INFLAMMATORY RESPONSES TO ACUTE SPINAL LOADING

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A thesis submitted in partial fulfillment of the requirements for the
Master of Science degree in Human Kinetics

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Abstract

Currently, low back disorder (LBD) research focuses primarily on mechanical variables to assess whether acute or cumulative task demands exceed the capacity of the tissue; however, it is important to assess how other non-mechanical variables affect tissue capacity in a time-dependent manner. The current investigation sought to explore physiological responses to an acute lifting task (similar to a typical assembly line task), as lifting has been implicated as a risk factor in the development of LBDs. Twelve participants completed two experimental sessions of two hours of repetitive symmetrical lifting from floor to knuckle height under a low force, high repetition condition (LFHR; box weighted at 5% maximum lifting strength, five lifts per minute) and a high force, low repetition condition (HFLR; 25% maximum lifting strength, one lift per minute), such that the external biomechanical work was equivalent between conditions. These sessions were completed one week apart, with full-body motion capture and ground reaction forces measured throughout. Systemic inflammation was assessed with blood sampling at baseline, 0, 4 and 24 hours post-lifting on both days, and samples were assayed using an ELISA for interleukin 6 (IL-6) and interleukin 8 (IL-8). Participants also completed psychological questionnaires including the Tampa Scale for Kinesiophobia-General (TSK-G), Pain Catastrophizing Scale, Visual Analogue Scale (VAS, participants 1-4) and Borg CR-10 Scale of Exertion (participants 5-12). There was a significant main effect of time on both IL-6 and IL-8 (Baseline, 0, 4, 24 hours), as well as interaction effects of condition (HFLR and LFHR) and time. The LFHR condition caused greater inflammation in both IL-6 and IL-8 at 0 and 4 hours post-lifting, likely due to significantly higher cumulative spinal loading in this condition. Significant correlations between body fat percentages, peak and cumulative loading were found to exist in both the LFHR condition and the HFLR condition, lending strength to the hypothesis that some of these measures may be able to predict physiological responses to acute stresses, and subsequently, risk of acute injury.

Acknowledgements

I would like to acknowledge the invaluable roles of everyone else in my life that had a hand in allowing this thesis to come together; it may only be my name on the cover, but I certainly wouldn't have been able to do it alone!

Firstly, I would like to thank my committee for their guidance and role in helping to shape this thesis. Secondly, I'd like to thank my supervisor, Dr. Ryan Graham, for his unwavering support throughout this entire process. Thank you for being there when I needed a hand (AKA frustrated Matlab emails at 11 pm) but also knowing when to step back and let me try to figure things out on my own. Thank you for allowing me to pursue my own ideas and for continually fostering my "research mind" by listening to my endless "potential" ideas for my project and supporting me even when they didn't work out (which was often). I definitely learned that sometimes it is best to stick to the KISS formula! More than that, I want to thank you for encouraging me to remember to keep a balance in my life, and that I can only spend so many hours in front of a screen or in the lab. I truly cannot thank you enough for all that you have done for me, and I'm looking forward to working together for the next four years!

Next, I would like to thank my labmates for their support in so many capacities throughout my masters. Gwyneth, Kristen, Eric, Matt and Junior, from day one I was incredibly fortunate to have a group of people I clicked so well with. Over the last two years, the new additions to the lab (Mohammed, Brent, Shawn) have only added to how deeply I appreciate each and every one of you and how supportive this environment is. Thank you for helping me get through many late nights spent in the lab on projects in my first year (Kristen); for the lunchtime euchre games (thank you for being patient with me when I was learning) and for the lab dinners that always inevitably turned into all-night events because we were having way too much fun. To my labmates that had the unfortunate luck of becoming my housemates as well (Gwyn, Brent), thank you for making sure I didn't spend too much time absorbed in this and making sure I took regularly scheduled Handmaid's Tale (or Portugal) breaks; you two truly saved my sanity during this process.

To a few special friends that helped me along the way, thank you Kat, Kelsey, Kaitlyn and Kaleigh; you may all share the same first letter of your name but you also all share an unwavering loyalty and are all an integral part of my support system. Thank you for believing in me no matter how far away we are, for answering those late night stressed out phone calls because something seemed monumentally wrong, but always being able to put things in perspective for me and have me laughing by the end of the calls no matter what. You guys are all amazing and I'm lucky to have such amazing friends.

Finally, to my family. Mom, dad, Kolton, I can't even begin to put into words how much I truly appreciate how supportive you are and everything that you do for me. Thank you for always being there when I need you; even though we may be 700+ kilometres apart, you never fail to pick up the phone to listen to me ramble on about my day or what new discovery I've made in my research, even though I'm pretty sure half the time I jump between six topics at once. Thank you for always supporting my decisions, no matter how crazy, and for being able to give me room to make my own mistakes (even though I have no idea how you don't say "I told you so" after some of them). I love you all and I would not be able to do this without you guys.

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Abbreviations

ANOVA	Analysis of Variance
CK	Creatine Kinase
EMG	Electromyography
ES	Effect Size
GCS	Global Coordinate System
IL-6	Interleukin 6
IL-8	Interleukin 8
L_4/L_5	Region on low back at lumbar vertebrae 4 and 5
LBD	Low Back Disorders
LBP	Low Back Pain
LCS	Local Coordinate System
METS	Metabolic Equivalent Minutes
MMH	Manual Materials Handling
MVC	Maximal Voluntary Contraction
NIOSH	National Institute for Occupational Safety and Health
PCS	Pain Catastrophizing Scale
STD	Standard Deviation
TNF-α	Tumour Necrosis Factor alpha
TSK-G	Tampa Scale for Kinesiophobia- General
WSIB	Workplace Safety and Insurance Board of Ontario
VAS	Visual Analogue Scale

CHAPTER 1: INTRODUCTION

It is well documented that low back disorders (LBDs) are one of the greatest global health burdens, with up to 36% of the population per year experiencing either first time or recurrent episodes of LBDs (Hartvigsen et al., 2018; Hoy et al., 2014, 2010; Steenstra et al., 2005). The massive impact that this disorder has on individuals, communities and industries is reflected in the Global Burden of Disease 2015 study, in which LBDs were found to be the leading condition of Global Years Lived with a Disability (YLD) topping the list of causes for YLD in 101 of 187 countries surveyed worldwide (Abajobir et al., 2017; Vos et al., 2016). Moreover, a number of researchers have concluded the disorder is no longer confined to developed countries, but is also becoming insidious in low- and middle-income countries (Hoy et al., 2003; Ory et al., 1997). Up to 80% of the global population will experience a LBD at some point in their life, a problem that is expected to continue rising (Walker, 2000). Economically, LBDs also create an enormous strain on health care systems, accounting for over $100 billion in direct and indirect costs in the United States per year, which include medical visits, surgeries and lost time and productivity claims (Katz, 2006).

LBDs have been identified as a leading cause of work-related musculoskeletal disorders and have consistently made up the greatest portion of insurance claims made to the Workplace Safety and Insurance Board of Ontario since 2002, comprising 17% of all claims in 2017 alone (WSIB, 2017). Certain industries exhibit a pervasiveness of LBDs even greater than the average observed in most workplaces, such as those with a high proportion of manual materials handling (MMH) tasks, which have been identified as a significant risk factor in the development of LBDs (da Costa and Vieira, 2010; Kumar and Mital, 1992; Mital et al., 1993). More specifically, in a systematic review, Kuiper and colleagues identified lifting as a specific factor that places

individuals at greater risk for developing a LBD; a finding that was consistent in six studies examining occupational groups (Kuiper et al., 1999). Much research to date has focused on studying these industries with a large number of lifting tasks in an effort to reduce LBDs, but in spite of this LBD incidence has continued to rise and thus the focus of investigation needs further refinement in order to maintain effectiveness.

Traditionally, ergonomic attempts to reduce work-related LBDs have been aimed at altering the mechanical loading of the spine, focusing on the magnitude of the load as well as the frequency of repetition. However, this can prove problematic as it is estimated that approximately 85% of cases cannot be directly linked to specific pathoanatomical diagnoses (e.g. fractures, disc herniation, or failure of spinal tissues (i.e. muscles, ligaments, tendons)), implying that other non-mechanical causes must contribute significantly to LBDs (Deyo and Weinstein, 2001; Elrich, 2003). Non-mechanical causes that have been suggested include biochemical and inflammatory responses as well as psychosocial and psychological factors.

With respect to the magnitude of loading, researchers have focused on examining the effects of *in vitro* inflammatory markers (i.e. studies using partial or dead organisms), specifically focusing on mechanisms in chronic disorders (Le Maitre et al., 2007a, 2005; Risbud and Shapiro, 2014). Certain psychological states have also been associated with chronic pain and LBDs, with negative states and psychosocial environments intensifying the detriments observed in LBD cases (Dionne, 2005; Klyne et al., 2016; Pincus et al., 2002). While researchers have previously investigated the roles of biochemistry and psychology in relationship to chronic LBDs, there is far less research done on the acute implications of these moderators on an individual's risk of developing a LBD. The few studies that have focused on inflammation following acute lifting

tasks failed to consider known moderators of injury risk simultaneously (e.g. sex, psychosocial or psychological environment), instead focusing solely on psychosocial aspects (Davis and Marras, 2003; Marras et al., 2000) or psychological influences on inflammation in acute low back pain patients (Klyne et al., 2016).To date, there have only been two *in vivo* (i.e. whole, living organisms) investigations that examine a combination of inflammatory responses and moderating factors, by investigating inflammation in conjunction with personality traits (Splittstoesser et al., 2012) or inflammation in response to varying magnitudes of loading (Yang et al., 2011).

Yang and colleagues demonstrated that pro-inflammatory marker levels are greater when repetitively lifting a heavier versus lighter loads; however, the population in this study was young, male and in generally excellent fitness. Furthermore, the external biomechanical work was greater in the heavier condition as participants performed the same number of lifts in each load scenario. Thus, the next logical step is to examine inflammatory responses to lifting when loads are different, but the cumulative load (i.e. total external biomechanical work) is held constant by altering the lifting frequency; this is the purpose of the current study. In an occupational sense, if a 25 kg box containing five smaller boxes of 5 kg each needs to be lifted from the floor to a workbench, the worker could choose to lift the entire box at once or lift each 5 kg box one at a time. In a practical sense, the study will aid in answering the question of whether it is more detrimental to back health to lift a heavy load less frequently or a lighter load more frequently, especially when done repetitively over the course of a workday. In addition, collecting information on moderating factors such as adiposity, psychology and sex will add valuable insight into whether certain psychological and biochemical characteristics can be predictive in the onset of LBDs and establishing appropriate preventative measures.

CHAPTER 2: LITERATURE REVIEW

2.1 Prevalence and Sub-classifications of Low Back Disorders

LBDs are equally prevalent among both sexes, representing the greatest, most costly cause of disability in the workplace to those under 45 years of age (Andersson, 1999). Since 1990, LBDs have been reported as the second most common cause of physician visits, trailing only the common cold, a figure which the National Institute of Health revealed to have changed very little as of 2002 (Deyo et al., 2006; Hart et al., 1995). Furthermore, the global prevalence of LBDs is on the rise as of late. In 2010, the Global Disability Adjusted Life Years were reported at 83 million years lost due to disability, up from 58.2 million just two decades prior (Hoy et al., 2014; Vos et al., 2012). This rapidly growing problem is an area that warrants a great deal of investigation and research to alleviate the burden. Due to the increased frequency at which LBDs are occurring, it is likely that the relevance of research in this area will increase accordingly and the need for a more clarified understanding of the source of such disorders will be crucial to managing this issue.

Categorically, LBDs can be described as either pathoanatomical or idiopathic in nature. Pathoanatomical LBDs can be attributed to some visible, structural cause, as any one of the anatomical structures in or surrounding the spinal column is subject to failure; an inherent property of any biomaterial (Devereaux, 2009). Subsequently, some common disorders that have a specific associated pathology include those of herniated discs, sciatica, age-related degenerative disc diseases and spinal stenosis (Deyo and Weinstein, 2001). In the remaining cases of LBDs that are classified as idiopathic and non-specific in nature (i.e. neuromuscular, general pain, etc.), several theories have been formed. Some researchers suggest there may be a psychological or psychosocial component, including links between LBDs and anxiety, depression, stress and negative body image (Andersson, 1999). Others suggest a biological and biochemical basis in the form of

increased genetic expression and anabolic protein content, as well as increased cytokines and chemokines with pro-inflammatory properties (Bachmeier et al., 2009; Kepler et al., 2013; Le Maitre et al., 2007b, 2005). It is clear that mechanical loading tolerance is multifaceted and is likely subject to the complex influences of many of these factors, especially in the case of nonspecific work-related musculoskeletal disorders. The current study attempts to address the existing gap by assessing a selection of these factors (i.e. cytokines and psychological states in conjunction with one another, as evidence suggests all of these may contribute to the development of work-related musculoskeletal disorders by altering biomechanical criteria (Marras et al., 2016).

2.2 Mechanical Tissue Tolerance and Spinal Loading

Two factors that are directly related to the spinal column's ability to resist damage, and subsequently prevent LBDs, are the issues of tissue tolerance (i.e. capacity) and spinal loading (i.e. demand). These two concepts are closely intertwined, as tolerance of a tissue dictates the magnitude of the load that can be placed on the vertebral column before injury occurs (Marras et al., 2016).

Spinal loading refers to the forces placed on the spinal column in 3 axes: compression (vertical), shear (horizontal-lateral or anterior-posterior) and torsion (rotational). While a large portion of the load on the spine is created by the musculature as it is activated to both support and mobilize the spinal column (McGill, 1992), Brinckmann and colleagues (1989) have suggested that the vertebral body is the weak link when examining compressive forces. The vertebral body becomes even less effective when there is some form of disc degeneration. Pollintine and colleagues (2004) have observed a resistance to compression of only 19% prior to fracturing in the anterior portion of the body in in vitro studies applying loading via mechanical impactor devices

(Pollintine et al., 2004). Even small amounts of vertebral damage have been found to cause increased stress in the adjacent intervertebral discs (IVDs), which could perpetuate lower back pain (Adams et al., 2000). Further compounding weaknesses that can arise in the IVD, some researchers have found that compressive "creep" loading (i.e. submaximal forces occurring over a sustained time period) can also force water from the IVD, causing losses of disk height in the range of 1-2 mm (McMillan et al., 1996). This "creep" loading can occur relatively frequently, as Adams and Dolan (2005) suggested, stating that it is possible to observe these effects throughout the course of a day simply due to a sustained posture, and in the absence of any vertebral body damage. Consequently, such changes in the IVD can contribute to the development of pain or LBDs, as the disc can no longer perform its cushioning function as intended and the structural integrity of the spinal system is lessened.

As tissue tolerance is related to mechanical integrity, it is important to note that there are several factors that can significantly impair tolerance: magnitude of loading, repetitiveness of loading and duration of exposure. The magnitude of a load is crucial; if the peak force of a loading bout exceeds bone and tissue tolerance, the spinal column can buckle and an acute injury such as a vertebral endplate fracture can occur (van Dieën et al., 1999). Secondly, even at submaximal levels, repetitive loading can result in the accumulation of micro-damage and increased stiffness in supporting tissues, which ultimately reduces the tissue's tolerance threshold (Callaghan and McGill, 2001; Kumar, 1990). Finally, it has been demonstrated that mechanical properties of a tissue exhibit diurnal variations, as well as more chronic changes such as those that occur over decades of stress on the tissue. Diurnal variations in tissue properties are a result of the IVD losing water content and subsequently decreasing in volume (up to 20% over a day), while long-term changes in tissue properties are mostly associated with aging and degenerative changes, which can

be primarily observed in the degradation of the extracellular matrix (Adams and Dolan, 2005; Botsford et al., 1994; Marras et al., 2016). Thus, for many years it was believed that frequency and magnitude of tasks affecting tissue tolerance should be the focus of ergonomic interventions in the workplace; however, the prevalence of LBDs has continued to rise steadily in spite of corrective efforts.

One explanation for the increased prevalence of LBDs in the workplace, especially in assembly line settings, is that workers are being subjected to an increased number of lower force tasks, as the higher force tasks have been rectified, or at least mitigated, by ergonomic measures such as lift-assist devices or mechanical hoists. As a result, there is a shift towards more frequent low force motions; thus, while the magnitude or force aspect of spinal loading is often managed appropriately, the repetition increases as a consequence to maintain productivity targets. While peak loads have been the focus of several investigations to mitigate LBDs, cumulative loading is believed by many researchers to be just as important as instantaneous loading, if not more, as its effects are more insidious in nature (Howarth and Callaghan, 2013). Therefore, this may partially explain the rise in the prevalence of LBDs in this industry despite attempts to make ergonomic corrections (Marras et al., 2009; Punnett and Wegman, 2004).

2.3 *In vitro* and *In vivo* Spinal Load and Tolerance

Thus far, much of the current knowledge base on LBDs has stemmed from a structural or mechanical perspective, utilizing partial cadaver or animal tissues to test spinal loading *in vitro* with the goal of developing tolerance levels that should not be exceeded, especially in workplace design (NIOSH 1981, 1994). However, this line of thinking neglects to address two major issues: a lack of pathological cause and *in vitro* limitations. As discussed previously, up to 85% of LBDs

do not have a visible pathology that is identifiable by means of traditional imaging and diagnostic techniques and therefore potentially develop as a result of some cause other than mechanical failure of tissues. In addition, utilizing an *in vitro* approach has its own s(Crisco and Panjabi, 1991)et of limitations: *in vitro* models can vary significantly from living tissues (Bass et al., 1997), and animal models are only justifiable to an extent in translating findings to human spinal work (Smit, 2002). An *in vitro* approach also negates much of the spinal tolerance that an *in vivo* human spine would impart, due to a lack of musculature as well as other connective tissues. To illustrate this point, buckling has been shown to occur at compression loads as low as 88 N in the lumbar spine *in vitro* without musculature (Crisco and Panjabi, 1991), in contrast to the *in vivo* limit set by NIOSH (3400 N of compressive force; NIOSH, 1998). Secondly, without neural and other connective tissues, it is difficult to ascertain the effects that these externally imposed forces may exert on tolerance levels (i.e. reflexive and neural responses to loading, cascading immune response to damage, etc.). Therefore, there is a fundamental difference between *in vitro* and *in vivo* tests: supportive tissues and biochemistry play an enormous role *in vivo* that cannot be imparted during an *in vitro* test (Crisco et al., 1992). Scholz and Woolf (2002) have also shown that pain caused by tissue injury can be propagated at the cellular level prior to observing any structural tissue damage, further adding strength to the hypothesis that perhaps biomechanical loading induces biochemical changes which can lead to the development of LBDs (Scholz and Woolf, 2002).

2.4 Non-mechanical Risk Factors

2.4.1 Physiology

An area of research that is attracting a large amount of interest is to determine non-mechanical causes of LBDs by studying the early immune responses to work stress, tissue infection or injury. Thus far, it is known that there are two distinct phases of immune responses to any of

these events: a primary and secondary immunological phase (Miles et al., 2008). During the primary phase, muscle damage initiates the infiltration of inflammatory cells and potentially pro-inflammatory macrophages (James et. al., 2018), to the site of damage, where subsequently small biological molecules (i.e., cytokines, chemokines) are produced to regulate the inflammatory process during the secondary immunological response phase (Miles et al., 2008). Cytokines are biological molecules that are most often implicated in mediating inflammatory responses to tissue damage, infection or injury. It is important to note that not all inflammation is necessarily bad, as some degree of inflammation is often necessary to initiate tissue repair and rebuilding (Splittstoesser et al., 2012). Conversely, Splittloesser and colleagues (2012) also state that prolonged inflammation can affect healthy tissue catabolically (i.e. by breaking it down), and thus the development of chronic inflammation can be considered more destructive than productive.

2.4.1.1 Chronic Implications

Many researchers have addressed the role that cytokines and chemokines play in the persistence of LBDs, especially in deteriorating diseases such as degenerative disc disease. Increased levels of pro-inflammatory cytokines such as Tumour Necrosis Factor alpha (TNF-α) have been identified in patients with low back pain (LBP), with some researchers identifying up to 60% of clinical patients as possessing clinically-significant elevated TNF levels, while only 12% of controls exhibited the same elevated levels (Wang et al., 2008). Cytokines including Interleukin-6 (IL-6), Interleukin 1 (IL-1) and Prostaglandin E2 (PGE_2) have been found in degenerated discs of patients with LBDs (Burke et al., 2002). Moreover, the cytokine PGE_2 has also been implicated in sensitizing spinal nerve roots to pain, which further exacerbates the suffering of LBD patients (Zeilhofer, 2005). TNF-α and Interleukin 8 (IL-8), in addition to those molecules previously mentioned, have been shown to act in conjunction with matrix-degrading

factors to mediate the catabolic processes of local nerve irritation, inflammation and pain around an injured IVD (Kang et al., 1995, Kang et al., 1995, Ahn et al., 2002). It is clear then that recovery time is crucial in the maintenance of tissue integrity, as inadequacy in this temporal domain places an individual at an elevated risk of incurring some form of damage to spinal tissues from any of the multitude of cytokines liable to arise as a result.

2.4.1.2 Acute Implications

While the presence of pro-inflammatory cytokines has been well documented in chronic LBDs and pathologies, less work has been done in the realm of studying inflammation in an acute LBD episode, defined as pain or injury lasting less than 12 weeks in duration (Bigos et al., 1994). However, this is an important population to study because all LBDs must begin as acute conditions and progress over time to chronicity. More specifically, any form of biomechanical loading and physical activity elicits an inflammatory response and places stress on tissues surrounding the spine, which normally resolves if ample time is given following the cessation of the stress (Yang et al., 2011). Chronic LBDs are usually, at least partially, a result of a failure to cease the upregulation of these initial immune responses (Klyne et al., 2016).

With respect to research on the acute inflammatory response as a result of loading, Yang, Marras and Best (2011) attempted to examine biochemical pathways in response to a lifting task, and found that transient inflammation is present in tasks that many individuals who work in industrial settings would perform as part of their work duties. The most responsive cytokine to loading conditions, IL-6, showed a 28% increase in controls by the afternoon (consistent with diurnal variations (Vgontzas et al., 2005) and a 68% and 234% increase in each of their loading conditions (2.3 kg and 11.3 kg, respectively). However, there were two main drawbacks to their

study design. Firstly, while the researchers manipulated the magnitude of load lifted, they imposed a delimitation by neglecting the effect of frequency and thus could not speculate on how this may have affected tissue tolerance in relation to biochemical responses. Secondly, altering the magnitude of the load in such a manner also induced different levels of cumulative spinal loading in the participants, which has been linked to detrimental effects on spinal tissue and thus is an important consideration when examining LBD development risk (Waters et al., 2006).

Similarly, Splittstoesser and associates (2012) found elevated inflammatory markers, namely creatine kinase (CK), IL-8 and IL-6, following a 2 hour lifting protocol, which have been utilized as indicators of damage to muscle. These elevated levels were not resolved in a 20-hour follow-up test, indicating the potential for a cumulative inflammation cascade, which could perpetrate a decreased tissue tolerance and have negative implications for the low back health of workers exposed to sequential days of lifting. As previously mentioned, cumulative loading *in vitro* has been shown to cause significant increases in levels of TNF-α, IL-6, IL-1β and IL-8, especially at the level of L_4/L_5 vertebrae (King et al., 2009); thus, there is potential for similar effects to be observed in the systemic circulatory system. In addition, systemic cytokine levels are known to be significantly correlated with adiposity (Park et al., 2005), age and sex (Bermudez et al., 2002), which adds yet another layer of complexity to the understanding of the multifactorial nature of LBDs, and are factors which were not considered in either of the aforementioned studies

The idea that tissue tolerance decreases in accordance with repeated tissue inflammation as a result of exposure level and loading is best described by Barr and Barbe (2004), who proposed a conceptual model in which low repetition and force can be suitably rectified and resolved by repeated bouts of acute inflammation. However, in the case of highly repetitive loading that

exceeds a threshold or lacks a suitable recovery period, the loaded tissue lacks adequate time to heal and inflammation is persistent, which decreases tissue tolerance and ultimately can lead to tissue failure (Barr and Barbe, 2004). Therefore, the goal of the present thesis was to induce repetitive loading in an *in vivo* situation in order to investigate whether 24 hours was an adequate time for the inflammatory response to subside after performing a common workplace task like either of those imposed in this investigation.

2.4.2 Psychology and Adiposity

Psychosocial and psychological factors have been implicated as contributors to an increased risk of the development of LBDs, and have also been identified as potential moderators of lifting mechanics (Davis and Marras, 2003). A great body of evidence supports the notion that psychosocial variables play a role in the performance of workers, in which researchers agree that job dissatisfaction, social isolation and poor relationship quality all negatively affect performance (Elfering et al., 2002; Linton, 2000).

Furthermore, negative psychological states have the ability to significantly alter pro-inflammatory cytokine profiles in individuals, as is evidenced by the findings of Miller and colleagues (2002) who discovered that chronic stress significantly impaired the immune system's ability to combat the production of pro-inflammatory cytokines. A growing number of researchers are linking the development of negative mindsets following an acute LBD episode with a person's tendency to progress to chronicity, highlighting yet another issue that cannot be assessed *in vitro* (Dionne, 2005; Hurwitz et al., 2003; Pincus et al., 2002). Assessing aspects of psychological states such as fear of pain, fear of movement and perceptions of pain may provide valuable insight as to whether the individual is at risk of further complications should they experience an acute LBD episode. Assessing these psychological factors in conjunction with inflammation also has merit,

as recent work has demonstrated significant differences in depressive symptoms, fear avoidance and pain catastrophizing between healthy controls and those with LBP (Klyne et al., 2016). Adiposity has also been shown to exert an effect on circulating inflammatory levels, especially in the chronic sense. Chronically, associations have been found with increased levels of IL-6, C-reactive protein (CRP) and increased Body Mass Index (BMI) (Bermudez et al., 2002), as well as TNF-α with weight, BMI, waist and hip circumference, and parallels with visceral adipose tissue and IL-6 and CRP levels (Park et al., 2005). This suggests a possible link with adipose tissue and a generally higher baseline pro-inflammatory profile, which could place individuals at greater risk for developing LBDs. Identifying these risky characteristics in advance of the development of LBDs could be a considerably more effective strategy than correcting them following an injury.

In the spinal biomechanics community, stability of the spinal column is an area of great interest as it is currently believed that achieving an optimal level of stability functions as a preventative quality as far as the development of LBDs (Reeves et al., 2007). Possessing enough stiffness so as not to overextend the normal range of motion following a perturbation, but also enough mobility that you can adapt to a reasonable number of alternative patterns of motion is essential to the maintenance of an injury free spinal system (Graham et al., 2015; Granata and England, 2006). Recently, it has been demonstrated that the psychological characteristics of an individual can also modify spinal stability following an induced LBP episode. More specifically, those with high pain catastrophizing differentially modify stability in response to the induced pain by adopting a stabilizing approach to spinal control (Ross et al., 2017). Finally, it is recognized that if individuals strongly identify with pain catastrophizing and fear of movement, these factors can contribute to sedentary behaviours following an acute injury. These sedentary behaviours can lead to the development of chronic pain as well as further detriments to emotional welfare (Hurwitz

et al., 2003). Therefore, investigating these potential moderating factors of inflammation are crucial in understanding the inflammatory responses to acute exercise in order to gain a more complete understanding of what may lead to the development of LBDs.

CHAPTER 3: PURPOSE

The purpose of this investigation was to determine whether a symmetrical lifting task with varying load magnitude and frequency, while maintaining common external biomechanical work, would induce a varied inflammatory profile over a 24-hour period. This was based on the idea that if a worker in, for example, an automotive assembly plant, were to be faced with the task of moving stack of boxes throughout the workday, each weighing 10 kg and totalling 50 kg altogether, they could theoretically choose to lift the entire load at once, if that was within their capabilities, or move each 10 kg box individually. Thus, the current study was designed to evaluate which of these choices would induce greater inflammation, and whether variables such as adiposity, pain-catastrophizing, or kinesiophobia scores could potentially moderate these levels. This was achieved by testing a heavy and light load condition with equivalent external work by varying the frequency of the two tasks; the heavier condition (high force, low repetition; HFLR) consisted of 25% of the participant's maximal lifting strength at a rate of once per minute, while the lighter condition (low force, high repetition; LFHR) reduced the load to five percent and increased the frequency to five times per minute. Each participant completed both conditions separated by a period of one week, and each task was performed for two hours. A secondary aim was to evaluate the effect that loading condition had on lifting mechanics throughout the task and determine whether any variation could help explain changes in inflammation between the conditions.

It was hypothesized that the HFLR condition would induce greater peak spinal loads, and subsequently cause greater levels of micro-damage in the tissues of the low back due to this added weight and strain on the participant (Parkinson and Callaghan, 2007). Theoretically, this should induce greater levels of inflammation in response to this task condition, as inflammation is usually a direct reflection of level of injury and damage to tissues or infection (Barr and Barbe, 2004).

CHAPTER 4: METHODOLOGY

4.1 Participants

Twelve participants (6M, 6F) aged 24.05 ± (4.83) years with a minimum of one year of experience in weightlifting were recruited from the university population. All were recruited through advertisements around the university, social media and verbal advertisements. Ethical clearance was obtained from the University of Ottawa Research Ethics Committee and adhered to the Declaration of Helsinki. All participants provided informed consent (written and oral) prior to commencing any experimental procedures. Demographics can be found in Table 1 below. Physical Activity levels by participant can be found in Appendix B. All participants were classified as either "High" or "Moderate" with respect to their physical activity levels. Body fat percentage was quantified using a Dual X-Ray Absorptiometry Scan (DEXA). Full body composition measurements, including bone mineral density and tissue mass by type from DEXA scans can be found in Appendix C.

Table 1: Participant Demographics and Anthropometrics

	N	Height (cm) **Mean (SD)**	Weight (kg) **Mean (SD)**	Age (years) **Mean (SD)**	Body Mass Index (BMI) **Mean (SD)**	Body Fat (%) **Mean (SD)**
Female	6	165.00 (6.19)	62.48 (5.47)	23.30 (2.96)	22.97 (1.82)	30.35 (5.78)
Male	6	177.16 (4.99)	73.26 (4.71)	25.60 (5.93)	23.61 (1.76)	18.75 (6.94)
Total	12	171.08 (8.23)	67.88 (7.42)	24.05 (4.83)	22.58 (1.54)	24.55 (8.63)

Participants were recruited from the general university population and met the inclusion criteria outlined in the consent letter. Note: SD=Standard deviation.

Participants were not in receipt of an active worker's compensation claim and had not incurred a low back injury within the last year. