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# Fatigue, patient reported outcomes, and objective measurement of physical activity in systemic lupus erythematosus

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## Abstract

**Objective—**Fatigue is a common symptom in systemic lupus erythematosus (SLE), and engaging in physical activity (PA) may reduce fatigue. We aimed to characterize relationships between fatigue, other health status measures assessed with the Patient Reported Outcomes Measurement Information System (PROMIS) instruments, and accelerometer-based PA measurements in patients with SLE. The internal consistency of each PROMIS measure in our SLE sample was also evaluated.

**Methods—**This cross-sectional study analyzed 123 adults with SLE. The primary fatigue outcome was Fatigue Severity Scale (FSS) score. Secondary outcomes were Patient Reported Outcomes Measurement Information System (PROMIS) standardized T-scores in seven health status domains. Accelerometers were worn for seven days, and mean daily minutes of light, moderate/vigorous, and bouted (10 minutes) moderate/vigorous PA were estimated. Cronbach's alpha was determined for each PROMIS measure to assess internal consistency. Relationships

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**Conflict of Interest Statement**

The authors declare that there are no conflicts of interest.

between FSS, PROMIS, and PA were summarized with Spearman partial correlation coefficients (r), adjusted for average daily accelerometer wear time.

**Results—**Mean FSS (4.3, SD 1.6) was consistent with clinically relevant levels of fatigue. Greater daily and bouted moderate/vigorous PA minutes correlated with lower FSS (r=−0.20, p=0.03 and r=−0.30, p=0.0007, respectively). For PROMIS, bouted moderate/vigorous PA minutes correlated with less fatigue (r=−0.20, p=0.03). PROMIS internal consistency was excellent, with Cronbach's alpha >0.90 for each domain. Mean PROMIS T-scores for fatigue, pain interference, anxiety, sleep disturbance, sleep-related impairment, and physical function were worse than reported for the general U.S. population. More moderate/vigorous PA minutes were associated with less pain interference (r=−0.22, p=0.01). Both light PA and moderate/vigorous PA minutes correlated with better physical function (r=0.19, p=0.04 and r=0.25, p=0.006, respectively).

**Conclusion—**More time spent in moderate/vigorous PA was associated with less fatigue (FSS and PROMIS), less pain interference, and better physical function (PROMIS). PROMIS had excellent internal consistency in our SLE sample, and six of seven PROMIS measures indicated poorer average health status in SLE patients compared to the general U.S. population.

### Keywords

systemic lupus erythematosus; physical activity; fatigue; patient-reported outcomes

## Introduction

Systemic lupus erythematosus (SLE) is a chronic inflammatory disease with protean manifestations.[1] Fatigue is a pervasive symptom in SLE, with 80–90% of patients reporting some degree of fatigue.[2–4] Fatigue is associated with poorer health-related quality of life in SLE patients[5] through its impact on family life, work, social life, emotional wellbeing, and cognition.[6,7] SLE patients implicate fatigue for missed work days, impaired concentration, and inability to complete instrumental activities of daily living such as cooking or cleaning.[6] Fatigue in SLE is likely multifactorial and caused by disordered sleep, anxiety and depression, pain, polypharmacy, comorbidities, and possibly disease activity.[8]

Physical activity (PA) is a potential therapeutic strategy for managing fatigue in SLE patients. Participation in aerobic exercise programs has been associated with favorable changes in patient-reported fatigue.[9–12] An important limitation of these studies is a reliance on self-reported PA performed during unsupervised periods, which is prone to inaccuracies. Individuals tend to underestimate their daily walking distance, overestimate their energy expenditure, and overestimate time spent in moderate/vigorous PA with patient-reported PA instruments.[13–16] One SLE pilot study addressed this problem by tracking home PA sessions using a gaming console fitness program.[17] However, PA performed during routine activities, such as housework, was still not captured with this method. Objectively measuring the amount and intensity of PA performed in routine activities would further refine our understanding of duration and type of activity necessary to mitigate fatigue in SLE patients. The relationship between fatigue and a broader range of PA types and intensities remains an important area of investigation.

The accelerometer is a validated tool used to objectively measure continuous, routine, daily PA and distinguishes time spent performing activities of different intensities.[18] Accelerometers have been used to document PA in patients with other rheumatic diseases,[19–22] but rarely in SLE. Accelerometer responsiveness to change in PA level has also been reported in patients with osteoarthritis and rheumatoid arthritis.[23] We have previously reported that some accelerometer-based PA measures correlate with self-reported PA as assessed by the International Physical Activity Questionnaire (IPAQ) in SLE patients.[16] A primary aim of this investigation was to characterize relationships between fatigue and daily PA measured with an accelerometer in an SLE cohort. We hypothesized that more time spent in PA objectively measured with an accelerometer would be associated with lower patient-reported fatigue. Further, others have reported no change in SLE disease activity or damage following aerobic exercise programs,[9, 12, 17] but associations between objective PA and these SLE indices have not been reported. We thus evaluated cross-sectional associations between objectively measured PA and SLE disease activity and damage indices.

A second aim of the study was to assess other health status measures that are relevant to SLE patients using the Patient Reported Outcomes Measurement Information System (PROMIS). PROMIS was developed to allow standardized comparison of health status across different chronic diseases. Advantages of this system include ease of use, lower question burden than traditional patient-reported outcome measures, measurement precision, and benchmarks referenced to the general U.S. population.[24] Favorable psychometric properties of PROMIS measures have been demonstrated in patients with other rheumatic disease, including osteoarthritis, rheumatoid arthritis, scleroderma, and juvenile-onset SLE.[25–28] The use of the PROMIS instruments in adults with SLE has not been previously reported.

For our second study aim, we obtained PROMIS scores for fatigue, pain interference, anxiety, depression, sleep disturbance, sleep-related impairment, and physical function. We estimated the internal consistency of each PROMIS measure in our SLE sample. Correlations between accelerometer-based PA measurement and PROMIS scores were also assessed. Longitudinal improvements in pain intensity, anxiety, depression, and physical fitness with participation in PA have been demonstrated in other SLE cohorts,[11, 17] and it has also been suggested that lack of exercise contributes to poor sleep quality. [29] We expected that more time spent in PA would correlate with less pain interference, anxiety, depression, sleep disturbance, and sleep-related impairment and with better physical function. Quantifying associations between accelerometer-based PA assessments and patient-reported health status measures has implications for future study of PA as an intervention to improve patient-reported outcomes, particularly fatigue, in persons with SLE.

## Materials and Methods

The Activity in Lupus to Energize and Renew (ALTER) study is a cross-sectional investigation designed to test the primary hypothesis that subjective fatigue severity is inversely related to objectively-measured PA in patients with SLE. ALTER participants were previously enrolled in the Chicago Lupus Database, an ongoing registry of persons ≥18 years of age who meet at least 4 of the 1982 or updated 1997 American College of

Rheumatology criteria for SLE.[30, 31] Exclusion criteria were pregnancy, acute medical illness requiring hospitalization, and inability to provide informed consent. ALTER participants were recruited from November 2011 to December 2012 by letters, phone calls, and in-person invitations during outpatient visits. ALTER was designed to enroll 130 participants to test our primary hypothesis, and assumed at most 10–15% attrition, in order to yield about 110 evaluable participants for analysis. Using a (conservative) two-sided statistical test with $\alpha$=0.05 and $\beta$=0.10 (90% power), we estimated that we required n=112 participants to detect a correlation of 0.30 between our primary outcome of fatigue, measured by FSS, and our PA measures. For 80% power, we expected to be able to detect correlations as small as 0.25 with n=123 evaluable participants. The Institutional Review Board at Northwestern University approved the study protocol. Study participants provided written informed consent prior to enrollment according to the Declaration of Helsinki.

## Data Collection

Each participant was evaluated at a single study visit. This study visit consisted of completion of patient-reported outcome measures and interview and examination by a trained physician. Information on race/ethnicity and occupation was obtained by questionnaire. Trained personnel measured height and weight to calculate body mass index (BMI). Disease activity was determined with the Safety of Estrogens in Lupus Erythematosus-National Assessment—Systemic Lupus Erythematosus Disease Activity Index (SELENA-SLEDAI). SELENA-SLEDAI scores range from 0–105, with a score <4 indicating inactive disease.[32] Blood and urine samples were collected during the study visit and analyzed to determine the SELENA-SLEDAI score. Cumulative organ damage was assessed with the Systemic Lupus International Collaborating Clinics/American College of Rheumatology-Damage Index (SLICC/ACR-DI), with a maximum score of 46.[33] Information on anti-malarial, corticosteroid, and immunosuppressant use (mycophenolate mofetil, azathioprine, methotrexate, cyclosporine, leflunomide, and tacrolimus) was collected. Clinical records were surveyed for a concurrent diagnosis of fibromyalgia. Finally, participants were instructed on use of the accelerometer and to maintain a daily log of time spent in water and cycling activities that may be underestimated by the accelerometer.

