Understanding the importance of sedentary time in chronic pain

by

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The student author, whose presentation of the scholarship herein was approved by the program of study committee, is solely responsible for the content of this dissertation. The Graduate College will ensure this dissertation is globally accessible and will not permit alterations after a degree is conferred.

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ABSTRACT

High sedentary time (SED) is a public health concern and reductions of SED may significantly improve health outcomes. Perceptions, determinants, and associations with other health aspects, such as pain, are understudied. The purpose of this dissertation was to 1) examine the relationship between SED and pain symptoms and pain processing in people with chronic low back pain (cLBP), 2) compare levels of self-efficacy for reducing SED to increasing moderate to vigorous physical activity (MVPA), and 3) explore perceived determinants of reducing SED in people with cLBP. Results from study one suggests no relationship between SED and pain in people with cLBP. Study two results show that people are more confident in their ability to reduce SED compared to increase MVPA, and adults have similar levels of confidence in meeting daily SED related goals. Study three found that common barriers for reducing SED include environmental constraints, social norms, and productivity, while helping individuals develop coping plans, restructure their physical environments, develop habits surround sitting less, and using self-monitoring tools are perceived as helpful. This dissertation adds to current literature on associations between SED and pain, and perceptions and determinants of reducing SED. This may help in the refinement of SED interventions for treatment of cBLP and other health outcomes, as well as in understanding confidence for changing SED and MVPA behaviors to potentially aid in refinement of current SED and MVPA guidelines.

CHAPTER 1. GENERAL INTRODUCTION

Chronic pain, defined as pain lasting longer than 3 months, is prevalent and costly. In the United States alone, 20.4% of adults live with chronic pain (Dahlhamer et al, 2016). Worldwide, the prevalence is even higher, at 30.3% (Elzahaf, Tashani, Unsworth, & Johnson, 2012). Chronic pain is more common in females and increases with age (Fayaz, et al, 2016).

One type of chronic pain that is especially prevalent is chronic low back pain (cLBP). This condition is the number one cause of disability in the world, and effects over 540 million people at any given time (Global Burden of Disease, Injury Incidence, Prevalence Collaborators, 2015). In addition to suffering from daily aches and pain, those with cLBP often experience other negative mental and physical ailments. Patients commonly report cognitive impairments and sleep disturbances, and suffer from mental health conditions, like depression and anxiety (Stubbs et al, 2016). Chronic low back pain also negatively effects society, as treatment, work disability, and loss productivity lead to significant economic burden (Hartvigsen et al, 2018).

To date, symptoms of cLBP have primarily been managed with pharmaceutical and surgical treatments. However, recent evidence suggests these methods are largely ineffective, costly, and result in significant harmful side effects (Machado, 2015; Qaseem, Wilt, McLean, & Forciea, 2017). Based on this, experts in the field currently recommend the use of non-pharmacological treatment for pain management and found effective alternative non-pharmacological treatments could significantly reduce both societal and individual burden (Foster et al, 2018).

Increasing regular physical activity (PA) is one behavioral treatment that has established benefits for individuals with cLBP. Aerobic exercise, muscle strengthening, and flexibility training have all improved pain symptoms (Gordon & Bloxham, 2016). However, interventions targeting PA frequently report high attrition rates and low long-term adherence (Linke, Gallo, & Norman, 2011). This likely results, at least in part, from low levels of self-efficacy for obtaining recommended amounts of PA and/or lowered levels of self-efficacy following failed attempts to be regularly physically active (Choi, Lee, Lee, Kang, & Choi, 2017). In addition, individuals with cLBP may have maladaptive pain-beliefs (e.g. exercise will increase my pain) about engaging in regular PA. Thus, examining other behavioral approaches that may be perceived as more feasible for improving pain is warranted.

Decreasing sedentary time (SED) may be one such approach. Sedentary time is defined as time spent in sedentary behavior, which is any waking behavior characterized by an energy expenditure of ≤1.5 metabolic equivalents (METs), while in a sitting, reclining or lying posture (Tremblay et al., 2017). Research has demonstrated that reducing SED has mental and physical health benefits for both healthy and patient populations, including improvements in mood, stress, sleep, and cardiometabolic risk factors (Patterson et al, 2018; Ellingson et al, 2018; del Pozo-Cruz et al, 2018). Decreasing SED may also influence pain. Previous studies show that highly sedentary individuals with and without chronic pain are less able to modulate pain compared to less sedentary counterparts (Ellingson et al, 2012; Naugle, Ohlman, Naugle, Riley, & Keith, 2017), and a recent intervention reported reduced symptoms of low back pain following reductions in SED (Gibbs et al, 2018). Thus, current literature suggests that reducing SED may be beneficial for pain management. However, more information is needed regarding the influence that sedentary patterns (e.g. sustained verse bouts) have on pain perception and symptoms of pain conditions.

Moreover, preliminary evidence suggests that, in contrast to interventions targeting PA, sedentary interventions have high retentions rates, good adherence, and are rated as favorable by participants (Thraen-Borowski, Ellingson, Meyer, and Cadmus-Bertram, 2017; Guitar, MacDougall, Connelly, & Knight, 2018). Thus, decreasing SED may be a behavioral treatment that is perceived as beneficial and more achievable than increasing PA. Consequently, it may be more effective for treating chronic pain because patients are confident they can actually do it. However, self-efficacy for decreasing SED has not been examined. Furthermore, little is known about factors that influence perceived ability to reduce SED in individuals with chronic paiN.

The studies proposed below are intended to address these gaps to increase our understanding regarding the influence of SED on chronic pain and its' feasibility for use as a treatment.

Study 1

Primary Aim

The purpose of the first study is to examine how objectively measured SED is associated with symptoms of low back pain, and measures of pain processing including pain sensitivity, temporal summation, and exercise-induced hypoalgesia in individuals with cLBP and healthy adults.

Hypothesis 1A

It is hypothesized that higher levels of total sedentary time (total SED) will be associated with greater symptoms of low back pain, increased pain sensitivity, increased pain temporal summation, and blunted exercise-induced hypoalgesia in individuals with cLBP.

Hypothesis 1B

Given the potential for prolonged sedentary time (SED accumulated in bouts 60+ minutes) to have stronger relationships with health outcomes (Healy et al., 2011), a second hypothesis is that there will be an association between prolonged SED and pain (including symptoms, sensitivity, facilitation, and EIH).

Hypothesis 1C

Lastly, the third hypothesis is that associations between SED and pain (including symptoms, sensitivity, temporal summation and exercise-induced hypoalgesia) will be stronger in individuals with cLBP compared to healthy adults (HA).

Study 2

Primary Aim

The purpose of this study is to compare perceived self-efficacy for increasing physical activity to perceived self-efficacy for decreasing sedentary time among healthy adults and individuals with chronic pain.

Hypothesis 1A

Perceived self-efficacy will be lower for increasing PA compared to decreasing SED, with greater differences for individuals with chronic pain compared to healthy adults.

Secondary Aim

A secondary aim is to explore which prescriptions of PA (e.g. increasing steps per day, increasing minutes of moderate to vigorous physical activity) and sedentary time (e.g. decreasing total hours per day, accumulating 250 steps each hour to break up sedentary blocks of time) are perceived as more attainable in healthy adults and individuals with chronic pain. Finally, a third aim is to examine differences in self-efficacy for overcoming common barriers to PA and SED in healthy adults and individuals with chronic pain.

Study 3

Primary Aim

The purpose of this study is to qualitatively understand what factors influence one's ability to reduce sedentary time during a theory-based sedentary intervention for individuals with chronic low back pain.

Taken together, results from these three studies will improve our understanding of relationships between SED and pain, and perceptions surrounding changing this set of behaviors. Based on this, researchers will be able to design more effective sedentary interventions through targeting aspects of sedentary time that are particularly relevant for pain (e.g. longer bouts, particular domains, etc.) and utilizing factors that promote sedentary behavior change and work to minimize those that do not, in pursuit of reducing pain symptoms. It is my intention that this work will contribute to finding an economical, efficacious and sustainable treatment for chronic pain conditions and improve quality of life of all those suffering from such conditions.

CHAPTER 2. REVIEW OF LITERATURE

Chronic Low Back Pain

Low back pain is defined as "pain, muscle tension, or stiffness localized below the costal margin and above the inferior gluteal folds, with or without sciatica" (Chou, 2011). It is classified as acute when symptoms resolve within 6 weeks, subacute for symptoms lasting 6-12 weeks, and chronic if experienced for longer than 12 weeks (Frymoyer, 1988). Low back pain is also classified as specific when caused by a known underlying pathological condition (tumor, disc herniation, or fracture) or non-specific when no direct cause can be identified (Chou, 2011).

Worldwide, low back pain is the leading cause of disability, with over 540 million people affected at any given time (Global Burden of Disease, Injury Incidence, Prevalence Collaborators, 2015). Eighty percent of US adults have or will experience low back pain during their life (Rubin, 2007). While most patients experience acute or sub-acute pain, an estimated 4-14% experience cLBP (Parthan, Evans, & Le, 2006). Due to its prevalence and profound influence on health and wellbeing, the impact of cLBP is taxing to both the individual and society. This section is intended to further describe the impact of cLBP and current treatment options, as this condition will be the focus of studies in this dissertation.

Individual and Economical Burden

The high prevalence rates mentioned above cause large financial burdens. The total cost of LBP is estimated to be between $100 and $200 billion annually when considering both direct and indirect costs (Katz, 2006). The greatest components of direct medical cost are physical therapy (17%), inpatient services (17%), pharmacy (13%), and primary care (13%), with other significant contributions coming from outpatient services, diagnostic imaging, specialist visits, surgery, chiropractic care, and mental health care (Dagenais, Caro, & Haldeman, 2008). Gore and colleagues (2012) estimated the mean individual health care cost for cLBP patients to be $11,829 per person. While direct costs are substantial, indirect cost (e.g. work absenteeism, reduced productivity) are thought to account for two-thirds of the total economic burden (Katz, 2006). A systematic review of 18 studies estimating indirect cost for low back pain found sick leave, work absences, early retirement, lost household productivity, and inactivity to be the main contributors (Dagenais, Caro, & Haldeman, 2008). Compared to acutely ill patients, individuals with cLBP have twice the total medical cost (indirect and direct) (Becker et al, 2010).

While direct and indirect costs associated with low back pain are significant, Dagenaies and colleagues (2008) identify a third category of costs termed intangible costs. These "costs" reflect the decreases in quality or enjoyment of life resulting from living with this condition. Low back pain is associated with cognitive impairments, including decision making skills that are correlated with pain duration and intensity (Tamburin, et al., 2014). Many patients experience mental illnesses as well, including major depression and anxiety (Sagheer, Khan, & Sharif, 2013; Stubbs et al, 2016). Chronic low back pain is also associated with increased sleep disturbances and distress, decreased sleep duration, decreased sleep quality, greater time to fall asleep, and decreased day time functioning levels (Kelly, Blake, Power, O'keeffe, & Fullen, 2011). Notably, the intensity of patient LBP is directly proportional to the severity of these symptoms (Hong, Kim, Shin, & Huh, 2014).

Treatment for cLBP

Current treatments for cLBP typically include both non-pharmacological and pharmacological options. Pharmacological treatment has primarily been prescribed for pain management, despite adverse consequences. The most common medications used by cLBP patients include: opioids (79.0%), NSAIDS (56.1%), Tramadol (17.5%), anti-depressants (34.4%), Benzodiazepines (26.8%), and muscle relaxants (41.5%) (Gore et al., 2012). Seventynine percent of cLBP patients use opioids, filling an average of 6.4 prescriptions person per year. Interventional therapies and surgery, including glucocorticoid injection, discectomy, spinal fusion, and laminectomy, are also commonly used. However, recently Foster et al. (2018) summarized evidence surrounding pharmacological and surgical treatments and concluded that these types of treatment are not recommended, have limited supportive evidence of effectiveness, and should only be used cautiously in limited situations. Final guideline messages from this report included that opioid prescription is discouraged and interventional strategies like surgery have a very limited role ("if any") in treatment of low back pain.

Foster et al. (2018) instead highly recommend non-pharmacological treatment options, with advice to remain active, and use education, exercise therapy, and cognitive behavioral therapy as first-line treatment options. Yoga, mindfulness training, and massage may also be effectively used as second-line treatments. Further, this report specifically endorsed the use of exercise as a first-line line treatment option of cLBP, as aerobic, resistance, and flexibility training have all been shown to repeatedly reduce symptoms of low back pain (Liddle, Baxter, & Kamp; Gracey, 2004). Further research is needed, however, to better identify the dose-responses of exercise on treatment outcomes.

Non-pharmacological treatment options, like exercise, are promising. However, many studies show that adoption of and adherence to a physically active lifestyle is low, even for healthy adults. Individuals with cLBP experience additional barriers, like fear-avoidance (fear that being active will aggravate symptoms and/or induce greater pain) and predisposed treatment beliefs, that can make adherence to exercise for treatment for cLBP especially challenging. Reports show that adherence to prescribed exercise for treatment of low back pain to be less than 50% (Kolt & McEvoy, 2003; McLean, Moffett, Sharp, & Gardiner, 2013). The effectiveness of exercise as a treatment is dependent upon adherence. Thus, finding an alternative behavioral treatment that has higher retention and adherence is necessary. Reducing sedentary time may fill this gap and the following sections provide a basic overview of the neurobiology of pain as well as a rationale and additional information about the potential benefits of reducing sedentary time.

Neurobiology of Pain

To understand how changing PA and SED may alter pain perception in individuals with cLBP, it is useful to know about the multifaceted neurobiological mechanisms that underlie pain. Pain is often described in terms of neural pathways, with peripheral mechanisms giving rise to ascending spinal pathways and central nervous system processing activating descending spinal pathways. The primary physiological mechanisms underlying the experience of acute pain are briefly discussed below, as they have direct relevance to Study 1 of the proposed work. Less is known about mechanisms underlying chronic pain, but current knowledge in this area, specifically regarding mechanisms of cLBP, is also discussed.

Potential Mechanisms of Chronic Low Back Pain

The bulk of what is known regarding central nervous system processing of pain comes from studies that use an acute peripheral stimulus applied to the skin to evoke pain. From this body of work, it is now known that pain signals do not ascend from the periphery to the central nervous system unchanged. Rather, each level of sensory processing, from peripheral to central, is subject to both inhibitory and excitatory signals that can decrease or exacerbate an individual's perception of pain. Inhibitory signals (e.g. endorphins that bind to μ-opioid receptors) can reduce pain transmission while excitatory signals (e.g. increasing release of Substance P) can facilitate and enhance pain transmission. Chronic pain may result from disruptions or dysregulations anywhere along this pathway. Over-activation of afferent processing (e.g. transmission of nociceptive signals from the periphery to the CNS) and improper inhibition of efferent processes (e.g. reduced inhibitory signaling from the dorsal prefrontal cortex) are two prominent mechanisms that may contribute to cLBP and other chronic pain conditions.

Sensory processing in these patients may change because of long-term exposure to noxious stimuli from the periphery. For example, many individuals with cLBP have an initial injury to the low back which may lead to important changes in the way pain-related information is processed both peripherally and centrally. First, the spinothalamic tract, the primary tract that sends pain-related information to cortical areas of the brain, may strengthen. Chronic peripheral stimulation could cause more rapid neuronal firing and increased activation of glia, which provide support and insulation to sensory and motor neurons transmitting signals. Supporting this hypothesis is evidence that individuals with cLBP have higher levels of translocator protein, a marker of activated glia, which could speed efferent transmission and make this pathway less receptive to inhibitory signaling (Loggia et al, 2015). Lower numbers of GABAergic neurons responsible for spinal levels pain inhibition have also been reported in individuals with chronic pain (Polgar, Gray, Riddell, & Todd, 2004). Further, the structure of the primary somatosensory cortex in the brain may adapt in response to the increasing signals. For example, larger representations of missing limbs on primary somatosensory regions have consistently been observed in individuals with phantom limb pain, with the severity of these structural changes correlated to the magnitude of the pain (Flor, Nikolajsen & Staehelin, 2006). Other possible functional reorganizations that might occur in chronic pain conditions include changes in either white or grey-matter integrity, altered pain processing connectivity, increased brain glial activation, and/or alterations in descending inhibitory pathways, all which may contribute to the transition from acute to chronic pain (Kuner & Flor, 2017).

Motor processing may similarly be modified by cLBP. Individuals with cLBP often develop specific pain behaviors to compensate for the discomfort they experience (Vlaeyen and Linton, 2000). These behaviors may result in structural changes in primary motor areas in the brain (Tsao, Galea, & Hodges, 2008). For example, muscles used to minimize movement of the injured muscle and/or structure may activate more regularly, which may increase the size of those primary motor areas. Further, the descending pathways to those muscles may also strengthen, creating more automatic maladaptive motor behaviors (Ossipoy, Morimura, & Porreca, 2014). These sensory and motor alterations underlie why treatment of CLBP, and chronic pain in general, is so difficult.

As part of the first study in this project, I will be indirectly assessing the function of pain processing and pain modulation in patients with cLBP. The specific methods associated with this will be detailed in Chapter 3. Included in the sections below is an overview of two forms of pain modulation: pain facilitation (in the form of Temporal Summation) and pain inhibition (in the form of Exercise-Induced Hypoalgesia). These sections are intended to provide sufficient background to understand the purpose and methods associated with this aim.

Pain Processing

Pain Facilitation

Pain facilitation refers to the transmission of pain via afferent tracts from peripheral receptors to the CNS. As mentioned above, individuals with cLBP may have a more robust and faster transmission of painful stimuli. One way of assessing pain facilitation is a protocol termed temporal summation. Temporal summation (also called wind-up) is the increased perception of pain following repetitive stimuli. A single, brief stimulus may not be perceived as painful. However, if multiple stimuli are presented close together in time, they may become increasingly painful. Individuals with cLBP often exhibit exaggerated temporal summation, meaning they often rate multiple trains of stimuli as significantly more painful compared to pain-free adults. This likely indicates abnormal processing in the central nervous system. Levels and patterns of physical activity and SED may influence pain facilitation. Study 1 will examine relationships between SED and temporal summation.

Pain Inhibition

Pain inhibition is simply a reduction in the perception of pain. A large body of research has demonstrated that acute exercise can reduce the perception of pain via inhibition. This phenomenon, known as exercise-induced hypoalgesia (EIH), is defined as a decrease in pain sensitivity during and following exercise (Ellingson & Cook, 2014). It is demonstrated by increases in pain threshold and tolerance, along with decreases in reported pain intensity and unpleasantness ratings to experimental pain stimuli applied during and post-exercise (Koltyn, 2000). In healthy populations, large hypoalgesic effects ($d \geq 0.8$) have been observed following aerobic, resistance, and isometric exercise (Naugle et al., 2012). Exercise-induced hypoalgesia has been observed with a range of exercise intensities and durations, using a variety of pain stimuli, including thermal, chemical, electrical, and pressure, applied in different areas of the body. Thus, acute exercise is thought to have a widespread inhibitory effect on central nervous system processing of pain and can be used to assess the status of the pain modulatory system in both healthy and patient populations.

The effects of EIH in chronic pain populations are less clear. Specifically, some individuals with chronic pain report hyperalgesia, or an increase in sensitivity to pain, (Whiteside, Hansen, & Chaudhuri, 2004) while others report a hypoalgesic response, similar to healthy adults following acute exercise sessions (Hoffman, Shepanski, Machenzie, & Clifford, 2005; Newcomb, Koltyn, Morgan, & Cook, 2011). Further research on this response and mechanisms behind it are needed and may aid in the understanding of CNS mechanisms contributing to different pain conditions. Moreover, no studies have investigated the influence that SED has on EIH in chronic pain nor healthy adults. The next section will future define and discuss SED, which will be a key component of this dissertation.

Sedentary Time and Behavior

Reducing sedentary time (SED) may influence pain processing and symptoms of chronic pain. Though often incorrectly used interchangeably with physical inactivity, SED is time spent in sedentary behaviors, which are defined as any waking behavior categorized by a sitting, reclining, or lying posture, in which the individual is expending less than 1.5 Metabolic Equivalents (METs) (Tremblay et al., 2017). Changes in transportation, entertainment, and work have created environments that promote prolonged sitting, often in place of physical activity. Thus, adults are becoming more sedentary and less active, and each of these behaviors appears to independently contribute to overall health and wellbeing. While the benefits of increasing PA to prevent and treat cLBP have been well documented, less is understood about the potential detrimental effects of SED on pain or the potential pain-related benefits of sitting less. A central goal of this dissertation is to add to the current body of literature surrounding SED and its relationship with cLBP. This section provides a brief overview on how SED is assessed and the general relationships that are seen with various health outcomes. It also describes how SED may influence pain symptoms and pain processing and provides an overview of the effectiveness of SED interventions thus far.

SED Assessment

Accurately assessing SED is an important first step when examining the impact this set of behaviors has on health. Common practices for assessing SED include self-report questionnaires and objective wearable devices. Questionnaires are frequently used, as these measures are easily administered to large samples with low participant burden. They also provide critical contextual information regarding the behavior (e.g. the activity performed while sedentary). Examples include the Marshall Sitting Questionnaire, International Physical Activity Questionnaire, SIT-Q-7d, and Sedentary Behavior Questionnaire, among others. Studies, however, repeatedly demonstrate low validity with these types of measures, with many potential sources of error, e.g. underreporting due to perceived social desirability, over-reporting due to co-occurring behaviors, like eating while watching television, etc. (Prince, LeBlanc, Colley, & Saunders, 2017).

Objective, device-based assessments, like waist-worn accelerometers and inclinometers positioned on the thigh, have higher reliability and validity for assessing SED (Byrom, Stratton, McCarthy, & Muehlhausen, 2016). The ActiGraph accelerometer is one waist worn monitor that is frequently used to assess PA because it accurately differentiates moderate and vigorous intensity PA (Aadland & Ylvisaker, 2015). However, due to monitor position, it often miscategorizes light activity as sedentary time. For example, the ActiGraph may classify standing (a non-sedentary behavior) as sedentary, rather than light activity. The activPAL inclinometer (worn on the thigh) is one specific device that is frequently used to assess SED because it accurately differentiates between sitting and standing positions that other monitors often fail to do. For this reason, it is often considered a gold standard for assessing SED. However, the activPAL is less accurate at discriminating between higher intensities (e.g. moderate vs. vigorous). Therefore, having participants simultaneously wear the activPAL and ActiGraph monitors and integrating the data via the Sojourns Including Posture procedure provides a highly accurate representation of SED and all other PA intensities (Ellingson, Schwabacher, Kim, Welk, & Cook, 2016).

Because of the different assessment methods, various terms are used when reporting SED. The Sedentary Behavior Subcommittee of the 2018 Physical Activity Guidelines Advisory

Committee recommended the following terms be used when reporting SB: self-reported sitting (domain specific or total), television viewing, screen time, and data from objective, device-based assessments (PA Guidelines, 2018). Sedentary behavior is also described in terms of how it was accumulated. A SED bout is operationally defined as a period of uninterrupted sitting (e.g. sustained, prolonged), while a break in SED is a non-sedentary period between two sedentary bouts (Physical Activity Guidelines Advisory Committee, 2018). Moreover, it is also described contextually in the activity performed when seated, such as leisure, occupation, and transportation. Research has demonstrated that the way SED is accumulated (e.g. prolonged vs. short bouts) and the context of the behavior (e.g. TV watching, socializing with friends) can have significant impacts on health outcomes associated with SED. As such, these issues are further discussed in the following section.

SED and Health

SED and Physical Health

Individuals may accumulate recommended levels of MVPA and be still be highly sedentary (Owen, Healy, Matthews, & Dunstan, 2010; Tremblay, Colley, Saunders, Healy, & Owen, 2010). Each behavior is independently associated with health-related biomarkers and risks for development of chronic, noncommunicable disease. For example, after controlling for MVPA, higher levels of prolonged SED are associated with increases in BMI, waist circumference, adverse blood-glucose levels, and poor lipid profiles (Owen et al., 2010). Further, there is strong evidence of an association between SED and risks for all-cause mortality, cardiovascular disease, type 2 diabetes, metabolic syndrome, and obesity (Biswas et al, 2015; de Rezende, Lopes, Rey-Lopez, Matsudo, & do Carmo Luiz, 2014). Recent reviews also report links between prolonged SED and increased risk of cancers, including colorectal, endometrial, lung, and breast cancer (Lynch & Leitzmann, 2017), and, more generally, a 13% increased risk for all-cancer mortality (Lynch, Mahmood, Boyle, 2017).

In addition to effects on physical health, SED is related to mental health. Higher SED is associated with higher levels of depression, anxiety, and bipolar disorder (Teychenne et al, 2012; Teychenne et al., 2015), as well as symptoms that influence mental health, like higher stress, poor sleep, and overall lower well-being (Kline et al, 2016; Sanchez-Villegas et al, 2008). Moreover, Ellingson et al. (2018) observed that decreases in total SED even predicted improvements in mood, sleep, stress, and overall well-being.

More longitudinal and experimental evidence, like the previous study, is beginning to accumulate showing that small reductions in SED can significantly improve health risks. Henson et al (2016) found improvements in postprandial metabolic responses after breaking up 30 minutes of prolonged sitting with 5 minutes of standing and/or walking. Frequent breaks in SED also significantly improved glycemic control compared to prolonged SED in individuals with Type 2 Diabetes (Paing et al, 2018). Similar to these findings, a systematic review by Chastin et al. (2015) concluded that breaking up SED with short, frequent breaks of light-intensity PA reversed the cardiometabolic effects (e.g. glucose response, BMI) associated with prolonged SED. Therefore, helping individuals break up prolonged periods may also be important for physical and mental health.

