Published in final edited form as:
Pain Manag. 2013 November ; 3(6): 467–474. doi:10.2217/pmt.13.46.

Impact of chronic musculoskeletal pain on objectively measured daily physical activity: a review of current findings

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SUMMARY

Chronic pain affects a wide range of outcomes that are typically assessed using self-reported methodologies, which are susceptible to recall biases, current mood and pain intensity. Physical activity (PA) is an important component of the pain experience that can be objectively assessed with accelerometers, which are small, lightweight devices that measure the duration, frequency and intensity of PA over time. Accelerometry provides opportunities to compare actual and perceived PA, to design individually customized treatments, to monitor treatment progress, and to evaluate treatment efficacy. Thus, this technology can provide a more refined understanding of the relationships among symptoms, perceptions, mood, environmental circumstances and PA. The current paper examines patterns of PA in chronic musculoskeletal pain conditions and identifies potential clinical applications for accelerometry.

Chronic pain is a global public health problem. In the USA alone, chronic pain afflicts approximately 100 million adults and costs the nation US$560–635 billion annually in healthcare and lost productivity [1,2]. Chronic pain involves a complex integration of sensory, emotional, cognitive and behavioral components that impacts a wide range of outcomes, including pain intensity, emotional function, and physical function and activity [3,4]. Typically, these outcomes are assessed using patient reports obtained from standardized questionnaires and daily diaries, or are elicited through discussions between patients and their healthcare providers. Although self-reported assessments can help guide clinical care [5], permit monitoring over time and assess responses to treatments, they are prone to recall biases (e.g., memory and recency effects) and influenced by current mood and pain intensity [6,7]. Indeed, multiple investigations have demonstrated that there are substantial differences in estimations of daily levels of physical activity (PA) when assessed by self-reported measures in comparison to objective methodology [8,9]. Moreover, self-reports usually measure experience and behavior at a single point in time or assess an averaged experience over a recalled period of time. However, it is well known that pain can vary considerably over time depending on a range of factors, including activity, mood and

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Financial & competing interests disclosure
The authors have no other relevant affiliations or financial involvement with any organization or entity with a financial interest in or financial conflict with the subject matter or materials discussed in the manuscript apart from those disclosed.
No writing assistance was utilized in the production of this manuscript.

environmental factors that can impact physical function [10–13]. The ability to objectively monitor clinically relevant outcomes, such as physical function and activity, over time would improve our understanding of the dynamics and influence of pain in daily life and potentially improve pain management.

Accelerometers are small, lightweight devices that objectively measure the duration, frequency and intensity of PA over several days or weeks. As the cost, quality and miniaturization of accelerometers have improved over the past two decades, the number of research studies using this technology to investigate the impact of chronic musculoskeletal pain has increased substantially. In the current paper, we examine PA patterns based on accelerometry in three of the most prevalent musculoskeletal conditions associated with pain, namely osteoarthritis (OA), chronic lower back pain (CLBP) and fibromyalgia (FM), and we assess potential clinical applications of accelerometry for pain management.

Osteoarthritis

OA affects approximately 27 million people in the USA, and pain experienced from OA is the primary reason that people seek treatment [14]. Pain resultant from OA severely impacts the ability of patients to engage in activities of daily living, work and other activities they enjoy [15], making OA the leading cause of disability in the USA [14]. One of the primary treatment modalities demonstrated to be effective to reduce pain and improve functional capacity in OA patients is PA [16], and the 2002 Exercise and Physical Activity Conference (EPAC) work group has recommended that patients with knee OA accumulate 30 min of at least moderate-intensity PA on 3 or more days per week [17].

Although it is well established that PA remits general health benefits in addition to improving function and reducing pain for patients with OA, people with knee OA are particularly inactive [18]. For example, in a national US survey, 44% of people with arthritis were classified as inactive (i.e., reporting no sustained 10-min periods of moderate or vigorous PA per week) [19], but this rate is often overestimated when measured by self-report in comparison to using objective measures like accelerometry. Recent investigations measuring PA using accelerometry have found that most people with OA do not participate in the minimum amount of PA recommended by EPAC for knee OA patients [20–22]. Adults with knee OA accumulate very little moderate to vigorous activity, with 48.9% of participants being considered inactive and only one in ten adults meeting PA guidelines [22]. Although still far below recommended PA guidelines, men demonstrated significantly higher rates in all PA intensities compared with women [20,21]. All investigations concluded that the proportions of both men and women who meet PA recommendations are substantially lower when measured using accelerometry compared with self-reported estimates.