## Outcome Measures

**Physical Activity—**PA was measured using a GT3X ActiGraph accelerometer (ActiGraph; Pensacola, FL), a small triaxial accelerometer, [34] as previously described[16]. Briefly, participants were instructed to wear the accelerometer positioned at the natural waistline over the right hip during waking hours for 7 consecutive days. Monitoring began at midnight following the study visit and ended at midnight of the seventh day. Participants then returned the accelerometers to the research center and data analyzed using the manufacturer's software.

The GT3X triaxial accelerometer measures acceleration on the vertical, antero-posterior, and medio-lateral axes. Triaxial vector magnitude was calculated for each minute as the vector magnitude of the three uniaxial counts.[18] Light and moderate/vigorous PA were identified on a minute-by-minute basis from vector magnitude values of 200–2690 and >2690 vector magnitude counts/min, respectively.[18,35] Bouted moderate/vigorous PA was defined as the

occurrence of ≥10 consecutive minutes of activity above the moderate/vigorous threshold, allowing for up to 2 minutes of interruptions below that threshold during the bout.[36] Average daily minutes of light, moderate/vigorous, and bouted moderate/vigorous PA were calculated. An example of light PA is pushing a grocery cart (1.5–2.9 Metabolic Equivalents of Task [METs]); moderate/vigorous PA is exemplified by walking quickly to catch a plane (≥3.0 METs). A valid day of monitoring was based on evidence of ≥10 hours of accelerometer wear time, after identifying periods of non-wear using algorithms developed by Choi and colleagues.[37, 38] Analyses were limited to persons with ≥4 valid days of monitoring.

**Fatigue Severity Scale—**The primary fatigue outcome was the Fatigue Severity Scale (FSS), a 9-item questionnaire that assesses the impact of fatigue on patient functioning during the preceding 2 weeks. The maximum score is 7 with higher scores indicating worse fatigue. A score ≥4 is considered a clinically relevant level of fatigue.[7] The FSS has validated psychometric properties and is commonly used for measuring fatigue in SLE.[2, 7]

**PROMIS—**Secondary patient-reported health status measures, or domains, were assessed with the PROMIS instruments. PROMIS was developed as a Roadmap/Common Fund initiative by the National Institutes of Health (NIH) to produce standardized health status measures across different medical illnesses.[39] PROMIS scores are reported using a T-score metric, which rescales a raw score into a standardized score with a mean of 50 and a standard deviation (SD) of 10. For the domains measured in this study, a score of 50 is the average for the general U.S. population.[39] The higher the PROMIS T-score, the more of that domain the patient experiences. For example, a higher physical function score indicates a higher level of daily functioning (better health), while a higher fatigue score reflects increased fatigue (poorer health). Participants completed the original English Version 1.0, 8a PROMIS 8-item short forms on paper for fatigue, pain interference, anxiety, depression, sleep disturbance, sleep-related impairment, and physical function. Participants indicated their response using a 5-item response scale based on their experience in the preceding 7 days, except physical function, which does not have a timeframe. If a short form question was skipped, raw scores were pro-rated based on number of items completed and converted to a T-score, in accordance with the PROMIS instrument scoring manuals.[40]

Formal definitions of PROMIS domains are detailed elsewhere.[41] Briefly, the fatigue item bank evaluates fatigue frequency, intensity, duration, and impact on an individual's daily functioning. Anxiety measures feelings of fear or worry, and depression assesses negative mood and views of oneself. Pain interference questions assess the influence of pain on daily life. Sleep disturbance measures sleep quality and restfulness, while sleep-related impairment characterizes impaired alertness resulting from sleep problems. Physical function items measure ability to perform instrumental activities of daily living and degree of disability.

