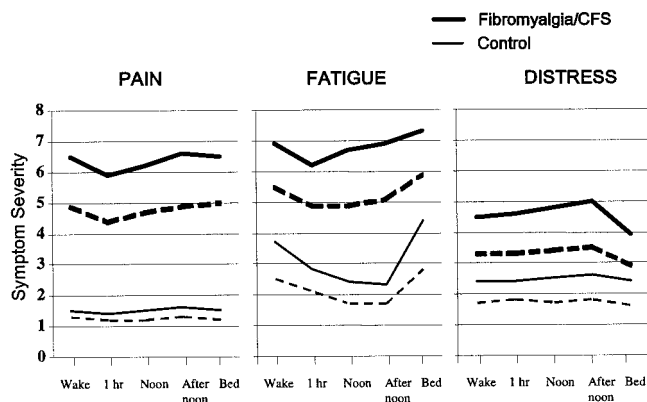


Figure 2. Diurnal variation in peak (solid lines) and average (broken lines) symptoms, comparing fibromyalgia/chronic fatigue syndrome (CFS) patients ($n = 38$) with healthy sedentary controls ($n = 27$) during 5 wake-time-adjusted time points throughout the day. Standard errors (not shown) varied from 0.07 to 0.44. Peak levels indicate the maximum symptom rating in that particular time point, as reported on 1 of the 5 observation days, and were higher in patients than in controls (all $P < 0.01$).

tom assessment were better predictors of symptom ratings than were assessments made over shorter, separate 5-minute segments. Proximal 5-minute segments (in the –15 minutes to 0 minutes range prior to symptom report) did not reveal stronger relationships with symptom ratings than more distal segments (range –30 minutes to –15 minutes) (data not shown).

Mixed-effects modeling revealed that 30-minute activity levels were negatively correlated with pain ($P = 0.031$) and fatigue ($P < 0.001$), and positively correlated with distress ($P < 0.001$). Table 4 presents bivariate correlations between average 30-minute activity levels with subsequent symptom ratings at the 5 points of assessment throughout the day. Consistent with the

Table 4. Correlation between 30-minute activity levels and subsequent symptoms throughout the day*

| Activity level | Ambulatory symptom report | | |
|--------------------------------|---------------------------|---------|----------|
| | Pain | Fatigue | Distress |
| Upon awakening | –0.09 | –0.09 | –0.05 |
| One hour after waking up | –0.08 | –0.16† | –0.03 |
| Before lunch | –0.21‡ | –0.22‡ | 0.07 |
| Late afternoon | –0.16† | –0.09 | 0.22‡ |
| 30 minutes before going to bed | –0.11 | –0.12 | 0.07 |

* Values are bivariate correlation coefficients. Negative correlations indicate that lower activity levels are related to higher levels of symptoms.

† $P < 0.05$.

‡ $P < 0.001$.

Table 5. Crosscorrelation analysis examining lagged associations between activity levels and symptom reports*

| Symptom | Ambulatory activity level | | |
|----------|-----------------------------------|---|-----------------------------------|
| | Activity preceding symptom report | Activity concurrent with symptom report | Activity following symptom report |
| Pain | -0.04 | -0.12† | -0.12† |
| Fatigue | 0.01 | -0.17† | -0.16† |
| Distress | -0.01 | 0.10† | -0.02 |

* Values are lagged crosscorrelation coefficients. Negative correlations indicate that lower activity levels are related to higher levels of symptoms.

† $P < 0.05$.

mixed-model analysis, pain and fatigue were negatively correlated with activity levels, indicating that the activity levels were lower among individuals with higher levels of these symptoms, whereas distress displayed positive associations with activity levels, particularly during mid-day observations.

Lagged crosscorrelational analyses were performed to examine whether activity was a predictor of subsequent pain and fatigue ratings, whether associations were primarily concurrent, or whether pain and fatigue preceded subsequent activity levels. As shown in Table 5, the results suggest that fatigue was associated with lower concurrent and subsequent activity levels ($P < 0.05$), whereas activity levels were not predictive of subsequent fatigue. A similar pattern of results was found for lagged crosscorrelations of ambulatory activity levels with pain.

DISCUSSION

Using objective assessments of physical activity, this study documents that patients with FM and CFS have markedly reduced levels of peak activity, whereas average activity levels are not different from those of sedentary control subjects. Peak activity, but not average activity, also has an association with self-reported measures of physical function, suggesting that patients are reporting their inability to engage in high-level activities when completing such questionnaires. Symptoms such as pain and fatigue are associated with lower concurrent and subsequent activity levels. In contrast, activity levels are not a predictor of subsequent symptoms. These results may be particularly relevant to the design of behavioral activation programs, because activity levels appear to be contingent on, rather than predictive of, symptoms of pain and fatigue during activities of daily life.