When designing interventions to increase rates of PA, it is necessary to understand intervening or modifiable factors (e.g., pain and fatigue) that can influence physical inactivity [22,23]. Greater accuracy in the strength of these associations can be achieved using objective measurement techniques such as accelerometry. For example, using accelerometry with a sample of women with knee or hip OA, Murphy and colleagues not only found that OA patients were significantly less active than age-matched pain-free controls, but that fatigue was more strongly related to inactivity and escalated throughout the day [23]. In fact, compared with pain intensity, fatigue was more strongly associated with PA. The negative relationship between fatigue and PA was replicated in a separate sample of hip and knee OA patients [24], but no significant associations were found between pain intensity and PA. In addition, Murphy and colleagues assessed the pain coping strategies (e.g., resting, pacing, guarding and task persistence) used by knee OA patients finding, for example, that patients that used the highest level of pacing behaviors had the least severe reduction in activity versus those that reported little pacing [24]. Taken together, these findings provide evidence that treatment efforts for OA patients should incorporate methods to increase general healthy living practices and reduce fatigue as well as pain when striving to increase PA.

Chronic low back pain

People with CLBP often report high levels of disability, which results in a reduction in the quantity and quality of activity in which they are able to participate [25]. This is effectively leading to increased utilization of healthcare services [26]. As with OA, exercise is recommended over passive treatments for CLBP [27], but the impact of pain or disability from CLBP on PA participation has not been confirmed.

A recent meta-analysis of 14 investigations in CLBP patients concluded that high levels of disability are associated with low levels of PA [28]. Unfortunately, this conclusion is confounded by the method in which PA was assessed, as the authors acknowledge that they did not distinguish between studies utilizing self-reported versus objectively based assessments. Specifically, the majority of studies cited in this meta-analysis using self-reported PA assessment found a strong relationship between disability and reduced PA, while the majority of studies cited that used objective measurements of PA found no such relationship. Although pain-free controls are relatively accurate in subjectively reporting their PA, CLBP patients' objective and subjective ratings of PA are often weakly correlated [9]. Efforts have been taken to use accelerometry to understand factors that may contribute to patients' inaccuracies in reporting their daily PA. In one such investigation of patients with CLBP, Huijnen and colleagues investigated if depression and/or greater pain intensity resulted in a large discrepancy between objective and subjective measurements of PA [29]. Although these authors found no significant associations between depression or pain intensity and objective PA, they did find that higher depression scores were predictive of a larger discrepancy between objective and subjective ratings of PA. Thus, patients that had higher depression scores were less accurate in judging their PA.

Consistent with the findings of Huijnen and colleagues [29], when measured by accelerometry, many case–control studies conclude that there are generally no significant differences in PA between CLBP patients and pain-free controls [28,30,31], nor strong associations between physical disability and PA [28]. In studies where no control group was used and the relationship between pain intensity in CLBP patients and PA was assessed instead, back pain intensity often fails to be associated with daily mean PA levels or reductions in PA [29,32]. By contrast, those studies relying on subjective assessments of PA have consistently found significant negative associations between physical disability in people with CLBP and PA [28], supporting the concerns that patients have difficulty in accurately reporting their daily PA.