**Statistical Analysis—**Results from our study are summarized using means ± SD as well as medians and interquartile ranges (IQRs) for continuous variables, as appropriate, depending on whether the distributions are approximately Gaussian or not. Frequencies and percentages are used to summarize categorical variables. Internal consistency of each

PROMIS instrument is assessed with Cronbach's alpha, a statistic calculated from the pairwise correlations between individual items (raw scores) in the same instrument. Only data from participants who completed all 8 questions for a specific PROMIS measure are included in the internal consistency calculation for that measure. Cronbach's alpha values ≥0.9 are considered to be evidence of excellent internal consistency. Spearman's rank correlation coefficient (r) is used to estimate the associations of fatigue (FSS) and PROMIS T-scores with each of 3 accelerometer-based PA measures (light PA min/day, moderate/vigorous PA min/day, and bouted moderate/vigorous PA min/day). Spearman correlation coefficients for accelerometer-based variables are adjusted for mean daily accelerometer wear time. A correlation coefficient (adjusted for wear time, if appropriate) is considered to be statistically significantly different than zero if the 2-sided p-value is <0.05. All analyses were performed using SAS statistical software version 9.2 (Cary, NC).

## Results

Among 167 eligible persons invited to participate, 18 declined due to scheduling conflicts and an additional 19 declined due to health concerns or other personal reasons. One hundred thirty patients initially enrolled in ALTER. One participant failed to fulfill SLE classification criteria when review of a skin biopsy did not confirm malar or discoid skin lesions, and was excluded. The final study includes data from the remaining 129 participants; 123 of these had valid accelerometer data available for analysis. Characteristics of ALTER participants compared to the remaining members of the Chicago Lupus Database have been previously reported.[16]

Characteristics of study participants with ≥4 valid days of accelerometer monitoring are shown in Table 1. Participants were predominantly female and Caucasian, and average age was 45.3 years (SD 10.8). Professional or technical were the most commonly reported occupations (41.5%) followed by homemaker or student 21.7%). Mean BMI was 27.9 kg/m$^2$ (SD 8.0), and 30.9% and 25.2% of participants were obese or overweight, respectively. Mean SELENA-SLEDAI and SLICC/ACR-DI scores were 2.3 (SD 2.8) and 1.7 (SD 2.2), respectively. Among SLE-related medications, 84.6% of participants were taking an anti-malarial, and 47.5% were taking an immunosuppressant. Mean prednisone dose for the 58 (47.5%) participants taking corticosteroids was 10.0 mg. Only 13.0% of participants carried a diagnosis of fibromyalgia (from clinical chart review), and mean hemoglobin was 12.3 g/dl.

Mean FSS was 4.3 (SD 1.6) (Table 2). Mean PROMIS T-scores for fatigue, pain interference, anxiety, sleep disturbance, and sleep-related impairment were each approximately one-half SD above the standardized U.S. population mean of 50 (Table 2). Mean PROMIS physical function T-score was about one-half SD below the U.S. mean. We also report 95% confidence intervals for each of the mean T-scores based on our data (Table 2). These intervals exclude the U.S. mean of 50 for the above mentioned six PROMIS measures, thus providing statistical evidence that this sample significantly differs from the general U.S. population. Mean PROMIS depression T-score was similar to the U.S. population mean. Since PROMIS scores have not previously been reported in adults with SLE, we calculated the internal consistency estimate (Cronbach's alpha) for each PROMIS

measure. Each Cronbach's alpha was between 0.91 and 0.98 (Table 3). PROMIS fatigue scores also strongly correlated with FSS (r= 0.84, p<0.001).

Accelerometer data showed that, 109 participants had six valid days of monitoring, while only 14 had four or five valid days. Accelerometers were worn for 14.3 hours/day on average (Table 4). Most of this time was spent in light PA (mean 346.5 min/day). On average, participants spent 38.4 min/day in moderate/vigorous PA. Mean and median times spent in bouted moderate/vigorous PA were 10.8 and 3.9 min/day, respectively, and 37 (30.1% of 123) participants did not perform any 10-minute bouts of moderate/vigorous PA.

Spearman correlations for health status measures with PA are shown in Table 5. More daily and bouted moderate/vigorous PA minutes were each significantly correlated with lower FSS (r= −0.20, p=0.03; and r= −0.30, p=0.0007; respectively). Time spent in light PA was not associated with FSS. Bouted moderate/vigorous PA was weakly correlated with lower PROMIS fatigue scores, while both daily and bouted moderate/vigorous PA were associated with lower PROMIS pain interference scores. Light and moderate/vigorous PA were associated with higher PROMIS physical function scores. No significant relationships between PA and anxiety, depression, sleep disturbance, or sleep-related impairment were found.