SED and Pain

SED and Pain in Healthy Adults

While reducing SED may improve physical and mental health, less is known about the influence SED has on other aspects of health, such as pain. More specifically, little is known about how SED impacts pain sensitivity, pain facilitation, and EIH. Recent work has begun to investigate this relationship in healthy populations. Ellingson and colleagues examined the relationship between pain sensitivity and varying activity levels, finding significant differences in pain intensity and unpleasantness for individuals with greater levels of vigorous activity, but non-significant results for moderate activity and SED (Ellingson, Colbert, & Cook, 2012). However, in this study SED was assessed with a waist-worn accelerometer, so light intensity activities (like standing or slow walking) that can be beneficial for those with chronic pain, may have mistakenly been classified as SED. The researchers also commented that further research is warranted as this sample consisted of relatively active, healthy female participants that may not be representative of the general population.

SED and Pain in Chronic Pain Patients

Studies that observe relationships between SED and pain levels in patients with chronic pain are limited. Cross-sectional survey data has demonstrated a positive association between SED and pain symptoms in this population (Gupta et al., 2015; Santos et al, 2017; Korshoj et al., 2018; Hanna, Daas, El-Shareif, Al-Marridi, Al-Rojoub & Adegboye, 2019). In support of this relationship, Segura-Jimenez et al. (2017) investigated the association between objectively assessed SED and pain (including assessment of tender points using pressure algometry, the Fibromyalgia Impact Questionnaire, and Multi-dimension Fatigue Inventory) in individuals with fibromyalgia. The authors concluded that SED is positively associated with levels of pain, fatigue, and overall impact of fibromyalgia, independent of MVPA. Further, Naugle and colleagues (2017) found that higher levels of SED and lower light physical activity per day (assessed with accelerometers) were significantly associated with less pain inhibitory function, assessed using conditioned pain modulation.

Moreover, Ellingson et al. (2012) found that SED is negatively related to brain activity during pain modulation in fibromyalgia patients. Specifically, results demonstrated significantly lower levels of activity in the dorsolateral prefrontal cortex, contralateral postcentral gyrus, and contralateral precentral gyrus (areas involved in pain processing and modulation), in fibromyalgia patients that accumulated larger amounts of prolonged SED compared to their less sedentary fibromyalgia patients. These results suggest avoidance of prolonged bouts of SED may improve the ability to modulate pain in this population (Ellingson, Shields, Stegner, & Cook, 2012).

These studies provide initial insight to the relationship between SED and pain in chronic pain populations. However, most of the data thus far has been collected using self-reported SED and/or pain symptom questionnaires. Moreover, objective SED monitor data published to date comes from wrist-worn or waist-worn monitors that often misclassify SED. Further research using thigh-worn accelerometery and psychophysical pain assessments is warranted to more thoroughly understand the relationship between SED and, not only pain symptoms, but pain processing (e.g. pain sensitivity, facilitation, and inhibition). Additionally, intervention data is needed to evaluate the causal direction.

SED Interventions for Treatment of Chronic Pain

Novel studies have begun investigating the utility of decreasing SED to improve pain symptoms, on the assumption that this set of behaviors may be perceived as more modifiable than increasing MVPA. Thorp and colleagues (2014) studied differences in fatigue, musculoskeletal discomfort, and work productivity after reducing SED in individuals with back pain. They reported a 31.8% reduction in low back pain discomfort in individuals engaging in intermittent breaks from prolonged SED compared to a standardize sitting control group (Thorp, Kingwell, Owen, & Dunstan, 2014). Additionally, the Stand Back randomized trial used a 6-month multicomponent intervention to target a reduction of SED in cLBP patients with desk jobs (Gibbs et al., 2018). The intervention group received education regarding health risks associated with SED, cognitive behavioral therapy, a sit-to-stand desk attachment, and a wrist-worn activity monitor with idle alert prompts. This intervention yielded significant reductions of SED per day (average 1.5-hour reduction) and perceptions of disability, compared to a wait-list control group. The very large daily changes in SED (leading to improvements in pain symptoms) may be associated with perceptions that changing SED is relatively doable, as people may have higher levels of self-efficacy for changing SED compared to changing PA. Self-efficacy is described further in the following section.

Self-efficacy, Physical Activity, and Sedentary Time

Self-efficacy is an individual's confidence and beliefs about their ability to successfully perform a desired behavior (Bandura, 1992). It is influenced by personal accomplishments, vicarious experience (watching people similar to oneself complete behavior), social persuasion, and emotional arousal/physiological response (Bandura, 1977). Self-efficacy is a key construct in many behavior change theories, including Social Cognitive Theory, Theory of Planned Behavior, Health Belief Model, and Health Action Process Approach. With regards to PA behaviors, self-efficacy may improve behavior change by influencing both motivation and self-regulation, or the ability to self-monitor and evaluate performance. Bandura (1994) explains that individuals engage in behaviors they feel competent in and are confident that they can complete, while avoiding ones they do not. These beliefs determine how much effort the individual is willing to put forth to accomplish the behavior, how long they will persevere when faced with obstacles, and how resilient they will be when faced with adverse events. In short, the greater their self-efficacy, the greater their effort, perseverance, and resilience during a behavior change.

Previous research demonstrates that self-efficacy predicts PA behavior. Correlational, longitudinal, and intervention studies overwhelmingly demonstrate that increases in self-efficacy translate to greater improvements in PA (McAuley et al, 2000). Levels of self-efficacy continually predict PA and/or exercise adoption, adherence, frequency and intensity, reliably found in a variety of samples, ranging from children to older adults (Oman & King, 1998; McAuley, 2000; Conn, Burks, Pomeroy, & Cockran, 2003; McAuley et al, 2007). Further, intervention studies that integrate strategies for improving self-efficacy enhance maintenance of the behavior following the intervention (McAuley et al, 2003). Moreover, self-efficacy has also been shown to mediate the relationship between PA, disability, and physical functioning.

While self-efficacy repeatedly predicts PA behavior, low levels of self-efficacy may also play a role in why individuals do not engage in or maintain regular PA. When objectively assessed, only 9.6% of U.S. adults obtain recommended levels of PA (Tucker, Welk, & Beyler, 2011). Moreover, interventions aiming to increase PA frequently have high attrition rates and low long-term adherence to behavior change (Linke, Gallo, & Norman, 2011).This may result from individuals either having low levels of self-efficacy for obtaining recommended amounts of PA and/or lower levels of self-efficacy from past experiences, vicarious experiences, or maladaptive emotional arousal during exercise (McAuley, 2000).

This may be especially true for individuals with chronic pain, as self-efficacy is related to maladaptive pain beliefs, like fear-avoidance and kinesiophobia, defined as fear of movement. In these cases, individuals avoid PA because of fear that the movement will result in pain, aggravate pre-existing symptoms, or create a belief pain or issue (Panhale, Gurav, & Nahar, 2016). Self-efficacy is negatively associated with fear-avoidance beliefs in individuals with chronic pain (de Moraes Vieira, de Góes Salvetti, Damiani, & de Mattos Pimenta, 2014). In other words, low levels of self-efficacy are associated with high levels of avoidance of exercise due to pain. In support of this La Touche and collegues (2019) demonstrated that in simple movement tasks (e.g. lumbar range of motion, multi-directional reach test), individuals with CLBP who had low self-efficacy also had reduced range of motion, greater pain with movement, and higher pain-related beliefs, compared to individuals with high self-efficacy. Interestingly, Meier et al. (2016) examined neural correlates of kinesiophobia and found that patients with CLBP had greater brain activity in the amygdala and insular cortex when shown video clips of potentially harmful back movements compared to pain-free controls. This may support that individuals with chronic pain experience heightened negative psychophysiological responses during PA, further lowering self-efficacy. Taken together, evidence to date suggests that individuals with chronic pain may have different emotional arousals and/or psychophysiological responses to movement or even the idea of movement that may relate to reduced self-efficacy for engaging in PA activity.

Decreasing SED appears to be feasible in chronic pain patients, as highlighted above, but little is known about the influence of self-efficacy on this behavior change. Individuals may have higher levels of perceived self-efficacy for sitting less compared to increasing PA or exercise. Little is known about how self-efficacy surrounding PA differs between individuals with chronic pain and healthy people. To date, no studies have compared levels of self-efficacy for increasing PA to decreasing SED in healthy adults, nor explored these differences in individuals with chronic pain. Study 2 of this dissertation will examine and compare these perceptions using a survey measure developed specifically for this study. Additionally, this study will also examine which metrics (e.g. steps, minutes, etc.) and quantities of increasing PA and decreasing SED are perceived as more feasible by both healthy adults and those with chronic pain.

Information about self-efficacy for overcoming reported barriers related to reducing SED may also be helpful in identifying major challenges individuals face when reducing SED and being able to compare those challenges with those individuals face when trying to increase PA. Aim 3 of Study 2 is designed to help fill this gap by comparing perceived self-efficacy for overcoming barriers to increasing PA to perceived self-efficacy for overcoming those for reducing SED.

Determinants of Sedentary Time

As highlighted above, self-efficacy is one determinant that may influence an individual's ability to reduce their SED. However, many other factors also likely appear related to this set of behaviors. A better understanding of these determinants is needed to develop the effective ways to improve individual and public health via intervention. When determinants are identified, researchers are able to choose behavior change theories and strategies with constructs that align with those factors to provide a framework for the intervention, predict behavior, and help explain outcomes. Thus, identifying determinants of SED, and specifically focusing on modifiable factors, is a necessary step. While there is abundant information about determinants of PA, less is known about determinants of SED. This section provides an overview of what is currently known in this area, which will be the focus of Study 3 of this dissertation.

In healthy adults, past research has identified a wide variety of modifiable and non-modifiable factors that influence SED. These are summarized below in Table 1 and described herein. A systematic review of correlates of SED in adults 18-65 reported intrapersonal, interpersonal, social, and environmental factors associated with SED, loosely defined as total sedentary or sitting time, time spent watching TV, screen time (in any domain i.e., leisure or work), occupational sitting time or transport related sitting time (O'Donoghue et al, 2016). For intrapersonal factors, greater age, higher BMI, lower socioeconomic status, higher leisure time screen time, pre-existing chronic disease, higher caloric snaking, and higher levels of depressive symptoms, anxiety, stress and fatigue were all associated with greater SED. There was no associations with alcohol intake or sex, while greater perceived health and perceived benefits of reducing SED were associated with less sitting. Additionally, no consistent associations were found for the influence of social interactions, including marital status, number of children, social norms, or social interactions. However, living in a neighborhood with lower social-economic status was associated with higher SED and specifically, higher levels of screen time. Finally, inconsistent and sometimes contradictory results were found for environmental factors, including walkability, aesthetic features, neighborhood safety, and proximity to destination. Thus, authors concluded more research is needed to identify the actual impact of these factors on SED. Similarly, a systematic review of determinants of SED in older adults reported that increased age, being unemployed or retired, living alone, and pre-existing health conditions were associated with higher SED (Chastin et al, 2015). Results were inconsistent for the association between sex and marital status and SED, and higher education was associated with lower levels of sitting.

Table 1. Correlates and Determinants of SED in Adults

Demographic Factors	**Psychosocial Factors**	**Environmental Factors**
Age -	Depression -	Walkability ∅
Gender ∅	Anxiety -	Proximity to Destinations ∅
Higher BMI -	Perceived Stress -	Aesthetic Features ∅
Marital Status, # Children ∅	Pain -	Neighborhood Safety ∅
Pain -	Perceived Health Status +	
Education Level +	Perceived Benefits of Behavior +	
Functional Limitations -	Social Normative Behaviors ∅	
Socioeconomic Status -	Living Alone -	
Pre-existing Chronic Disease -	Leisure Screen Time -	
Unemployed, Retired -	Caloric Snaking -	
	Alcohol Intake -	

Note: + = Positive Association; - = Negative Association; ∅ = No or Inconsistent Association

While informative, most research in this area thus far has been focused on demographic factors and other quantitatively assessed correlates, rather than examining qualitative perspectives from individuals about their sitting behaviors or following attempts to reduce SED. Of the qualitative research that exists, the majority of studies have focused on older adults. For example, in 11 community dwelling older women, a semi-structured qualitative interview revealed many similarities between determinants that influence PA and those that influence SED, including self-efficacy, functional limitations, and stereotypes associated with aging (Chastin et al, 2014). Other determinants specific to sitting included higher pain and lower perceived locus of control (e.g. lack of environmental resources or facilities, cultural/societal norms). Adding to this, a study by Greenwood-Hickman and colleagues (2015) used semi-structured interviews following an intervention to reducing sitting in obese and overweight older adults to examine determinants of SED. They reported that pre-existing health conditions, enjoyment of sedentary behaviors, unsupportive environments, and fatigue all created barriers when attempting to reduce sedentary time, while learning about how the behavior affected health, awareness training regarding sitting patterns, and increased reminders to break up sitting were motivating and facilitated reducing sedentary time. In college-aged adults, qualitative focus groups revealed that SED is influenced by multiple levels of determinants, from intrapersonal factors (enjoyment of competing sedentary activities), interpersonal (social norms), physical environment (facilities on campus, weather), macro-environment (cultural norms to sit), as well as university moderators (exams, sitting in class) (Deliens, Deforche, De Bourdeaudhuij, & Clarys, 2015). The authors concluded that using ecological approaches to promote behavior change may be most successful with this population. However, authors commented that participants often misidentified SED for inactivity.

These data are informative. However, further study is warranted. In addition to the paucity of work in this area, previous studies primarily focus on healthy adults and older adults. Additional and/or different determinants may exist for subpopulations with high levels of SED, such as individuals with cLBP. To date, no studies have been published that examine determinants for decreasing SED in individuals with cLBP. Qualitative insight to the challenges participants encountered during interventions when beginning and attempting to sustain reductions in SED could provide key insight for strategically planning future interventions and for translation to other settings. Study 3 of this dissertation is designed to fill this gap to.

CHAPTER 3. METHODS

Study 1

Participants

Data for the present study come from baseline data of a larger study examining the utility of wearable technology and theory-driven strategies to reduce SED in individuals with cLBP (approval #: 18-068-00; see Appendix A). Participants for this study will be recruited from electronic mailing lists and flyers throughout the community. Participants will be included if they were: between the ages 25-60, not taking immunomodulatory medication, on stable medication regimen over the past 8 weeks and willing to maintain current medications, not pregnant or planning on becoming pregnant, willing to wear a Fitbit monitor for 3 months, not currently using a commercial activity monitor with an idle alert feature, and able to regularly access the internet or a smartphone. Participants will be excluded if: they had injuries or health conditions that prevented them from safely participating in physical activity, did not have chronic low back pain defined as experiencing symptoms every day or nearly every day for longer than 3 months, or not experiencing elevated symptoms of depression (PHQ-9 $\leq$ 5), with the latter two criteria being specific to the chronic pain group only.

Procedures

Interested participants will attend an orientation visit during which they will read and signed an informed consent document and complete a demographic survey. They will then complete the Minimal Data Set for Low Back Pain questionnaire to verify eligibility. If eligible, participants will be given an overview of the psychophysical thermal pain assessment procedures that occur during the second visit (described in more detail below). This includes a verbal description of the pain stimulus and opportunity to experience several stimuli, followed by clear instructions over the two tests and rating scales that would be used during the second session. They will then be presented with multiple painful and non-painful thermal stimuli and practiced using the associated rating scales. Finally, they will be issued two accelerometers (activPAL and ActiGraph, described in more detail below) to assess PA and SED over the following week.

Participants will return approximately 1 week later for Visit 2. During Visit 2, after accelerometers are returned and compliance with wear time was verified, participants will complete self-reported estimates of sedentary time and pain symptoms using the SIT-Q-7d (administered via interview) and the McGill Pain Questionnaire- Short Form (administered electronically), respectively. Next, they will undergo the psychophysical pain testing, including sensitivity and facilitation using the Medoc Pathway Pain & Sensory Evaluation System. During these assessments, thermal stimuli is applied to the thenar eminence of the left hand of the participant using a Medoc Pathway Sensory Analyzer equipped with a CHEPS Peltier thermode. Prior to each test, participants will be reminded of the specific instructions and rating scales for each test and given the opportunity to ask questions.

To assess pain sensitivity, participants will be presented with 10 thermal stimuli that lasted 10-seconds each. The stimuli consisted of a range of temperatures including 41, 43, 45, 47, and 49 degrees. These stimuli were presented in a randomized order, with a 60 second inter-stimulus-interval; no participants received a 49-degree stimulus as the first temperature presented. Figure 1 illustrates this protocol. Immediately following each stimulus, participants will be asked to rate their perception of its pain intensity and pain unpleasantness, using the Gracely Box pain rating scales, attached in Appendix B and C, respectively (Gracely et al, 1978).

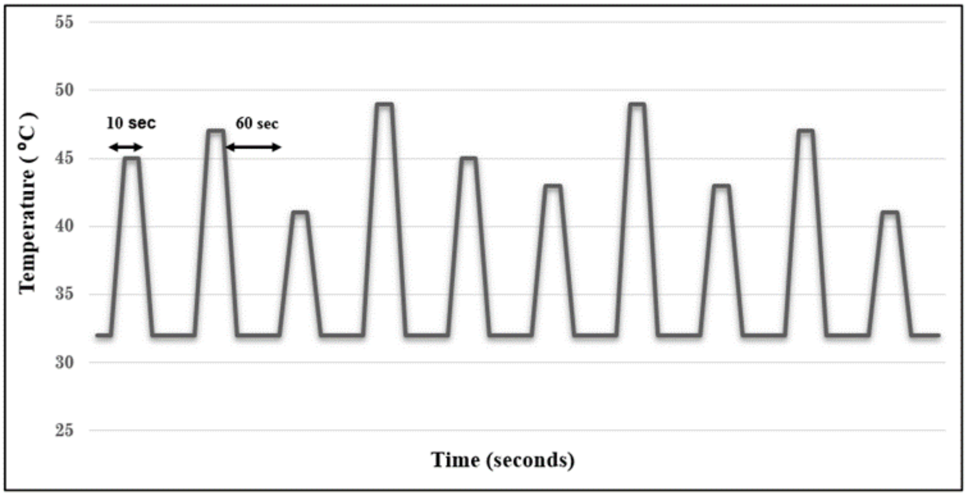

Figure 1. Pain Sensitivity Protocol

After a 2-minute break, pain facilitation will be assessed. To do so, a standard temporal summation protocol will be employed (Koltyn, Knauf, & Brellenthin, 2013) and is pictured below in Figure 2. Specifically, participants will be presented with 10, 0.5 second heat stimuli that increased at a rate of 30° C/second with a 0.5 second inter-stimulus interval. The baseline and destination temperatures for the stimuli are: 1) baseline 35°C, peak 45°C, 2) baseline 36°C,peak 47°C, 3) baseline 37°C, peak 48°C, 4) baseline 38°C, peak 49°C, with stimuli 5-10) baseline 38°C, peak 51°C, consistent with previous literature. After exposure to the 1st, 5th, and 10th stimuli, participants rate late pain sensations (1-2 seconds after each pulse) using a standard 0-100 Numerical Pain Scale (NPS), attached in Appendix D.

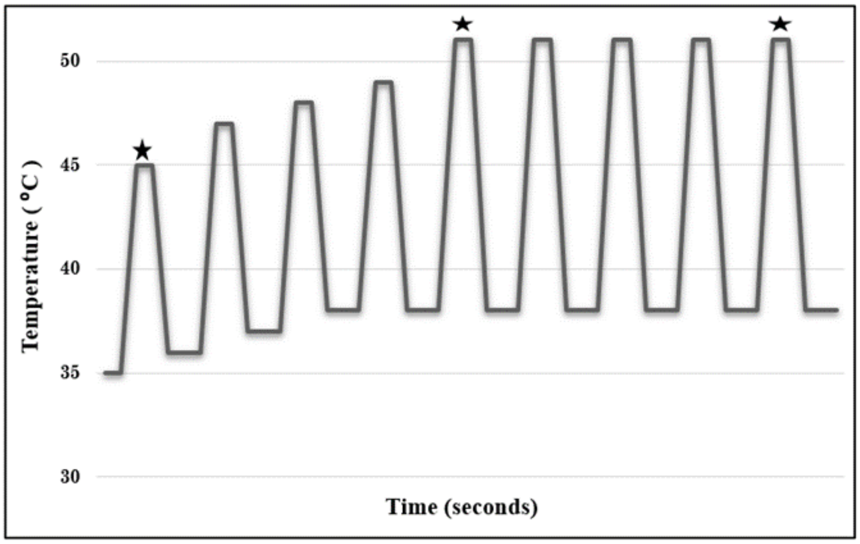

Figure 2. Pain Facilitation Protocol

In order to assess exercise-induced hypoalgesia (EIH), a form of pain inhibition, participants will then complete a 30-minute moderate exercise session on a Lode Corival Recumbent bike. After a 1-minute warm up, participants will be instructed to cycle at a pace of 60-70 revolutions per minute while self-selecting the resistance to maintain a "somewhat hard" level the entire session, after which completing at 2-3-minute cool down. Participants will report perceived exertion, leg muscle pain intensity, and low back pain intensity during warm up, minutes 5, 10, 15, 20, 25, 30, and during cool down. Perceived exertion will be assessed using the Borg's 6-20 RPE scale (attached in Appendix E), while leg and lower back pain intensity will be assessed using the 0-10 muscle pain intensity scale (Cook et al., 1997). To assess EIH, immediately following exercise, the pain sensitivity protocol will again administered (using the procedures mentioned above).

Measures

Questionnaires

During both study visits, participants will complete multiple questionnaires. A demographic survey (shown in Appendix F) will be administered during the first visit. During the first visit, the Minimal Data Set for Chronic Low Back Pain will also administered (shown in Appendix G). This questionnaire is used to assess the intensity of pain symptoms, interference of LBP on daily activities, functional status, impact on mental health, impact on sleep quality, and to better characterize the sample. This information regarding low back pain was strongly recommended in the Report of the NIH Task Force on Research Standards for Chronic Low Back Pain (Deyo et al, 2014).

The Short Form McGill Pain Questionnaire (SF-MPQ) will also be used to assess the intensity of pain symptoms specific to the low back over the past week and is attached in Appendix H. The MPQ queries about the type of pain experienced, asking patients to rate their pain level based on 10 sensory descriptors (shooting, burning, sharp, etc.), four affective descriptors (exhausting, killing, fearful, etc.), and one evaluative descriptor (mild, moderate, severe, etc.) (Melzack, 1975). For each descriptor, participants rate their pain from 0 (No pain) to 3 (Severe). In addition, participants report overall pain using a 10-centimeter visual analogue scale, anchored with "no pain" and "worst pain imaginable" and a numerical rating using the Present Pain Intensity (PPI), with ratings from 0 (no pain) to 5 (excruciating pain). This questionnaire has demonstrated high internal consistency (α=0.76-0.78) and construct validity in previous studies (Wright, Asmundson, & McCreary, 2011; Melzack, 1987).

Physical Activity and Sedentary Time

Physical activity and sedentary behaviors will be assessed objectively using activPAL3 (Physical Activity Technologies, Glasgow, UK) activity monitor. The activPAL3 (AP) is a small triaxial accelerometer that uses thigh position to classify physical activity as sedentary, upright or stepping. Participants will be instructed to place the device on the midline of the thigh on either leg. Participants will be asked to simultaneously wear both monitors during all waking hours, removing only for water-based activities. In previous studies, this monitor demonstrated high reliability and validity in free living conditions (Jarrett, Fitzgerald, & Routen, 2015; Kozey-Keadle, Libertine, Lyden, Staudenmayer, & Freedson, 2011). To accompany the monitor, participants will be given a log sheet and asked to record time on/off for each monitor and waking hours (e.g. sleep and wake times).

Pain Assessments

Gracey Box SL Scales will be used to assess pain intensity and pain unpleasantness during the pain sensitivity protocol (Gracely et al., 1978). Both scales range from 0 (no pain or neutral) to 20 (extremely intense or very intolerable), with verbal anchors along the right side to differentiate between numbers. Participants will be asked to select a single number that best represents the pain sensation following each stimulus, using the prompt “How much did that hurt?” for pain intensity and “How much did that bother you?” for pain unpleasantness. Both scales have been well-validated to assess each dimension of pain (Gracely et al., 1978).

For the temporal summation procedure, participants will use a 1-100 Numerical Pain Scale to rate pain delayed pain sensations, consistent with previous literature (Staud et al, 2006). This scale begins at 0 and increases incrementally by 5 to 100, with verbal descriptive words for intervals of 10 (e.g. 10=warm, 50=moderate pain, 100=intolerable pain), with 20 (described as a barely painful sensation) used as the pain threshold. This scale has consistently been used and found advantageous to assess pain rating during and following repetitive stimuli (Vierck et al., 1997).

Analysis

Descriptive statistics including demographic information and activity level will be used to characterize the sample. Means and standard deviations will be calculated for continuous variables and proportions calculated for categorical variables.

Means and standard deviations will also be calculated for each pain temperature rated in the pain sensitivity assessment. Histograms of pain intensity and pain unpleasantness ratings for each of the five temperatures will be created to determine which temperature best reflected discrimination for pain sensations.