Although both objective and subjective forms of PA assessment can be used to examine differences in rates of overall daily PA, accelerometry can be particularly useful in characterizing daily patterns of PA. Indeed, van Weering and colleagues found that although mean levels of PA were similar between CLBP patients and controls, patients had significantly higher PA in the morning and significantly lower PA in the evenings during the weekdays, while the two groups showed similar patterns on the weekends [31]. Although these authors did not measure pain intensity during the course of the day, they interpreted their findings in light of the current literature on PA in CLBP patients indicating that for CLBP patients, pain intensity may be lower in the morning, warranting greater activity, but as the day progresses and pain worsens, PA is reduced. A similar pattern was observed in a smaller study of CLBP patients and matched controls that used accelerometry to measure PA as time spent walking, time spent standing, and the number of steps taken. The authors concluded that people with CLBP exhibit an altered pattern of activity, as patients took fewer steps overall and fewer steps in the evening after a workday, whereas the number of steps taken throughout the day remained constant in pain-free controls [33]. Future research should be conducted, not only to understand how patterns of PA differ for patients, but also to understand factors that may contribute to changes in PA. Studies addressing this question and utilizing accelerometry are being undertaken. For example, Alschuler and colleagues identified that pain sensitivity, fear of movement and solicitous responses from significant others all significantly contributed to variance in objective PA in CLBP patients [34].

Fibromyalgia

Although less prevalent than OA or CLBP, FM can be debilitating and result in physical, psychological and social dysfunction [35]. Consistent with the research on OA and CLBP, FM research indicates that exercise interventions effectively improve the functional capacity and overall well-being of FM patients. These findings have similarly lead to the American Pain Society issuing recommendations for FM patients to perform moderate intensity exercise two-to-three-times per week.

Few studies have been conducted to characterize PA levels in FM patients. The findings are inconclusive, but generally point to a reduction in PA in FM patients. Specifically, both Korszun and colleagues [36] and Kop and colleagues [37] investigated differences in PA in adult FM patients in comparison to pain-free controls using a wrist-mounted accelerometer. Although neither of these studies found that mean daily PA differed between patients and controls, Kop and colleagues found that FM patients spent significantly less time in high-intensity PA, which was associated with self-reported detriments in physical function. Kop and colleagues went on to analyze the temporal associations between self-reports of pain and fatigue in association with PA. They demonstrated that although PA did not predict pain or fatigue, both pain and fatigue were associated with lower concurrent and subsequent PA, indicating that FM patients may alter their PA dependent upon their pain intensity and other symptoms (e.g., fatigue, which is especially prevalent in FM patients). McLoughlin and colleagues sought to extend these findings, and instead characterized PA in FM patients using an accelerometer worn on the hip [38]. Using this methodology, they found that FM patients evidenced significantly lower objective daily and average PA, as well as lower moderate- and vigorous-intensity PA in comparison to matched controls. Wrist-mounted accelerometers pose limitations to accurately capturing PA, with one being that wrist-mounted accelerometers primarily assess activity counts from upper-body movement. McLoughlin noted that this difference could possibly account for the inability of previous investigations to detect differences in daily PA between patients and controls. Additional research is needed to investigate the impact that placement of the device has on PA measurement, particularly in individuals with chronic pain disorders. For example, in an individual with lower extremity pain, PA measurements may differ if a hip-mounted versus wrist-mounted accelerometer was used, as a wrist-worn device may not capture gait patterns altered due to lower extremity pain that would be captured with a device worn on the hip.

FM can occur in children and adolescents, with a similarly deleterious impact on PA as evidenced by objective measures of PA [39]. Investigators demonstrated that only 23% of their participants with juvenile FM met PA recommendations [40]. Although higher pain ratings were not significantly associated with lower PA, pain intensity was significantly lower among the participants in the highest quartile of PA versus the lowest quartile of PA. Building upon this research using a case–control design of children with chronic pain [41], investigators found reduced mean activity, as well as lower daytime and peak activity among adolescents with chronic pain in comparison to controls. Similar to the findings above, there was no significant association between pain intensity and PA, warranting further investigation into the causal factor of reduced PA in juvenile pain patients. Interestingly, when both objective and subjective measures of PA were assessed in FM patients, very weak correlations were evidenced between these two forms of measurement [38,40,41], consistent with conclusions drawn in OA and CLBP populations. Overall, it appears that moderate- and vigorous-intensity activity, rather than levels of general activity, are reduced in FM patients versus controls, but more research using similar methodologies is needed to understand physical activity in FM patients, including examining patterns, bouts and peak activity levels.