We also assessed the impact of SLE disease activity and damage on PA and health status measures. There was no significant association between SELENA-SLEDAI score and physical activity indices. SLICC/ACR-DI scores weakly correlated with moderate/vigorous PA min/day after adjusting for accelerometer wear time (r= −0.23, p=0.01), but no significant associations with light or bouted moderate/vigorous PA were found. There were no associations between SLE disease activity or damage and FSS or PROMIS-fatigue scores.

Finally, we evaluated the influence of weight on PA measures. When stratified by BMI, individuals with BMI <25 kg/m$^2$ (normal BMI) had more daily minutes of light PA and bouted moderate/vigorous PA than those with BMI ≥25 kg/m$^2$, but there was no significant difference in daily moderate/vigorous PA minutes (data not shown). Weak correlations between FSS and bouted moderate/vigorous PA held in each BMI stratum (r= −0.31, p=0.02 for BMI <25 kg/m$^2$ and r= −0.28, p=0.02 for BMI ≥25 kg/m$^2$). Correlations between FSS and daily moderate/vigorous PA minutes in each stratum were similar in magnitude to unstratified analyses but no longer significant (r= −0.18, p=0.20 for BMI <25 kg/m$^2$ and r= −0.20, p=0.11 for BMI ≥25 kg/m$^2$). A weak correlation between bouted moderate/vigorous PA minutes and PROMIS physical function scores was seen in the BMI ≥25 kg/m$^2$ participants (r= 0.25, p=0.04). No significant correlations were found between PA and PROMIS measures among individuals with BMI <25 kg/m$^2$.

## Discussion

This is the first study in persons with SLE to assess daily, continuous, objective PA with an accelerometer and its relationship with fatigue. Our data support the primary hypothesis that increased time spent in PA, objectively measured by an accelerometer, correlates with less

fatigue in a cross-sectional SLE cohort. Mean FSS score was consistent with a clinically relevant level of fatigue, and more time spent in moderate/vigorous PA was associated with lower FSS scores. This relationship held within normal and overweight/obese BMI strata. This is also the first study to report results of PROMIS measures in adult SLE patients, with good internal consistency. Mean PROMIS T-scores were consistent with more fatigue, pain interference, anxiety, sleep disturbance, sleep-related impairment, and worse physical function in our SLE patients than the general U.S. population. We further correlated these patient-reported outcome measures to objective PA, expecting more active persons to have better physical function and lower scores in all other PROMIS domains. This secondary hypothesis was supported when comparing time spent in moderate/vigorous PA to PROMIS scores for pain interference and physical function, and for bouted moderate/vigorous PA to PROMIS scores for fatigue. No significant correlations were found between PA and anxiety, depression, sleep disturbance, or sleep-related impairment.

While causality cannot be established in this cross-sectional study, other longitudinal studies have reported improved fatigue in exercising SLE patients.[9–12, 17] Tench and colleagues randomized SLE patients to an exercise program, relaxation techniques, or no intervention. The patients in the exercise group were seen once every 2 weeks for a supervised exercise session and otherwise self-reported physical activity. After 12 weeks, significant improvement in the Chalder Fatigue Scale was found in the exercise group compared to controls.[9] More recently, Yuen and colleagues reported improved FSS scores in a small pilot study of SLE patients following a 10 week PA intervention, using a gaming console to track PA sessions. Participants wore accelerometers during the study period to evaluate total accelerometer counts, a measure of overall PA, but no increase in total counts was found. Correlations between accelerometer PA measurements and fatigue were not reported.[17]

Associations between patient-reported fatigue and time spent in PA objectively measured with an accelerometer have also been reported in other healthy and diseased patient populations. For instance, higher levels of daily PA (based on accelerometer counts) is associated with less fatigue in patients with rheumatoid arthritis and knee or hip osteoarthritis. [42,43] Similar findings have been reported among post-menopausal women,[44] a general geriatric population,[36] fibromyalgia patients,[46] and breast cancer survivors.[47] Compared to a representative sample of U.S. adult women from the 2003–2004 National Health and Nutritional Examination Survey (NHANES),[36] our SLE patients spent more time on average in moderate/vigorous PA. Mean daily minutes of light and moderate/vigorous PA in our SLE patients was also higher than women with radiographic knee osteoarthritis from the Osteoarthritis Initiative.[48] Finally, our SLE patients spent less time in light PA but more time in moderate/vigorous PA than recorded by a cohort of rheumatoid arthritis patients.[49]