Ambulatory monitoring techniques can be useful in the assessment of patients with FM and CFS, because these assessments provide unique information about the interrelation between activities and symptoms as they occur in patients' actual circumstances of daily life. Physical activity levels are recorded more accurately using ambulatory activity monitoring as compared with retrospective self-report (23,24). The present observations indicate that peak, but not average, daytime activity levels are reduced in FM/CFS patients versus controls, which is consistent with the findings in previous literature (23,27). Korszun and colleagues used ambulatory actigraphy to show that FM patients have similar mean daytime activity levels as that of controls, and also noted evidence of sleep disturbances in those with FM (23). However, our study is the first to perform complex, repeated-measures analyses of the results of ambulatory actigraphy and symptom reports, and we document clear differences between FM/CFS patients and controls with respect to peak activity levels and symptoms. In addition, no differences were found in ambulatory activity levels between patients with a primary diagnosis of FM and patients with a primary diagnosis of CFS. This observation may reflect the common phenotypic presentation of FM, CFS, and other chronic multisymptom illnesses (1,7).

The finding that individuals with FM and CFS have lower peak activity levels may help explain why patients with FM and CFS rate their physical function as being poor. Studies examining self-reports of other symptoms, such as pain, have demonstrated that when individuals are asked to retrospectively report pain levels over a period of time, their recall is biased by the most severe pain experienced during that period, so that the self-reported pain does not reflect a true "average" pain experience (33,34). In contrast to these prior observations, the present study revealed that the *average* ambulatory symptom levels, when collected reliably using electronic time-stamps, were slightly better predictors of retrospective self-reported measures when compared with *peak* ambulatory symptom levels. Ambulatory peak activity levels were better predictors of retrospective self-reported physical function, but not with retrospective pain reports. Further studies with larger sample sizes are needed to evaluate whether ambulatory recording techniques can be used to further improve the reliability of symptom assessments in patients with chronic pain and fatigue.

Our findings regarding actigraphy assessment of sleep function corroborate other available data regarding sleep in FM/CFS (3,4,35,36). Some studies have

suggested that restful sleep in patients with FM is followed by reduced pain and fatigue upon awakening (3,35). The present study revealed higher levels of pain and fatigue upon awakening as compared with later hours in the morning. We also found evidence of longer sleep latency, reduced sleep efficiency, and more movement during sleep among patients versus controls. However, no significant associations were observed between sleep measures and subsequent reports of pain or fatigue (results not shown). A dissociation between self-reported sleep measures and objectively assessed sleep patterns as they relate to symptoms has been reported by other investigators as well (37). The lack of association between sleep and subsequent symptoms may reflect selection criteria (patients were not preselected to have sleep disorders) and restriction of range (pain and fatigue ratings were consistently high throughout the day).

Our third hypothesis postulated that bouts of exercise would be followed by increased pain and fatigue. No support was found for such an association. This study confirms a prior report by Sisto et al (14), in which ambulatory activity levels assessed 1 week following maximal exercise testing were not lower than activity levels assessed during the preceding week. We did find that symptoms of fatigue and pain were predictive of a subsequent reduction in activity levels. It is possible that patients avoided high-intensity activity levels during their usual activities of daily life, thereby precluding evaluation of the effects of high-intensity activity levels on subsequent symptoms. These results may therefore not be generalizable to patients engaging in intensive exercise or those participating in structured exercise programs. Nonetheless, high activity levels did occur and were not followed by substantial increases in pain or fatigue. Thus, the present findings suggest that high-level activities do not necessarily lead to an increase in symptoms, and support the notion that exercise or behavioral activation programs should address fear or avoidance of physical activity.

There are several potential limitations regarding the interpretation of the present findings. First, participants in this research study may not be representative of the larger populations of FM patients. Nonetheless, demographic and symptom severity data in the present study are comparable with those noted in other studies in this spectrum of disorders. Second, combining FM and CFS patients could be a potential limitation of this study. We elected to examine both groups because of the substantial overlap in clinical presentation (55% of the participants had both conditions even though they were selected on the basis of a single diagnosis), similar

behavioral and neurobiologic correlates, and parallel responses to exercise interventions. Consistent with this perspective, no differences were found in activity levels when comparing FM with CFS. A third potential limitation of this study is the reliance on statistical techniques, instead of experimental manipulations of physical activity, to assess the relationship between activity levels and symptoms. This approach precludes control over the level of exercise, and is limited by the fact that both symptoms and activity levels are significantly auto-correlated. Finally, these results may not be directly transferable to clinical settings involving exercise interventions, because patients were assessed during usual activities, not in the setting of specific exercise instructions.

In summary, this study shows that when FM/CFS patients are compared with control subjects with similar overall activity levels, they have reduced peak levels of activity and no consistent exacerbation of symptoms after periods of increased activity. This suggests a vicious cycle whereby symptoms may lead to inactivity, and inactivity (via both neurobiologic and psychological mechanisms) leads to increased symptoms. Patients attribute exacerbations of symptoms to a wide range of factors, including exercise, and therefore, fear or avoidance of increased activity and exercise may occur and further reinforce this cycle (38). Future mechanistic and interventional studies will be necessary to confirm these findings, and to determine if more effective interventions can be designed to simultaneously target physical activity and symptom management.

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