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EXAMINING THE RELATIONSHIP AMONG WEIGHT STATUS, PHYSICAL ACTIVITY, AND PAIN AFFECTING ACTIVITY IN A NATIONALLY REPRESENTATIVE SAMPLE

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EXAMINING THE RELATIONSHIP AMONG WEIGHT STATUS, PHYSICAL ACTIVITY, AND PAIN AFFECTING ACTIVITY IN A NATIONALLY REPRESENTATIVE SAMPLE

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BY THE COMMITTEE CONSISTING OF

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ABSTRACT

Chronic pain has been considered as one of the leading causes of decreased quality of life and disability in adults. Recent evidence suggested that physical activity level, weight status, age, and other demographic characteristics could play a role in determining whether an individual will experience pain during usual activities. Additionally, greater pain prevalence has been observed among obese and female populations; however, few studies have been conducted in these populations and the current results are conflicting. **PURPOSE:** The purpose of this study was to examine the relationship among physical activity, weight status, body composition, and pain impacting a person's ability to perform usual activities using a nationally representative sample (NHANES 2011-2012). Additionally, it explored the effects of demographic variables such as age, sex, ethnicity, education, and the presence of an arthritis diagnosis, all of which have been previously shown to impact physical activity, weight status, or body composition, on the relationship among our variable of interest. **METHODS:** Data from the 2011-2012 NHANES report was used in this study. NHANES consists of a series of interviews and interviews that assess demographic, socioeconomic, health, medical and dietary variables as well as physical exam and laboratory data. From this survey variables were selected that provided demographic, pain, self-reported physical activity, BMI, and body composition data. **RESULTS:** There were significant differences in body composition and physical activity levels among males and females ($P < 0.05$). Males had a greater prevalence of being more active compared to females as well as having more lean mass, less fat mass, and lower % body fat. Significant differences in the prevalence of chronic pain ($P < 0.05$) were found for the following variables: age, race/ethnicity, education level, annual household income, BMI, total physical activity, recreational physical activity, and arthritis diagnosis. When controlling for all other variables, significant results were also found for the odds of moving up in a pain category ($P < 0.05$) within the following variables: age, race/ethnicity, annual household income, total physical activity and arthritis diagnosis. **CONCLUSIONS:** In conclusion, we found that not meeting the weekly physical activity guidelines will significantly increase one's chance of reporting a greater prevalence of pain making it difficult to perform usual activities when not controlling for fat mass.

CHAPTER I

INTRODUCTION

Pain is a complex sensation experienced by all individuals. Nahin (2015) estimates that nearly 56% of adults in America reported having pain within a 3-month time span. In general, pain is a discomforting feeling that acts as a protective mechanism from tissue damage (Swieboda et al., 2013). Pain can be classified into three different types: Nociceptive, inflammatory, and pathological. Nociceptive pain functions to protect the body against a potentially harmful, or noxious, stimulus. Similarly, inflammatory pain also functions to protect the body so that it may heal after injury or tissue damage. Lastly, pathological pain is maladaptive pain that is the result of nervous system dysfunction or injury. These maladaptive changes within the nervous system can lead to long term, or chronic pain (Woolf, 2010). Chronic pain is one of the leading reasons that medical attention is sought by adults. According to Dahlhamer et al. (2018) nearly 20% of adults suffer from a chronic pain condition that contributes to diminished mobility and overall quality of life. In the United States alone, long term disability due to chronic pain results in roughly 50 million lost working days. In addition to physical disability, chronic pain can also significantly contribute to psychological disorders. It has been found to be associated with both anxiety and depression as well as impacting sleeping, eating habits, and relationships (Majedi et. al 2020).

While nearly all individuals will experience pain during their lifetime, certain population groups are more prone to experiencing acute and chronic pain. As individuals age, the prevalence of chronic pain increases (Ray et al., 2011). According to Meucci et al. (2015), chronic low back pain increases in a linear fashion from age 30 to age 60. In addition to aging, Meucci et al. (2015) also noted that chronic pain was more prevalent in females compared to males. Research showed that women tended to experience both widespread chronic pain and localized chronic pain more frequently than men (Umeda & Kim, 2019).

In addition to sex and age, obesity appears to play a role in whether or not an individual experiences pain. McKendall & Haier (1983) report that individuals who were obese were found to be significantly more sensitive to pain than individuals who were not obese. Conversely, Torensma et al. (2016) found that pain thresholds were higher in obese populations. Despite these equivocal results on whether obesity directly contributes to pain, evidence has shown that individuals who were obese were at a greater risk for developing co-morbidities like heart disease, type II diabetes, and metabolic syndrome (Seaman, 2013). Interestingly, these co-morbidities have also been shown to function as risk factors for developing chronic pain—indicting that obesity may also indirectly influence chronic pain (Booth et al., 2017). It has also been observed that chronic pain can lead to obesity due to the limitations that it places on physical activity levels (Arranz et al., 2013). A potential confounding factor in examining the relationship of obesity and chronic pain that has not been widely studied is the role of body composition. It is known that elderly individuals and females experience pain at higher rates than their younger and male counterparts (Majedi et al., 2020). Additionally, both female and elderly population groups tend to have a greater percent body fat (at the same BMI), which could suggest that either increased fat mass or reduced muscle/lean mass may influence pain. As individuals age there is a loss of appendicular and trunk lean mass and a gain of central adiposity, both of which have been shown to be associated with heightened pain levels, although an exact mechanism has not yet been identified (Toda et al., 2000). As such, additional research is needed to determine the nature of the relationship among obesity, body composition and pain.

Among age, sex, and body composition, physical activity may also play a large role in determining one's quality of life. Increased physical activity has been shown to reduce the risk of developing chronic diseases such as type II diabetes, heart disease, and arthritis (Booth et al., 2012). Additionally, the risk for developing chronic pain has been found to increase in individuals who have one or more cardio-metabolic comorbidities (Booth et al., 2017). Therefore, since increased physical activity can minimize the risk for chronic diseases, which themselves are risk factors for developing chronic pain, it is plausible that increased physical activity may also play a role in limiting the development of chronic pain. Currently, treatment for chronic pain poses an issue among individuals due to severe medication side effects that may suppress energy, mobility and ability to perform exercise; all of which are imperative for improving quality of life (Dale & Stacey 2016). As a result, there has been an increased interest in utilizing exercise as a mode of pain modulation. Exercise has been widely shown to lead to acute reductions in pain sensitivity, referred to as exercise-induced hypoalgesia (EIH), which has been observed in both healthy and some clinical pain populations (Lima et al., 2017). However, while exercise does have the capacity to reduce pain sensitivity, Ambrose & Golightly (2017) highlight that there is little available evidence on the most beneficial exercise regimen for alleviating pain instead of exacerbating it in individuals with certain chronic pain conditions like osteoarthritis (OA). Therefore, it is imperative to understand how chronic pain conditions such as OA function so that an ideal exercise treatment can be detailed.

Osteoarthritis (OA) has been found to be one of the most common sources of disability and chronic pain in individuals, especially as they age. Osteoarthritis is the most common disease of the joints in humans (O'Neill & Felson, 2018). In 2018 ~14 million Americans reported a diagnosis of OA in the knee joint alone (Vina & Kwoh, 2018). While OA can affect many aspects of an individual’s well-being, pain is the most prevalent symptom of the disease (O’Neill & Felson, 2018). However, individuals with symptomatic OA also report negative impacts on their mental health. Vina & Kwoh (2018) discuss that individuals with OA are more likely to develop symptoms of depression, insomnia and mood impairments. The most common cause of OA appears to be joint degeneration associated with aging, however, individuals who are obese tend to be at a greater risk for OA than non-obese individuals. Furthermore, there is an increased risk in females in comparison to males (Sinusas, 2012). Therefore, it is critical to understand the mechanisms of pain in both healthy and clinical populations and how they can be mitigated or exacerbated by obesity and/or body composition (O’Neill & Felson, 2018). The aim of this study is to determine how age, sex, body fatness, and physical activity work to influence pain in healthy individuals as well as those with a diagnosis of OA.

Purpose

The purpose of this study was to examine the relationship among physical activity, weight status, body composition, and pain impacting a person’s ability to perform usual activities using a nationally representative sample (NHANES 2011-2012). Additionally, it explored the effects of demographic variables such as age, sex, ethnicity, education, and the presence of an arthritis diagnosis, all of which have been previously shown to impact physical activity, weight status, or body composition, on the relationship among our variable of interest.

Research Questions

1. Are previously supported measures such as age, sex education level, and ethnicity related to reports of pain making it difficult to perform usual activities?
2. Is weight status, determined by body mass index, related to reports of pain making it difficult to perform usual activities??

3. Does meeting weekly physical activity recommendations, relate to reports of pain making it difficult to perform usual activities?
4. Is DXA determined body composition related reports of pain making it difficult to perform usual activities?
5. When controlling for age, sex, education, and ethnicity, are weight status, physical activity and or body composition related to pain making it difficult to perform usual activities?

Hypotheses

1. Individuals of lower age, who are male, who have a college education, and who are white will report pain makes it difficult to perform usual activities to a lesser degree.
2. There will be a difference in the extent that pain makes it difficult to perform usual activities between individuals with a high weight status (overweight or obese by BMI) and individuals with a normal weight status.
3. Individuals who are more physically active will report pain makes it difficult to perform usual activities to a lesser degree.
4. There will be a difference in the extent that pain makes it difficult to perform usual activities between individuals with a higher percentage of lean tissue than adipose and individuals with a lower percentage of lean mass than adipose tissue.

Sub-Hypotheses

a. When controlling for age, sex, education, and ethnicity, individuals with a higher weight status will report pain makes it more difficult to perform usual activities.
b. When controlling for age, sex, education, and ethnicity, individuals with a lower physical activity level will report pain makes it more difficult to perform usual activities.

c. When controlling for age, sex, education, and ethnicity, individuals with a greater percentage of fat mass will report pain makes it more difficult to perform usual activities.

Significance

Chronic pain is one of the largest contributors to decreased quality of life in adults according to Mitsi & Zachariou (2018). It has been found that pain can be influenced by a variety of factors such as sex, age, physical activity levels and body composition (Sinusas, 2012). Currently, the growing prevalence of chronic pain has led to a growing opioid dependency issue resulting from painkiller prescriptions used for pain management (Mitsi & Zachariou, 2018). There is reason to suggest that fat mass may have an effect on pain; however, these effects are not fully understood and have not been widely studied yet. Thus, it is imperative to understand how pain functions among various population groups in order to determine the best prevention and treatment methods moving forward.

Limitations

1. Results will only be representative of the 2011-2012 NHANES Survey population
2. Results will only be applicable to pain with usual activities.

Delimitations

1. Those who are age 20 > years
2. Women who reported not being pregnant

Assumptions

1. Subjects responded to the NHANES survey truthfully

Operational Definitions

1. **Chronic Pain:** pain felt by an individual on most or all days for at least 6 months (Dahlhamer et al., 2018)
2. **Body Mass Index:** A statistical index that takes into account the height and weight of an individual to estimate body fat (Weir & Jan, 2020)
3. **Dual energy X-ray absorptiometry (DEXA):** Imaging scan used to estimate regional and total measures of bone mineral density, fat mass, and lean mass (Peppa et al., 2017)
4. **Osteoarthritis:** A degenerative disorder of the cartilage in joints that is associated with hypertrophic alterations in the bone (Sinusas, 2012)

CHAPTER II

LITERATURE REVIEW

As previously stated, the purpose of this study is to describe the relationship among body composition, osteoarthritis, physical activity, and pain upon movement using a nationally representative sample. The following chapter aims to provide background information from literature on the prevalence of pain in adults with and without osteoarthritis and how it varies with demographics, body composition, and physical activity.

Effect of pain on QOL

Chronic pain is defined as pain felt by an individual on most or all days for at least 6 months (Dahlhamer et al., 2018). A study done by Dahlhamer et al. (2018) analyzed the prevalence of chronic pain in the U.S. and found that nearly 20% of American adults report suffering from chronic pain. Consequently, chronic pain has been found to be related to poor health outcomes and diminished quality of life among adults in the U.S. It is also one of the leading causes of long-term disability in adults around the globe (Majedi et al., 2020). In particular, Wettstein et al. (2019) discuss that the lower back has been found to be one of the most common sites for chronic pain in adults and that it greatly affects one's physical functioning.

While pain can affect physical functioning, factors such as age, obesity, and physical activity also play a role in how individuals are affected by pain. Specifically, age and BMI have been observed as two of the most prominent risk factors for chronic pain (Majedi et al., 2020). In a study that examined quality of life and obesity, Cameron et al. (2012) found there to be an inverse relationship between obesity and quality of life. They discussed that as the BMI of an individual increased, both their physical and mental quality of life was decreased. In particular, the diminished physical quality of life was associated with increased bodily pain. Majedi et al. (2020) discuss that both age and BMI are also associated with longer pain duration in comparison to other risk factors. One possible reason for this is due to the inadequate treatments for chronic pain that are available for individuals within these populations, specifically the elderly. The use of prescription analgesics in older individuals can be dangerous, thus lower doses or over the counter medication is preferred. As a result, their pain may be undertreated which increases the duration of their pain. Dale and Stacey (2016) also discuss that for this reason it is important that other methods of treatment, like exercise, be considered for reducing chronic pain.

The way pain functions within the human body is complex and thus, the way that it is treated must be complex as well. Dale and Stacey (2016) discuss that pain treatment often includes a combination of medication, lifestyle changes, physical activity, or rehab, among many other treatment options. While exercise and pharmacological treatments have proved to be useful mechanisms for treating pain; both are not without their drawbacks. Medication use for treatment of chronic pain poses an issue for several reasons including severe side effects and opioid dependency (Mitsi & Zachariou, 2016). Some of the most common negative side effects that can be induced by pain medications are depressed energy levels, mobilily, ability to exercise and even memory. This occurs because most medications that are used to treat chronic pain work as central nervous system depressants within the body. Typically to minimize these depressing effects individuals will take a lower medication dosage, which ultimately leads to less pain relief; a similar effect of that seen in elderly populations (Dale & Stacey, 2016). As a result, exercise, among other methods of treatment have been relied on to supplement or replace pain medication. Vaegter et al. (2020) discuss a phenomenon known as exercise induced hypoalgesia (EIH), which refers to the reduction in pain sensitivity that has been observed in individuals following a bout of exercise. This trend has been consistently observed in individuals who lack chronic pain conditions (Vaegter et al., 2016). However, in individuals with chronic pain conditions this same response is not as prominent. Physical activity in those with chronic pain conditions, such as OA, can even work to exacerbate pain rather than reduce it (Vaegter et al., 2020). For this reason, when considering elderly and obese populations, where chronic pain conditions are more common, exercise may be not be the most effective method of pain reduction. Thus, as pain has such a significant effect on so many individual's quality of life, it is imperative that we understand how it functions in a variety of populations so that ideal treatment methods can be identified for each of those populations. Secondly, studies like the one conducted by Vaegter et al. (2016) utilize only a small sample of subjects, thus utilizing a larger sample size is also imperative for understanding pain in a more comprehensive manner.

Prevalence of Pain on Activity

Both acute and chronic pain are associated with physical disability in some capacity. While acute pain has been observed to affect more individuals than chronic pain, chronic pain tends to be more severe and debilitating in nature (McCarthy et al., 2009). Nevertheless, Nahin (2012) discusses that roughly 126 million Americans experience pain within any given 3-month period. As pain contributes to physical disability, it has been found to have a profound impact on movement. Neige et al. (2018) take an interesting approach in discussing how even the anticipation of pain can affect movement. Particularly in individuals with acute pain, they find that protective mechanisms and movements are implemented to limit pain felt while being active. They go on to discuss that these protective actions may temporarily lead to pain relief on movement; however, they can possibly create lasting consequences within the body leading to chronic pain.

While pain of movement affects individuals from several different population groups, the likelihood of being afflicted by pain does vary depending on certain demographic variables; many of which are not within the individual's control. One population group in particular that most commonly experiences pain on movement is elderly populations. Like mentioned earlier in this chapter, Majedi et al. (2020) discuss that elderly individuals with chronic pain experience longer duration of pain in part due to their inability to rely on medications as treatment methods. Blyth and Noguchi (2017) delve into the relationship among aging and pain prevalence. As individuals age there is increased likelihood that they will develop one or more medical conditions that might contribute to pain and increased disability. In fact, they discuss a systematic review conducted by Marengoni et al. (2011) that noted at least 55% of individuals aged 60 or higher had 2 or more medical conditions. Despite pain being more prevalent in aging populations, Wettstein et al. (2019) found that the rated intensity of the pain did not change with age. They also report a higher reported quality of life in older individuals with chronic pain. This is attributed to changes in the way pain is experienced and perceived as individuals age.

In addition to age, pain also varies depending on sex. In a study conducted by McCarthy et al. (2009), chronic pain was found to be more prevalent in females compared to males. Schopper et al. (2013) discuss that this can be attributed to genetic, hormonal, or anatomic differences; however, there is still little known about the exact mechanisms within the body that are responsible for these discrepancies. Several studies have found that while both men and women may experience chronic pain, women are more likely to report pain and seek treatment for it than men are. Demographics from a study conducted in a pain neurologist's clinic showed that over the course of 1 year, roughly 66% of the patients seen were women (Santos Ferreira & Speciali, 2014). This could be due in part to the fact that when women experience pain, they tend to experience it at a greater intensity (Mills et al., 2011). Additionally, when compared to males with pain, females with pain were more likely to develop negative coping mechanisms, ultimately leading to higher instances of chronic pain and decreased quality of life (El-Shormilisy et al., 2015).

Pain Perception

Nearly 20% of all American adults will experience chronic pain at some point in their life, because of this it is important to understand the underlying mechanisms of pain and pain modulation so that preventative measures can be made moving forward. Pain pathways in the body are comprised of a complex system that functions to detect the noxious stimulus and generate a protective response to that stimulus (Bourne et al., 2014). An individual perceives pain when specialized sensory receptors called nociceptors transmit an electrical signal from the periphery to the central tissues within the body. The generation of an electrical stimulus occurs when a peripheral nociceptor detects a noxious stimulus (Black, 2012). There are two primary types of afferent nerve fibers that detect a noxious stimulus: Unmyelinated C fibers and myelinated Aδ fibers (Kuner, 2010). These nociceptors can be excited by mechanical, thermal or chemical noxious stimuli. Aδ fibers are activated in response to mechanical or thermal stimuli and elicit a sharp, quick pain response; whereas C fibers are activated by chemical stimuli and elicit a slow burning or aching pain (Bourne et al., 2014). The mode of transmission and destination of the stimulus is dependent on which type of afferent fiber was activated. For example, when a C fiber is activated by a noxious stimulus, the signal travels down the paleospinothalamic tract to the reticular formation, periaqueductal gray (PAG), hypothalamus, amygdala, and portions of the thalamus (Black, 2012).

The inputs that are received and transmitted by these nociceptors play a role in modulating the pain within the body. This modulation of pain can be represented by both hyperalgesia and hypoalgesia (Black, 2012). Pain modulation within the nociceptive pathways is multidimensional and can occur in response to a variety of stimuli. A theory known as the Gate-control theory, originally coined by Melzack and Wall (1965), states that non-nociceptive afferent fibers within the body provide input to interneurons in the dorsal horn which activates them. This in turn works to inhibit nociceptor activity, which blunts their input from the peripheral nervous system, thus blunting the pain perception.

In a review conducted by Mitsi and Zachariou (2016), pain modulation and perception in chronic pain individuals is discussed. They propose that the midbrain dopamine center serves a critical role in the modulation of pain (Mitzi and Zachariou, 2016). The mesolimbic dopamine system has been shown to modulate how nociceptive stimuli is perceived within the body as well as various symptoms associated with chronic pain (Mitzi and Zachariou, 2016). In a study conducted by Dennis and Melzack (1983), dopaminergic agents were found to lessen an individual's perception of pain; however, in the case that this system is defective the perception of pain can be exacerbated (Saadeé Atweh et al., 1997).

Prevalence of Osteoarthritis

When examining chronic pain populations, it is a common find that many individuals have at least 1 chronic disease or comorbidity that contributes to their pain. Currently, the most prevalent chronic joint disease in adult populations is osteoarthritis (OA) (O'Neill & Felson, 2018). OA is characterized as degenerative disease involving the articular cartilage. One of the most common symptoms that is associated with this disease is pain. Individuals with OA often experience pain in their joints as well as stiffness, which can contribute to loss of function and decreased quality of life (Sinusas, 2012). The most common risk factors associated with OA include being female, age, obesity, and genetics. OA considered a geriatric disease as it is most prevalent in elderly or middle-aged populations (Shekhar et al., 2015). The most frequently affected joints are typically the knees, hips, hands, and spine. Interestingly, the disease often affects joints unilaterally, meaning that one side of the body could be functioning normally while the other is debilitated (Sinusas, 2012).

With OA, the mechanisms that contribute to pain are not fully understood and vary from individual to individual. It is known that typically the pain is focused in the affected joint, however, it can occasionally radiate toward nearby joints (O'Neill & Felson, 2018). It is also important to note that OA is a disease that affects the joint as a whole. This includes not only the cartilage, but the surrounding bone and synovium as well (Dieppe, 2004). While pain is considered the most prominent symptom associated with OA, it usually only occurs intermittently in the early stages of the disease.

In order to get a better understanding of the mechanisms of pain in OA, it is important to observe the structural changes that occur and the nerve mechanisms that are affected (O'Neill & Felson, 2018). Loeser et al. (2012) discuss the changes that occur within the articular cartilage and how it affects the joint as a whole. In individuals without OA, the articular cartilage functions as a smooth surface that facilitates efficient joint movement. Whereas, in OA patients, cells called chondrocytes are activated which ultimately leads to an injury like response within the joint. This causes events such as cartilage loss, cartilage calcification, and bone spur formation to occur. While cartilage loss is a significant structural change that occurs with OA, articular cartilage receives no neural innervation and thus cannot be a source of pain in moderate or mild cases of the disease. Thus, O'Neill & Felson (2018) discuss several studies that utilized MRI on OA patients both with and without pain to determine possible structural sources of pain. Felson et al. (2001) discuss that one structural change associated with pain in 401 OA patients are bone marrow lesions. They found that nearly 77% of individuals who reported knee pain also had bone marrow lesions. Hill et al. (2007) also discuss that changes in synovitis in OA patients seen on MRI were associated with knee pain severity. In particular, they found that the more the synovitis increased the more the pain increased.

While the articular cartilage itself receives no neural innervation, there are still nociceptors that are found within the joint which can elicit pain. The nociceptors within the joint of OA patients can be stimulated both by chemical and mechanical stimuli to create a pain response. When a nociceptor is stimulated, there is an action potential that is generated and transmitted through C fibers and Aδ fibers. When a signal is transmitted via C fibers a slow, burning pain sensation is elicited, whereas Aδ fibers transmit sharp pain. These afferent fibers are responsible for transmitting pain signals from the joint to the spinal cord where the signal is processed. Once the signal is processed, descending fibers work to modulate the pain signals in the spinal cord. When inflammation or injury occurs with OA, it can lower the required threshold to excite the nerves in the joint, thus increasing the responsiveness of the nociceptors. As a result, individuals with OA can be more likely to experience heightened levels of pain and sensitivity in the afflicted joint (O'Neill & Felson, 2018). Although some mechanisms of the way pain functions in OA patients is thought to be understood, there is still much to be learned about how this disease functions within the body. Gaining a thorough understanding of these pain mechanisms is crucial in providing better treatments and therapy that can improve physical functioning.

Relationship Among Body Composition and Pain

Just as age, sex, and OA play a role in whether or not an individual may experience daily pain, body composition can affect pain as well. The weight of an individual has been shown to have a profound impact on the musculoskeletal system. Particularly, in obese populations the prevalence of musculoskeletal conditions is greater than in non-obese population groups. It is important to understand how obesity affects pain, as obesity rates are continuing to increase worldwide. Currently obesity affects roughly a third of North American adults (Price et al., 2013). Body mass index (BMI) is utilized to quantify obesity. Obesity is grouped into three classes based on BMI: class I, class II, and class III. Classes II and III are generally more severe in nature and are associated with more comorbidities and health complications. The mechanical stress placed on the musculoskeletal system in obese individuals lead to chronic pain and limited functional capacity (Arranz et al., 2013). Seaman (2013) discusses one factor that contributes to pain in obese individuals, which is systemic inflammation. He notes that metabolic syndrome is quite prevalent in obese individuals and results in increased levels of inflammation and can even cause chronic inflammation states. Chronic pain thus increases because the inflammation promotes nociceptor activity leading to heightened pain responses. In addition to increases in nociception, the inflammation caused by metabolic syndrome can lead to a handful of comorbidities that also contribute to pain such as rheumatoid arthritis and OA.

In a study involving 107 obese patients an inverse relationship between body weight and quality has been observed, so that as body weight increases reported quality of life decreases. Obese individuals are more prone to depending on others for daily physical functioning and have shown decreases in their disability-free years of life (Sirtori et al., 2012). Both chronic pain and obesity have an effect on quality of life; however, they also have a significant effect on one another as well. Like previously mentioned in this section, obesity contributes to chronic pain due to the mechanical and inflammatory stress that it places on the body. Conversely, chronic pain can lead to obesity due to the limitations it puts on physical activity and movement. As these two continue to affect one another, it creates a cycle of increased pain which causes increased body weight and so on (Arranz et al., 2013). For this reason, it is critical to find treatment or exercise methods that can be tolerated in order to reduce both pain and obesity.

Not only is obesity related to chronic pain in general, but associations have also been observed between obesity and other comorbidities as well as demographic variables. For instance, OA can be impacted by many different factors; however, obesity is commonly observed in individuals with OA. The center for disease control (CDC) found that more than 31% of adults who are obese also were clinically diagnosed with OA, compared to 16% in individuals who are not obese (Anandacoomarasamy et al., 2008). In addition to increased OA prevalence, obesity is also associated with increased pain, specifically low back pain. Low back pain is considered one of the most significant contributors to disability in adults worldwide according to Brady et al. (2019). In their study involving 150 patients, they found that baseline fat mass was positively associated with both low back disability and intense low back pain. They also report that low back pain had a stronger association with android fat in comparison to gynoid fat. Android fat, or central adiposity, becomes more prevalent as individuals age due to the loss of muscle mass. Toda et al. (2000) discussed that as individuals age, they tend to lose at least some of their trunk and appendicular lean mass. This in combination with increasing central adiposity work to increase the prevalence of pain in aging adults. However, this trend is not always observed in all populations, as discrepancies have been observed among men and women in whether or not muscle loss will contribute to pain. Additionally, this study only included 330 patients, and while that is a sufficient sample size, a larger and more representative sample could work to provide better insight as to how lean mass relates to pain.

Relationship Among PA and Pain

Physical activity is beneficial for a multitude of reasons, but perhaps one of the most important aspects of life that physical activity impacts is chronic disease prevalence. However, before discussing the impact physical activity has in diseased populations it is important to understand how it functions in healthy individuals. Exercise plays a crucial role in determining an individual's overall health and well-being (Naugle et al., 2012). In particular, exercise has been found to have an analgesic effect in healthy individuals. This reduction in pain perception occurs as a result of endogenous opioid release in response to exercise (Borisovskaya et al., 2020). Naugle et al. (2012) found that pain was consistently reduced in healthy populations following acute bouts of aerobic, isometric, and dynamic resistance exercise. In regard to aerobic exercise, they note that the pain reduction was the greatest following moderate-high intensity work. They also discuss that the pain reduction was the greatest both during and immediately following an isometric contraction. However, this EIH response was not as consistently found in individuals with widespread chronic pain.

Physical activity has been found to minimize the risk of developing a multitude of chronic diseases (Warburton et al., 2006). Thus, physical inactivity can contribute to the development of chronic disease among individuals. This includes, but is not limited to chronic pain, OA, rheumatoid arthritis, accelerated aging, and type II diabetes (Booth et al., 2012). Like previously mentioned, individuals with 1 or more comorbidities are at a greater risk for developing chronic pain. Therefore, it can be inferred that physical activity plays a large role in determining an individual's risk for experiencing pain on a daily basis. When considering pain, there are both primary and secondary pathologies that contribute to pain. The primary pathology is typically related to the tissue disorders like OA or fibromyalgia. While secondary pathologies include more of the psychological consequences that are associated with chronic pain such as fear of movement or anxiety. In many disease states, it is difficult to fully define the primary pathology, which in turn makes treatment and pain relief difficult. Therefore, focusing on the secondary pathologies can be even more beneficial in alleviating pain. This is where physical activity comes into play, exercise regimens have shown to be successful in alleviating both chronic musculoskeletal pain as well as the fear and anxiety associated with movement in chronic pain patients (Booth et al., 2017).

Currently there are recommended exercise guidelines for the general population, but there are not really any strict guidelines set out for chronic pain populations. This is in part due to the fact that exercise treatment in individuals with pain may actually be more beneficial when it is individualized. Additionally, the current evidence regarding exercise's effect on chronic pain symptoms and pathology is limited, but it has proven to be useful in providing pain relief and improved quality of life in some capacity (Ambrose & Golightly, 2015). Physical activity, while helpful on its own, has been observed to be the most beneficial for pain relief when used in a multimodal treatment regimen (Dale & Stacey, 2016). One form of exercise that has been shown to improve musculoskeletal pain, is aerobic exercise. Aerobic exercise includes activities such as running, biking, and swimming and can be performed at a wide range of intensities. Moderate to low intensity aerobic exercise has been found to improve symptoms associated in chronic pain. Higher intensity exercise can also improve chronic pain; however, it can be more difficult for individuals with pain conditions to tolerate exercise at higher intensities. Additionally, resistance training has been found to have similar effects on pain as aerobic exercise does. In fact it has also been observed to improve not only pain, but also quality of life and well being. It is also of importance to note that the aforementioned exercise methods tend to work best when used in conjunction with one another (Ambrose & Golightly, 2015).

While physical activity can work to improve pain in the general population as well as in chronic pain populations, it can also be a limitation in these chronic pain populations. Chronic pain is commonly found in OA and obese/overweight populations, both of which are often overlap with each other. The evidence regarding exactly how these populations respond to physical activity is limited; however, there are some instances in which exercise has been found to improve pain and physical functioning (Arulshud et al., 2017). Roddy et al. (2005) found that individuals with OA of the knee had improvements in pain with aerobic walking and quadriceps strengthening exercises. However, the pain outcomes following quadriceps strengthening were inconsistent due to variations in the intensity and methods in which strengthening was achieved. This variance is likely due to the ill-defined intensity of exercise that is needed to improve OA symptoms. Additionally, in obese populations exercise often leads to weight loss which can work to alleviate OA symptoms and thus reduce pain sensations some (Arulshud et al., 2017). However, it is not always that simple. Obese individuals with OA are more often than not found to gain weight than lose it due to their perceived inability to perform physical activity due to their pain (Ekram et al., 2016). Likewise, often individuals within obese and OA populations are of an older age, which makes physical activity even more difficult to do (Arulshud et al., 2017). Thus, it is important that individuals with chronic pain conditions limiting movement are educated on the importance of physical activity as treatment and how it can be performed safely and comfortably in conjunction with other treatment methods (Ekram et al., 2016). While there is evidence that physical activity works to improve quality of life, pain and functioning in chronic pain populations, it is limited. There is still research that needs to be done to determine the optimal intensity and type of exercise that can be tolerated to improve pain outcomes for these populations.

CHAPTER III

METHODOLOGY

Introduction

The following chapter will discuss the steps that were used to evaluate the relationship among body composition, osteoarthritis, physical activity, and pain upon movement using data collected from the 2011-2012 National Health and Nutrition Examination Survey (NHANES).

Sample Population

The data utilized were collected from the 2011-2012 NHANES report. NHANES involves interviews and surveys that assess demographic, socioeconomic, health, medical and dietary variables, as well as physical examinations and measurements, and laboratory data. The data were collected in a manner that allows for it to be a nationally representative sample of the US civilian population, which makes our study unique because our results will be generalizable to the US adult population; a characteristic that previous studies do not possess. The specific variables that are measured vary from year-to-year depending on the particular study objective for that year. The major survey objectives each year are typically:

1. To determine the number/percentage of the U.S. population and of the specified subgroups that have chosen disease(s) and risk factors.
2. Monitor the fluctuations in prevalence, awareness, treatment and control of the chosen disease(s)
3. Monitor risk behavior trends as well as environmental exposures
4. Study how diet, nutrition, and health interact with each other
5. Analyze new public health issues as well as emerging technologies

6. Determine health characteristics that are linked to modality data across a wide array of individuals

In order to select a sample that was representative of all 50 states NHANES uses the following multistage probability design:

1. Selection of small counties/small groups of adjacent counties as primary sampling units (PSUs)
2. Selection of a block/group of blocks within PSUs that contain a cluster of households
3. Selection of households within the blocks
4. Selection of individuals within a given household

For the 2011-2012 survey, a total of 13,431 individuals were chosen from 30 different locations to participate. Out of the 13,431 individuals selected, 9,756 participants or roughly 76% completed the interview process and 9,338 underwent a physical examination. Additionally, the 2011-2012 survey oversampled Non-Hispanic Asians, Non-Hispanic African Americans, low-income Non-Hispanic Whites, and elderly Non-Hispanic adults.

Interview Process

The first portion of the survey was the household interview questionnaire, which consisted of four separate sub-questionnaires. The first being a screener questionnaire, or "Screener Module 1", which encompassed a doorstep interview of a selected household. The purpose of this screener was to determine if any household members were eligible to partake in the survey. The second questionnaire was the relationship questionnaire, or "Screener Module 2." The relationship questionnaire was administered within each home to determine family units. The first two questionnaires were given to an adult member within the selected household that was at least 18 years old. The family questionnaire was then administered to each family unit within the household to determine information about each family such as insurance coverage, income, food security, etc. Lastly, the sample person questionnaire was administered individually to each participant to determine demographic, socioeconomic, health and dietary history. If the participant was 16 or older they were then interviewed directly, however, participants under the age of 16 had an adult proxy answer for them.

Once the household interview process was completed, the mobile examination center (MEC) questionnaires were administered. This portion of the interview consisted of topics like sexual health and substance use and consisted of two sub-questionnaires. The MEC was administered to subjects who were at least 8 years old. The computer-assisted personal interviewing (CAPI) questionnaire was administered first by a trained MEC interviewer. Then the audio-computer-assisted self-interviewing (ACASI) questionnaire was administered. During this portion of the interview the participant responds to questions that are heard via headphones and read on a computer touch screen. There is not an interviewer present during this portion of the MEC interview process. Additionally, no proxies could be used for the ACASI portion due to the sensitive nature of the questions. Thus, individuals who were mentally impaired or unable to understand any of the language options were not eligible to participate.

Variable Selection

Given our interest in examining potential relationships among variables previously shown to be associated with pain and disability due/related to pain (e.g. age, sex, education, ethnicity, diagnosis of osteoarthritis, weight status) as well as DXA derived measures of body composition and self-reported physical activity on pain's impact on physical function we chose data from the 2011-2012 report. While pain data was available in previous year's reports, the 2011-2012 report was the only report that included both pain and whole body DXA information, both of which were imperative for our study.

For this report, we selected the following questionnaires from the 2011-2012 NHANES to derive our variables of interest from:

- Demographic Questionnaire
- Current Health Status Questionnaire
- Medical Conditions Questionnaire
- Body Mass Index Questionnaire
- DEXA Questionnaire
- Physical Activity Questionnaire

Chronic Pain Assessment

Pain was assessed using the responses from the current health status questionnaire. This questionnaire includes data collected from personal interviews regarding an overall assessment of health, quality of life over the past month, illness in the past month, blood donations and AIDS testing. From this questionnaire, we specifically chose to include the variable that evaluates whether or not an individual felt that pain made it difficult for them to accomplish their usual activities. Interviewees were asked to report on how many days within the past 30 days that pain made it hard for them to do usual activities. Participants answered with a number between 0-30 days. They way in which this variable was recorded was not continuous, thus, for statistical analysis pain status was split into “artificial” categories. These categories were as follows: 1) never/non (zero reported days of pain making it hard for usual activities), 2) sometimes (1-29 reported days of pain making it hard for usual activities), 3) always (30 reported days of pain making hard for usual activities). These categories were selected based on a histogram that showed pain counts and a clustering effect was observed on each end of the histogram.

Self-Reported Physical Activity

Self-reported physical activity was measured during the household interview using the Physical Activity Questionnaire (PAQ). This particular questionnaire was modeled after the Global Physical Activity Questionnaire (GPAQ) from the World Health Organization (WHO). The PAQ asks questions that are related to an individual's daily activities, sedentary activity, leisure time and physical activity. We included all of the questions from this particular questionnaire in order to get a comprehensive view of each subject's activity level. The self-reported physical activity was used to calculate the MET (metabolic equivalents) minutes of physical activity accumulated by each participant. Based on the GPAQ recommendations, a MET value of 4 was assigned to moderate exercise and a MET value of 8 was assigned to vigorous exercise. Once the MET minutes of total activity were calculated, physical activity was further split into categories based on whether or not the ACSM physical activity guidelines had been met. For total physical activity the categories were as follows: 1) Met guidelines (>600 MET minutes) or 2) Insufficiently active (599-0 MET minutes). Additionally, physical activity was further grouped based on recreational physical activity only. The groups were determined by whether or not an individual met the ACSM physical activity guidelines purely through recreational activity. The categories were as follows: 1) Met guidelines (>600 MET minutes), 2) Insufficiently active (599-360 MET minutes), 3) None 0 MET minutes).

Body Composition Variables

Body composition variables were drawn from the body measures and whole body DEXA physical examination portion of the survey. The body measures can be used to predict a variety of different health outcomes; however, we selected the variables that would tell us about body weight and obesity. We specifically chose to use body mass index (kg/m^2). For analysis, BMI was split into three categories based on the normative data. The categories include normal weight (<25 kg/m^2), overweight (25-29.9 kg/m^2), and obese (>30 kg/m^2). The DEXA was used to measure both lean and fat mass for the entire body. These measures include but are not limited to total body mass, bone mineral content, fat mass, lean body mass, etc. For our analysis we chose to include the following variables: total fat mass, total lean mass (excluding bone mineral content), and percent body fat.

Other Variables

Demographic variables assessed in the 2011-2012 NHANES survey include individual, family, and household information. We selected the variables that provided information on the subject's sex, ethnicity, education level, and age. Of these variables, age was further split into the following groups: young adults (20-35 yrs.), middle aged adults (36-55 yrs.), and older adults (56+). Arthritis was assessed using the medical conditions questionnaire, which included self-reported interview data that encompassed a wide array of medical conditions found in both children and adults. The particular question we chose asked participants whether or not a doctor or other health professional had ever told them that they have arthritis. The participant could answer with "yes" or "no".

Inclusion Criteria

- U.S. Citizens who completed the 2011-2012 NHANES

Exclusion Criteria

- Individuals who did not complete all of the questionnaires and examinations for variables of interest

- Individuals younger than 20 years old
- Individuals who were pregnant at the time of the survey

Statistical Methods

SPSS complex samples software was used for all analysis. Based upon recommendations from the CDC on proper analysis, the 2-year MEC weighting statistics were used to weight the sampled population. Differences in the frequency or percentage of the sample exhibiting a certain characteristic across the three pain making it hard for usual activity categories were examined using the Rao-Scott chi-square test. An ordinal logistic regression was used to estimate the relationship among PA categories, weight status, body composition, and appearance in a certain pain category while controlling for other covariates such as age, sex, ethnicity, and education level. The data will be presented as frequencies/percentages and standard error (SE). The level of significance was set at $P < 0.05$.

CHAPTER IV

RESULTS & DISCUSSION

Participant Characteristics

Table 1 shows weighted means for the US population split by sex using a general linear model and t-test as well as a Rao-Scott Chi-Square test of independence. Significant differences between men and women were observed among age, DEXA body composition variables, total physical activity, and recreational physical activity ($P < 0.05$). In general, the women (48.3± 0.80 yrs) were older than the men (46.7 ± 0.89 yrs). Females had both higher percent body fat (38.7 ± 0.37 kg) and fat mass (30.3 ± 0.50 kg) than males (27.1 ± 0.25 kg) and (24.6 ± 0.44 kg) respectively. Conversely, males had a higher lean mass (61.0 ± 0.40) compared to females (43.9 ± 0.31 kg).

When comparing physical activity, men had a higher prevalence of being sufficiently active (71.8 ± 1.6 %) and a lower prevalence of being insufficiently active (28.2 ± 1.6 %) based on total activity than women (58.5 ± 1.8 %) and (41.5 ± 1.8 %) respectively. Additionally, the same trend between men and women was observed for recreational physical activity only. Women had a slightly higher prevalence of having no recreational activity (46.7 ± 2.5 %) than men did (42.8 ± 2.6 %). Lastly, no significant differences were found for BMI between males and females.

Table 1. – Participant characteristics

Parameter	Unweighted Count	Men	Women	P-Value
Age (yrs)	5463	46.7 ± 0.89	48.3 ± 0.80	< 0.001[a]
BMI (kg/m^2)	5146	28.5 ± 0.23	28.9 ± 0.24	0.061[a]
DXA Body Fat Percent (%)	2708	27.1 ± 0.25	38.7 ± 0.37	< 0.001[a]
DXA Lean Mass (kg)	2725	61.0 ± 0.40	43.9 ± 0.31	< 0.001[a]
DXA Fat Mass (kg)	2708	24.6 ± 0.44	30.3 ± 0.50	< 0.001[a]
Total Physical Activity				
Sufficiently Active (%)	3162	71.8 ± 1.6	58.5 ± 1.8	< 0.001[b]
Insufficiently Active (%)	2062	28.2 ± 1.6	41.5 ± 1.8	
Recreational Physical Activity				
Sufficiently Active (%)	1796	43.2 ± 2.1	35.4 ± 1.8	< 0.006[b]
Insufficiently Active (%)	794	14.0 ± 1.3	17.9 ± 1.1	
None (%)	2636	42.8 ± 2.6	46.7 ± 2.5	

Values are presented as weighted means or frequencies ± SE of US population. BMI – Body mass index; Total physical activity – self-reported from the GPAQ and calculated as MET·min of activity per week. Recreational physical activity - self-reported from the GPAQ and calculated as MET·min of activity per week. [a] comparison of men vs. women using a general linear model and t-test. [b] comparison of men vs. women across activity levels using a Rao-Scott Chi-square test of independence.

Physical Activity Levels

The weighted mean MET minutes of physical activity per week, split by sex, are displayed in table 2. Men averaged significantly more total MET minutes of physical activity (4517.7 ± 245.7 min) than females (2245.3 ± 126.0 min). When physical activity was split into moderate and vigorous activity, males had significantly more MET minutes of both vigorous work physical activity (1773.9 ± 170.0 min) and vigorous recreational physical activity (660.1 ± 71.1 min) than women (443.9 ± 47.2 min) and (355.7 ± 50.5 min) respectively. Additionally, men were found to have significantly greater moderate work physical activity (1181.6 ± 83.0 min) and moderate travel physical activity (478.0 ± 40.2 min) than females (705.3 ± 41.9 min) and (342.3 ± 46.9 min) respectively. However, no significant differences were found in total MET minutes of moderate recreational physical activity between males and females. Additionally, no significant differences were found between males and females for total sitting time.

Table 2. – Self-reported physical activity levels

Parameter	Unweighted Count	Men	Women	P-Value
Total PA (MET·min·wk^{-1})	5463	4517.7 ± 245.7	2245.3 ± 126.0	< 0.001[a]
Vigorous Work PA (MET·min·wk^{-1})	5463	1773.9 ± 170.0	443.9 ± 47.2	< 0.001[a]
Moderate Work PA (MET·min·wk^{-1})	5463	1181.6 ± 83.0	705.3 ± 41.9	< 0.001[a]
Moderate Travel PA (MET·min·wk^{-1})	5463	478.0 ± 40.2	342.3 ± 46.9	0.005[a]
Vigorous Rec PA (MET·min·wk^{-1})	5463	660.1 ± 71.1	355.7 ± 50.5	< 0.001[a]
Moderate Rec PA (MET·min·wk^{-1})	5463	423.7 ± 24.7	397.6 ± 24.7	0.44[a]
Sitting Time (min·wk^{-1})	5463	378.1 ± 6.7	375.6 ± 6.7	0.73[a]

Values are presented as weighted means ± SE of US population. Values are self-reported from the GPAQ and calculated as MET·min of activity per week. [a] comparison of men vs. women using a general linear model and t-test.

Prevalence of Pain Making it Hard for Usual Activities

Table 3 shows the prevalence of pain on movement in the weighted 2011-2012 NHANES population with demographic data of adults in the US using a Rao-Scott x^2 test of independence. All but one of the demographic variables assessed were significantly associated with the presence of pain on movement ($P < 0.05$). These results show a significant difference in pain with age, with younger adults showing a greater prevalence of no pain (81.3 ± 1.7 %) compared to middle aged and older adults. Furthermore, younger adults also have a lesser prevalence of both sometimes pain (17.5 ± 1.6 %) and always pain (1.2 ± 0.3 %) compared to middle aged and older adults. In addition to age, significant differences in pain were found for race/ethnicity as well as for education levels. Among the different ethnicity groups, the highest prevalence of never having pain was found in both Mexican Americans (82.1 ± 1.6 %) and Non-Hispanic Asians (86.0 ± 0.9 %). Conversely, the highest prevalence for having pain always was the Other group (8.5 ± 2.7 %). Individuals with a college degree or above had the highest prevalence in the never pain group (81.4 ± 1.4 %), while individuals without a high school diploma had the greatest prevalence in the always pain group (9.4 ± 1.3 %). Additionally, there were significant differences in pain based on household income. Individuals who made >65K per year had the greatest prevalence in the never pain category (80.8 ± 1.0 %) and the lowest prevalence in the always pain category (2.4 ± 0.5 %).