Accelerometer-based PA assessment has certain advantages over self-reported PA measures. Accelerometers are able to objectively determine quantitative changes in PA. For example, self-reported time spent in moderate/vigorous PA (using the IPAQ) was higher than measurements obtained from accelerometers in one study.[16] Detailing both PA duration and intensity continuously throughout the day allows a more comprehensive description of the relationships between PA and fatigue. Finally, accelerometer responsiveness to change in PA over time has been established in rheumatic disease populations. A change in total

accelerometer counts from baseline to 6 months after PA counseling was detected in patients with osteoarthritis and rheumatoid arthritis.[23]

A second novel aspect of our study is the use of PROMIS instruments to evaluate health status measures in adults with SLE.[50] PROMIS offers several unique qualities and advantages over most measures: 1) comparability, with standard measures and common health status domains and metrics allowing for comparisons across domains and diseases; 2) reliability and validity, with all metrics for each domain having been rigorously reviewed and tested 3) flexibility, with options for different forms and different types of administration; and 4) inclusiveness, encompassing all people, regardless of literacy, language, physical function, or life course stage.[24]

Validity of PROMIS instruments in other rheumatic diseases, including osteoarthritis and scleroderma, has been established.[25–27] Validity of PROMIS measures was also reported in childhood-onset SLE.[28] The relevance of PROMIS domains to Asian adults with SLE was evaluated through focus groups of English-speaking Asians with SLE.[51] PROMIS item banks offered an appropriate set of core questions for SLE, but the authors recommended development of items that address concerns such as family/reproductive health to enhance the use of PROMIS instruments in SLE.[51] The PROMIS library does not currently include items to address these issues. The internal consistency of the PROMIS measures, evaluated with Cronbach's alpha for each domain, was excellent in our adult SLE sample. PROMIS fatigue T-scores also strongly correlated with FSS scores, supporting a relationship between this PROMIS instrument and fatigue. Further psychometric testing and comparison to other legacy patient-reported outcome instruments should be conducted.

The PROMIS T-scores for fatigue, pain interference, anxiety, sleep disturbance, sleep-related impairment, and physical function in our SLE patients were consistent with poorer health status compared to the general U.S. population in these domains. Compared to a cohort of patients with systemic sclerosis, our SLE patients reported similar fatigue, better physical function, and more sleep disturbance.[26] Our SLE patients also had more fatigue but better physical function than a cohort of osteoarthritis patients.[27] However, minimal clinically important differences for PROMIS measures are still being established in rheumatic disease populations.

PA measures were significantly correlated with some of the PROMIS domains in persons with SLE. More time spent in moderate/vigorous PA was associated with less fatigue, less pain interference, and better physical function. A similar relationship was seen between time spent in light PA and better physical function. PROMIS instruments may be useful for evaluating the relationship between PA and these health status domains in future SLE studies. In our study, PA did not correlate with PROMIS anxiety, depression, sleep disturbance, and sleep-related impairment scores. However, the distribution of time participants spent in moderate/vigorous PA was skewed, and nearly one third of our sample did not perform any bouts of moderate/vigorous PA during the accelerometer monitoring period. It is possible that associations could be found among the subset of SLE patients who more regularly engage in moderate/vigorous PA.