Clinical applications

Among people with a variety of chronic pain conditions, increasing PA can lead to improvements in physical function and mobility, as well as decreased pain and disability [16,27]. Accelerometry is a useful technology to capture the amount and patterns of PA in people with various painful conditions accurately, although there are many logistical and methodological factors associated with the use of accelerometry that need to be considered when adopting use (Box 1), including the application of appropriate data processing algorithms for the age and functional status of the population studied [42]. Nonetheless, accelerometry can be used in a clinical setting, in conjunction with other self-reported and objective assessment tools, to create an individualized treatment plan for each patient.

There is mounting evidence that individualized treatment plans are efficacious in clinical trials conducted to modify a variety of health-related behaviors, such as teaching pacing strategies and increasing PA [43–45]. For example, Schepens and colleagues found that in patients with OA, those that received a tailored-activity pacing program showed significantly greater improvement in knee stiffness than the general intervention group [44]. In order to create a tailored treatment program, it is important to characterize PA levels and patterns accurately, and accelerometry can make a significant contribution. As discussed previously, accelerometry has been used successfully to characterize changes in activity duration and intensity within a single day and longer periods of time, as well as to discriminate between changes in activity between weekdays and weekends, with the identification of variability being used to design PA regimens.

In addition to global assessments of activity patterns, accelerometry can be used to assess other pain-related outcomes. For example, the device can provide detailed information about characteristics of gait such as variability of movement, balance, stride time and stride length. These gait parameters can be analyzed further to evaluate balance and fall risk, and have been used successfully to discriminate between gait patterns of older adults with balance problems and those without [46]. Accelerometers have also been widely used to characterize the relationship of pain with patterns and quality of sleep, which is found to be compromised in many patients with chronic pain [47,48].

Rather than using accelerometry in isolation, self-report measures of various patient symptoms and personal characteristics (e.g., psychological health, marital status and employment status) should also be collected to develop a unique intervention for each patient. Using this type of comprehensive approach, clinicians can gain a better understanding of the patient's perceptions of their activity and actual activity, as well as factors that precede, influence or result from PA. For example, Allen emphasizes the importance of understanding the timing of behaviors and symptoms relative to PA, such as self-reported ratings of pain intensity, fatigue, or medication usage, and assessing how variability in these events relates to variability in PA [10]. In addition to physical symptoms, it is also valuable to measure the underlying beliefs and motivations of the patient, such as beliefs in the effectiveness of an intervention to increase wellbeing, motivation to change, and perceived self-efficacy to perform activity [49,50], in addition to a host of other indicators of emotional distress like depression or fear of activity [51].

Murphy and colleagues provide an excellent illustration of the use of accelerometry to create a tailored treatment program for patients with knee and hip OA [50]. Specifically, the primary aims of their intervention is to use accelerometry to create a tailored-activity pacing (i.e., achieving balance between periods of activity and rest that enable the accomplishment of valued activities) intervention, and determine the effectiveness of this program on fatigue, pain and physical function. While wearing the accelerometry device for two 7-day periods (i.e., baseline and treatment follow-up), patients are asked to provide momentary pain and fatigue severity ratings directly into the device (five-times per day). Using these data, in addition to scores from various self-reported measures of health and wellbeing collected at baseline, the occupational therapist is able to generate a report for each patient that describes how their symptoms relate to their patterns of PA. Using this report, the therapist can then create an activity pacing program specific to the patient that details how the patient should incorporate activity pacing into his or her life. In addition, the follow-up monitoring period allows the investigators to assess the impact of this activity pacing program on fatigue, pain and physical function. As the use of this technology evolves, there are many ongoing investigations of its application in a variety of clinical conditions, as well as the establishment of the Society of Ambulatory Assessment [101].