To test hypothesis 1 and hypothesis 2, bivariate correlation coefficients (Pearson's r) will independently evaluate associations of total sedentary time (total SED) and sedentary time accumulated in bouts longer than 60 minutes (prolonged SED) with symptoms of cLBP (MPQ total), pain intensity at 49°C and pain unpleasantness at 49°C in the cLBP sample. Statistical significance will be set at 0.017 to account for 3 correlations (MPQ total, intensity, and unpleasantness) for each SED variable (total and prolonged). Subsequently, to test hypothesis 3, linear regression analyses will be conducted to examine associations between SED (total and prolonged) and pain symptoms (MPQ total), pain intensity at 49°C and pain unpleasantness at 49°C in both HA and those with cLBP. These associations will be examined in two models, with and without covariates. Model 1 will only include predictors of interest, including total SED, prolonged SED, group, interaction between group and total SED and interaction between group and prolonged SED. Due to risk of multicollinearity with inclusion of these interaction terms, both interactions will be mean centered. Model 2 will include predictors of interest, along with covariates, including: sex, age, depressive symptoms (PHQ-9), and MVPA.

Study 2

Procedures

Participants will be recruited via a mass email sent to university alumni (approval #: 18-414-00; see Appendix I). Individuals under the age of 18 will be excluded from the study; there are no other exclusionary criteria. Participants will be asked to complete an online survey which included basic demographic information, the International Physical Activity Questionnaire Short Form, and questions developed specifically for this study inquiring about participants' confidence in changing physical activity and sedentary behaviors. Upon completion of the survey, participants will be entered into a raffle to receive a $25 gift card.

Measures

Self-Efficacy for Changing Sedentary Time and Physical Activity Survey

The survey used in this study was developed at Iowa State University in the Wellbeing and Exercise Lab. Questions were adapted from the Self-Efficacy and Exercise Habits Survey (Sallis, Pinski, Grossman, Patterson, & Nader, 1988). The scale consists of several items that ask participants to rate their level of confidence to complete varying types and amounts of activity. Each question was rated on a Likert-style scale from 0 (Not at all Confident) to 10 (100% Confident). The full survey is provided in Appendix J.

The survey was reviewed by a panel of experts in physical activity, sedentary time, and health promotion for content validity. Pilot data was then obtained to explore the reliability of this survey. In two samples (n=1,000 each), this survey demonstrated high internal consistency, with Cronbach's Alpha's of 0.89 and 0.95. The intraclass correlation for the first sample was 0.884, with a 95% Confidence Interval from 0.875 to 0.892 ($F(1800, 10800)$, $p < 0.001$). The intraclass correlations for the second sample was 0.95, with a 85% Confidence Interval from 0.947 to 0.954 ($F(1569, 15726$, $p <0.001$).

Physical Activity

The International Physical Activity Questionnaire - Short Form (shown in Appendix K) will be used to assess physical activity and SED. This measure asks participants to recall their vigorous activity, moderate activity, walking, and sitting by reporting days per week and hours/minutes per day for each category. This measure has demonstrated varying levels of reliability and validity in previous studies, with reliability correlation coefficients ranging from 0.32 to 0.88 and fair to moderate criterion validity (N=781, p=0.30, 95% CI 0.23-0.36) (Craig et al, 2003; Lee, Macfarlane, Lam & Steward, 2011). It was selected specifically to reduce participant burden and to minimize survey fatigue, due to numerous questions within Self-Efficacy Survey, as recommended by previous studies (Craig et al, 2003).

Analysis

Analyses will be completed using R 3.6.3 (R Core Team, 2018) and R studio (R Studio Team, 2015). Survey data will be checked for completeness and data will be excluded if participants did not respond to at least 1 question examined in Aim 1 or Aim 2. Within this sample, missingness of the remaining data will be graphically explored for the entire survey and for questions used in Aim 1 and Aim 2 individually. Chi-square tests will be used to determine if there was evidence to suggest a dependence between missingness on Aim 1 and Aim 2 questions and the demographic variables, using a Bonferroni correction to account for multiplicity with significance set at 0.00045 for Aim 1 (8 SE questions, 14 demographic questions) and 0.00032 (11 SE questions, 14 demographic questions). Additionally, data will be removed if uninterpretable (e.g., invalid age) or excessive physical activity or sitting on IPAQ-SF was reported (PA>960 minutes/day, sitting>20 hr/day) (IPAQ Research Committee, 2005).

After data cleaning, descriptive statistics of demographic information and activity level will be used to characterize the sample, with means and standard deviations used for continuous variables and proportions for categorical variables.

To examine Aim 1 of the study, a paired t-test will be used to evaluate differences in SE for increasing 30 minutes of MVPA compared to decreasing SED by 30 minutes each day. Cohen's d will be used to examine the magnitude of differences (Cohen, 1988), using thresholds of 0.20 as small, 0.50 as moderate, and 0.80 as large effect sizes.

To examine Aim 2, equivalence testing will be used to compare SE for increasing MVPA by 5, 10, 20 and 30 minutes to SE for decreasing SED by 30 minutes, 1, 2, and 3 hours, for a total of 16 comparisons. Pairwise difference tests will be used to evaluate equivalence and conducted (using emmeans R package) with a 90% confidence intervals associated with each difference. For these comparisons, the null hypothesis (of nonequivalence) will be rejected if mean scores of SE were within 10% of one another (i.e. using a 90% CI). Post hoc analyses will be performed using Tukey methods to adjust for multiple comparisons between the 4 MVPA and 4 SED questions.

To explore Aim 3, means and standard deviations of the questions that inquire about different types (e.g., steps per day, minutes of MVPA per day) and amounts (e.g., 5,000 steps, 10,000 steps) of activity and SED will be computed.

Study 3

Procedures

Data for this study will be collected following the same larger study investigating the utility of a theory-based sedentary intervention to reduce symptoms of chronic low back pain, described in Study 1. As part of the study, participants are provided with a commercial activity monitor and a health coach and instructed to reduce their sedentary time in ways that fit with their current lifestyle. Specifically, participants are instructed to reduce total sedentary time per day and break up prolonged sedentary periods during an 8-week trial. Following the intervention, participants will complete a semi-structured phone interview about factors that influenced their ability to reduce sedentary time during the 8-week period. These conversations will be recorded using an audio recording platform and transcribed by a member of the study staff.

Measures

Semi-structured interviews will be used to collect data for this study. A standard set of questions will guide the conversations, and the interviewer will have the ability to modify the interview with follow up questions and/or probes based on participant responses. The questions chosen for this specific interview were selected based on study objectives and previous qualitative semi-structured interviews also designed for investigating determinants of sedentary time (Chastin, Fitzpatrick, Andrews, & DiCroce, 2014). Experts in the field reviewed the questions to ensure appropriate language was used and questions aligned with study objectives. The full questionnaire is attached in Appendix L.

Analysis

A thematic analysis will be used to identify key themes from the structured interviews, following processes recommended by Miles, Huberman, and Salacia (2014). This type of analysis was selected because the research question aligns with the ‘contextual’ and ‘diagnostic’ categories outlined by Ritchie and Spencer (1994) for framework analysis. Further, this type of analysis has been used in similar qualitative study over determinants of sedentary time (Chastin, Fitzpatrick, Andrews & DiCroce, 2014) and recommended for qualitative studies in psychology (Parkinson, Eatough, Holmes, Stapley &Midgley, 2016). This process begins with familiarization, which includes research staff members individually listening to the audio-recordings and reading the transcribed documents, before individually coding each interview.

Next, the study team collectively identifies thematic categories (second cycle coding). For the purposes of this study, a thematic category is one that illustrates something important about the data with specific regard to the research question and is a patterned response among many participants (Braun & Clarke, 2006). Using this framework, each interview will then be indexed, in which relevant transcript text are copied and sorted into the decided upon categories. This process then allows for charting, where summaries of each category are created. Finally, data will then mapped and interpreted by the research team, allowing for interpretation of the findings.

CHAPTER 4. ASSOCIATION BETWEEN SEDENTARY TIME AND PAIN PROCESSING IN INDIVIDUALS WITH CHRONIC LOW BACK PAIN AND HEALTHY ADULTS

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Abstract

Little is known about the relationship between sedentary time (SED) and pain symptoms and pain sensitivity in people with chronic low back pain (cLBP). The purpose of this study was to examine associations between monitor-assessed SED and symptoms of low back pain and pain sensitivity in individuals with cLBP and healthy adults (HA). Sixty participants (40 cLBP, 20 HA) wore an activPAL activity monitor to measure physical activity and SED prior to completing pain questionnaires (McGill Pain Questionnaire) and psychophysical thermal pain sensitivity testing (rating unpleasantness and intensity). Bivariate correlation coefficients (Pearson's r) examined associations between pain outcomes and SED. Linear regressions compared differences in these relationships in people with cLBP compared to HA. There were no significant correlations. Regression models predicting pain symptoms were significant, with group as a significant predictor. Regression models predicting pain sensitivity were non-significant, with sex as the only significant predictor. These results are inconsistent with previous self-reported data examining this relationship and suggest that SED may not be associated with

pain symptoms or processing in people with cLBP. Other activity-related behaviors, such as increasing moderate-to-vigorous physical activity, may be a more useful target for treating low back pain and improve pain processing.

Introduction

Chronic low back pain (cLBP) is prevalent, costly, and debilitating. It is the number one cause of disability in the world and effects over 540 million people at any given time (Global Burden of Disease, Injury Incidence, Prevalence Collaborators, 2015). In addition to suffering from daily aches and pain, those with cLBP often experience other negative mental and physical ailments. Patients commonly report cognitive impairments and sleep disturbances, and a majority suffer from mental health conditions, like depression and anxiety (Stubbs et al, 2016). Chronic low back pain also negatively effects society as treatment, disability, and lost productivity contribute to a significant burden economically and socially (Hartvigsen et al, 2018). Pharmacological treatments and surgeries are commonly prescribed for cLBP; however, these treatments are often accompanied by negative side effects (e.g. dependency and addiction, long-term recovery) and there is insufficient evidence of their effectiveness (Foster et al., 2018). Recently, non-pharmacological treatment options were strongly recommended for the treatment of cLBP by experts in the field (Buchbinder et al., 2018), and may be helpful in not only treating symptoms but correcting underlining abnormalities in pain processing (e.g., hypersensitivity, allodynia) that are characteristic of people with cLBP (Baron et al., 2016). Understanding behavioral factors related to symptoms of back pain and pain processing may help develop more efficacious behavior-based, and even pharmacological, treatments.

Individuals with cLBP often have higher levels of sedentary time (SED) than pain-free adults (Van Weering et al., 2011) and SED may be associated with cLBP. Sedentary time is any time spent in sedentary behaviors, which are waking behaviors where an individual is expending less than 1.5 METS while in a seated, reclined or lying position (Tremblay et al., 2018). High levels of SED are associated with a 3.5-fold increased risk of developing cLBP (Citko et al., 2018). Additionally, high self-reported sitting (i.e. greater than 10 hours/day) was a significant predictor of back pain in university employees (Hanna et al., 2019). Further, objectively assessed SED has been associated with severity of pain symptoms, sensitivity, and facilitation (examined via psychophysical pain testing) in other populations, such as older adults and those with fibromyalgia (Ellingson et al., 2012, Naugle et al., 2017; Segura-Jiménez et al., 2017). Taken together, SED may be associated with the presence and severity of chronic pain, but this has been relatively unexplored in individuals with cLBP.

Limitations in previous research include relying on self-reported sedentary behaviors and focusing solely on symptoms, as opposed to examining underlying physiological pain processing. As such, how SED relates to pain in cLBP remains unclear. Research that employs psychophysical pain testing and objective SED assessments in cLBP patients will help to understand these relationship and their impact on symptoms of low back pain. Therefore, the purpose of this study was to examine how objectively measured SED is associated with symptoms of low back pain, and measures of pain processing including pain sensitivity, temporal summation, and exercise-induced hypoalgesia in individuals with cLBP and healthy adults. It was hypothesized that higher levels of total sedentary time (total SED) would be associated with greater symptoms of low back pain, increased pain sensitivity, increased pain temporal summation, and blunted exercise-induced hypoalgesia in individuals with cLBP. Given the potential for prolonged sedentary time (SED accumulated in bouts 60+ minutes) to have stronger relationships with health outcomes (Healy et al., 2011), a second hypothesis was that there would be an association between prolonged SED and pain (including symptoms, sensitivity, facilitation, and EIH). Lastly, the third hypothesis was that associations between SED and pain (including symptoms, sensitivity, temporal summation and exercise-induced hypoalgesia) would be stronger in individuals with cLBP compared to healthy adults (HA).

Methods

Participants

Data for the present study come from baseline data of a larger study examining the utility of wearable technology along with theory-driven strategies to reduce total and prolonged SED in individuals with cLBP and elevated symptoms of depression. Participants, including individuals with cLBP and HA, were recruited from electronic mailing lists and flyers throughout the community. Inclusion criteria were: between the ages 25-60, not taking immunomodulatory medication, on stable medication regimen over the past 8 weeks and willing to maintain current medications, not pregnant or planning on becoming pregnant, willing to wear a Fitbit monitor for 2 months, not currently using a commercial activity monitor with an idle alert feature, able to regularly access the internet or a smartphone, and not currently having injuries or health conditions that prevented safe participation in physical activity. Participants with cLBP were excluded if: they did not have cLBP defined as experiencing symptoms every day or nearly every day for longer than 3 months or were not experiencing elevated symptoms of depression (Patient Health Questionnaire-9 [PHQ-9] ≤ 5). HA were excluded if: they were currently taking anti-depressant medication, reported experiencing cLBP, or were experiencing elevated symptoms of depression (PHQ-9 > 5).

Procedures

Participants first attended an orientation visit during which they read and signed an informed consent document and completed a demographic survey. They then completed the Minimal Data Set for Low Back Pain questionnaire and Patient Health Questionnaire (PHQ-9) to verify eligibility, based on above criteria. Eligible participants were then given an overview of the psychophysical pain assessment procedures that occur during the second visit. This included a verbal description of the thermal pain stimulus, instructions for each tests and their associated rating scales, and presentations of multiple painful and non-painful thermal stimuli to allow for acclimation and practice using the associated rating scales. Finally, they were issued an accelerometer to assess SED and physical activity over the following week.

Participants returned approximately 1 week later for Visit 2. During Visit 2, after accelerometers were returned, participants completed self-reported pain symptoms using the McGill Pain Questionnaire-Short Form. Next, they completed psychophysical pain testing, including sensitivity and facilitation using the Medoc Pathway Pain & Sensory Evaluation System (Medoc Advanced Medical Systems, Israel). During these assessments, thermal stimuli were applied to the palm (thenar eminence) of the left hand using a CHEPS Peltier thermode (Medoc Advanced Medical Systems, Israel). Prior to each test, participants were reminded of the instructions and rating scales and given the opportunity to ask questions.

To assess pain sensitivity, participants were presented with 10 thermal stimuli, lasting 10 seconds each. Temperatures were 41, 43, 45, 47, and 49 degrees Celsius, with each temperature being presented twice. Temperatures increased from a baseline of 32°C at a rate of 8°C/second. The first stimulus received was always 45 degrees to ensure no participant received a 49 degree stimulus first. The following 9 stimuli were presented in a randomized order, with a 60-second inter-stimulus-interval. Immediately following each stimulus, participants were asked to rate their perception of its pain intensity and then its pain unpleasantness, using Gracely Box pain rating scales (Gracely et al, 1978).

After a 2-minute break, pain facilitation was assessed. Similar to the protocol used by Koltyn and colleagues (2012), participants were presented with a train of ten, 0.5-second heat stimuli that increased and decreased at a rate of 30° C/second with a 0.5-second inter-stimulus interval. The baseline and destination temperatures for the stimuli were: 1) baseline 35°C, peak 45°C, 2) baseline 36°C, peak 47°C, 3) baseline 37°C, peak 48°C, 4) baseline 38°C, peak 49°C, with stimuli 5-10) baseline 38°C, peak 51°C. Immediately following the 1st, 5th, and 10th stimuli, participants rated late pain sensations (1-2 seconds after each pulse) using a standard 0-100 Numerical Pain Scale.

Lastly, to assess exercise-induced hypoalgesia (EIH), participants then completed a 30-minute moderate intensity exercise session on a Lode Corival Recumbent bicycle (Lode B.V., Netherlands). After a 1-minute warm up, participants were instructed to cycle at a pace of 60-70 revolutions per minute while adjusting the resistance to maintain a “somewhat hard” level of exertion for the 30 minutes. This was followed by a 2-3-minute cool down. Participants reported perceived exertion (i.e. RPE), leg muscle pain intensity, and low back pain intensity during warm up, minutes 5, 10, 15, 20, 25, 30, and during cool down. Perceived exertion was assessed using Borg’s 6-20 RPE scale (Borg, 1998) with the prescribed intensity being equivalent to a ‘13.’ Leg and lower back pain intensity were assessed using the 0-10 muscle pain intensity scale (Cook et al., 1997). To assess EIH, immediately following exercise, the pain sensitivity protocol was again administered and ratings were compared pre and post-exercise.

Measures

Pain Questionnaires

During both study visits, participants completed multiple questionnaires. A demographic survey and the Minimal Data Set for Chronic Low Back Pain were administered during the first visit. The Minimal Data Set is used to assess the intensity of pain symptoms, interference of low back pain on daily activities, functional status, impact on mental health, and the impact on sleep quality. The NIH Task Force on Research Standards for Chronic Low Back Pain strongly recommends use of this measure for research on cLBP (Deyo et al, 2014).

Pain symptoms were also assessed with the Short Form McGill Pain Questionnaire (SF-MPQ). This is a psychometrically strong instrument (α=0.76-0.78) used to assess the intensity of pain symptoms specific to the low back over the past week (Wright, Asmundson, & McCreary, 2011; Melzack, 1987). For each descriptor, participants rated their pain from 0 (No pain) to 3 (Severe). In addition, participants reported overall pain using a 10-centimeter visual analogue scale, anchored with “no pain” and “worst pain imaginable” and a numerical rating using the Present Pain Intensity (PPI), with ratings from 0 (no pain) to 5 (excruciating pain). Due to experimenter error, two sensory descriptors were inadvertently not included in the assessment. To be able to compare these results with previous research, an average sensory score was imputed for the two missing values. A sum of all sensory and affective descriptors was then calculated for a total pain symptom score (MPQ Total), with higher scores indicating greater intensity of back pain symptoms.

Depressive Symptoms Questionnaire

The Patient Health Questionnaire-9 (PHQ-9) was used to evaluate presence of depressive symptoms. This is a 9-quesiton instrument used to assess presence and severity of depressive symptoms, with scores categorized 0-4, 5-9, 10-14, 15-19, and 20-27 as minimal, mild, moderate, moderately severe, and severe depression, respectively. This questionnaire has demonstrated excellent reliability (Cronbach's α =0.86-0.89) and validity (Kroenke, Spitzer, & Williams, 2001).

Monitor Assessed Physical Activity and Sedentary Time

Physical activity and sedentary time were assessed objectively using activPAL3 (PAL Technologies, Glasgow, UK) activity monitor provided to each participant for 7 full days. The activPAL3 (AP) is a small triaxial accelerometer that is worn on the thigh to classify activity as sedentary, upright or stepping. In previous studies, this device has demonstrated excellent reliability and validity of SED in free living conditions (Lyden, Keadle, Staudenmayer, & Freedson, 2017).

Participants were instructed to place the device on the midline of the thigh on either leg and wear the monitor during all waking hours, removing it only for water-based activities (e.g., swimming). Monitor data were checked for sufficient wear-time. Specifically, the monitor must have been worn for at least 4 days, including a minimum of 3 weekdays and 1 weekend day, which has been shown have high reliability with monitor wear time of 7 days (ICC = 0.80) (Barreira et al., 2016). Each of these days was only considered valid if it was worn for at least 20 hours. Sleep time was parsed out from each day's sitting/lying time automatically using PALanalysis (version 8.10.8.76).

Three variables were used from the monitor data. First, average minutes of sitting per day were used to assess total SED. Average minutes per day spent sitting in bouts longer than 60 minutes were used to asses prolonged SED. Lastly, minutes of stepping time with a cadence ≥100 were used to assess moderate to vigorous physical activity (MVPA). This cadence is associated with a moderate intensity (assessed with indirect calorimetry) and recommended as a cut point for MVPA for step-based activity data (Tudor-Locke & Rowe, 2012).

Psychophysical Pain Rating Scales

Gracey Box SL Scales were used to assess pain intensity and pain unpleasantness during the pain sensitivity protocol (Gracely et al., 1978). Both scales range from 0 (no pain or neutral) to 20 (extremely intense or very intolerable), with verbal anchors along the side to differentiate between numbers. Participants were asked to select a single number that best represents the pain sensation following each stimulus, using the prompt “How much did that hurt?” for pain intensity and “How much did that bother you?” for pain unpleasantness. Both scales have been well validated to assess these two dimensions of pain (Gracely et al., 1978).

For the temporal summation procedure, participants used a 1-100 Numerical Pain Scale to rate delayed pain sensations, consistent with previous literature (Staud et al, 2006). This scale begins at 0 and increases incrementally by 5 to 100, with 0 indicating “no sensation,” 0-19 indicating warm sensations (increasing warmth), 20 as the threshold for pain, 21-99 as painful (increasing painfulness), and 100 indicating “withdrawal from stimulus.” This scale has been strongly associated with 6 other measures of pain intensity and recommended for both clinical and research use (Jensen, Karoly, Braver, 1986).

Statistical Analysis

Descriptive statistics including demographic information and activity level were used to characterize the sample. Means and standard deviations were calculated for continuous variables and proportions were calculated for categorical variables.

Means and standard deviations were also calculated for each pain temperature rated in the pain sensitivity assessment. Histograms of pain intensity and pain unpleasantness ratings for each of the five temperatures were created to determine which temperature best reflected discrimination for pain sensations. A greater distribution of ratings were overserved for 49°C for both intensity and unpleasantness, so this temperature was selected for all analyses (see Appendix 1).

Temporal summation data were determined to be invalid because participants did not experience pain (i.e. most participant pain ratings on Numerical Pain Rating scale were under the pain threshold of ‘20’) during the protocol. Though this protocol has been used previously for this purpose and was successfully piloted in our lab, we failed to consider how the order of testing procedures could influence physiological responses like sensitization (i.e. becoming less sensitive due to exposure to pain). Having this protocol follow the pain sensitivity procedures was the likely culprit. Further, our EIH data were also determined to be invalid. In contrast to previous research and our own pilot testing, a majority of participants did not experience EIH, potentially suggesting a fault in the protocol (e.g., the intensity of the exercise was insufficient to induce hypoalgesia). As such, pain symptoms and pain sensitivity (intensity and unpleasantness) were the only pain outcomes statistically evaluated. Proposed analyses and results specific to temporal summation and EIH will not be discussed further.

To test hypothesis 1 and hypothesis 2, bivariate correlation coefficients (Pearson’s r) independently evaluated associations of total sedentary time (total SED) and sedentary time accumulated in bouts longer than 60 minutes (prolonged SED) with symptoms of cLBP (MPQ total), pain intensity at 49°C and pain unpleasantness at 49°C in the cLBP sample. Statistical significance was set at 0.017 to account for 3 correlations (MPQ total, intensity, and unpleasantness) for each SED variable (total and prolonged). Subsequently, to test hypothesis 3, linear regression analyses were conducted to examine associations between SED (total and prolonged) and pain symptoms (MPQ total), pain intensity at 49°C and pain unpleasantness at 49°C in both HA and those with cLBP. These associations were examined in two models, with and without covariates. Model 1 only included predictors of interest, including total SED, prolonged SED, group, interaction between group and total SED and interaction between group and prolonged SED. Due to risk of multicollinearity with inclusion of these interaction terms, both interactions were mean centered. Model 2 included predictors of interest, along with covariates, including: sex, age, depressive symptoms (PHQ-9), and MVPA.

Results

Sixty participants were enrolled in the study (40 cLBP, 20 HA). Three participants from the HA group did not meet activity monitor wear-time requirements and were excluded from the analyses, leaving 40 individuals with cLBP and 17 HA (n=57). Demographic information, pain symptoms, and monitor-assessed behavior are reported in Table 1. Briefly, our sample varied in age (25-58) and gender (65% female) and were primarily white, married, and working full time. Many were also highly educated and financially secure. As should be expected, there were significant differences between groups in pain symptoms (MPQ Total) and depressive symptoms (PHQ-9). All other group differences were non-significant. Average pain intensity and unpleasantness ratings are also reported in Table 2.