There are several limitations to our study. Participants were not specifically evaluated for concurrent use of sedating medications or comorbidities that contribute to fatigue, such as fibromyalgia, anemia, mood disorders, or sleep disorders. However, chart review and mean hemoglobin level supported low rates of fibromyalgia and anemia, respectively. FSS and PROMIS questionnaires were completed just prior to the start of accelerometer monitoring and do not directly capture health status during the week of PA data collection. Also, accelerometers do not capture PA time spent in water activities or cycling. Review of activity logs suggest that time spent in these activities was minimal (data not shown). PA associated with upper extremity movements, such as resistance training, was not assessed in activity logs and is also likely to be underestimated. There is a known complex relationship between occupation and PA, with higher status occupations associated with more leisure time PA but less occupational PA.[52] We are unable to determine the amount of time spent in leisure versus occupational PA, so this association was not assessed in our SLE patients. Mean FSS score for our sample was on the lower end of the clinically relevant range, so results may not be applicable to SLE patients with more severe fatigue. Similarly, SELENA-SLEDAI and SLICC/ACR-DI scores were consistent with low SLE disease activity and damage, so results may not generalize to persons with more active or severe disease. Finally, in our prior publication based on these detailed accelerometer data,[16] a uniaxial non-wear algorithm was used.[36] More recently, a non-wear algorithm was specifically developed for triaxial accelerometers to improve reliable detection of monitor wear and was utilized for this analysis.[37, 38] Thus, the number of participants with valid days of accelerometer wear in the current study differs slightly from our prior publication[16] (n=120 previously versus n=123 in the current study).

In conclusion, our SLE study participants spent relatively little time in moderate/vigorous PA on average, with one third of participants completing no bouts of moderate/vigorous PA. SLE patients who spent more time in moderate/vigorous PA measured with an accelerometer had less fatigue by both FSS and PROMIS fatigue measures. We secondarily assessed health-status measures with the PROMIS instruments, which had excellent internal consistency in our sample. SLE patients reported worse health status than the general U.S. population in all but one PROMIS domain. Further, more time spent in moderate/vigorous PA was associated with less pain interference and better subjective physical function. This cross-sectional study supports the feasibility of using accelerometers in future studies of PA with an SLE cohort. Upcoming investigations will employ an intervention aimed at increasing PA, followed by assessment of longitudinal changes in accelerometer-based PA measurements, FSS, and PROMIS health status measures.

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## Table 1

Descriptive characteristics (n=123)

| Characteristics | % (n) or Mean ± SD |
|---|---|
| Women | 94.3 (116) |
| Caucasian Race/Ethnicity | 54.5 (67) |
| Age (years) | 45.3 ± 10.8 |
| Occupation (n=106) | |
| Professional/Technical | 41.5 (44) |
| Homemaker or Student | 21.7 (23) |
| Clerical | 14.2 (15) |
| Managerial | 9.4 (10) |
| Service | 7.5 (8) |
| Sales | 3.8 (4) |
| Craftsman | 0.9 (1) |
| Laborer | 0.9 (1) |
| BMI (kg/m$^2$) | 27.9 ± 8.0 |
| Weight | |
| Normal (BMI <25 kg/m$^2$) | 43.9 (54) |
| Overweight (BMI 25.0–29.9 kg/m$^2$) | 25.2 (31) |
| Obese (BMI ≥30 kg/m$^2$) | 30.9 (38) |
| SELENA-SLEDAI score | 2.3 ± 2.8 |
| SLICC/ACR score (n=121) | 1.7 ± 2.2 |
| Current medication use | |
| Anti-malarial | 84.6 (104) |
| Corticosteroids (n=122) | 47.5 (58) |
| Prednisone dose (mg) (n=58) | 10.0 ± 10.5 |
| Immunosuppressant | |
| Mycophenolate mofetil | 17.9 (22) |
| Azathioprine | 11.4 (14) |
| Methotrexate | 10.6 (13) |
| Cyclosporin | 0.8 (1) |
| Leflunomide | 0.8 (1) |
| Tacrolimus | 0.8 (1) |

Continuous variables are summarized as mean ± standard deviation (SD) and categorical variables as percentage (n) of patients. BMI = body mass index; SELENA-SLEDAI = Safety of Estrogens in Lupus Erythematosus National Assessment - Systemic Lupus Erythematosus Disease Activity Index; SLICC/ACR = Systemic Lupus International Collaborative Clinics/American College of Rheumatology Damage Index.