In addition to utilizing accelerometry to understand characteristics of the patients' PA, this technology can also be used effectively during treatment by providing real-time feedback about PA. For example, mobile applications (smart phone applications) have been created that capture PA data and generate motivational messages dependent upon the activity level of the patient, while also displaying graphical representations of the patients' PA [52]. Other devices have been developed that recognize different forms of activity, and provide personalized exercise and fitness plans in addition to individualized coaching [53]. Online social networking platforms have even been developed for accelerometry devices that encourage people using the device to make public postings regarding their activities, make 'friends' with others using the device, set PA goals and compare their scores to others. There is evidence that this type of intervention is efficacious for increasing PA participation, in comparison to people not using online networks [54]. Thus, it is possible that these technologies can be utilized to increase PA participation, as well as teach proper activity pacing to gradually increase PA within the limits of the patient's abilities. Usability studies have further demonstrated that these technologies are user-friendly and accessible to older populations [42,53].

Conclusion

In summary, accelerometry provides opportunities to examine PA objectively in chronic pain patients, a much-needed tool that can allow clinicians to design individually customized treatments, to monitor treatment progress and evaluate treatment efficacy. Accelerometry should not be viewed as a replacement for patient self-reports of PA as these perceptions likely influence willingness to engage in PA and how patients view their capabilities and disability status. The development of advanced technologies will permit greater availability and utility of objective measures both in research and clinical practice. Thus, this technology can provide a more refined understanding of the relationships among symptoms, perceptions, mood, environmental factors and objectively measured PA.

Future perspective

Over the next decade there is high potential for the development of accelerometry as a tool to deliver feedback to patients on their PA patterns and to assist with encouraging patients to gradually increase the volume and intensity of their daily activity. Furthermore, as devices miniaturize, data storage capacity increases and signal processing algorithms improve, accelerometry will not only inform patients and clinicians about various characteristics of PA but also identify impairments in movement (i.e., gait and balance) that are amenable to rehabilitation. Large observational studies with long-term follow-up will be needed to investigate changes in activity patterns with advancing age in patients with and without chronic musculoskeletal pain, and to investigate responses to pain treatments. Intervention studies will be instrumental for establishing clinically-meaningful change metrics for accelerometry-based outcomes.

Acknowledgments

Preparation of the manuscript was supported in part by a grant received from the NIH/National Institute of Arthritis and Musculoskeletal and Skin Diseases (R01AR059102).

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Excellent example of a promising clinical application of accelerometry to improve symptom management.

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101. Society of Ambulatory Assessment. www.ambulatory-assessment.org

Practice Points

- Self-reported measures of physical activity (PA) are widely used in studies of chronic pain as a clinically informative outcome; however, self-reported measures are only modestly correlated with objectively measured PA using accelerometry. The discordance between these forms of measurement appear greater in chronic pain patient populations, possibly due to comorbid conditions such as depression.
- Accelerometry has been used effectively, in both clinical settings and community-based studies, to objectively characterize duration, frequency and intensity of PA in painful, chronic musculoskeletal conditions.
- In studies that use accelerometry to assess PA, patients with chronic lower back pain, osteoarthritis and fibromyalgia generally have decreased levels of higher intensity activity.
- As the technology for accelerometry advances, it will increasingly be used as a tool to deliver feedback to patients on their PA patterns and to assist with encouraging patients to gradually increase the volume and intensity of their daily activity. Accelerometry provides the opportunity to improve understanding of the relationships among parameters of PA (e.g., quantity, intensity and patterns), symptoms (e.g., pain and fatigue), sleep and medication use over the course of a day and across a number of days.

Box 1. Logistical and methodological considerations for accelerometry

Selection of device model, hardware & software, characteristics & support

- Uniaxial or triaxial
- Sampling frequency
- Epoch length
- Signal filtration
- Sleep and/or physical activity metrics
- Battery life
- Memory capacity
- Data transfer method (device docking unit, USB and wireless)
- Intra- and inter-device reliability and validity

Placement of the device

- Hip, wrist, leg, ankle or other (pain site-specific vs general)
- Method of attachment

Data collection

- Number of days or weeks
- Inclusion of week days and weekend days

Data processing

- Device-specific software algorithms and/or raw signal data
- Definitions of valid wear time
- Intensity, duration and bouts of activity (or inactivity)
- Population-specific cutpoints for activity counts

Other practical/logistical considerations

- Delivery and return of the accelerometer
- Staff training