For both total physical activity and recreations physical activity only, significant differences were found in pain prevalence. BMI was found to have a significant effect on pain prevalence. Individuals who were of a normal weight status had a higher prevalence of never pain (78.5 ± 2.2 %) and a lower prevalence of always pain (3.5 ± 1.0 %) compared to overweight and obese populations. Those who were sufficient in physical activity, according to ACSM guidelines, had a greater prevalence of no pain and lesser prevalence of pain sometimes and pain always compared to sedentary and insufficient individuals. Lastly, individuals with a diagnosis of arthritis had a significantly lower prevalence of no pain (53.0 ± 2.4 %) as well as a higher prevalence of pain sometimes (31.5 ± 2.3 %) and pain always (15.5 ± 1.6 %) compared to individuals without an arthritis diagnosis.

Table 3 – Prevalence of pain making it hard to perform usual activities

	Never	Sometimes	Always	P-Value
Unweighted count (n)	3888	1026	312	
Weighted (%)	74.2 ± 1.2	20.2 ± 1.0	5.6 ± 0.6	<0.001[b]
Sex (%)				0.46[b]
Men	75.3 ± 1.2	19.3 ± 1.2	5.4 ± 0.8	
Women	73.2 ± 1.7	21.1 ± 1.3	5.8 ± 0.6	
Age Groups (%)				<0.001[b]
20-35 yrs	81.3 ± 1.7	17.5 ± 1.6	1.2 ± 0.3	
36-55 yrs	73.5 ± 2.0	19.7 ± 1.8	6.8 ± 0.7	
56+	68.9 ± 2.3	23.1 ± 2.0	8.0 ± 0.8	
Race / Ethnicity (%)				<0.001[b]
Mexican American	82.1 ± 1.6	14.7 ± 1.9	3.2 ± 1.0	
Other Hispanic	78.0 ± 2.3	18.5 ± 1.9	3.5 ± 0.9	
Non-Hispanic White	72.3 ± 1.4	21.4 ± 1.2	6.3 ± 0.8	
Non-Hispanic Black	75.0 ± 1.7	19.9 ± 1.4	5.1 ± 0.7	
Non-Hispanic Asian	86.0 ± 0.9	12.0 ± 1.0	2.0 ± 0.5	
Other Race	61.7 ± 3.6	29.8 ± 3.8	8.5 ± 2.7	
Education Level (%)				<0.001[b]
<High school	69.4 ± 1.9	21.2 ± 2.1	9.4 ± 1.3	
High school or equivalent	75.1 ± 2.7	18.1 ± 2.2	6.9 ± 1.3	
Some college of AA	69.2 ± 1.3	24.7 ± 1.1	6.1 ± 0.8	
College grad or above	81.4 ± 1.4	16.5 ± 1.5	2.1 ± 0.4	
Annual Household Income (%)				<0.001[b]
<$35K	67.2 ± 1.8	23.3 ± 1.3	9.4 ± 1.2	
$35-<$65K	73.1 ± 2.1	21.5 ± 2.0	5.4 ± 1.6	
>$65K	80.8 ± 1.0	16.8 ± 0.9	2.4 ± 0.5	
BMI Category (%)				0.034[b]
Normal	78.5 ± 2.2	18.1 ± 1.8	3.5 ± 1.0	
Overweight	74.9 ± 2.0	20.1 ± 1.6	5.0 ± 1.2	
Obese	69.9 ± 2.0	22.4 ± 1.6	7.7 ± 1.0	
Total Physical Activity (%)				<0.001[b]
Insufficient	69.9 ± 2.0	21.8 ± 1.5	9.2 ± 0.8	
Sufficient	77.0 ± 1.1	19.4 ± 1.0	3.6 ± 0.5	
Recreational Physical Activity (%)				<0.001[b]
None	69.9 ± 1.6	21.4 ± 1.3	8.6 ± 0.9	
Insufficient	73.0 ± 2.2	22.3 ± 2.0	4.7 ± 1.0	
Sufficient	79.6 ± 1.6	18.0 ± 1.3	2.4 ± 0.5	
Arthritis Diagnosis (%)				<0.001[b]
Yes	53.0 ± 2.4	31.5 ± 2.3	15.5 ± 1.6	
No	80.6 ± 1.0	16.8 ± 0.9	2.6 ± 0.3	

Values are presented as weighted frequencies ± SE of US population. BMI – Body mass index, Normal 17.5-24.9, Overweight 25.0-29.9, Obese ≥ 30.0; Total physical activity – self-reported from the GPAQ and calculated as MET·min of activity per week. Recreational physical activity - self-reported from the GPAQ and calculated as MET·min of activity per week. [b] comparison of men vs. women across activity levels using a Rao-Scott Chi-square test of independence.

The weighted frequency of being within a given pain category based on BMI and total physical activity is shown in table 4. Significant differences in pain were found between the 5 BMI categories ($P = 0.015$) Individuals who were of a normal weight status had a significantly greater prevalence in the never pain category (78.5 ± 2.2 %) compared to overweight (74.9 ± 2.0 %), Obese I (72.2 ± 2.5 %), obese II (70.0 ± 3.0 %), and obese III (62.3 ± 2.7 %) groups. Additionally, those with a normal weight status also had a significantly lower prevalence of being in the sometimes pain category (18.1 ± 1.8 %) and the always pain category (3.5 ± 1.0 %) than the other BMI weight classes.

Significant differences in pain were also found among the total physical activity groups (P < 0.001). Those who obtained a sufficient amount of physical activity through vigorous activity only had the greatest prevalence in the pain never category (82.3 ± 1.8 %). Individuals who were insufficiently active had the greatest prevalence in the always pain category (9.2 ± 0.8 %) and the second lowest prevalence in the pain never category (69.1 ± 2.0 %). Lastly, those with the lowest prevalence in the pain always category were individuals who obtained a sufficient amount of physical activity with neither vigorous nor moderate activity (1.7 ± 1.3 %).

Table 4 – Prevalence of pain making it hard to perform usual activities

	Never	Sometimes	Always	P-Value
BMI Category (%)				0.015[b]
Normal	78.5 ± 2.2	18.1 ± 1.8	3.5 ± 1.0	
Overweight	74.9 ± 2.0	20.1 ± 1.6	5.0 ± 1.2	
Obese I	72.2 ± 2.5	21.5 ± 1.9	6.3 ± 1.3	
Obese II	70.0 ± 3.0	22.8 ± 3.1	7.2 ± 1.4	
Obese III	62.3 ± 2.7	24.7 ± 2.8	13.0 ± 2.4	
Total Physical Activity (%)				<0.001[b]
Insufficient	69.1 ± 2.0	21.8 ± 1.5	9.2 ± 0.8	
Sufficient (Vigorous Only)	82.3 ± 1.8	14.5 ± 1.5	3.3 ± 1.1	
Sufficient (Moderate Only)	76.2 ± 1.6	19.0 ± 1.4	4.7 ± 0.9	
Sufficient (Both Vig and Mod)	76.3 ± 2.0	21.1 ± 1.9	2.5 ± 0.7	
Sufficient (Neither Vig or Mod)	66.5 ± 12.6	31.8 ± 13.2	1.7 ± 1.3	

Values are presented as weighted frequencies ± SE of US population. BMI – Body mass index; Total physical activity – self-reported from the GPAQ and calculated as MET·min of activity per week. Recreational physical activity - self-reported from the GPAQ and calculated as MET·min of activity per week. [b] comparison of men vs. women across activity levels using a Rao-Scott Chi-square test of independence.

The prevalence of pain making it hard to perform usual activities separated by physical activity and weight status is shown in Table 5. No significant interaction between pain and weight status was found among individuals who were insufficiently active. Additionally, there was not a significant interaction between pain and weight status when looking at individuals who were sufficiently active.

Table 5. Prevalence of pain making it hard to perform usual activities

	Insufficiently Active			Sufficiently Active		
Pain Status	Normal	Overweight	Obese	Normal	Overweight	Obese
Never	73.6 ± 3.7	70.6 ± 2.5	65.5 ± 2.4	80.4 ± 2.0	76.9 ± 2.2	73.2 ± 2.5
Sometimes	20.3 ± 2.7	20.7 ± 1.9	23.6 ± 1.8	17.2 ± 1.8	19.7 ± 1.9	21.5 ± 2.1
Always	6.1 ± 1.8	8.7 ± 2.3	10.9 ± 1.2	2.4 ± 0.8	3.3 ± 1.0	5.3 ± 1.2
P-Value		*0.20[b]*			*0.21[b]*	

Values are weighted percentage ± SE of the US adult population. [b] P values from the Rao-Scott Chi-square test of independence.

Odds Ratio Reporting

Table 6 displays the odds ratios of being within a given pain category. Within age, moving from the young adult category to the older adult category it's 1.12 times more likely that you will move up in a pain category. Additionally, when moving from middle aged adult to the older adult group, it's 0.73 times more likely that you will move up in a pain category. Within education level, when moving from the college graduate category to the < high school category you are 1.48 times more likely to move up in a pain category. Similarly, moving from high school degree/equivalent to < high school you are 1.37 times more likely to move up in a pain category. When moving from some college/AA group to < high school you are 0.92 times more likely to move up in a pain group. Significant differences were also found between the household income groups. Moving from the >65K annually group to the <35K annually group you are 1.93 times more likely to be in a higher pain category. A similar trend was found between the 35K-65K group and the >35K group, in which you would be 1.33 times more likely to move up in a pain category when moving from the former group to the latter. Lastly, among the arthritis groups when mobbing from individuals who do not have a diagnosis of arthritis to those who do, you are 3.45 times more likely to move up in a pain category.