**Table 2**

Patient-reported outcome measures (n=123)

| Outcome Measure | Mean ± SD | 95% CI | Median (IQR) |
|---|---|---|---|
| Fatigue Severity Scale (FSS) | 4.3 ± 1.6 | 4.0, 4.6 | 4.4 (3.1, 5.7) |
| PROMIS Measure[a] | | | |
| Fatigue | 56.2 ± 9.7 | 54.5, 57.9 | 55.6 (50.4, 63.3) |
| Pain Interference | 55.3 ± 10.2 | 53.5, 57.1 | 55.8 (47.9, 62.8) |
| Anxiety | 54.5 ± 8.3 | 53.0, 56.0 | 53.2 (49.4, 60.4) |
| Depression | 49.8 ± 9.2 | 48.1, 51.4 | 50.9 (38.2, 55.1) |
| Sleep Disturbance | 56.0 ± 10.5 | 54.2, 57.9 | 56.1 (50.3, 63.3) |
| Sleep-Related Impairment | 55.4 ± 9.0 | 53.8, 57.0 | 55.1 (48.9, 62.3) |
| Physical Function | 43.8 ± 8.7 | 42.2, 45.3 | 43.1 (38.2, 49.6) |

SD = standard deviation; CI = confidence interval; IQR = interquartile range; PROMIS = Patient Reported Outcomes Measurement Information System.

[a]PROMIS measures are scored using a T-score metric, mean=50, SD=10 referenced to the U.S. general population. A 95% CI that excludes the value 50 indicates a statistically significant difference from the general U.S. population mean value.

**Table 3**

Internal consistency of PROMIS measures

| PROMIS Measure[a] | Cronbach's Alpha |
|---|---|
| Fatigue (n=123) | 0.966 |
| Pain Interference (n=119) | 0.980 |
| Anxiety (n=122) | 0.941 |
| Depression (n=121) | 0.947 |
| Sleep Disturbance (n=123) | 0.928 |
| Sleep-Related Impairment (n=121) | 0.919 |
| Physical Function (n=122) | 0.963 |

PROMIS = Patient Reported Outcomes Measurement Information System

[a]Participants that did not complete all 8 questions for a PROMIS measure were eliminated from the Cronbach's alpha calculation for that measure

## Table 4

Objective daily physical activity by accelerometer measures (n=123).

| Accelerometer Measure | Mean ± SD | Median (IQR) |
|---|---|---|
| Wear time (hours/day) | 14.3 ± 1.3 | 14.4 (13.4, 15.5) |
| Light PA time (min/day)[a] | 346.5 ± 90.5 | 350.0 (290.8, 406.0) |
| Moderate/Vigorous PA time (min/day)[b] | 38.4 ± 29.6 | 30.8 (19.3, 49.3) |
| Bouted Moderate/Vigorous PA time (min/day)[c] | 10.8 ± 15.7 | 3.9 (0.0, 14.4) |

SD = standard deviation; IQR = interquartile range; PA = physical activity

[a]Defined as 200–2690 vector magnitude counts/min

[b]Defined as >2690 vector magnitude counts/min

[c]Defined as moderate/vigorous PA minutes occurring with bouts of 10 minutes allowing for 2 minute interruption

## Table 5

Correlations for objective physical activity and heath outcome measures: Adjusted[a] Spearman correlation (r) and p-value (n=123)

| Health Status Measure | Light PA[b] | Moderate/Vigorous PA[c] | Bouted Moderate/Vigorous PA[d] |
|---|---|---|---|
| FSS | −0.15 (0.10) | **−0.20 (0.03)** | **−0.30 (0.0007)** |
| PROMIS | | | |
| Fatigue | −0.14 (0.12) | −0.10 (0.25) | **−0.20 (0.03)** |
| Pain Interference | −0.15 (0.09) | **−0.22 (0.01)** | **−0.29 (0.001)** |
| Anxiety | 0.08 (0.36) | −0.005 (0.95) | −0.07 (0.42) |
| Depression | −0.12 (0.17) | −0.15 (0.10) | −0.16 (0.07) |
| Sleep Disturbance | −0.10 (0.29) | −0.13 (0.15) | −0.17 (0.07) |
| Sleep-Related Impairment | −0.10 (0.29) | −0.05 (0.59) | −0.10 (0.30) |
| Physical Function | **0.19 (0.04)** | **0.25 (0.006)** | **0.33 (0.0003)** |

Bold type indicates statistically significant results. PA= physical activity; FSS = Fatigue Severity Scale; PROMIS = Patient Reported Outcomes Measurement Information System.

[a]Adjusted for average daily accelerometer wear time

[b]Defined as 200–2690 vector magnitude counts/min

[c]Defined as >2690 vector magnitude counts/min

[d]Defined as moderate/vigorous PA minutes occurring with bouts of 10 minutes allowing for 2 minute interruption