Table 1. Descriptive data of cLBP and healthy adult samples.

	cLBP (n=40)	**HA (n=17)**	***p* value**
Participant Characteristics			
Age	41 ± 10	41 ± 11	0.91
Sex (% female)	68 (27)	58.8 (10)	0.54
Race (% white)	85 (34)	76.5 (13)	0.81
Employment Status (% full-time)	85 (34)	71 (12)	0.06
Marital Status (% married)	70 (28)	71 (12)	0.62
Income (% ≥100,000)	35 (14)	47 (8)	0.36
Education	43 (17)	9 (53)	0.43
PHQ-9	5.5 ± 3.7	1.2 ± 1.7	<0.01*
MPQ Total	8.2 ± 4.5	0.4 ± 0.7	<0.01*
Number of valid AP days	6.2 ± 1.3	7 ± 1.4	0.43
Sitting Time (min/day)	694 ± 92	665 ± 70	0.25
Prolonged sitting (min/day)	247 ± 109	245 ± 74	0.36
MVPA (min/day)	24 ± 16	22 ± 15	0.68

Income: Annual household income. Data are presented as mean ± SD or % (n). p-values represent results of independent sample t-tests between cLBP and Healthy Control; *p≤0.05

Table 2. Average pain intensity and sensitivity ratings for each temperature for cLBP and HA

		41	43	45	47	49
Intensity	cLBP	0.43 ± 1.2	1.4 ± 1.6	4.3 ± 3.6	6.2 ± 4.3	12.2 ± 5.6
	HA	0.24 ± 0.4	0.65 ± 0.95	3.4 ± 2.9	3.9 ± 3.3	11.3 ± 6.1
Unpleasantness	cLBP	0.20 ± 0.69	0.61 ± 1.0	1.8 ± 2.2	4.3 ± 3.6	10.4 ± 5.7
	HA	0.18 ± 0.43	0.15 ± 0.39	0.47 ± 0.62	2.4 ± 2.2	8.9 ± 5.2

Data are mean ± SD of each group at each temperature (°C)

Nonsignificant correlations were found between total SED (Aim 1) and prolonged SED (Aim 2) with pain symptoms, pain intensity at 49°C, and pain unpleasantness at 49°C in individuals with cLBP (Table 3). Person correlation coefficients between total SED and pain variables were all less than 0.1. There were non-significant negative, weak associations between prolonged SED and pain symptoms, pain intensity, and pain unpleasantness.

Table 3. Pearson correlations between pain symptoms and sedentary time in cLBP.

		Total SED	Prolonged SED
Pain Symptoms	Pearson Correlation	.015	-.250
	Sig.	.929	.120
Pain Unpleasantness	Pearson Correlation	-.097	-.091
	Sig.	.550	.577
Pain Intensity	Pearson Correlation	-.008	-.058
	Sig.	.960	.722

Linear regressions were used to examined group differences influence the relationship between SED and pain outcome variables (Aim 3). For pain symptoms (see Table 4), both Model 1 (F(5, 51)=9.258, p<0.001; r2=0.48) and Model 2 (F(9, 47)=5.225, p<0.001; r2=0.50) were significant overall. Group was the only significant predictor in both models (β =-0.685 and -0.721, p<0.000).

Table 4. Pain symptoms Model 1 and Model 2 results.

	Model 1				Model 2			
	B	SE	β	Sig.	B	SE	β	Sig.
(Constant)	9.321	8.955		.303	11.609	9.429		.224
Total SED	.006	.015	.104	.676	.007	.016	.117	.665
Prolonged SED	-.007	.013	-.128	.611	-.008	.014	-.156	.561
Group	-3.864	.598	-.685	<.001*	-4.066	.747	-.721	<.001*
Group x Total SED	-.002	.010	-.066	.798	-.003	.010	-.091	.738
Group x Prolonged SED	.002	.009	.052	.839	4.261E-5	.009	.001	.996
Sex	-	-	-	-	.091	1.209	.008	.940
Age	-	-	-	-	-.015	.060	-.029	.805
PHQ 9	-	-	-	-	-.054	.196	-.039	.783
MVPA	-	-	-	-	-.062	.042	-.186	.145

Pain symptoms (MPQ-Total) dependent variable in both models. Model 1includes only main predictors. Model 2 includes covariates. *p≤0.05

Neither of the models for pain unpleasantness (Table 5) were significant (Model 1: F(5, 51) = 0.769, p=0.576, r2 =0.07; Model 2: F(9, 47) = 1.384, p=0.223, r2 =0.209). Model 1 and Model 2 for pain intensity (see Table 6) were also not significant (Model 1: F(5, 51) = 0.393, p=0.852, r2 =0.04; Model 2: F(9, 47) = 1.032, p=0.429, r2 =0.165). Sex was a significant covariate in both pain unpleasantness (β=0.352, p=0.016) and pain intensity (β=0.303, p=0.041) models.

Table 5. Pain unpleasantness Model 1 and Model 2 results.

	Model 1				**Model 2**			
	B	SE	β	Sig.	B	SE	β	Sig.
(Constant)	7.058	12.622		.579	.671	12.548		.958
Total SED	.007	.021	.108	.745	.006	.021	.091	.788
Prolonged SED	-.002	.018	-.029	.931	-.011	.019	-.199	.555
Group	-.998	.842	-.167	.242	-.714	.994	-.120	.476
Group x Total SED	-.010	.013	-.252	.463	-.009	.013	-.225	.509
Group x Prolonged SED	-.003	.012	-.082	.810	.003	.012	.095	.779
Sex	-	-	-	-	4.026	1.609	.352	.016*
Age	-	-	-	-	.058	.079	.107	.467
PHQ 9	-	-	-	-	.037	.261	.025	.889
MVPA	-	-	-	-	-.007	.055	-.019	.903

Pain unpleasantness dependent variable in both models. Model 1includes only main predictors. Model 2 includes covariates. *p≤0.05

Table 6. Pain intensity Model 1 and Model 2 results.

	Model 1				**Model 2**			
	B	SE	β	Sig.	B	SE	β	Sig.
(Constant)	2.604	13.305		.846	-3.894	13.359		.772
Total SED	.019	.022	.287	.398	.015	.023	.221	.525
Prolonged SED	-.012	.019	-.204	.550	-.019	.020	-.326	.348
Group	-.524	.888	-.085	.558	.130	1.058	.021	.903
Group x Total SED	-.015	.014	-.367	.296	-.013	.014	-.307	.382
Group x Prolonged SED	.005	.013	.123	.723	.011	.013	.295	.398
Sex	-	-	-	-	3.593	1.713	.303	.041*
Age	-	-	-	-	.075	.084	.134	.379
PHQ 9	-	-	-	-	.206	.278	.136	.462
MVPA	-	-	-	-	.014	.059	.039	.809

Pain intensity dependent variable in both models. Model 1includes only main predictors. Model 2 includes covariates. *p≤0.05

Discussion

The purpose of this study was to examine associations between SED (total and prolonged) with pain (both symptoms and sensitivity) and to explore differences between people with and without cLBP. Our results suggest neither total SED nor prolonged SED were associated with pain measures in our sample of individuals with cLBP. Additionally, presence/absence of cLBP did not appear to influence the relationship between SED and pain. Sex was a strong predictor of pain sensitivity, with women experiencing greater pain than men. Therefore, none of our hypothesis were supported. This may suggest that the present project had insufficient power to find significance in predictors of interest due to the sample size and multiple independent variables included in each model. Equally likely, our hypotheses regarding these cross-sectional relationships were incorrect, and instead suggest that further research of changes in SED (i.e. prospective or experimental research) and other behavioral factors (e.g. exercise) may be warranted as they may be more strongly associated with pain symptoms and pain processing in this population.

Nonetheless, these data evaluate novel associations between monitor-assessed SED with self-reported pain symptoms and psychophysical thermal pain sensitivity in people with cLBP. Our results suggest there may not be an association between the amount of time someone is sedentary and their pain symptoms. These results are inconsistent with cross-sectional data showing high self-reported SED is associated with greater self-reported symptoms of low back pain (Hanna et al., 2019). It also differs from psychophysical pain processing data in other chronic pain populations, which found greater SED to be associated with higher pain sensitivity and temporal summation in people suffering from fibromyalgia (Ellingson et al., 2012) and in older adults (Naugle et al., 2017). Intervention studies targeting reductions in SED to improve back pain also report improvement in pain symptoms with reductions in SED (Gibbs et al., 2018; Thorp et al., 2014). Cross-sectional and intervention studies in cLBP published so far, however, lack monitor-assessed SED and psychophysical pain testing. Because of the strong methods used in this study (i.e. activPAL assessed SED, psychophysical thermal pain testing, and pain symptoms questionnaires), these results may be more representative of the true relationship between SED and pain symptoms and processing in this population. Larger studies that employ similar methods in people with cLBP are needed to confirm or refute these findings.

Further, the presence of cLBP did not appear to significantly influence the relationship between SED and pain outcomes (i.e. interaction term between group and SED factors was not significant). While both pain symptom models were significant overall, group was the only significant predictor, which was expected based on cLBP inclusion criteria. Lack of significance of total and prolonged SED in the Model 1 regression for pain symptoms suggests other factors may contribute more to back pain symptom severity. Interestingly, while not significant in this sample, the second strongest predictor in Model 2 was MVPA. This may mean that targeting MVPA would be more influential than targeting SED for improving symptoms of cLBP. Also, changes in SED behavior, rather than current SED level, may be more helpful in treating low back pain symptoms. Interventions targeting increases in MVPA, decreases in SED, or both have reported symptoms improvement corresponding with the change in behavior (Gibbs et al., 2018; Gordon & Bloxham, 2016). However, as mentioned above, published SED intervention studies only utilize self-reported SED measures, with are often subject to misreporting of MVPA and SED. Monitor-assessed data that differentiates between sleep, SED, light intensity activity, and MVPA and changes of these behaviors are needed in activity-based interventions targeting cLBP to determine how these behaviors and their interrelations influence symptoms of back pain.

Similar to results above, presence of cLBP did not influence the relationship between SED and pain sensitivity. Individuals with cLBP commonly report hypersensitivity, however, neither group nor group by SED interactions were predictive of pain sensitivity. Our cLBP sample was slightly more sensitive, on average rating the higher temperatures more painful by ~1 point on the 0-20 scale compared to HA. The relationship between SED and pain sensitivity did not appear to be different for those with cLBP compared to HA, so other factors likely contribute more to the hypersensitivity experienced by patients with cLBP. Sex was the only significant predictor of pain sensitivity in this study. This is consistent with previous psychophysical thermal pain reports that show women have higher pain sensitivity to heat pain, possibly due to hormonal changes with menstruation (also associated with cLBP), differences in central pain modulation, and greater fear of pain before receiving pain stimuli (Wijnhoven et al., 2006; Neziril et al., 2011; Horn, Alappattu, Gay, & Bishop, 2014). Additional research is needed that examines other demographic (including sex), psychosocial, and behavioral factors that influence pain sensitivity in both HA and cLBP to understand which most contribute to hypersensitivity in cLBP.

There were several limitations and strengths of this study. These data were cross-sectional baseline data from a larger intervention study, so this study was not powered to detect significance with the present sample size and number of predictors. Additionally, participants were provided brief instructions about the activity monitor with generic information about what it was assessing before wearing it, so it is possible they changed current activity behaviors because of the surveillance. Activity-related changes over the week could influence pain symptoms, which were subsequently reported. Also, all psychophysical pain testing was conducted by a female researcher so gender stereotypes regarding pain perception may have influenced participant ratings on pain sensitivity tests, despite the research team's effort to minimize this occurrence (e.g., standardized scripts, minimal conversation, professionalism). Nonetheless, there are notable strengths as well. This study used monitor-assessed SED and physical activity behaviors, which adds to current research examining relationships between self-reported SED and pain. The use of psychophysical thermal pain testing and standardization of the heat pain procedures (e.g., introduction to pain testing, standardized scripts, and single researcher administering thermal pain) were also methodological strengths of this study. Additionally, this sample included both healthy, pain-free adults and individuals currently suffering from low back pain to understand differences in pain symptoms and pain processing.

Conclusion

Inconsistent with previous cross-sectional research based on self-reported pain symptoms, this study did not find an association between SED (total or prolonged) and low back pain symptoms or pain sensitivity (unpleasantness or intensity), nor differences in the strength of this relationship for those with or without cLBP. Other behavioral factors may be more strongly associated with symptoms of cLBP, so further studies examining how sleep, SED, light intensity physical activity, MVPA, and their interrelations influence pain symptoms is needed. Comparing our findings with intervention studies that employ similar methods would also be helpful in understanding if changes in SED can influence pain symptoms. Similarly, it is likely other demographic, psychosocial, or behavioral factors, or their changes, contribute to the hypersensitivity experienced by many cLBP patients. Future research should examine the unexpected discrepancy between relationships for self-reported and monitor-assessed SED with pain symptoms and sensitivity.

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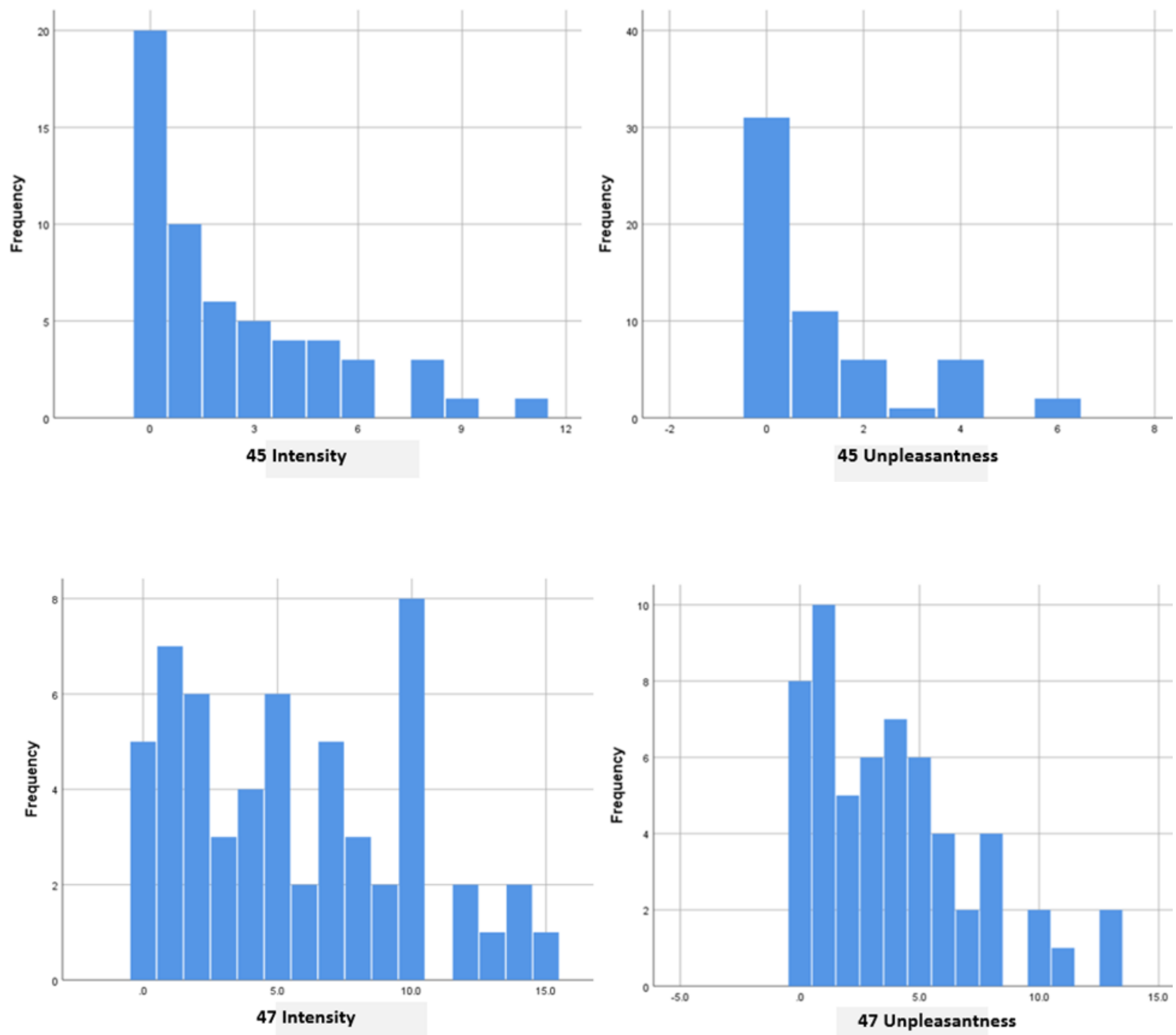
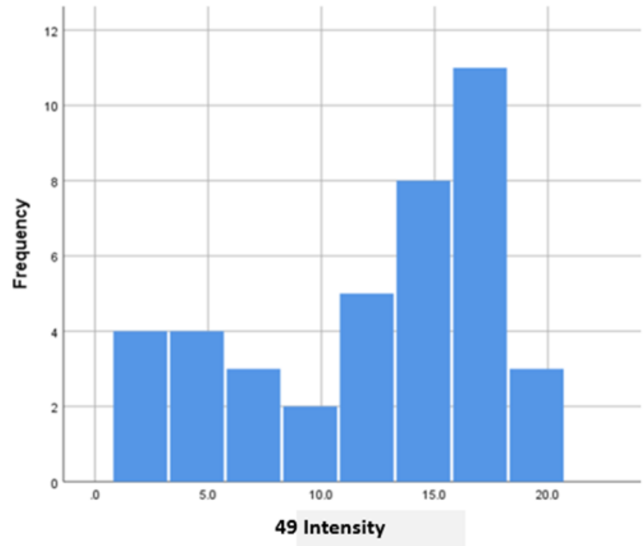
Appendix 1. Pain Histograms

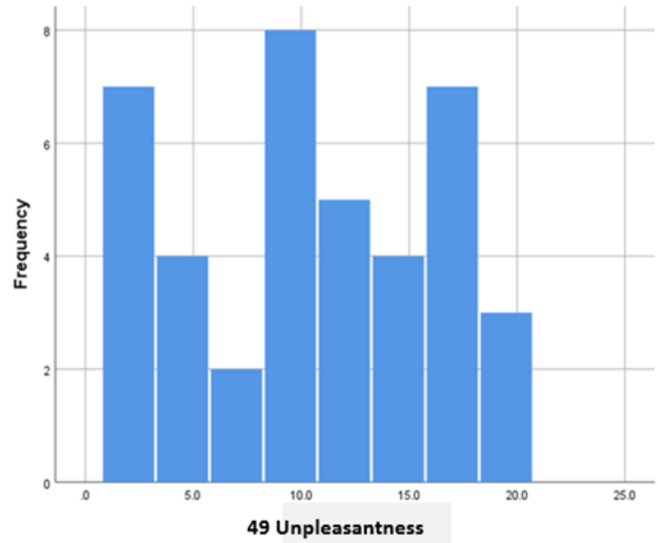
Histograms of ratings of pain intensity and pain unpleasantness for 45□C, 47□C and 49□C. Y-axis shows frequency, or number of participants, and x-axis shows rating scores 0-20. The top histograms show distribution of full sample (n=57), and the bottom histograms show distribution in cBLP sample (n=40).

Full Sample



cLBP Sample


Frequency
12
10
8
6
4
2
0
.0
5.0
10.0
15.0
20.0
49 Intensity


Frequency
8
6
4
2
0
.0
5.0
10.0
15.0
20.0
25.0
49 Unpleasantness

CHAPTER 5. COMPARING SELF-EFFICACY FOR REDUCING SED TO SELF-EFFICACY FOR INCREASING PA

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Abstract

To compare self-efficacy (SE) for increasing moderate to vigorous physical activity (MVPA) with SE for reducing sedentary time (SED). Via electronic survey, adults self-reported SE (0-10 scale) for various types and amounts of increasing MVPA and decreasing SED and reported current physical activity. Self-efficacy for increasing MVPA and decreasing SED by 30 minutes were compared, followed by equivalence testing to compare SE for increasing daily PA (increments of 5, 10, 20 and 30 minutes) to decreasing daily SED (30 minutes, 1, 2, and 3 hours). There was a significant difference in SE for increasing MVPA compared to decreasing SED by 30 minutes (mean difference = -3.74 [-3.54 to -3.94]), with a large effect size (Cohen's d = 1.30). Equivalence testing showed that SE was within 10% for changing 1) +5 minutes/day MVPA with -30 SED minutes/day, 2) +10 MVPA minutes/day with -30 or -60 SED minutes/day, and 3) +30 MVPA minutes/day with -120 SED -minutes/day. On average, individuals reported high confidence in accumulating 5,000 steps/day, standing up and moving each hour, and sitting

fewer than 10 hours/day. Large differences in SE existed for obtaining recommended levels of MVPA between active and inactive adults. Individuals have greater confidence in reducing SED than increasing MVPA by the same amount and feel able to decrease it roughly five-fold compared to increasing MVPA. Adults appear to have greater SE for changing SED than PA, which could result in substantial health benefits. Research comparing health benefits of reducing SED and increasing MVPA at a 5:1 ratio may help determine which is the better intervention target.

Introduction

Behavioral interventions commonly target increasing moderate to vigorous physical activity (MVPA) to improve health outcomes. However, many people are unsuccessful at adopting and/or adhering to national or international MVPA guidelines (Linke, Gallo, & Norman, 2011) and the overall MVPA rates in the US remain low (2018 Physical Activity Guidelines). Exercise self-efficacy (SE) is one's self-confidence for engaging in exercise-related behaviors (Bandura, Freeman, & Lightsey, 1999). Current population levels of MVPA may result from many people having low SE for obtaining recommended levels of physical activity, such as 150 minutes of moderate, 75 minutes of vigorous, or a combination of the two (2018 Physical Activity Guidelines) or other common guidelines such as 30 minutes of MVPA per day. Low levels of exercise SE following failed attempts to be regularly physically active limit the likelihood of people increasing their MVPA in the future (Choi, Lee, Lee, Kang, & Choi, 2017). Thus, exercise self-efficacy is important to consider when attempting to change behavior to improve health.

Behavior-specific self-confidence, or SE, for accomplishing a behavior is associated with engagement in that behavior (Marcus et al., 1992). Higher SE is associated with greater adoption of healthy behaviors, higher frequency of the behavior, and better maintenance of the behavior over time (Lox, 1994; Strecher et al., 1986). In other words, those with greater behavior-specific SE are more likely to begin a new healthy behavior and stick with it. Therefore, understanding perceived SE for activity-related behaviors may help in predicting initiation, adoption, and maintenance of those behaviors and ultimately lead to predicting improvements in health.

High levels of sedentary time (SED) are associated with the presence of chronic conditions and mortality independently of MVPA (Ekelund et al., 2016), and reducing SED is an alternative behavioral approach for improving health outcomes. Sedentary behaviors are defined as waking behaviors with a low energy expenditure (≤1.5 metabolic equivalents (METs)), while in a sitting, reclining or lying posture (Tremblay et al., 2018). Interventions designed to reduce SED tend to have high adherence and retentions rates and are often viewed favorably by participants (Thorp et al., 2014; Thraen-Borowski, Ellingson, Meyer, and Cadmus-Bertram, 2017; Gibbs et al., 2018). While it may be perceived as challenging for individuals to increase moderate and vigorous intensity physical activity (MVPA), they may have greater levels of confidence in their ability to change their sedentary patterns.

However, whether individuals have greater SE for reducing SED compared to increasing physical activity has not been empirically tested. Thus, the primary aims of this study are to 1) compare levels of SE for reducing SED to levels of SE for increasing MVPA in healthy adults, 2) determine what amounts of each behavior people perceive as having similar SE to change, 3) explore which descriptions of change in SED and MVPA are perceived as more attainable, and 4) explore if there are differences in which descriptions feel more attainable based upon current physical activity level. Results of this study will aid in the understanding of where and how perceptions of SE for these two different behaviors differ to help in the development/refinement of more effective behavior change interventions that may lead to better long-term retention, adherence, and health effects.

Methods

Procedures

Participants were recruited via a mass email sent to alumni from Iowa State University. Individuals under the age of 18 were excluded from the study but there were no other exclusionary criteria. Participants completed an online survey which began with the International Physical Activity Questionnaire Short Form (Craig et al., 2003), followed by questions developed specifically for this study inquiring about SE in changing physical activity and sedentary behaviors, and ended with demographic questions. Upon completion of the survey, participants were entered into a raffle to receive a $25 gift card.

Measures

Self-reported physical activity

The International Physical Activity Questionnaire - Short Form (Craig et al., 2003) was used to classify participant levels of MVPA and SED according to the categorical scoring provided by the original IPAQ Research Committee (2005). This measure has demonstrated varying levels of reliability and validity in previous studies, with reliability correlation coefficients ranging from 0.32 to 0.88 and fair to moderate criterion validity (Craig et al, 2003; Lee, Macfarlane, Lam &; Steward, 2011). The short form was selected to limit participant burden and minimize survey fatigue, due to numerous questions within the SE survey, as recommended by previous studies (Craig et al, 2003). From the IPAQ responses, participants were grouped categorically, as low, moderate or high MVPA level.

Self-Efficacy for Changing SED and Physical Activity Survey

The survey used in this study was developed at Iowa State University in the Wellbeing and Exercise Laboratory. Questions were adapted from the Self-Efficacy and Exercise Habits Survey (Sallis, Pinski, Grossman, Patterson, & Nader, 1988). The scale asks participants to rate their level of confidence to complete varying types and amounts of both MVPA and SED that are commonly recommended, to compare SE for each behavior. Each question was rated on a scale from 0 (Not at all Confident) to 10 (100% Confident), similar to the Self-Efficacy for Exercise Scale (Resnick & Jenkins, 2000). Questions for Aim 1 and 2 asked participants to report level of confidence for increasing daily MVPA by 5, 10, 20, and 30 minutes and decreasing daily SED by 30, 60, 120, and 180 minutes. Questions for Aim 3 and 4 asked participants to indicate level of SE for accumulating 150 minutes of MVPA per week and 30 minutes of MVPA per day; accumulate 5,000, 7,500, and 10,000 steps per day; sit fewer than 6, 8, 10, and 12 hours each day; stand up and move at least once each hour; and accumulate 250 steps each hour of the day. Two versions of the survey were created to counterbalance for the order that MVPA and SED questions were asked (version 1: all MVPA questions first; version 2: all SED questions first). Birth month was used to pseudo-randomize order, with all who responded their birthday was in January-June receiving version 1 and July-December receiving version 2. Survey instructions and questions used in this study are provided in Appendix 1. Prior to data collection, the survey was reviewed by a panel of experts in physical activity, SED, and health promotion for content validity.