Table 7 also presents the odds ratios of being in a given pain category; however, for this analysis physical activity was only included as total physical activity instead of also incorporating recreational physical activity. When this was done there was a significant odds ratio for total physical activity. When moving from sufficiently active to insufficiently active you are 1.28 times more likely to move up a pain category.

Table 8 shows correlations between continuous variables with BMI. Percent body fat, total fat mass, and total lean mass were all significantly correlated with BMI. However, total fat mass had the strongest correlation (R = 0.91) with BMI. Thus, fat mass was used in place of BMI in the third odds ratio analysis (shown in table 9). Table 9 shows the odds ratios of being in a given pain category when controlling for total fat mass instead of BMI. When controlling for fat mass, the odds of moving up in a pain category is no longer affected by age, race/ethnicity, and physical activity. Additionally, the total amount of fat mass has no significant effect on the odds of moving up in a pain category. However, significant differences in the odds of moving up in a pain category were still observed for education, income, and arthritis.

Table 6 – Odds of moving up a pain category with a move from one dependent variable category to another.

Overall fit – Psuedo R Squared: 0.15 (Nagelkerke)

Variable	**Odds Ratio**
Age Group (p= 0.02)	
20-35 to 56+	1.12
36-55 to 56+	0.73
Race/Ethnicity (p < 0.001)	
Education (p = 0.01)	
College grad to < High school	1.48
Some college or AA to < High school	0.92
High school or Equivalent to <High school	1.37
Annual Household Income (p < 0.001)	
>$65K to <$35K	1.93
$35K<$65K to <35K	1.33
BMI Category (%) (p = 0.45)	
Normal to Obese	1.24
Overweight to Obese	1.09
Total Physical Activity (%) (p = 0.10)	
Sufficient to Insufficient	1.17
Recreational Physical Activity (%) (p = 0.53)	
Sufficient to None	1.19
Insufficient to None	1.01
Arthritis Diagnosis (%) (p < 0.001)	
"No" to "Yes"	3.45

Table 7 – Odds of moving up a pain category with a move from one dependent variable category to another

Overall fit – Psuedo R Squared: 0.15 (Nagelkerke)	
Variable	**Odds Ratio**
Age Group (p= 0.01)	
20-35 to 56+	1.12
36-55 to 56+	0.73
Race/Ethnicity (p < 0.001)	
Education (p = 0.005)	
College grad to < High school	1.53
Some college or AA to < High school	0.94
High school or Equivalent to <High school	1.39
Annual Household Income (p < 0.001)	
>$65K to <$35K	1.94
$35K<$65K to <35K	1.33
BMI Category (%) (p = 0.42)	
Normal to Obese	1.25
Overweight to Obese	1.11
Total Physical Activity (%) (p = 0.01)	
Sufficient to Insufficient	1.28
Arthritis Diagnosis (%) (p < 0.001)	
"No" to "Yes"	3.43

Table 8 – Correlations among continuous variables

	BMI	**%Fat**	**Lean**	**Fat**	**Total PA**	**Vig PA**	**Mod PA**
BMI	---	0.55*	0.57*	0.91*	-0.04	-0.14*	-0.03
%Fat		---	-0.28*	0.77*	-0.26*	-0.26*	-0.15*
Lean			---	0.32*	0.17*	0.17*	0.10*
Fat				---	-0.14*	-0.14*	-0.10*
Total PA					---	0.89*	0.75*
Vig PA						---	0.36*
Mod PA							---

Table 9 – Odds of moving up a pain category with a move from one dependent variable category to another: Controlling for Percent body fat from DXA rather than BMI

Overall fit – Psuedo R Squared: 0.15 (Nagelkerke)	
Variable	**Odds Ratio**
Age Group (p= 0.13)	
Race/Ethnicity (p = 0.1)	
Education (p < 0.001)	
College grad to < High school	1.67
Some college or AA to < High school	0.88
High school or Equivalent to <High school	1.19
Annual Household Income (p = 0.002)	
>$65K to <$35K	1.92
$35K<$65K to <35K	1.38
Total Fat Mass (p = 0.18)	
Total Physical Activity (%) (p = 0.63)	
Arthritis Diagnosis (%) (p < 0.001)	
"No" to "Yes"	4.34

Discussion

The aim of this study was to examine the relationship among physical activity, pain, weight status, and body composition using a nationally representative sample, while also exploring the confounding demographic variables such as age, sex, ethnicity, socioeconomic status and education as well as the effects of having an arthritis diagnosis. This study found that when not controlling for fat mass, whether or not an individual met the ACSM physical activity guidelines influenced the prevalence with which they reported pain making it hard to perform usual activity. However, their weight status had no effect on their pain prevalence. Additionally, significant demographic (education, ethnicity, socioeconomic, but not sex) influences were also observed.

In regard to sex, differences in both physical activity levels and body composition were found between men and women. In general, females had higher mean percent body fat and fat mass and a lower lean mass than males did. This is consistent with findings from a study conducted by Schorr et al. (2018) in which DXA showed that females had higher percent body fat, higher fat mass and lower lean mass than males did. Additionally, compared to females, males had a significantly greater prevalence for being sufficiently active as well as a lower prevalence for being insufficiently active. A similar prevalence was observed in regard to recreational activity as well. The reason for these differences in physical activity is not fully understood, however, Molanorouzi et al. (2015) suggest that differences in motivation to be physically active among the two sexes could possibly account for any discrepancies. Conversely, a study conducted by Umeda and Kim (2019) also using NHANES data found there to be no sex differences in prevalence of meeting physical activity guidelines. When further breaking down physical activity into total MET minutes per week we found that males also had higher vigorous and moderate MET minutes of activity each week than females did for nearly all parameters. This included total physical activity, work related physical activity and travel related physical activity.

Physical activity has been known to reduce one’s risk for developing various types of chronic diseases which may also function to then reduce the risk for developing chronic pain conditions (Booth et al., 2012). Thus, the sex differences in physical activity found in our sample could lead us to believe that the prevalence of pain among males and females would also differ. However, when examining the prevalence of being in a given pain category (Never, Sometimes, Always) no significant differences were found between males and females. This contradicts previous findings which note that in comparison to males, females have a consistently higher prevalence of having severe pain related diseases as well more severe levels of pain and a greater frequency of pain across the body (Pieretti et al., 2016). This could likely be attributed to the fact that this study controlled for confounding variables like age, body composition, and BMI all of which contribute to varying pain prevalence among the two sexes. Thus, when these variables were removed, sex no longer had an effect on pain prevalence. While no sex differences in pain prevalence were observed in the present study, significant differences for age, ethnicity, income, and education levels were found. As hypothesized, individuals who were younger had significantly lower prevalence in the higher pain categories compared to middle age and older adults. Additionally, when controlling for all other demographic variables we found that the odds of moving up in a pain category increase significantly as you move up in an age group; thus, it can be concluded that aging has a significant impact on the prevalence of pain on movement. This is consistent with the current literature on pain and aging. Ray et al. (2011) note that ~61% of US older adults have reported chronic pain. This can likely be explained by the fact that as individuals age, they are more prone to developing one or more chronic conditions which pose as risk factors for chronic pain (Blyth & Noguchi, 2017). One of the most prevalent chronic pain conditions associated with aging is osteoarthritis. As expected, we found that individuals who have a diagnosis of OA had a significantly greater prevalence of having pain always and sometimes compared to individuals who do not have OA. These results were again confirmed in our final analysis, which found that having an arthritis diagnosis makes one significantly more likely to move up in a pain category. This can be attributed to the fact that typically in OA the most commonly reported symptom is pain (Sinusas, 2012).

When evaluating the prevalence of pain across ethnicity, education and income we found that those who had the greatest prevalence in the never having pain category were Non-Hispanic Asian individuals, those with a college degree, and those who had an annual household income of

>65K. For the most part this is similar to the current literature, however, recent studies regarding pain and ethnicity are not consistent in their findings. Wyatt (2013) reports that Mexican Americans and Non-Hispanic Black individuals experience the greatest prevalence of pain; whereas, in our study we found these two groups to have a higher prevalence in the never pain group compared to other races. Conversely, Janevic et al., (2018) note that White American's experience pain at a similar or greater prevalence than minority groups do, which is consistent with our findings. They also found that income/wealth and education status are more strongly associated with pain prevalence than race/ethnicity. Those who had a higher level of education also tend to have fewer occupational hazards, higher annual household income and consequently better access to health care, all of which could decrease the likelihood of developing chronic pain (Janevic et al., 2018).

In addition to demographic characteristics, body mass index and physical activity had a significant effect on the prevalence of pain. Individuals of a normal BMI had a lower prevalence of having pain always compared to overweight individuals and obese individuals. Obese individuals were also observed to have the lowest prevalence of never having pain. In a study conducted by Marcus (2004) increased BMI status was associated pain reported on more days out of the week. When further splitting BMI into the three classes of obesity, we found similar results in that those in obesity class III had the greatest prevalence of always having pain. This suggests that BMI could be playing a role in the prevalence in which an individual experiences pain. Although studies have shown that pain prevalence and severity are increased in obese and overweight individuals, the results are still inconsistent; with discrepancies that exist among various populations that have not yet been explained (Toda et al., 2000). Similarly, to BMI, physical activity has been known to reduce pain within healthy individuals (Vaegter et al., 2020);

whereas in clinical pain populations physical activity can actually work to exacerbate pain rather than reduce it (Lima et al., 2017). In our analysis, individuals who obtained a sufficient amount of total physical activity or sufficient amount of recreational physical activity had a significantly lower prevalence of having pain always compared to those who were insufficiently active. We also found that those who met the activity guidelines via vigorous activity only had a greater prevalence of never having pain, which could suggest that the intensity of activity plays a role in modulating pain. Ambrose & Golightly (2015) discuss that moderate and low intensity aerobic exercise could be beneficial for improving pain in clinical populations; however, these results have not been consistently found. There is still little known regarding the ideal exercise regimen to help improve pain among clinical populations (Arulshud et al., 2017).