Pilot data were obtained to explore the reliability of this survey in a sample of university-affiliated adults (n=1,704). Aim 1 and 2 questions, excluding the question regarding confidence in 5 minutes of MVPA (added after), demonstrated high internal consistency, with Cronbach's Alpha of 0.88. The intraclass correlation was 0.879, with a 95% Confidence Interval from 0.870

to 0.888. Aim 3 and 4 questions also demonstrated high internal consistency (Cronbach's α= 0.93, ICC=0.93, CI [0.925-0.935]).

Demographic Questions

Participants self-reported age, gender, race, education, marital status, employment status, and household income.

Statistical Analysis

Analyses were completed using R 3.6.3 (R Core Team, 2018) and R studio (R Studio Team, 2015), and the full reproducible code will be available as supplementary material with the published manuscript. Survey data were checked for completeness and data were excluded if participants did not respond to at least 1 question examined in Aim 1 or Aim 2. Within this sample, missingness of the remaining data was graphically explored for the entire survey and for questions used in Aim 1 and Aim 2 individually. Chi-square tests were used to determine if there was evidence to suggest a dependence between missingness on Aim 1 and Aim 2 questions and the demographic variables, using a Bonferroni correction to account for multiplicity with significance set at 0.00045 for Aim 1 (8 SE questions, 14 demographic questions) and 0.00032 (11 SE questions, 14 demographic questions). Additionally, data were removed if uninterpretable (e.g., invalid age) or excessive physical activity or sitting on IPAQ-SF was reported (PA>960 minutes/day, sitting>20 hr/day) (IPAQ Research Committee, 2005).

After data cleaning, descriptive statistics of demographic information and activity level were used to characterize the sample, with means and standard deviations used for continuous variables and proportions for categorical variables.

To examine Aim 1 of the study, a paired t-test was used to evaluate differences in SE for increasing 30 minutes of MVPA compared to decreasing SED by 30 minutes each day. Cohen's d was used to examine the magnitude of differences (Cohen, 1988), using thresholds of 0.20 as small, 0.50 as moderate, and 0.80 as large effect sizes.

To examine Aim 2, equivalence testing was used to compare SE for increasing MVPA by 5, 10, 20 and 30 minutes to SE for decreasing SED by 30 minutes, 1, 2, and 3 hours, for a total of 16 comparisons. First, to evaluate a potential order effect (i.e. from participants receiving all MVPA or SED questions asked first), 2 mixed linear regressions were computed and compared. Model 1 included question, participant ID (used as a random effect variable to account for dependence of observations from the same person), and survey question order (to examine order effect). Model 2 included only question and participant ID. The akaike information criterion (AIC) in Model 2 was smaller than Model 1 and question was highly significant in both models ($p<0.001$) while question order was not significant in Model 1 ($p=0.88$). Based on the AIC and non-significance of question order, there was not evidence of a question order effect. Thus, pairwise difference tests were selected to evaluate equivalence and conducted (using emmeans R package) with a 90% confidence intervals associated with each difference. For these comparisons, the null hypothesis (of nonequivalence) was rejected if mean scores of SE were within 10% of one another (i.e. using a 90% CI). Post hoc analyses were performed using Tukey methods to adjust for multiple comparisons between the 4 MVPA and 4 SED questions.

To explore Aim 3, means and standard deviations of the questions that inquire about different types (e.g., steps per day, minutes of MVPA per day) and amounts (e.g., 5,000 steps, 10,000 steps) of activity and SED were computed. All secondary questions that were assessed are reported along with results in Table 2.

For Aim 4, means and standard deviations of Aim 3 questions were computed based on physical activity group to examine differences between those who reported low, moderate, and high MVPA levels.

Results

From the mass email, 1272 individuals responded and completed the survey. Of these responses, 276 did not respond to any of the perspective questions and were excluded, leaving 996 individuals who responded to at least 1 SE question used in Aim 1 or Aim 2. Dependence of missingness on demographic characteristics was not found. Therefore, data were considered to be missing completely at random and non-responses were excluded from analyses for Aim 1 (n=940) and Aim 2 (n=921-942, depending on question).

The demographics and physical activity levels for all participants are summarized in Table 1. Briefly, this sample varied in age (44 ± 16) and gender (54% male) but was primarily white (87%), educated, and financially secure. Fifty percent of participants reported a high activity level, with 36% and 14% reporting moderate and low activity levels, respectively.

Table 1. Participant Characteristics for full sample (n=996).

	M ± SD or n(%)
Gender (% male)	540 (54)
Age	44 ± 16
Race (% white)	862 (87)
Employment (% employed for wages)	594 (60)
Marital Status (% married)	675 (68)
Household Income (% > $100,000)	430 (43)
Education (% college degree)	424 (43)
Physical Activity Level (n=985)	
Low Active	120 (12)
Moderate Active	362 (36)
High Active	503 (50)

Aim 1

There was a significant difference in confidence for increasing MVPA by 30 minutes compared to decreasing SED by 30 minutes (t(939)= -36.932, p<0.0001), with a large effect size difference (d = 1.30). Despite varying levels of confidence for increasing MVPA, most reported high confidence for reducing SED (Figure 1).

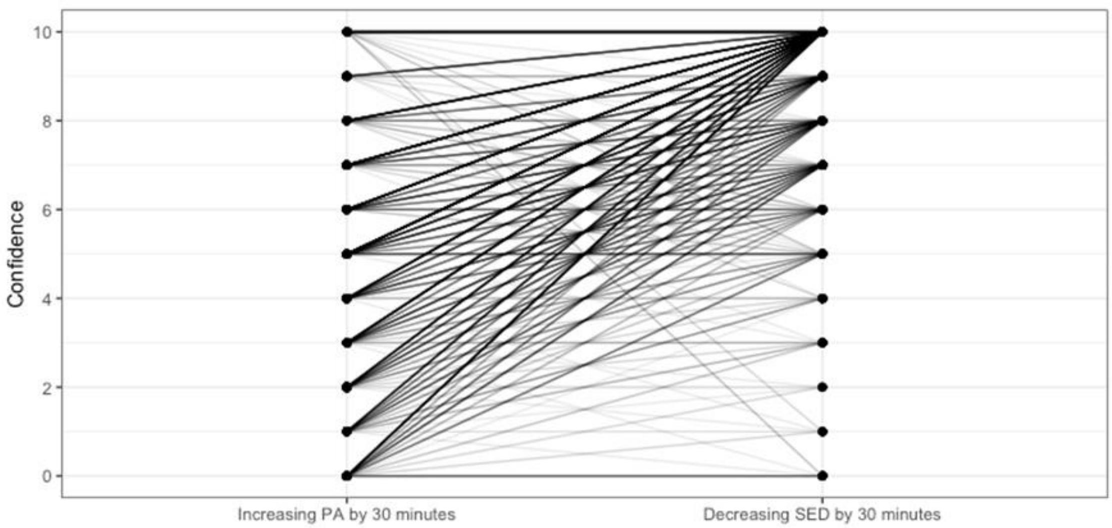

Figure 1. Confidence level of each individual for increasing PA by 30 minutes and decreasing SED by 30 minutes. A line connects the observations associated with an individual (e.g., level of confidence for increasing MVPA by 30 minutes connects to level of confidence for decreasing SED by 30 minutes reported by one individual). Darker lines indicate more individuals with that response pairing.

Aim 2

Equivalence testing showed that confidence was equivalent (i.e., within 10% for changing 1) increasing 5 minutes/day MVPA with decreasing 30 SED minutes/day, 2) increasing 10 MVPA minutes/day with decreasing 30 or 60 SED minutes/day, and 3) increasing 30 MVPA minutes/day with decreasing 120 SED -minutes/day, shown in Figure 2. A table of the contrasts, their estimates, and the corresponding 90% confidence interval are provided in Appendix 2.

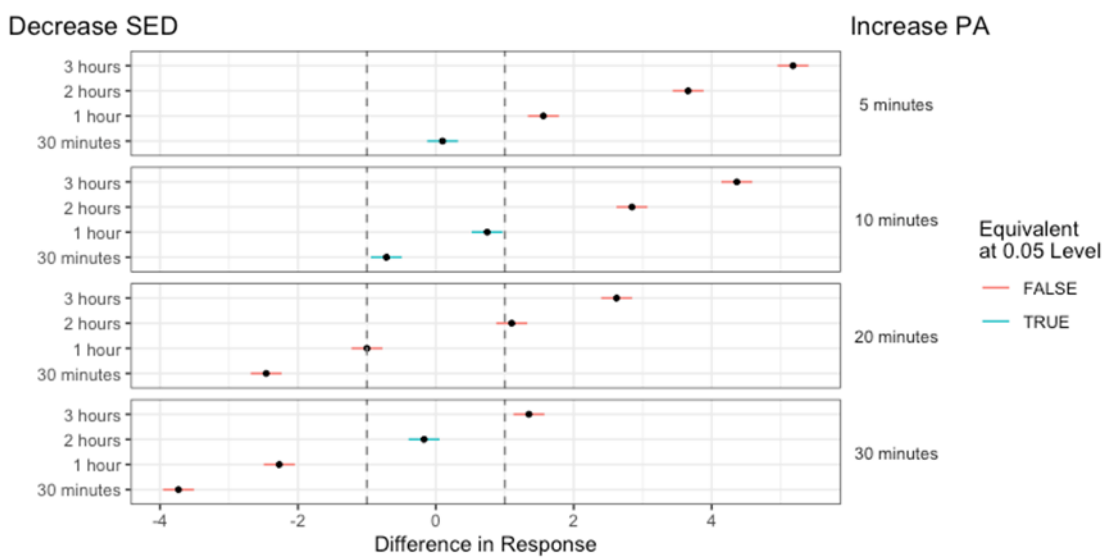

Figure 2. Confidence intervals for pairwise differences. Confidence intervals for each pairwise difference (mean of MVPA category minus mean SED category), grouped by MVPA change amount. Color specifies if differences fall within equivalence margins.

Aim 3

Means and standard deviations for each question are reported in Table 2 for the entire sample. In general, individuals high levels of SE (mean confidence >8 on 0-10 scale) in their ability to accumulate 5,000 steps/day, stand up and move each hour of the day, and sit fewer than 12 or 10 hours/day; however, there was substantial variability in responses. Participants had the lowest SE (mean confidence <6) in sitting for fewer than 6 hours/day and accumulating 10,000 steps /day.

Table 2. Summary statistics of Aim 2 questions.

Survey Question	**N**	**Mean SE**	**SD**
I can accumulate at least 150 minutes of moderate to vigorous physical activity each week.	937	7.5	2.8
I can accumulate at least 30 minutes of moderate to vigorous activity every day.	940	6.7	2.8
I can accumulate 10,000 total steps every day.	939	5.9	3.2
I can accumulate 7,500 total steps every day.	933	7.4	2.7
I can accumulate 5,000 total steps every day.	937	8.8	2.1
I can sit for fewer than 12 hours each day.	942	8.9	2.0
I can sit for fewer than 10 hours each day.	935	8.3	2.3
I can sit for fewer than 8 hours each day.	921	6.8	2.9
I can sit for fewer than 6 hours each day	928	5.2	3.4
I can stand up and move at least once during each hour of the day.	942	8.9	1.8
I can reduce my SED by accumulating at least 250 steps each hour of the day.	940	6.7	2.7

Aim 4

Confidence for meeting movement-based targets appeared to be influenced by current physical activity level, but little association between current activity and confidence for sedentary targets was apparent (Figure 3). Individuals who reported high levels of activity reported being very confident in accumulating 150 minutes of MVPA/week and 30 minutes of MVPA/day. Individuals who reported low MVPA reported low levels of confidence for accumulating 150 minutes of MVPA/week and 30 minutes of MVPA/day. A table of means and standard deviations are presented in Appendix 3.

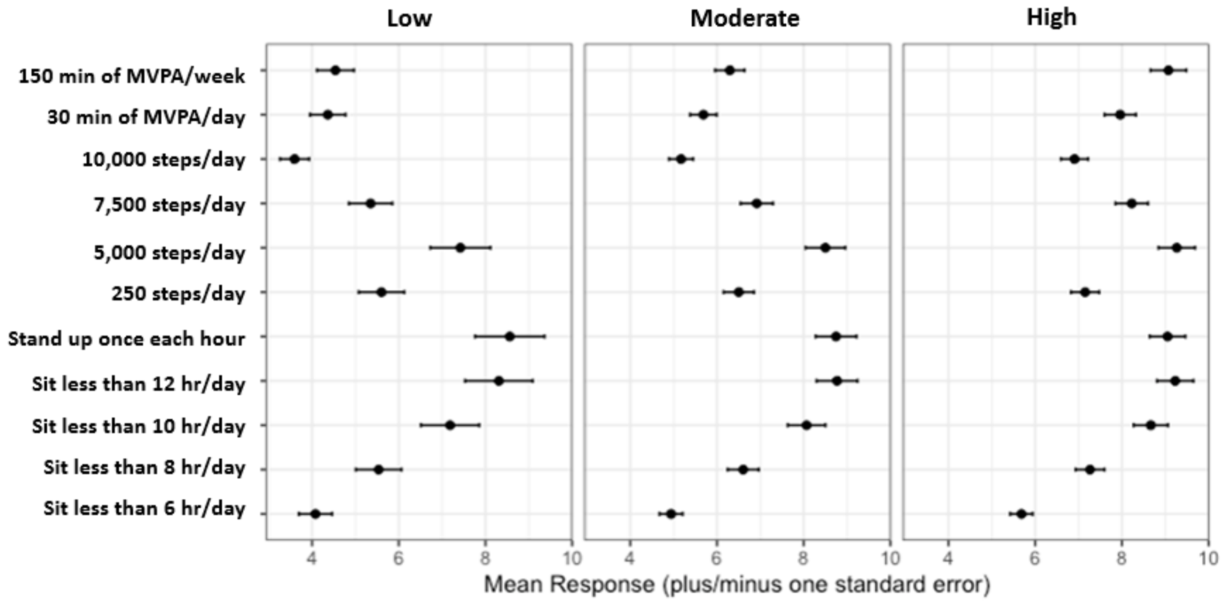

Figure 3. Dot and whisker plot of responses grouped by current activity level. Data are mean SE (rated 0-10) for each Aim 3 question with standard error bars for those who reported low, moderate and high activity levels on IPAQ-SF.

Discussion

The purpose of this study was to compare levels of SE for increasing MVPA to levels of SE for reducing SED. The present results indicate that adults have substantially more SE in their ability to reduce SED compared to increasing MVPA each day. Perceived SE for increasing MVPA by 30 minutes per day varies greatly between individuals, however, most people are very confident in their ability to reduce sitting each day by 30 minutes, with a very large effect size difference between the two (d=1.30). Moreover, individuals felt similarly confident that they could decrease SED by 30 minutes compared to increasing PA by 5 minutes/day, decrease SED by 1 hour compared to increase PA by 10 minutes/day, and decrease SED by 2 hours compared to increasing PA by 30 minutes/day. People appeared more confident with descriptions of activity that are step or SED oriented, regardless of current activity level. Those who were inactive, however, had low SE for obtaining recommended levels of MVPA each day compared to those who were active.

Individuals felt more able to reduce SED rather than increase MVPA, which may lead to greater changes in behavior and health over time. The health outcomes associated with changing the same amount of MVPA or SED are not equivalent, and data indicate that MVPA may be the most "potent health-enhancing behavior" per 30 minutes (Buman et al., 2014), and small increases can have considerable health enhancing effects (Moore, Patel, & Matthews, 2012). Yet, about 80% of US adults are inactive or insufficiently active, and therefore not obtaining the majority of the benefits of being active (2018 US Physical Activity Guidelines Report). There are noteworthy and positive benefits from reducing SED, and isotemporal substitution studies have investigated how replacing SED with other activity-related behaviors (i.e. sleep, light-intensity activity, or MVPA) influences health. Buman and colleagues (2014) found that substituting 30 minutes of SED with sleep, light activity or MVPA led to improvements in biomarkers associated with cardiovascular disease. Other studies also show replacing 30 minutes of SED with sleep, light activity or MVPA is associated with improvement in cognitive functioning, mood, stress, and sleep (Fanning et al., 2017; Ellingson et al., 2018; Meyer et al., 2020). Since our results suggest individuals have greater SE for reducing SED, focusing on this behavior may lead to greater changes in behavior, which may, over time, yield important improvements in health for people who feel unable to increase MVPA.

Where amounts of increasing MVPA and amounts of decreasing SED have matching health effects are largely unknown. Equivalence testing in this study matched where SE for increasing MVPA is the same for SE for decreasing SED, with SE for increasing MVPA by 1 minute roughly similar to SE for decreasing SED by 4-6 minutes. People feel confident in reducing SED by an amount roughly 5 times greater than increasing MVPA, so understanding how smaller changes in MVPA relate to larger changes in SED is of importance. The 2018 US Physical Activity Guidelines Report provides a heat map of the risk of all-cause mortality based on changing MVPA and/or SED (Figure 1-3, page 22), and shows how improvements in health change by increasing MVPA, decreasing SED, or a combination of these behaviors, with greater changes observed from increases in MVPA compared to decreases in SED (data from Ekelund, Steene-Johannessen, Brown, 2016). Where specific amounts of these behavior changes (e.g., increase MVPA 30 minutes/decrease SED 2 hours) have the same magnitude of effect on health (e.g., decrease risk of mortality by 5%) warrants further research and may be important in refining both SED and MVPA guidelines.

Participants had high SE for achieving step goals (e.g., 5,000 steps/day) and total SED (e.g., <10 or 12 hrs/day). Using behavioral goals based on these descriptions may help to facilitate activity-related behavior change, especially in inactive adults. Those with low MVPA had substantially lower SE for meeting daily and weekly physical activity recommendations and higher step goals (e.g., increase 10,000 and 7,500 steps/day) compared to those with high current MVPA levels. This aligns with the framework for physical activity guidelines for inactive and insufficiently active adults, which suggest reducing SED and any small increases in MVPA as beneficial targets for behavior change (2018 Physical Activity Guidelines). Focusing on SED-related outcomes inherently increases sleep, light activity, and/or MVPA, all of which are generally beneficial to health (Keadle et al., 2017). However, SE for achieving SED-related targets (<6, 8, 10 or 12 hrs/day) appeared to be similar between high and low MVPA groups, suggesting while "Do what you can" type promotion may be appropriate for MVPA, providing people with specific, time-based recommendations for SED may be more effective in promoting reductions in SED instead of to “Sit less.”

This study has several strengths and limitations. With regard to strengths, this study presents data from a large sample and includes self-reported physical activity and SE to meet a number of behavioral targets to investigate perspectives of messages from individuals at different current MVPA levels. It adds empirical evidence to previous assumptions that reducing SED is perceived as more achievable than increasing MVPA. Even so, there are several limitations. First, while a large sample, it is not representative of the total US population and data from other regions of the US that include greater diversity are needed. In addition, 86% of this sample reported being moderate or highly active, while only 14% reported low activity levels, which is slightly higher than other self-report physical activity data in US adults, where 60% self-report meeting MVPA guidelines (Tucker, Welk, & Beyler, 2011). Since individuals frequently over-report activity levels on self-report MVPA tools, future research exploring perceptions of activity in combination with monitor-assessed MVPA and SED is needed.

Conclusions

Individuals have greater SE for reducing SED than increasing MVPA by the same amount and feel able to decrease it roughly five-fold compared to increasing MVPA. As adults had similar confidence in meeting daily SED targets regardless of how active they were, achieving daily SED recommendations may be feasible for both those who are and those who are not currently physically active. The health benefits of reducing SED are well documented, and adults appear to have high SE for reducing SED, which could result in greater behavior change than attempting to increased MVPA and still confer substantial health benefits. The amount of change in each behavior that is required to achieve the same health benefits is not currently clear and warrants further research. Understanding the relative impact on health of SED and MVPA and then interfacing this with levels of SE for changing both MVPA and SED would help in focusing efforts on the most potentially impactful behavior changes. Understanding SE for changing SED and MVPA will aid in developing tailored messages and goals about behavior that may more consistently lead to adoption of behavior and improved health.

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Appendix 1. Self-Efficacy for Altering SED vs PA Survey

Self-Efficacy for Altering SED vs PA Survey

The following questions are intended to ask about your confidence in your ability to do several types of activities.

- When questions ask about **'moderate to vigorous activities'**, we define this as those activities that take physical effort and make you breathe harder than normal. You may break a sweat and feel your heartbeat much faster while doing these activities. Examples of these activities are brisk walking, swimming at a regular pace, gardening, running, fast swimming, and playing competitive soccer.
- **Resistance exercise** is physical activity that is designed to improve muscular fitness by exercising a muscle or a muscle group against external resistance. Squats, push-ups and sit-ups are examples of resistance exercise.
- **Sedentary behavior** is defined as any waking behavior done while sitting, reclining or lying down that requires little physical effort. Common sedentary behaviors include working at a desk, watching television, and playing video games in a seated or lying position.

Use the scale below to answer each of the following questions. The scale has the anchors of 0, indicating not at all confident, and 10, indicating entirely confident (100%). Please select the number that best represents how you feel right now.

Not at all Confident **Somewhat Confident** **100% Confident**

0 1 2 3 4 5 6 7 8 9 10

How confident are you that you can do the following?

Change-related questions

1. I can increase my moderate to vigorous physical activity by 5 minutes each day.
   a. I can increase my moderate to vigorous physical activity by 10 minutes each day.
   b. I can increase my moderate to vigorous physical activity by 20 minutes each day.
   c. I can increase my moderate to vigorous physical activity by 30 minutes each day.

2. I can increase the number of steps I take by 500 (equivalent to about 0.25 miles) each day.
   a. I can increase the number of steps I take by 1000 (~0.5 miles) each day.
   b. I can increase the number of steps I take by 2,000 (~1 mile) each day.
   c. I can increase the number of steps I take by 3,000 (~1.5 miles) each day.

3. I can reduce the total amount of time I spend sitting by 30 minutes each day.

a. I can reduce the total amount of time I spend sitting by 1 hour each day.
b. I can reduce the total amount of time I spend sitting by 2 hours each day.
c. I can reduce the total amount of time I spend sitting by 3 hours each day.

4. Prolonged SED is time spent seated or lying down while awake without getting up for extended periods of time (e.g., 30 or more minutes). Standing up to stretch or walking to use the restroom or get a drink of water are examples of ways to break up prolonged SED. Think about the time each day that you spend sitting for longer than 30 minutes. How confident you are that you could break up these prolonged periods of SED?
    a. I can break up prolonged SED at least 1 more time each day.
    b. I can break up prolonged SED at least 2 more times each day.
    c. I can break up prolonged SED at least 5 more times each day.
    d. I can break up prolonged SED at least 10 more times each day.

5. I can do resistance exercises at least 1 more time a week.
    a. I can do resistance training exercises at least 2 more time a week.
    b. I can do resistance training exercises at least 3 more times a week.

Outcome-related questions

1. I can accumulate 5,000 total steps every day.
    a. I can accumulate 7,500 total steps every day.
    b. I can accumulate 10,000 total steps every day.

2. I can accumulate at least 150 minutes of moderate to vigorous physical activity each week.

3. I can accumulate at least 30 minutes of moderate to vigorous activity every day.

4. I can stand up and move at least once during each hour of the day.

5. I can reduce my SED by accumulating at least 250 steps each hour of the day.

6. I can sit for fewer than 12 hours in total each day.

    a. I can sit for fewer than 10 hours each day.
    b. I can sit for fewer than 8 hours each day.

I can sit for fewer than 6 hours each day.

Appendix 2. SED vs PA Confidence Intervals

Table of Aim 1 contrasts, their estimates, and the corresponding 90% confidence intervals (adjusted using Tukey's method).

Contrast	Estimate	SE	LCL	UCL
pa_5min - pa_10min	0.8146452	0.0805058	0.5908485	1.0384420
pa_5min - pa_20min	2.5585105	0.0806191	2.3343987	2.7826224
pa_5min - pa_30min	3.8301283	0.0806612	3.6058997	4.0543570
pa_5min - sed_30min	0.0976233	0.0806476	-0.1265675	0.3218142
pa_5min - sed_1hr	1.5592385	0.0809957	1.3340798	1.7843971
pa_5min - sed_2hr	3.6586594	0.0808660	3.4338614	3.8834574
pa_5min - sed_3hr	5.1796580	0.0808426	4.9549248	5.4043911
pa_10min - pa_20min	1.7438653	0.0805301	1.5200008	1.9677297
pa_10min - pa_30min	3.0154831	0.0805783	2.7914847	3.2394815
pa_10min - sed_30min	-0.7170219	0.0805511	-0.9409446	-0.4930992
pa_10min - sed_1hr	0.7445932	0.0808846	0.5197434	0.9694430
pa_10min - sed_2hr	2.8440142	0.0807696	2.6194842	3.0685441
pa_10min - sed_3hr	4.3650127	0.0807462	4.1405476	4.5894778
pa_20min - pa_30min	1.2716178	0.0806845	1.0473244	1.4959112
pa_20min - sed_30min	-2.4608872	0.0806720	-2.6851458	-2.2366285
pa_20min - sed_1hr	-0.9992721	0.0810201	-1.2244985	-0.7740456
pa_20min - sed_2hr	1.1001489	0.0808904	0.8752831	1.3250147
pa_20min - sed_3hr	2.6211474	0.0808598	2.3963665	2.8459284
pa_30min - sed_30min	-3.7325050	0.0807202	-3.9568979	-3.5081121
pa_30min - sed_1hr	-2.2708898	0.0810684	-2.4962506	-2.0455291
pa_30min - sed_2hr	-0.1714689	0.0809387	-0.3964690	0.0535312
pa_30min - sed_3hr	1.3495297	0.0809081	1.1246145	1.5744448
sed_30min - sed_1hr	1.4616151	0.0809278	1.2366453	1.6865850
sed_30min - sed_2hr	3.5610361	0.0807910	3.3364464	3.7856258
sed_30min - sed_3hr	5.0820346	0.0807678	4.8575096	5.3065597
sed_1hr - sed_2hr	2.0994210	0.0811384	1.8738656	2.3249763
sed_1hr - sed_3hr	3.6204195	0.0811152	3.3949287	3.8459103
sed_2hr - sed_3hr	1.5209986	0.0809598	1.2959398	1.7460573

Appendix 3. SED vs PA Means and Standard Deviations

Table of means and SD for each Aim 3 questions by group.

Activity Level	Question	Mean	SD
High	150 min of MVPA per week	9.1	1.6
	250 steps each hour	7.2	2.6
	30 min of MVPA per day	7.9	2.3
	Sit less than 10 hours/day	8.7	1.9
	Sit less than 12 hours/day	9.2	1.6
	Sit less than 6 hours/day	5.7	3.4
	Sit less than 8 hours/day	7.3	2.8
	Stand up once each hour	9.1	1.7
	10,000 steps each day	6.9	2.9
	5,000 steps each day	9.2	1.7
	7,500 steps each day	8.2	2.4
Moderate	150 min of MVPA per week	6.3	2.8
	250 steps each hour	6.5	2.5
	30 min of MVPA per day	5.7	2.5
	Sit less than 10 hours/day	8.1	2.4
	Sit less than 12 hours/day	8.8	2.2
	Sit less than 6 hours/day	4.9	3.2
	Sit less than 8 hours/day	6.6	2.9
	Stand up once each hour	8.7	1.9
	10,000 steps each day	5.2	2.9
	5,000 steps each day	8.5	2.1
	7,500 steps each day	6.9	2.6
Low	150 min of MVPA per week	4.5	3.0
	250 steps each hour	5.6	2.7
	30 min of MVPA per day	4.4	2.6
	Sit less than 10 hours/day	7.2	2.9
	Sit less than 12 hours/day	8.3	2.4
	Sit less than 6 hours/day	4.1	3.3
	Sit less than 8 hours/day	5.5	3.3
	Stand up once each hour	8.6	1.8
	10,000 steps each day	3.6	2.8
	5,000 steps each day	7.4	2.7
	7,500 steps each day	5.4	2.9

CHAPTER 6. A QUALITATIVE ANALYSIS OF BARRIERS AND FACILITATORS TO REDUCING SEDENTARY TIME IN ADULTS WITH CHRONIC LOW BACK PAIN

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Abstract

Sedentary time (SED) is associated with many health outcomes, yet little is known about what factors influence one's ability to reduce SED. Even less is known about factors that influence the ability to reduce SED in specific populations who frequently report higher levels of SED, such as those with chronic low back pain (cLBP). The purpose of this study was to qualitatively explore participants' perceptions of factors that influenced their ability to reduce SED across an 8-week intervention to reduce total SED and SED in prolonged bouts for adults with cLBP. Three months after a theory-based intervention to break up and reduce sitting, semi-structured interviews explored factors that influenced reducing SED. Three researchers independently coded each conversation. Codes were then charted and mapped with participants reviewing their own transcripts and the merged codes. The research team then defined key

themes. Factors that were perceived to either facilitate behavior change or acted as barriers were identified and thematized as positive or negative determinants. Common barriers for reducing SED included environmental constraints, opposing social norms, and productivity; these barriers were frequently encountered in the workplace environment. Notably, back pain was not a frequently reported barrier. Common facilitators for reducing SED included habit development, self-monitoring tools, restructuring the physical environment, and social accountability. This sample of patients with cLBP had similar determinants for reducing SED as has been reported in non-patient populations and did not appear to need strategies specific to dealing with chronic pain. As work-related social norms and environmental factors were perceived as significant barriers to sitting less, workplace interventions that provide standing desks, offer standing meetings rooms, and/or institution-wide standing breaks may help reduce SED at work. The use of an activity monitor with sitting reminders and education regarding how to use the reminders as external cues to develop new sitting habits may also aid in adoption and adherence to this behavior change. Developing coping plans and finding ways to restructure physical environments were successful strategies implemented to overcome social and environmental barriers. Future interventions targeting SED reductions may benefit from incorporating these strategies.

Introduction

Recent data show that US adults are spending more of their time sedentary (Du et al., 2019). High sedentary time (SED) is associated with many health conditions including chronic pain (Grøntved & Hu, 2011; Patterson et al., 2019; Citko et al., 2018; Hannah et al, 2019). To effectively target reducing SED, a better understanding of factors that influence this set of behaviors is needed. While the research on determinants for increasing physical activity is vast across a variety of populations (Bauman et al., 2012), factors that influence reducing SED are less understood.

To date, research on determinants for reducing SED has focused primarily on demographic factors and correlates, rather than qualitatively asking individuals about factors they believe influence their sitting behaviors and their potential for change (Chastin et al., 2015; O'Donoghue et al, 2016; Buck et al., 2019). Further, the majority of qualitative studies evaluating SED have focused on healthy and/or older adults (Chastin et al., 2014; Greenwood-Hickman et al., 2015) who may have different perspectives than clinical populations, such as adults with chronic low back pain (cLBP). At present, no studies have been published that examine determinants for decreasing SED in individuals with cLBP, which is among the top five leading causes of disability worldwide (Vos et al., 2017).

Reducing SED may be especially relevant for individuals with cLBP, as high levels of SED are a risk factor for the development of cLBP (Citko et al., 2018; Hanna et al., 2019) and decreasing SED has been associated with improvements in back pain (Ojeben et al, 2016; Gibbs et al., 2018). To date, sedentary interventions have employed several behavior change strategies including habit theory and mHealth. Theoretically, these strategies may be particularly helpful for reducing SED by modifying individual micro-environments through creating reminders (e.g. cues from wearable technology) to stand and move, providing real-time feedback of the behavior, and/or generating friction against sitting (Ellingson et al., 2019; Rothman et al., 2015). However, the utility of these approaches from the patient's point of view is unclear as no studies have explored patient perspectives of the effectiveness of strategies like habit development and wearable technology following their attempts to implement these strategies to reduce SED.

Qualitative insight into the challenges that participants encounter during SED interventions, both in the initial adoption and maintenance phases, may provide valuable information about barriers and facilitators to changing SED. This information can then be used for developing interventions that are feasible from the patient perspective, lead to sustained SED behavior change, and ideally result in symptom improvement in individuals with cLBP. Therefore, the purpose of this study was to qualitatively examine patient-reported factors influencing their ability to reduce SED 3-months after an 8-week SED intervention for adults with cLBP.

Methods

Procedures

Data for this study were collected from participants who completed a theory-informed intervention targeting reductions in SED and improvements in symptoms of cLBP. In this study, participants completed a pre-intervention visit, an 8-week SED intervention, and a post-intervention visit. During the pre/post intervention visits, data regarding cLBP symptoms, sitting habits, and SED were collected. The SED intervention included provision of a commercial activity monitor (Fitbit Alta, Fitbit Inc., San Francisco, CA) and two sessions with a health coach trained in Motivational Interviewing, occurring immediately before the intervention period and at 4 weeks. During the first session, participants discussed their current sitting behaviors informed by data from 7 days of wearing an activPAL3 (PAL Technologies, Glasgow, Scotland, UK). These data revealed information regarding the time(s) of day and durations that most sitting occurred over the previous week. Additionally, health risks of prolonged sitting, strategies for changing sitting habits and developing new habits of sitting less (e.g. implementation of internal and external cues), and personal motivations for changing this behavior were discussed.

During the intervention, participants were instructed to reduce total SED per day and break up prolonged sedentary periods. To facilitate breaking up prolonged sedentary periods, they were specifically instructed to accumulate 250 or more steps in 8 or more hours of the day using the idle alert on the activity monitor as a reminder and external cue. Compliance to this 8 hour/day goal was monitored weekly by the study team and participants were contacted and reminded of these intervention requirements if they were not meeting them.

Three months after the intervention, after follow-up data were collected, participants completed a semi-structured phone interview with their health coach about factors that influenced their ability to reduce SED during the intervention. These conversations were recorded using an audio recording platform (Zoom Local Recorder, Zoom Video Communications, San Jose, CA) and stored for transcription.

Measures

Qualitative Interview

Semi-structured interviews were used to collect data for this study. A standard set of questions was used to guide conversations, with the interviewer modifying the interview with follow-up questions and/or probes based on participant responses (see interview script in Appendix 1). The questions chosen for this specific interview were selected based on study objectives and previous qualitative semi-structured interviews investigating determinants of sedentary time (Chastin, Fitzpatrick, Andrews, & DiCroce, 2014). Experts in exercise, health, and social psychology reviewed the questions to ensure appropriate language was used and questions aligned with study objectives.

Descriptive Health, Activity, and Habit Questionnaires

Descriptive data used in this study were collected with several measures before and after the intervention. A baseline demographic questionnaire was administered to characterize the sample, with respect to age, sex, race, education, marital status, occupational status, household income. The Minimal Data Set for Chronic Low Back Pain was used to quantify symptoms of cLBP and impact on daily life, as recommended in the Report of the NIH Task Force on Research Standards for Chronic Low Back Pain (Deyo et al, 2014). Scores on this questionnaire range from 8 (mild impact) to 50 (severe impact). The SIT-Q-7d was used to assess self-reported SED over 7 days in different domains, including eating meals, occupational, transportation, household/leisure activities, and screen-based activities (Wijndaele, 2014). Habit development was assessed using the Self-Reported Habit Index (SRHI) (Verplanken & Orbell, 2006). The SRHI includes 12 items scored on a Likert scale with anchors ranging from strongly agree (1) to strongly disagree (7), indicating strong habits (total score of 12) to weak habits (total score of 114). The behaviors included in this study were “frequently standing up,” “sitting when I could stand,” and “breaking up long bouts of sedentary activity,” with participants responding to all 12 items for each of these behavior prompts (3 prompts with 12 items each for a total of 36 responses).

Monitor-Assessed Activity

Physical activity and SED were assessed using activPAL3 activity monitors. The monitors were worn for 7 days (24 hours/day) one week prior to the start of the intervention and during the final week of the intervention. These are small triaxial accelerometers that are worn on the thigh and classify wear time as sedentary, upright or stepping. PALanalysis (version 8), the manufacturer’s associated software, provided data and graphics of total SED and different bout lengths of SED each day the monitor was worn, which were shared with participants during their first health coach session to educate them regarding their sitting behaviors. In previous studies, the activPAL3 has demonstrated excellent validity compared to direct observation for assessing SED and physical activity in free-living conditions (Lyden, Keadle, Staudenmayer, & Freedson, 2017).

Analysis

Descriptive statistics were calculated regarding participant characteristics and from pre/post intervention data to provide supplementary information regarding changes in habit development, self-reported SED, and monitor-assessed SED pre and post intervention.

A thematic analysis was used to identify key themes from the structured interviews, following processes recommended by Miles, Huberman, and Salacia (2014). Each interview was transcribed and independently cross-checked for errors. Three researchers (JL, KD and GC), responsible for coding the conversations, jointly created a deductive codebook (see Appendix 2) based on theoretical constructs used in the SED intervention (e.g. cues: habit theory; self-monitoring: mHealth) and previous literature of determinants of SED (e.g. social norms, environmental constraints, physical discomfort) to guide initial coding.

Following this, coders familiarized themselves with the data by reading each transcript several times. Coders then separately identified codes for each conversation, while refining codes and definitions in the codebook. After coding was complete, each participant was sent their coded transcription (with merged comments from all 3 coders) to review and provide corrections and/or clarification on their comments. Feedback from participants was then discussed by all three coders until a revised code was agreed upon.

Next, each interview was indexed, in which relevant text sections were copied and sorted into corresponding codes (i.e. charted). Subsequently, the coders met to review and compare coding and establish final thematic categories and associated definitions. For the purposes of this study, a thematic category was one that illustrates something important about the data with specific regard to the research question and is a patterned response among multiple participants

(Braun & Clarke, 2006). Summaries of the themes were mapped by creating a matrix to define each category and provide participant quotes that exemplified each theme. Then, a network display was created to explore potential relationships among themes. Finally, the research team met to discuss and interpret the findings.

Results

Participant demographic information is provided in Table 1. Table 2 provides information about participants' changes in activity levels and habits across the intervention. Overall, men and women were similarly represented, and the sample was predominately white. Most participants worked full time in a variety of occupations including office administration, scientist, custodian, and sales manager. All participants reported suffering from cLBP, defined as experiencing back pain every or every other day for longer than 3 months (Deyo et al, 2014). Most participants (82%) reported they had been suffering from cLBP symptoms for over 1 year. During the intervention, on average, participants broke up their sitting time through accumulating 250+ steps per hour on 9.0 ± 1.8 hours per day (based on data from the provided activity monitor). At the end of the intervention, participants reported sitting ~2 hours less than they reported sitting pre-intervention. ActivPAL-assessed behavior showed smaller changes, with participants sitting 36 minutes less and accumulating 966 more steps on average, per day. However, these changes in activity levels varied greatly across participants ranging from (sitting 41 minutes more to sitting 180 minutes less). Data from the SRHI showed that frequently standing up and breaking up longer bouts of sedentary time felt more habitual post-intervention, while sitting when they could stand felt less habitual.

Table 1. Participant characteristics prior to intervention (at baseline).

Demographic (n=11)	**Mean ± SD or n (%)**
Age (yrs.)	39 ± 9
Sex (% male)	6 (55)
Race (% white not Hispanic)	9 (82)
Employment Status (% full-time)	10 (91)
Income (% ≥ $100,000 yearly)	6 (55)
Education (% postgrad degree or higher)	4 (36)
Impact of cLBP (MDS)	21 ± 7

MDS: Minimal Data Set for chronic low back pain

Table 2. Change in sitting habits and activity levels.

Habit Development	**Pre**	**Post**	**Change**
Habit “Frequently standing up”	44 ± 13	60 ± 13	16 ± 8
Habit “Breaking up long bouts of sedentary time”	45 ± 15	62 ± 11	17 ± 12
Habit “Sitting when I could stand”	59 ± 15	48 ± 14	-10 ± 14
Self-Reported Sitting Time			
Occupational-related sitting (hr)	4.8 ± 2.7	3.3 ± 1.7	-1.5 ± 1.8
Number of breaks in work sitting time per day	4 ± 2	6 ± 6	2 ± 6
Number of breaks in screen time per day	2 ± 1	3 ± 2	1 ± 2
Weekday sitting (hr)	12 ± 2.6	9.3 ± 2.6	-2.7 ± 3.4
Weekend sitting (hr)	11.2 ± 4.1	8.6 ± 4.7	-2.5 ± 3.1
Change in total sitting (hr)	11.8 ± 1.93	9.1 ± 2.4	-2.6 ± 3.1
Monitor Assessed Sitting Time			
AP standing time (hr)	4.1 ± 1.1	4.9 ± 1.8	0.8 ± 1.1
AP sitting time (hr)	11.2 ± 1.4	10.6 ± 1.9	-0.6 ± 1.5
AP time spent in sitting bouts > 30 (hr)	6 ± 2.4	5.5 ± 1.8	-0.6 ± 2
AP time spent sitting in bouts > 60 (hr)	3.8 ± 2.4	2.8 ± 1	-1.1 ± 2.3
Total number of steps per day	8740 ± 2002	9609 ± 3254	966 ± 2894

Key Themes

Reported factors that were perceived to influence the ability to reduce or break up SED were thematized as positive or negative determinants. Negative determinants of reducing SED (i.e., perceived barriers that made is difficult to sit less) included environmental constraints, social norms and productivity. Positive determinants of reducing SED (i.e., perceived facilitators that made it easier to sit less) included habit development, self-monitoring tools, physical environment, and social accountability. These are each described in more detail below and the final matrix of determinants for reducing SED is included in Appendix 3.

Negative Determinants of SED

Environmental Constraints

Participants reported that environmental constraints, and particularly those related to the workplace, made it challenging to reduce sitting. Commonly reported examples were work-related tasks that typically require sitting, such as computer work or lab procedures that necessitate benchwork. Many tasks are time-sensitive, so taking a break to walk was perceived as impractical or impossible. Necessary transportation and weather were also reported to influence sitting time. Specifically, longer car trips and colder weather made it challenging to breaking up prolonged SED and reduce overall sitting.

"Most of it was just due to my requirements in the fact that a big portion of my job is computer based, so I'm either at home, in a home office sitting, or sitting in a pickup traveling … to an off-site meeting, so you know, unfortunately a big aspect of my job is sitting."

While taking breaks to walk was not perceived as feasible at work, using standing desks and backless chairs/stools were commonly reported techniques used during the intervention period to help break up and reduce sitting, despite environmental constraints. These ideas were coded as a positive determinant and are discussed below.

Social Norms

Participants stated it was difficult to sit less during certain social activities in which others were seated, especially when work-related. Many participants reported feeling uncomfortable or 'weird' when going against what they perceived as usual, seated workplace behavior. Others described feeling disrespectful if standing during seated meetings or disruptive to others if attempting to stand to break up prolonged sitting.

"We have trainings where it feels socially unacceptable to stand up when everyone else is sitting and paying attention. It felt just too uncomfortable to bring attention to myself I guess."

"It's kind of awkward if someone is standing in the back of the room, or the front of the room, or the side of the room when everyone else is sitting and talking"

Participants reported that work-related social norms surrounding sitting would need to be changed to reduce the impact of this barrier. For smaller, informal meetings, participants indicated walking meetings and standing meetings would be beneficial.

"We do have conference rooms that have taller desks in them, so if it's a smaller meeting with just a small team, there were standing level tables that we could stand at it, so I would try to book those conference rooms and then just stand."

For larger meetings, leadership from the meeting hosts would be needed. Participants indicated they could sit less if leaders of the meeting would state that they encourage standing, provide space in the room for standing (e.g. standing tables behind seating), or incorporate standing or walking breaks during the meeting.

"[If] whoever is running the meetings says, 'Hey let's take a five-minute break'. Whenever we get breaks, I take that as an opportunity to stand up and stretch and get water, so having the scheduled breaks when everybody is free [to] move around, feels less conspicuous."

Productivity

High concentration on work in combination with motivation to be productive was frequently reported as a barrier to reducing SED by participants. Participants reported ignoring prompts from the activity monitor to complete work tasks and/or not lose traction or progress on a task. Others stated they would lose track of time and not feel the monitor vibration because they were so focused.

“Even though I know I can get up and get away from the computer its hard if you're in the middle of something, and I just want to finish it and even if I get a reminder thing ‘you need to get up and move’, if I was in the middle of something I just want to finish it and I don't want to stop and come back, so that was probably the most difficult.”

Participants suggested more salient reminders of SED would be necessary during times when they were extremely focused on work. Ideas like apps that lock work items until a break is taken, multi-media (e.g. audio and vibratory) reminders, and *‘chairs that poke you’* were suggested.

“Maybe a Fitbit vibrating on your wrist isn’t enough and so you need something underneath you to poke you and get you up and moving.”

Additional feedback on participant preferences for SED prompts as well as frequency of prompts is presented in Appendix 4.

Participants reported that changing work-related social norms, such as institution-wide walking breaks each hour, could be valuable as it would demonstrate higher-level support for taking activity breaks from work.

"If I talk to my co-workers and just said 'Hey, let's all help each other with this and set an alarm and then just remind each other to all go for a 10-minute walk or go upstairs and walk around for a minute or two and then come back down,' and did it as a group effort thing, to remind each other."

Positive Determinants of SED

Habit Development

Education about habits and working on development of habits of sitting less was perceived as very influential in changing behavior. Participants expressed that implementation of external cues, such as vibratory reminders from the activity monitor, writing 'break' notes in margins of work documents and carrying a water bottle, were noticeable reminders to sit less. External cues from the activity monitor provided tailored feedback on SED with reliable, consistent reminders/prompts that were perceived as important in generating strong impulses for action over time.

"[The device] is a machine that doesn't forget that you need to move. It's going to give you that reminder consistently, and so I think that's the best way to form a habit is to be consistent."

Participants described how internal cues, like back pain, were helpful but less reliably prompted changes in behavior. Specifically, they indicated that back pain, as a cue, did not provide the consistency that external cues did and was more challenging to associate with sitting less. Further, internal cues may have been easier to dismiss, especially since cues like pain have been long-associated with other coping strategies like ignoring the pain or resting.

"I was better at listening to the outward cues than listening to the inward cues that my body is giving me. I feel like I could ignore those easier, the inward ones, just because I've been doing it for so long and ignoring them for so long."

"I associate being sore or being in pain…with me needing to rest and so by the time those presented themselves I didn't want to go and break up my daily routine."

Self-Monitoring Tools

Self-monitoring tools and strategies were consistently reported as facilitators to behavior change. Participants described that prior to enrollment in the study, they were uninformed regarding the health risks associated with SED and recommendations for sitting less. Additionally, they were largely unaware of their personal SED. During the intervention period, both sedentary idle alert prompts (e.g. obtain 250+ steps each hour) and physical activity data (e.g. steps per day) were reported as advantageous in working towards sitting less.

"The Fitbit was a huge part, so at ten till the hour, it buzzed at you to say get up and move, so that's a nice reminder."

"The movement reminders [were helpful] because once you start doing stuff, you don't always think about it so having [the monitor] was nice to remind you [that] you've been sitting for a long time [and] it's time to get up and move."

"It was really nice to have that constant reminder both at work and then in the evening because you'll sit down and watch TV… so having that reminder to break it up is really really nice. You don't realize how inactive you are throughout the day until you actually start seeing the numbers."

Some participants self-initiated coping planning for situations they anticipated would make sitting less more challenging.

"I made it a point when I write to keep the aims on the side [of a document] and in between aims, I take a break and go for a short walk for 5 minutes to gather my thoughts before I start working on the writing part. So not only is [it] helping with my movement requirements but it's also helping me refocus."

"Just traveling from location to location, there are times you could just strategically stop in the middle of an hour or on the hour—just stop at a rest stop or stop at a gas station to move around."

Physical Environment

Participants stated that having a physical environment supportive of standing was largely important to meeting their goals. Many reported using standing desks to alternate between sitting and standing throughout the workday. For those without standing desks, the use of a backless chair or stool was found to be helpful in breaking up prolonged sitting.

"I actually was able to get a standing desk so I can sit and stand at my desk. So, I could easily just move my desk so I could stand during a meeting. I wasn't able to move anywhere but at least I wasn't sitting."

"Something I did do in the lab, I changed my nice, cushy chair to a slightly more uncomfortable stool, where it's a little bit more comfortable to stand than it is to sit on it, and so that's really helped, just changing that out."

Social Accountability

Accountability was reported as a positive determinant by some participants. Having social support from family, co-workers, and the research team assisted in reducing SED. Other people's awareness of their behavioral goals and support of attempts to change their sitting habits was important for developing new routines of sitting less.

"Coworkers knew too [of my goal], so they knew that I need to get up and move and things like that too, so just kind of that awareness helped."

Thematic Network Mapping

A network display of reported positive and negative determinants in the context of the ecological model of behavior change (Sallis, Owen, & Fisher, 2008) is shown in Figure 1. Additionally, a network of hypothesized interrelationships between determinants based on interpretation of participant responses (not intended for publication) is included in Appendix 5. At the intrapersonal level, concentration/productivity were perceived barriers while self-monitoring and habit development were prominent facilitators of behavior change. Interpersonally, social norms of sitting were challenging to overcome. Having social accountability aided in accomplishing personal sitting goals and may be helpful for changing social norms. At the organizational level, environment constraints, primarily coming from work-related tasks, transportation, and the weather were barriers when attempting to sit less. Changing the physical environment by using standing desks and stools may help reduce the impact of this determinant.

Discussion

This study explored perceptions of factors that influenced participants' ability to reduce sitting after taking part in an intervention to reduce total and prolonged SED in 11 individuals with cLBP. Overall, social (sitting norms and work expectations) and environmental factors were reported as prominent barriers in reducing SED, while intrapersonal factors (self-regulation, habit development) were perceived as being helpful in changing sitting habits and overcoming negative determinants (Figure 1).