While independently, both physical activity and BMI had a significant effect on pain prevalence, when analyzed in conjunction with each other that effect was mitigated. Among both those who were insufficiently active and sufficiently active, weight status had no significant effect on the prevalence of being in a given pain category. Like mentioned above, there is some evidence that both physical activity and BMI have an effect on pain; however, it is not widely studied, and further research still needs to be conducted. Additionally, when controlling for all other demographic variables, BMI was not found to have an influence on pain. Although pain prevalence varied significantly based on BMI status in our initial analyses, when confounding variables were controlled for BMI alone had no influence in our sample. This suggests that variables such as age, sex, education, and ethnicity must be related to BMI and its effect on pain prevalence. Additionally, when controlling for fat mass in place of BMI, the significant effect that age, ethnicity, and physical activity had on the odds of moving up in a pain category was lost. This could likely be explained by the fact that fat mass is colinear with age, physical activity and ethnicity. Additionally, when controlling for all other variable fat mass itself did not have a significant effect on the odds of moving up in pain category.

While BMI was not found to have a significant influence on pain when controlling for demographic variables, whether or not you met the physical activity guidelines did have a significant impact on pain. When controlling for age, sex, ethnicity, and education individuals who were less active or did not meet the physical activity guidelines had significantly higher odds of moving up in a pain category. This indicates that even after removing confounding variables, meeting the physical activity guidelines alone is enough to influence an individual's pain category. This supports our hypothesis that individuals who have higher activity levels will report less pain while doing usual activities. However, when we split physical activity into total physical activity and recreational activity, there was no significant influence on pain, likely due to the fact that these categories are collinear with one another, which will impact their significance.

CHAPTER V

CONCLUSIONS

The purpose of this study was to examine the relationship among physical activity, pain, weight status, and body composition using a nationally representative sample, while also exploring the confounding demographic variables such as age, sex, ethnicity, socioeconomic status and education as well as the effects of having an arthritis diagnosis. In general, we found that age, ethnicity, socioeconomic status, and education all had a significant impact on the prevalence of being in a given pain category. As hypothesized, those who were younger and college educated had a lower prevalence of reporting that pain made it difficult for usual activity; however, no sex differences were found in pain prevalence, and non-Hispanic Asian individuals had a lower prevalence of pain rather than White individuals. Additionally, as expected, we observed that having a diagnosis of arthritis has a profound impact on an individual's pain status. Contrary to what we initially thought, no differences were found in pain among those with differing levels of fat mass, lean mass and % body fat. Differences in pain prevalence were found for BMI when we did not control for confounding variables, which affirms our hypothesis that pain prevalence will vary depending on weight status. However, we also discovered that when controlling for confounding variables, BMI alone did not have a significant influence on pain among our sample, which is contrary to what we hypothesized. Most importantly, our study found that when fat mass was not controlled for, not meeting the physical activity guidelines significantly increased the chances of moving up in a pain category, which confirms our hypotheses that those who are more physically activity will report that pain makes it difficult for usual activities to a lesser degree. This is important because it suggests that low levels of physical activity could in fact be influencing the prevalence of pain.

While our findings support the notion that physical activity does impact pain prevalence and severity, additional research should be conducted to further understand this relationship. Limitations of this study can be found in the nature of the questions available through NHANES. The way in which pain was assessed was not a direct measure of objective pain and, therefore, could be attributing to differences among our study and other studies that look into the prevalence of pain. Additionally, the interpretation of pain could vary among individual respondents and could potentially skew the data. Further studies looking into the relationship between pain and BMI and body composition should also be considered due to the inconsistent findings in current literature. Our study in particular is unique in that it is nationally representative and therefore, our results can be generalizable to the US adult population. Additionally, it helps lay the foundation for subsequent studies to be done that look more specifically into the role that physical activity might play in the prevention and treatment of chronic pain.

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APPENDIX

GLOBAL PHYSICAL ACTIVITY QUESTIONNAIRE (GPAQ)

WHO STEPwise approach to NCD risk factor surveillance

Surveillance and Population-Based Prevention
Prevention of Noncommunicable Diseases Department
World Health Organization
20 Avenue Appia, 1211 Geneva 27, Switzerland
For further information: www.who.int/chp/steps

Physical Activity			
Next I am going to ask you about the time you spend doing different types of physical activity in a typical week. Please answer these questions even if you do not consider yourself to be a physically active person. Think first about the time you spend doing work. Think of work as the things that you have to do such as paid or unpaid work, study/training, household chores, harvesting food/crops, fishing or hunting for food, seeking employment. *[Insert other examples if needed].* In answering the following questions 'vigorous-intensity activities' are activities that require hard physical effort and cause large increases in breathing or heart rate, 'moderate-intensity activities' are activities that require moderate physical effort and cause small increases in breathing or heart rate.			
Questions		**Response**	**Code**
Activity at work			
1	Does your work involve vigorous-intensity activity that causes large increases in breathing or heart rate like *[carrying or lifting heavy loads, digging or construction work]* for at least 10 minutes continuously? *[INSERT EXAMPLES] (USE SHOWCARD)*	Yes 1 No 2 *If No, go to P 4*	P1
2	In a typical week, on how many days do you do vigorous-intensity activities as part of your work?	Number of days └─┘	P2
3	How much time do you spend doing vigorous-intensity activities at work on a typical day?	Hours : minutes └─┴─┘ : └─┴─┘ hrs mins	P3 (a-b)
4	Does your work involve moderate-intensity activity that causes small increases in breathing or heart rate such as brisk walking *[or carrying light loads]* for at least 10 minutes continuously? *[INSERT EXAMPLES] (USE SHOWCARD)*	Yes 1 No 2 *If No, go to P 7*	P4
5	In a typical week, on how many days do you do moderate-intensity activities as part of your work?	Number of days └─┘	P5
6	How much time do you spend doing moderate-intensity activities at work on a typical day?	Hours : minutes └─┴─┘ : └─┴─┘ hrs mins	P6 (a-b)
Travel to and from places			
The next questions exclude the physical activities at work that you have already mentioned. Now I would like to ask you about the usual way you travel to and from places. For example to work, for shopping, to market, to place of worship. [insert other examples if needed]			
7	Do you walk or use a bicycle (*pedal cycle*) for at least 10 minutes continuously to get to and from places?	Yes 1 No 2 *If No, go to P 10*	P7
8	In a typical week, on how many days do you walk or bicycle for at least 10 minutes continuously to get to and from places?	Number of days └─┘	P8
9	How much time do you spend walking or bicycling for travel on a typical day?	Hours : minutes └─┴─┘ : └─┴─┘ hrs mins	P9 (a-b)
Recreational activities			
The next questions exclude the work and transport activities that you have already mentioned. Now I would like to ask you about sports, fitness and recreational activities (leisure), [insert relevant terms].			
10	Do you do any vigorous-intensity sports, fitness or recreational (*leisure*) activities that cause large increases in breathing or heart rate like [*running or football,]* for at least 10 minutes continuously? *[INSERT EXAMPLES] (USE SHOWCARD)*	Yes 1 No 2 *If No, go to P 13*	P10
11	In a typical week, on how many days do you do vigorous-intensity sports, fitness or recreational (*leisure*) activities?	Number of days └─┘	P11
12	How much time do you spend doing vigorous-intensity sports, fitness or recreational activities on a typical day?	Hours : minutes └─┴─┘ : └─┴─┘ hrs mins	P12 (a-b)

GPAQ, Continued

Physical Activity (recreational activities) contd.			
Questions		**Response**	**Code**
13	Do you do any moderate-intensity sports, fitness or recreational *(leisure)* activities that causes a small increase in breathing or heart rate such as brisk walking,(*cycling, swimming, volleyball*)for at least 10 minutes continuously? *[INSERT EXAMPLES] (USE SHOWCARD)*	Yes 1 No 2 *If No, go to P16*	P13
14	In a typical week, on how many days do you do moderate-intensity sports, fitness or recreational (*leisure*) activities?	Number of days └─┘	P14
15	How much time do you spend doing moderate-intensity sports, fitness or recreational (*leisure*) activities on a typical day?	Hours : minutes └─┴─┘ : └─┴─┘ hrs mins	P15 (a-b)
Sedentary behaviour			
The following question is about sitting or reclining at work, at home, getting to and from places, or with friends including time spent [sitting at a desk, sitting with friends, travelling in car, bus, train, reading, playing cards or watching television], but do not include time spent sleeping. *[INSERT EXAMPLES] (USE SHOWCARD)*			
16	How much time do you usually spend sitting or reclining on a typical day?	Hours : minutes └─┴─┘ : └─┴─┘ hrs min s	P16 (a-b)