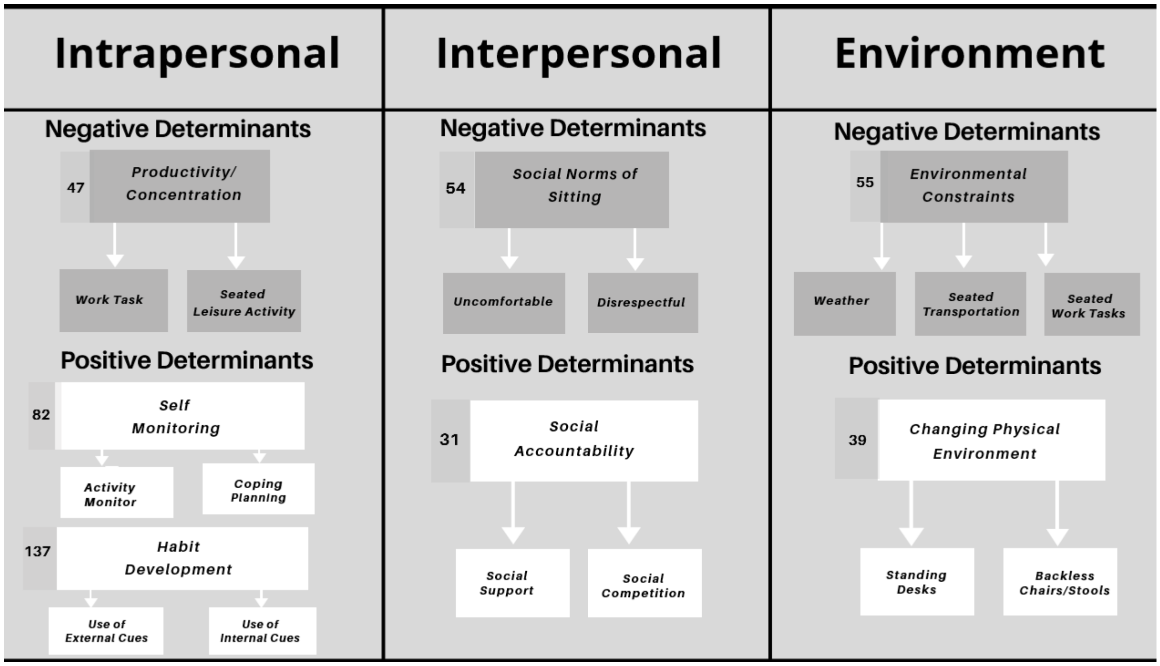

Figure 1. Network display of perceived determinants of reducing SED in context of an ecological model of behavior change. Arrows away from 7 themes indicate codes that were prominent within each theme. Numbers to the left of each theme indicate total number of times the theme was coded across the 11 transcriptions and among coders.

These findings are consistent with previous qualitative research on perspectives of reducing SED, especially regarding negative factors that influence sitting time. For example, Hadgraft and colleagues (2016) explored perspectives of the feasibility and acceptability of strategies to reduce SED in 20 office workers. They reported key factors including nature of work (e.g. sitting at computer, not wanting to lose concentration or productivity) and that common structural and social environments were conducive for sitting, which aligns closely with the barriers our participants experienced. Participants in the study by Hadgraft et al. also reported changing the work place structured environment, changing social norms at work (e.g. walking meetings, in-person communications), or employing wearable fitness monitors were favored strategies for reducing SED. Qualitative studies in other populations, including older adults, African-American women, and college students, have also found the physical environment and social norms to be prominent factors in changing this behavior (Chastin et al ., 2014; Warren et al., 2018; Deliens et al., 2015). In support of these findings, a recent systematic review by Rawling and colleagues (2019) examining 30 studies, also concluded that there are important determinants across levels of the ecological model, with the most influential determinants falling under socio-cultural and environmental/institutional categories. Similar to other populations, our sample of participants with cLBP reported being highly influenced by social and environmental factors indicating these factors as potentially high impact targets for future interventions targeting SED reductions.

Interestingly, physical pain and discomfort were not reported as barriers for reducing SED. This is in contrast to previous qualitative work. For example, studies have reported that pain and fatigue in older women (Chastin, 2014), health-related problems in African American women (Warren et al, 2018), and physical health/injuries and fatigue in college-students (Deliens, 2015) influenced sitting time. Moreover, our results showing a lack of influence of pain on ability to sit less are also in contrast to determinants for increasing physical activity, for which pain is a frequently cited barrier in this population (Schaller, Exner, Schroeer, Kleineke, & Sauzet, 2017). While individuals may associate higher intensity activities with greater pain, our data suggest that they may have lower movement-related fear beliefs when focusing on reducing sitting, as opposed to increasing activity. Thus, a key finding from this study is that individuals with cLBP may perceive goals to reduce SED as easier and more feasible than goals targeting increases in physical activity when seeking to improve pain and/or general health.

Theory-based strategies are typically used to overcome common barriers to behavior change and participants indicated several of these strategies were helpful in sitting less. The intervention in this study employed strategies from the Self-Determination Theory via Motivational Interviewing (e.g. intrinsic motivation), habit theory (prompts/cues), and mHealth (e.g. self-monitoring from activity monitor) (Deci & Ryan, 1985; Gardner, 2015; Sanders et al., 2016). While care was taken to not explicitly include motivational factors as part of the qualitative interview, constructs of mHealth, habit theory, and restructuring the physical environment were frequently reported as helpful for reducing SED. This is consistent with data from a review of behavior change theories for SED by Gardener and colleagues (2016) that found self-monitoring of behavior, problem solving, and restructuring social or physical environments to be the most promising behavior change techniques for reducing SED. Gardner et al. reported that ‘very promising’ interventions also utilized prompts/cues and habit formation strategies. Further, a meta-analysis of randomized controlled trials that implemented behavior change strategies also found that interventions targeting reductions in SED using mobile technology yielded a mean reduction of 41 minutes of SED per day, with prompts/cues, social support, and self-monitoring of behavior reported as important strategies (Stephenson et al., 2017). The use of habit formation, an activity monitor for self-regulation, and restructuring the environment not only demonstrate promising effects in reducing SED but were also reported as helpful by participants with cLBP.

Perspectives on the utility of habit theory for reducing SED may be especially important. Each participant reported that discussing and actively working on changing sitting habits was an important contributor to their success in reducing SED. Most participants felt they had adopted a strong habit of receiving an external cue from the activity monitor and standing or walking for a quick break. In other words, participants in this study expressed that they felt strong impulses toward action when encountering the cue. As noted above, the situations that were most difficult in following through with the habit routine were when concentrated on seated work and in seated, social situations in the workplace. These situations are examples of the impulse-behavior combination, “No behavior due to impulse inhibition” that Gardner (2015) proposed. In other words, participants experienced strong impulses toward standing/breaking sitting from the external cue from the activity monitor, but the impulse was inhibited due to stronger social and environmental constraints. Thus, other strategies for these specific times are needed to help individuals develop sustainable habits surrounding sitting less and using external cues effectively. Coping planning or developing situation-specific plans to overcome anticipated barriers, may mitigate the influence of social norms and environmental constraints (Schwarzer, 2008). Specifically, coping planning may aid in making standing and/or taking breaks from sitting more salient options that require less cognitive effort. In this study, participants reported that planning out breaks each hour during long drives and structuring intentional breaks into work tasks before beginning them aided in following through with the behavior. Preparing for anticipated barriers with detailed coping plans tailored to participants may be key in overcoming social and environmental determinants.

Habit development was reported by participants to be highly reliant on external cues. External cues were coded 61 times across the 11 transcripts as a facilitator of behavior change. Many participants admitted they were largely unaware of the amount of time they spent sitting and/or unaware of the associations sedentary time has with health outcomes prior to enrollment in the study. Therefore, if unaware and unable to recognize prolonged sedentary time, internal cues and associated rewards may not be salient enough to promote habit development and behavior initiation. Initial, weak habits reliant on internal cues may not translate into behavior maintenance, as the cue that triggers the habit may not be sufficient and/or the behavior may not be repeatedly performed. Having an external mechanism to help self-regulate the behavior (e.g. mHealth, activity monitors) may help initiate a new behavior by tracking and regularly prompting the behavior, and potentially lead to stronger, more sustainable habits. A downfall of wearable technology for habit development is that maintenance of the behavior is directly related to maintenance of the device; thus a lost, broken, or forgotten monitor would interfere with behavior change. However, if the activity monitor is consistently used during behavior initiation, new habits that are not reliant on the external monitor cues may also emerge (e.g., habitually planning breaks prior to beginning tasks, reserving standing meeting rooms, filling a water bottle each hour). How external cues from activity monitors facilitate the development of other external and internal cues not reliant on the monitor warrants investigation.

Strengths and Limitations

This study has several limitations. First, the sample was small and relatively homogenous, primarily consisting of white, highly educated adults, with relatively high incomes. However, their duration and frequency of pain symptoms was representative of cLBP patients in general. Although participants were asked to respond candidly during the qualitative interview, they may have responded in a way they perceived as favorable to the research team, as interviews for this study were performed by the health coach who also delivered the in-person intervention session and performed the 4-week phone call. There may also be inherent biases in the reporting of positive determinants, as participants were educated about habit development, instructed to use their activity monitors during the intervention period, and subsequently asked about the influence these factors had on their ability to sit less. Further, the theoretical strategies from SDT were not assessed, nor was the motivational interviewing fidelity, so little is known about the potential influence (or lack of influence) of the health coaching sessions, although both sessions for each participant were performed by the same health coach. In relation to this, it is plausible that other theoretical constructs that may have influenced behavior change may not have been reported because they were not probed for in the semi-structured interview.

Nonetheless, this study is informative and provides key information regarding determinants of sedentary time in individuals with cLBP, which has not been explored previously. Participants were encouraged to openly reflect and report on factors that influenced their ability to reduce SED. Further, these data provide participant perspectives following an intervention that focused on attempting to change SED. Thus, they may have a clearer idea of factors that influence change than individuals who have not recently undergone such an experience. In addition, the research team implemented several strategies during data collection and analysis to ensure trustworthiness of the qualitative data, including thick and thin descriptions of the data, triangulation of coding, member checking, incorporating some mixed-methods data, and demonstrating reflexivity (e.g. discussing potential biases) in reporting (Guba, 1981; Miles, Huberman & Saldana, 2014).

Conclusion

In this sample of adults with cLBP, barriers to reducing sitting were consistent with previous findings in healthy populations and included environmental constraints, social norms, and productivity. Conversely, developing new habits around sitting less, implementing self-monitoring strategies, restructuring the environment, and having social accountability made sitting less feel easier in individuals with cLBP. Accounting for these factors, workplace interventions may be more effective if they consider the use of standing desks, standing meeting rooms, and incorporating institution-wide standing/walking breaks to overcome work-related factors that hinder with one’s ability to reduce SED. Sedentary interventions will also likely benefit from considering using activity monitors to improve self-monitoring of sitting time and to serve as an external, real-time reminder to sit less. Importantly, education about how the reminders can serve as a external cues may be key in developing new sitting habits. Lastly, developing tailored coping plans for overcoming social sitting norms and inflexible environmental constraints may be particularly helpful for reducing SED.

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Appendix 1. Semi-Structured Qualitative Interview

Semi-Structured Qualitative Interview over Sedentary Intervention

After completing the 8-week intervention to reduce your sedentary time, we'd like to ask a few questions about your experience. Your responses are extremely valuable in helping us and other researchers develop similar interventions in the future. With that in mind, it is important that you are as honest and candid as possible.

First, thinking about your sedentary time over the 8-week period, what were the primary reasons you found yourself sitting for long periods of time?

- In which of these situations were you able to decrease or break up your sitting time?
    - What steps did you take to help you reduce your sitting during each of these situations?
    - Can you identify any factors that made this easier for you?
- Again, thinking of those situations where you were sitting for long periods of time, when was it most challenging to decrease or break up your sitting?
    - For those times when it could have been possible to decrease your sitting, tell me about how you tried to sit less during these times?
    - Can you identify any factors that made these times more difficult for you to reduce your sitting?
    - What do you think you would need in order to sit less during these times?

Now I'd like to talk about your experience with the Fitbit and how it influenced your ability to decrease or break up your sitting.

Overall, describe your experience using the Fitbit to help you reduce your sedentary time.

In terms of receiving prompts, how helpful were the reminders and feedback you received from the Fitbit and associated application?

- Would other prompts be more beneficial?
- If so, which types? (e.g. emails, texts, alarms)
- How frequently?

As part of the intervention, we also discussed sitting as a habit and strategies for forming new habits. How well do you feel you were able to build new habits?

- Overall, did thinking about habits help you decrease or break-up your sitting time?
- We talked about inward cues like pain or an emotion and outward cues like the fitbit or pillows on the couch blocking your seat. Thinking about both of these types of cues, which were most helpful in working toward developing a new habit?
- What cues were least helpful in working toward developing new habits?

Aside from the Fitbit, were there any other strategies or tools that helped you or reminded you to sit less?

If you were to design an intervention with unlimited resources to help you sit less, what would it look like?

Appendix 2. Deductive Codebook

Deductive Codebook		
Category: Negative Determinants, Abbreviation, Definition		
Occupational: Constraints	N_O_CONS	Job tasks require participant to be seated (e.g. working on the computer at seated desk, working on bench in lab)
Occupational: Productivity/Concentration	N_O_PROD	Standing or taking breaks disrupts concentration on work or reduces productivity
Social Norms: Feels Uncomfortable	N_SN_UNCO	Standing feels uncomfortable because other people are seated or do not take breaks
Social Norms: Disrespectful	N_SN_DISR	Participant indicates they feel disrespectful or impolite to others they are conversing with
Physical Discomfort	N_PHYSDIS	Participants indicates they did not stand or take breaks due to physical discomfort, such as pain, fatigue, or discomfort
Social Norms: Preferences	N_SN_PREF	Lack of motivation due because of enjoyment/pleasure from seated activity (e.g. movie, game, knitting); they prefer to sit during this activity
Access to Resources	N_ACCRES	Did not stand/break up because lack of resources, such as a standing desk to work
Time	N_TIME	Unaware of amount of SED time (e.g. lost track of time or did not even feel monitor prompt)
Habit	N_HB	Participant indicates a habit of sitting. They may be largely unaware of sitting time and/or sit due to routine.
Weather	N_WTHR	Weather (e.g. cold outside, extreme heat) provides barrier for reducing sitting.
Category: Positive Determinants		
Accountability	P_ACCT	Accountability from research team, co-workers and/or family
Activity Tracker: SED Prompts	P_FB_SB	Activity monitor for reminders when sedentary for prolonged time
Activity Tracker: PA Goals	P_FB_PA	Activity monitor for physical activity related data (e.g. steps per day)
Activity Tracker: Competition	P_FB_COMP	Using tracker to compete against self or others with daily SED or PA goals
Education	P_EDU	Education about risk factors associated with sitting and/or about viewing data on individual SED levels (e.g. activPAL data)
Social Norms: Change in Work Norms	P_SN_WKCH	Implementation of new social norms at work (e.g. walking meetings, break each hour to walk, team competitions)
Occupation: Change in Leadership	P_O_LEAD	Implementation of breaks in meetings/trainings by leaders/speakers
Physical Environment	P_ENVR	Changing environment (e.g. standing desk, stools instead of chairs)
Habit Development	P_HB_DEV	Development of habits for sitting less; feels natural to take breaks
Habit: External Cue	P_HB_EX	Attention to habits using external cues, such as FB, water bottle, or notes
Habit: Internal Cue	P_HB_IN	Attention to habits using internal cues, such as noticing cLBP or fatigue

Appendix 3. Matrix of Determinants

Matrix of reported determinants of reducing sedentary time in cLBP.
(-) : Factor perceived to negatively influences SED; (+) : Factor perceived to positively influences SED.

Determinants	Researchers Interpretation	Direct Quotes of Participants
Environmental Constraints (-)	Participants stated environmental constraints made it difficult to sit less. Examples include tasks that require sitting (e.g. computer work), weather, and lack of resources (e.g. standing desk).	*"If at a conference and so it's an hour and a half long presentation and so you're sitting during that time and so then to go and move and stand up and if you're taking notes or if you have your stuff with you, then you're either leaving your stuff at the tables to then go move like a high top table to stand at"*
Productivity (-)	Participants stated high concentration on work/activity and motivation to be productive made it difficult to sit less. Examples included ignoring prompts to complete work, losing track of time because of focus, and not wanting to lose progress.	*"Probably at work [it's hard to sit less], because even though I know I can get up and get away from the computer its hard if you're in the middle of something, and I just want to finish it and even if I get a reminder thing you need to get up and move like, if I was in the middle of something I just want to finish it and I don't want to stop and come back."*
Social Norms (-)	Participants stated is was difficult to sit less during certain social activities. Examples included feeling uncomfortable or disrespectful during work meetings and lacking motivation because of the enjoyment of a seated, social activity.	*"Sometimes we have like trainings where it feels socially unacceptable to stand up when everyone else is sitting and like paying attention"* *"It's kind of awkward if someone is standing in the back of the room, you know, or the front of the room or the side of the room when everyone else is sitting and talking."*
Social Accountability (+)	Participants stated having accountability from others helped reduce sitting. Examples included encouragement from family, co-workers, and/or research team to reach goals and using tracker to compete against self or others.	*"Having a little bit of accountability there helped as well. You know, honestly wearing a fitness tracker today wouldn't have the same impact, knowing that someone is not watching"* *"Coworkers knew too [of my goal], so they knew that I need to get up and move and things like that too, so just kind of that awareness helped."*
Self-Monitoring (+)	Participants stated that having tools to aid in self-monitoring of activity level was helpful in reducing sitting. Examples included SED prompts from the FB, PA data (e.g. steps per day), education of sitting time, and developing coping plans.	*"The Fitbit was a huge part, so at ten till the hour, it buzzed at you to say get up and move, so that's a nice reminder."* *"It was really nice having the movement reminders just because once you start doing stuff you don't always think about it and so that, having that there, was nice to remind you like you've been sitting for a long time it's time to get up and move"*
Physical Environment (+)	Participants stated that changing the physical environment at work and home were helpful in reducing sitting. Examples included using standing desk and backless chairs/stools in place of chairs.	*"Something I did do in the lab, I changed by my nice, cushy chair to a slightly more uncomfortable stool, where it's a little bit more comfortable to stand than it is to sit on it, and so that's really help just, just changing that out.* *"Having a standing desk was huge at work to be able to stand up and still work, where if I didn't have that flexibility, I think it would be hard."*
Habit Development (+)	Participants stated that knowledge about habits and working on development of habits for sitting less were helpful. Examples included implementing external cues (e.g. vibratory reminders from FB) and internal cures (e.g. back pain, fatigue) helped establish habits.	*"I think especially at night when I was watching TV, as soon as I start to feel any kind of discomfort in my hips or my back, I move off of the couch and stretch or, you know, stand up for a minute or go do something."* *"The reminders are helpful because it's hard to form a habit if you don't have reminders and I'm used to sitting. I needed something to remind you like, "oh you're supposed to get up and move", so that was helpful having that."*

Appendix 4. Activity Monitor Feedback

Participant feedback on preferences of activity monitor types and frequency.

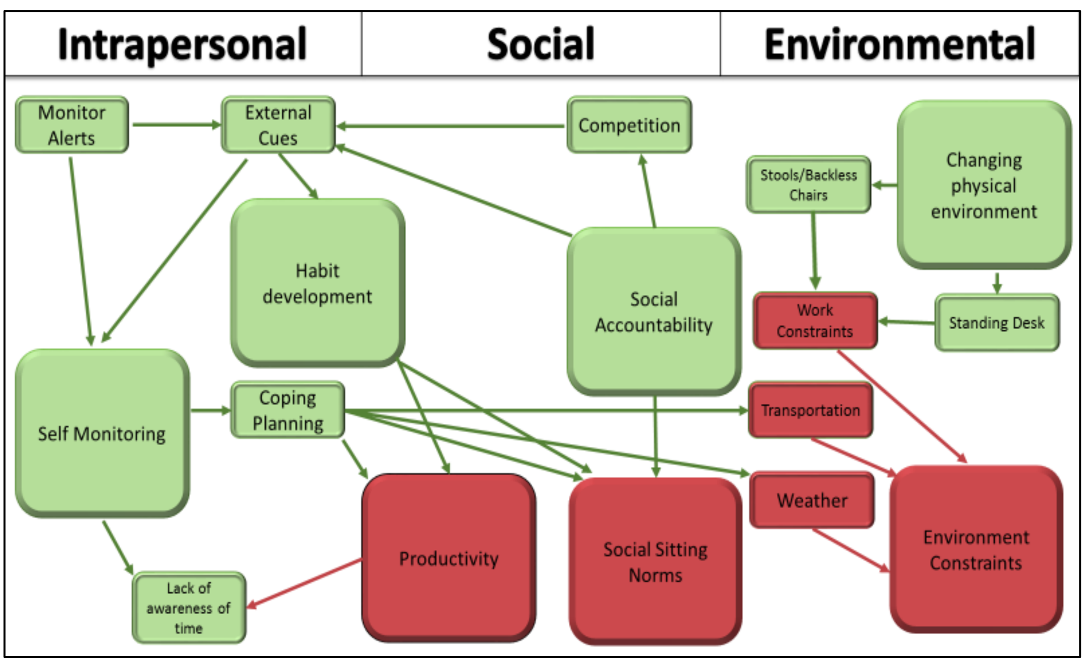
	Types of Prompts			
	Vibration from Monitor	Audio-Visual Prompt	Follow Up Prompt	Prompt from Seat
Number of participants	6	2	2	1
Justification	Subtle but salient reminder that are not noticeable or distracting to others	Attention-grabbing	Not always feel/notice the vibration, so a follow up prompt would be useful	Not always feel/notice vibration so more salient prompt needed

	Frequency of Prompts		
	Once/2 HRS	Once/HR	More than once/HR
Number of participants	1	6	4

Notes: Data are from participant transcripts (n = 11) based on responses when asked 1) "Would other prompts be more beneficial? If so, which types? (e.g., emails, texts, alarms)" and 2) "How frequently?" Participants responded freely to these questions and responses were grouped based upon response frequency in the associated categories.

Appendix 5. Network Display of SED Determinants

Figure of hypothesized interrelationship of perceived determinants of reducing SED based on interpretation of participant responses. The large box size represents the seven most prominent themes, while the small box size includes codes that were identified in the first cycle of coding.



CHAPTER 7. GENERAL CONCLUSION

This dissertation examined the relationship between pain symptoms and processing with SED in people with cLBP and then explored perceived determinants for reducing this behavior, along with self-efficacy for reducing SED compared to recommendations to increase moderate to vigorous physical activity. Sedentary time does not appear to be related to pain symptoms or processing in people with cLBP. Instead, other behavioral factors or changes in SED more likely contribute to improvement in cLBP, warranting further research.

Previous research suggests that reductions in SED do consistently improve other health outcomes, and people are more confident in changing SED compared to increasing MVPA. Reductions in SED may inherently increase other positive behaviors and improve health outcomes. Future studies should aim to determine the amount of change needed of each behavior (i.e. SED or MVPA) to achieve the same health benefits. Consideration of how SE is related to those findings would be helpful and potentially aid in better adoption of each behavior.

Consideration of determinants of reducing SED is also be helpful in understanding how to aid in behavior change and people with cLBP report similar social and environmental barriers in reducing SED as other populations. Constructs from Habit Theory, the Built Environment and mHealth may be important to include when targeting SED-related behavior change, such as coping planning, wearable activity monitors, and developing habits surround sitting less. Future research should investigate the utility of these strategies for reducing SED.

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APPENDIX A. STUDY 1 AND 3 IRB APPROVAL LETTER

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Institutional Review Board
Office for Responsible Research
Vice President for Research
2420 Lincoln Way, Suite 202
Ames, Iowa 50014
515 294-4566

Date: 3/8/2018

To: Dr. Jacob D. Meyer
239 Forker

From: Office for Responsible Research

Title: Influence of reducing sedentary behavior on symptoms, inflammation, and endocannabinoids in patients with chronic low back pain and elevated depressive symptoms

IRB ID: 18-068

Approval Date:	3/5/2018	**Date for Continuing Review:**	2/19/2020
Submission Type:	New	**Review Type:**	Full Committee

The project referenced above has received approval from the Institutional Review Board (IRB) at Iowa State University according to the dates shown above. Please refer to the IRB ID number shown above in all correspondence regarding this study.

To ensure compliance with federal regulations (45 CFR 46 & 21 CFR 56), please be sure to:

- **Use only the approved study materials** in your research, **including the recruitment materials and informed consent documents that have the IRB approval stamp.**
- **Retain signed informed consent documents for 3 years after the close of the study**, when documented consent is required.
- **Obtain IRB approval prior to implementing <u>any</u> changes** to the study by submitting a Modification Form for Non-Exempt Research or Amendment for Personnel Changes form, as necessary.
- **Immediately inform the IRB of (1) all serious and/or unexpected adverse experiences** involving risks to subjects or others; and (2) **any other unanticipated problems involving risks** to subjects or others.
- **Stop all research activity if IRB approval lapses**, unless continuation is necessary to prevent harm to research participants. Research activity can resume once IRB approval is reestablished.
- **Complete a new continuing review form** at least three to four weeks prior to the **date for continuing review** as noted above to provide sufficient time for the IRB to review and approve continuation of the study. We will send a courtesy reminder as this date approaches.

Please be aware that IRB approval means that you have met the requirements of federal regulations and ISU policies governing human subjects research. **Approval from other entities may also be needed.** For example, access to data from private records (e.g. student, medical, or employment records, etc.) that are protected by FERPA, HIPAA, or other confidentiality policies requires permission from the holders of those records. Similarly, for research conducted in institutions other than ISU (e.g., schools, other colleges or universities, medical facilities, companies, etc.), investigators must obtain permission from the institution(s) as required by their policies. **IRB approval in no way implies or guarantees that permission from these other entities will be granted.**

Upon completion of the project, please submit a Project Closure Form to the Office for Responsible Research, 202 Kingland, to officially close the project.

Please don't hesitate to contact us if you have questions or concerns at 515-294-4566 or IRB@iastate.edu.

APPENDIX B. PAIN INTENSITY SCALE

PAIN INTENSITY SCALE

20	
19	
18	EXTREMELY INTENSE
17	VERY INTENSE
16	INTENSE
15	STRONG
14	
13	SLIGHTLY INTENSE
12	BARELY STRONG
11	MODERATE
10	
9	
8	MILD
7	VERY MILD
6	
5	WEAK
4	VERY WEAK
3	
2	
1	FAINT
0	NO PAIN SENSATION

Gracely Box SL

APPENDIX C. PAIN UNPLEASANTNESS SCALE

PAIN UNPLEASANTNESS SCALE

20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0

VERY INTOLERABLE

INTOLERABLE

VERY DISTRESSING
SLIGHTLY INTOLERABLE
VERY ANNOYING
DISTRESSING
VERY UNPLEASANT

SLIGHTLY DISTRESSING

ANNOYING
UNPLEASANT

SLIGHTLY ANNOYING

SLIGHTLY UNPLEASANT

NEUTRAL

Gracely Box SL

APPENDIX D. PAIN FACILITATION NUMERICAL RATING SCALE

100	withdraw
95	intolerable
90	
85	
80	very strongly painful
75	
70	strongly painful
65	
60	slightly strongly painful
55	
50	moderately painful
45	
40	weakly painful
35	
30	very weakly painful
25	
20	barely painful
15	warm, not painful
10	slightly warm
5	slight sensation
0	no sensation

APPENDIX E. RATING OF PERCEIVED EXERTION SCALE

Borg RPE Scale

6	No exertion at all
7	Extremely light
8	
9	Very light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard (heavy)
16	
17	Very hard
18	
19	Extremely hard
20	Maximal effort

APPENDIX F. SUMIT DEMOGRAPHIC QUESTIONNAIRE

SUMIT Study Demographic Survey

Name ____

Date _______________

Sex: Male______ Female______ Other, please specify __________ Do not wish to respond ______

Phone: Preferred (______)_______________ Alternate (______)_____________

Email____

Height: ___________________

Weight: ___________________

Race (check one):
_____ (1) White not Hispanic
_____ (2) White Hispanic
_____ (3) Black not Hispanic
_____ (4) Black Hispanic
_____ (5) Asian
_____ (6) American Indian (Native American)
_____ (7) Other, please specify
____

Employment status:
_____ (1) Full time
_____ (2) Part time
_____ (3) Unemployed, looking for work
_____ (4) Unemployed due to health
_____ (5) Retired (for any reason)
_____ (6) Never worked outside the home
_____ (7) Student
_____ (8) Other, please specify
____

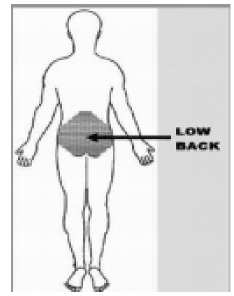
Marital status:
_____ (1) Married
_____ (2) Divorced
_____ (3) Never married
_____ (4) Widowed
_____ (5) Separated
_____ (6) Living as married

Income (please check the combined annual income of everyone in your household):
_____ (1) Less than $25,000
_____ (2) $25,000-$49,999
_____ (3) $50,000-$74,999
_____ (4) $75,000-$99,999
_____ (5) $100,000 or more

Education (check one):
_____ (1) Did not finish High School
_____ (2) High School Graduate
_____ (3) Some College
_____ (4) College Graduate (AD, BA, BS)
_____ (5) Some Postgrad
_____ (6) Graduate Degree (MS, MA, PhD, MD, etc.)

Have you ever used a pedometer or activity monitor to assess and/or monitor your physical activity?
_____(1) Yes, currently using one
_____(2) Yes, in the past 6 months, but not currently
_____(3) Yes, more than 6 months ago
_____(4) No, have never used one these devices

APPENDIX G. MINIMAL DATASET FOR LOW BACK PAIN



Minimal Dataset
(PROMIS items marked with [1]; STarT Back or nearly identical items marked with [2]; RTF Impact Classification items marked with *)

1. How long has low-back pain been an ongoing problem for you?
- ☐ Less than 1 month
- ☐ 1–3 months
- ☐ 3–6 months
- ☐ 6 months–1 year
- ☐ 1–5 years
- ☐ More than 5 years

2. How often has low-back pain been an ongoing problem for you over the past 6 months?
- ☐ Every day or nearly every day in the past 6 months
- ☐ At least half the days in the past 6 months
- ☐ Less than half the days in the past 6 months

3. In the past 7 days, how would you rate your low-back pain on average?*[1,2]

☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
1 No pain	2	3	4	5	6	7	8	9	10 Worst Imaginable pain

4. Has back pain spread down your leg(s) during the past 2 weeks?[2]
- ☐ Yes
- ☐ No
- ☐ Not sure

5. During the past <u>4 weeks</u>, how much have you been bothered by …	**Not bothered at all**	**Bothered a little**	**Bothered a lot**
• Stomach pain	☐	☐	☐
• Pain in your arms, legs, or joints other than your spine or back	☐	☐	☐
• Headaches	☐	☐	☐
• Widespread pain or pain in most of your body	☐	☐	☐

6. Have you ever had a low-back operation?
- ☐ Yes, one operation
- ☐ Yes, more than one operation
- ☐ No

7. If yes, when was your last back operation?

- ☐ Less than 6 months ago
- ☐ More than 6 months but less than 1 year ago
- ☐ Between 1 and 2 years ago
- ☐ More than 2 years ago

8. Did any of your back operations involve a spinal fusion? (also called an arthrodesis)

- ☐ Yes
- ☐ No
- ☐ Not sure

In the past 7 days…	**Not at all**	**A little bit**	**Somewhat**	**Quite a bit**	**Very much**
9. How much did pain interfere with your day-to-day activities?*[1]	☐	☐	☐	☐	☐
10. How much did pain interfere with work around the home?*[1]	☐	☐	☐	☐	☐
11. How much did pain interfere with your ability to participate in social activities?*[1]	☐	☐	☐	☐	☐
12. How much did pain interfere with your household chores?*[1]	☐	☐	☐	☐	☐

13. Have you used any of the following treatments for your back pain? *(Check all that apply)*

	Yes	**No**	**Not sure**
• **Opioid painkillers** (*prescription medications such as Vicodin, Lortab, Norco, hydrocodone, codeine, Tylenol #3 or #4, Fentanyl, Duragesic, MS Contin, Percocet, Tylox, OxyContin, oxycodone, methadone, tramadol, Ultram, Dilaudid*)	☐	☐	☐
If you checked yes, are you currently using this medication?............	☐	☐	
• **Injections** *(such as epidural steroid injections, facet injections)*	☐	☐	☐
• **Exercise therapy**..	☐	☐	☐
• **Psychological counseling, such as cognitive-behavioral therapy**..............	☐	☐	☐

The next two questions are for people who normally work outside the home.

14. I have been off work or unemployed for 1 month or more due to low-back pain.

- ☐ Agree
- ☐ Disagree
- ☐ Does not apply

15. I receive or have applied for disability or workers' compensation benefits because I am unable to work due to low-back pain.

- ☐ Agree
- ☐ Disagree
- ☐ Does not apply

Physical Function	Without any difficulty	With a little difficulty	With some difficulty	With much difficulty	Unable to do
16. Are you able to do chores such as vacuuming or yard work?*[1]	☐	☐	☐	☐	☐
17. Are you able to go up and down stairs at a normal pace?*[1]	☐	☐	☐	☐	☐
18. Are you able to go for a walk of at least 15 minutes?*[1,2]	☐	☐	☐	☐	☐
19. Are you able to run errands and shop?*[1]	☐	☐	☐	☐	☐

In the past 7 days...	Never	Rarely	Sometimes	Often	Always
20. I felt worthless[1]	☐	☐	☐	☐	☐
21. I felt helpless[1]	☐	☐	☐	☐	☐
22. I felt depressed[1]	☐	☐	☐	☐	☐
23. I felt hopeless[1]	☐	☐	☐	☐	☐

In the past 7 days...	Very poor	Poor	Fair	Good	Very good
24. My sleep quality was[1]	☐	☐	☐	☐	☐

In the past 7 days...	Not at all	A little bit	Somewhat	Quite a bit	Very much
25. My sleep was refreshing[1]	☐	☐	☐	☐	☐
26. I had a problem with my sleep[1]	☐	☐	☐	☐	☐
27. I had difficulty falling asleep[1]	☐	☐	☐	☐	☐

APPENDIX H. MCGILL PAIN QUESTIONNAIRE

SHORT-FORM McGILL PAIN QUESTIONNAIRE

PATIENT'S ID : ______________ DATE: ________

	NONE	MILD	MODERATE	SEVERE
THROBBING	0) ____	1) ____	2) ____	3) ____
SHOOTING	0) ____	1) ____	2) ____	3) ____
STABBING	0) ____	1) ____	2) ____	3) ____
SHARP	0) ____	1) ____	2) ____	3) ____
CRAMPING	0) ____	1) ____	2) ____	3) ____
GNAWING	0) ____	1) ____	2) ____	3) ____
HOT-BURNING	0) ____	1) ____	2) ____	3) ____
ACHING	0) ____	1) ____	2) ____	3) ____
HEAVY	0) ____	1) ____	2) ____	3) ____
TENDER	0) ____	1) ____	2) ____	3) ____
SPLITTING	0) ____	1) ____	2) ____	3) ____
TIRING-EXHAUSTING	0) ____	1) ____	2) ____	3) ____
SICKENING	0) ____	1) ____	2) ____	3) ____
FEARFUL	0) ____	1) ____	2) ____	3) ____
PUNISHING-CRUEL	0) ____	1) ____	2) ____	3) ____

NO PAIN |————————————————————| WORST POSSIBLE PAIN

PPI

0 NO PAIN ____
1 MILD PAIN ____
2 DISCOMFORTING ____
3 DISTRESSING ____
4 HORRIBLE ____
5 EXCRUCIATING ____

APPENDIX I. STUDY 2 IRB APPROVAL LETTER

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Institutional Review Board
Office for Responsible Research
Vice President for Research
2420 Lincoln Way, Suite 202
Ames, Iowa 50014
515 294-4566

Date: 10/05/2018

To: Jeni Lansing   Laura Ellingson-Sayen

From: Office for Responsible Research

Title: **Evaluation of Self-Efficacy for Changing Physical Activity verse Sedentary Behaviors**

IRB ID: **18-414**

Submission Type: Initial Submission   **Exemption Date:** 10/05/2018

The project referenced above has been declared exempt from the requirements of the human subject protections regulations as described in 45 CFR 46.101(b) because it meets the following federal requirements for exemption:

2: Research involving use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observations of public behavior, unless (i) Information obtained is recorded in such a manner that human subjects can be identified, and (ii) Any disclosure of the human subjects' responses outside the research could reasonably place the subject at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation.

The determination of exemption means that:

- **You do not need to submit an application for annual continuing review.**
- **You must carry out the research as described in the IRB application.** Review by IRB staff is required prior to implementing modifications that may change the exempt status of the research. In general, review is required for any *modifications to the research procedures* (e.g., method of data collection, nature or scope of information to be collected, changes in confidentiality measures, etc.), modifications that result in the *inclusion of participants from vulnerable populations*, and/or any *change that may increase the risk or discomfort to participants*. The purpose of review is to determine if the project still meets the federal criteria for exemption.

  In addition, ***changes to key personnel*** must receive prior approval.

Detailed information about requirements for submission of modifications can be found on our website. For modifications that require prior approval, an amendment to the most recent IRB application must be submitted in IRBManager. A determination of exemption or approval from the IRB must be granted before implementing the proposed changes.

Non-exempt research is subject to many regulatory requirements that must be addressed prior to implementation of the study. Conducting non-exempt research without IRB review and approval may constitute non-compliance with federal regulations and/or academic misconduct according to ISU policy.

APPENDIX J. SELF-EFFICACY FOR CHANGING ACTIVITY-RELATED BEHAVIORS SURVEY

Self-Efficacy for Changing Activity-Related Behaviors

Instructions: Most of the questions in this survey are answered by clicking a response to indicate your choice. Some questions may allow for multiple responses; for these, check all the boxes that apply to you. If you accidentally skip a question or find yourself unable to answer a question, a prompt will request that you reply. If you do not wish to respond, continue to the next question.

Anonymity and Confidentiality: The information you provide will remain confidential. None of the responses or personal information will be attributed to you as an individual.

1.What is your age? ______

2. What is your gender?
_____ (1) Male
_____ (2) Female
_____ (3) Other

3.Do you have any of the following health conditions?

	Currently	Previously	Never
Cardiovascular Disease (Heart Disease)			
Types 2 Diabetes			
Cancer (Lung Cancer, Breast Cancer, etc)			
Major Depressive Disorder			
Anxiety Disorder			
Other, please specify			

4. Do you currently suffer from chronic pain? If yes, please specify what type (if known) and the location(s) of your pain.
______ (1) No
______ (2) Yes, please specify the type(s) _____________ and location(s) ________________

5. What is your race (check all that apply)?
_____ (1) White not Hispanic
_____ (2) White Hispanic
_____ (3) Black not Hispanic
_____ (4) Black Hispanic
_____ (5) Asian
_____ (6) American Indian (Native American)
_____ (7) Other, please specify _________________________

6. What is your current marital status?
______ (1) Married or living as married
______ (2) Separated or Divorced
______ (3) Never married
______ (4) Widowed

7. What is your current living situation (check all that apply)?
______ (1) Alone
______ (2) With a significant other
______ (3) With one or more children
______ (4) With other adults/roommates
______ (5) With a dog

8. How many children under the age of 18 currently live in your household at least part of the time? _______

9. What is the highest level of education you have completed?
______ (1) Less than high school
______ (2) High School
______ (3) Some College
______ (4) Four-year college degree (AD, BA, BS)
______ (5) Some Postgrad
______ (6) Graduate Degree (MS, MA, PhD, MD, etc.)

9. What is your current employment status (check all that apply)?
______ (1) Employed full time
______ (2) Employed part time
______ (3) Undergraduate Student
______ (4) Graduate Student
______ (5) Unemployed- looking for work
______ (6) Retired
______ (7) Other, please specify ______________________________

10. Please indicate your annual household income (NOTE: for students and/or those living with roommates, please indicate your annual income considering anyone with whom you share finances):

_____ (1) Less than $25,000
_____ (2) $25,000-$49,999
_____ (3) $50,000-$74,999
_____ (4) $75,000-$99,999
_____ (5) $100,000 or more

Self-Efficacy for Altering SED vs PA

The following questions are intended to ask about your confidence in your ability to do several types of activities.

- When questions ask about **'moderate to vigorous activities'**, we define this as those activities that take physical effort and make you breathe harder than normal. You may break a sweat and feel your heart beat much faster while doing these activities. Examples of moderate intensity exercise are brisk walking, swimming at a regular pace, and gardening. Examples of vigorous activities are running, fast swimming, and playing competitive soccer.
- **Resistance exercise** is a form of physical activity that is designed to improve muscular fitness by exercising a muscle or a muscle group against external resistance. Squats, push-ups and sit-ups are examples of resistance exercise.
- **Sedentary behavior** is defined as any waking behavior done while sitting, reclining or lying down that requires little physical effort. Common sedentary behaviors include working at a desk, watching television, and playing video games in a seated or lying position.

Use the scale below to answer each of the following questions. The scale has the anchors of 0, indicating not at all confident, and 10, indicating very confident. Please select one number that best represents how you feel right now.

Not at all Confident **Somewhat Confident** **100% Confident**

0 1 2 3 4 5 6 7 8 9 10

How confident are you that you can do the following?

Change-related questions

1. I can increase my moderate to vigorous physical activity by 10 minutes each day.
    a. I can increase my moderate to vigorous physical activity by 20 minutes each day.
    b. I can increase my moderate to vigorous physical activity by 30 minutes each day.
    c. I can increase my moderate to vigorous physical activity by 45 minutes each day.
    d. I can increase my moderate to vigorous physical activity by 60 minutes each day.

2. I can increase the number of steps I take by 1000 (equivalent to about 0.5 miles) each day.
    a. I can increase the number of steps I take by 2,000 (~1 mile) each day.
    b. I can increase the number of steps I take by 5,000 (~2.5 miles) each day.

3. I can reduce the total amount of time I spend sitting by 30 minutes each day.
    a. I can reduce the total amount of time I spend sitting by 1 hour each day.
    b. I can reduce the total amount of time I spend sitting by 2 hours each day.
    c. I can reduce the total amount of time I spend sitting by 3 hours each day.

4. Prolonged sedentary time is time spent seated or lying down while awake without getting up for long periods of time (e.g., 30 or more minutes). Standing up to stretch or walking to use the restroom or get a drink of water are examples of ways to break up prolonged sedentary time. Think about the time each day that you spend sitting for longer than 30 minutes. How confident you are that you could break up these prolonged periods of sedentary time?
    a. I can break up prolonged sedentary time at least 1 more time each day.
    b. I can break up prolonged sedentary time at least 2 more time each day.
    c. I can break up prolonged sedentary time at least 5 more time each day.
    d. I can break up prolonged sedentary time at least 10 more time each day.

5. I can do resistance exercises at least 1 more day a week.
    a. I can do resistance training exercises at least 2 more days a week.
    b. I can do resistance training exercises at least 3 more times a week.

Outcome-related questions

1. I can accumulate 5,000 total steps every day.
    a. I can accumulate 10,000 total steps every day.
    b. I can accumulate 15,000 total steps every day.

2. I can accumulate at least 150 minutes of moderate to vigorous physical activity each week.

3. I can accumulate at least 30 minutes of moderate to vigorous activity every day.

4. I can stand up and move at least once during each hour of the day.

5. I can accumulate at least 250 steps each hour of the day.

6. I can sit for less than 12 hours in total each day.

    a. I can sit for less than 10 hours each day.
    b. I can sit for fewer than 8 hours each day.

7. I can do resistance training exercises at least two days each week, doing 8-12 repetitions of 8-10 different exercises that target large muscle groups.

Process-related questions

1. I can get up earlier each day to fit in time to exercise.
2. I can find time during school or work hours to exercise.
3. I can make time after school or work to exercise.
4. I can stay up later each evening to fit in exercise.
5. I can increase the amount of walking I do by parking further from work, taking the stairs instead of the elevator, and getting up to visit coworkers/peers instead of sending emails/texts.
6. I can reduce the amount of sitting I do before school or work.
7. I can reduce the amount of sitting I do at school or work.
8. I can reduce the amount of sitting I do after school or work.
9. I can get from place to place using active forms of transportation, like walking or cycling instead of driving or taking the bus.
10. I can stand or move around while I complete daily tasks that I usually do seated.

Barrier-related questions – what will stop you?

1. Even when my friends/family/peers do not regularly exercise, I can stick to my exercise routine. (social norms)
2. I can stick to my exercise routine even when I am busy or feel that I don’t have time. (time)
3. I can stick to my exercise routine even when I feel very tired. (fatigue)
4. I can stick to my exercise routine even when I don’t feel motivated. (motivation)
5. I can stick to my exercise routine even when I don’t feel well or have minor aches and pains. (pain/health)

6. I can stick to my exercise routine even without resources (e.g., gym membership or exercise equipment) to assist me. (resources/environment)

7. I can stick to my exercise routine even when I am feeling sad, discouraged, or unhappy. (mood)

8. I can stand up and move each hour of the day even when others around me are seated, like during a meeting, in class, or in a waiting room. (social norms)

9. I can stand up and move each hour of the day even when I am busy or feel that I don't have time. (time)

10. I can stand up and move each hour of the day even when I feel very tired. (fatigue)

11. I can stand up and move each hour of the day even when I don't feel motivated. (motivation)

12. I can stand up and move each hour of the day even when I don't feel well or have minor aches and pains. (pain/health)

13. I can stand up and move each hour of the day, even without resources (e.g., a standing desk or activity tracker) to assist me. (environment)

14. I can stand up and move each hour of the day even when I am feeling sad, discouraged, or unhappy. (mood)

APPENDIX K. INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE-SHORT FORM

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE (August 2002)

SHORT LAST 7 DAYS SELF-ADMINISTERED FORMAT

FOR USE WITH YOUNG AND MIDDLE-AGED ADULTS (15-69 years)

The International Physical Activity Questionnaires (IPAQ) comprises a set of 4 questionnaires. Long (5 activity domains asked independently) and short (4 generic items) versions for use by either telephone or self-administered methods are available. The purpose of the questionnaires is to provide common instruments that can be used to obtain internationally comparable data on health–related physical activity.

Background on IPAQ
The development of an international measure for physical activity commenced in Geneva in 1998 and was followed by extensive reliability and validity testing undertaken across 12 countries (14 sites) during 2000. The final results suggest that these measures have acceptable measurement properties for use in many settings and in different languages, and are suitable for national population-based prevalence studies of participation in physical activity.

Using IPAQ
Use of the IPAQ instruments for monitoring and research purposes is encouraged. It is recommended that no changes be made to the order or wording of the questions as this will affect the psychometric properties of the instruments.

Translation from English and Cultural Adaptation
Translation from English is supported to facilitate worldwide use of IPAQ. Information on the availability of IPAQ in different languages can be obtained at www.ipaq.ki.se. If a new translation is undertaken we highly recommend using the prescribed back translation methods available on the IPAQ website. If possible please consider making your translated version of IPAQ available to others by contributing it to the IPAQ website. Further details on translation and cultural adaptation can be downloaded from the website.

Further Developments of IPAQ
International collaboration on IPAQ is on-going and an ***International Physical Activity Prevalence Study*** is in progress. For further information see the IPAQ website.

More Information
More detailed information on the IPAQ process and the research methods used in the development of IPAQ instruments is available at www.ipaq.ki.se and Booth, M.L. (2000). *Assessment of Physical Activity: An International Perspective*. Research Quarterly for Exercise and Sport, 71 (2): s114-20. Other scientific publications and presentations on the use of IPAQ are summarized on the website.

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the **last 7 days**. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

Think about all the **vigorous** activities that you did in the **last 7 days**. **Vigorous** physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. Think *only* about those physical activities that you did for at least 10 minutes at a time.

1. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, digging, aerobics, or fast bicycling?

   _____ **days per week**

   ☐ No vigorous physical activities → ***Skip to question 3***

2. How much time did you usually spend doing **vigorous** physical activities on one of those days?

   _____ **hours per day**

   _____ **minutes per day**

   ☐ Don't know/Not sure

Think about all the **moderate** activities that you did in the **last 7 days**. **Moderate** activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal. Think only about those physical activities that you did for at least 10 minutes at a time.

3. During the **last 7 days**, on how many days did you do **moderate** physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis? Do not include walking.

   _____ **days per week**

   ☐ No moderate physical activities → ***Skip to question 5***

4. How much time did you usually spend doing **moderate** physical activities on one of those days?

_____ **hours per day**

_____ **minutes per day**

☐ Don't know/Not sure

Think about the time you spent **walking** in the **last 7 days**. This includes at work and at home, walking to travel from place to place, and any other walking that you have done solely for recreation, sport, exercise, or leisure.

5. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time?

_____ **days per week**

☐ No walking → ***Skip to question 7***

6. How much time did you usually spend **walking** on one of those days?

_____ **hours per day**

_____ **minutes per day**

☐ Don't know/Not sure

The last question is about the time you spent **sitting** on weekdays during the **last 7 days**. Include time spent at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading, or sitting or lying down to watch television.

7. During the **last 7 days**, how much time did you spend **sitting** on a **week day**?

_____ **hours per day**

_____ **minutes per day**

☐ Don't know/Not sure

This is the end of the questionnaire, thank you for participating.

APPENDIX L. SEMI-STRUCTURED QUALITATIVE INTERVIEW

Semi-Structured Qualitative Interview over Sedentary Intervention

After completing the 8-week intervention to reduce your sedentary time, we'd like to ask a few questions about your experience. Your responses are extremely valuable in helping us and other researchers develop similar interventions in the future. With that in mind, it is important that you are as honest and candid as possible.

First, thinking about your sedentary time over the 8-week period, what were the primary reasons you found yourself sitting for long periods of time?

- In which of these situations were you able to decrease or break up your sitting time?
  - What steps did you take to help you reduce your sitting during each of these situations?
  - Can you identify any factors that made this easier for you?
- Again, thinking of those situations where you were sitting for long periods of time, when was it most challenging to decrease or break up your sitting?
  - For those times when it could have been possible to decrease your sitting, tell me about how you tried to sit less during these times?
  - Can you identify any factors that made these times more difficult for you to reduce your sitting?
  - What do you think you would need in order to sit less during these times?

Now I'd like to talk about your experience with the Fitbit and how it influenced your ability to decrease or break up your sitting.

Overall, describe your experience using the Fitbit to help you reduce your sedentary time.

In terms of receiving prompts, how helpful were the reminders and feedback you received from the Fitbit and associated application?

- Would other prompts be more beneficial?
- If so, which types? (e.g. emails, texts, alarms)
- How frequently?

As part of the intervention, we also discussed sitting as a habit and strategies for forming new habits. How well do you feel you were able to build new habits?

- Overall, did thinking about habits help you decrease or break-up your sitting time?
- We talked about inward cues like pain or an emotion and outward cues like the Fitbit or pillows on the couch blocking your seat. Thinking about both of these types of cues, which were most helpful in working toward developing a new habit?
- What cues were least helpful in working toward developing new habits?

Aside from the Fitbit, were there any other strategies or tools that helped you or reminded you to sit less?

- If you were to design an intervention with unlimited resources to help you sit less, what would it look like?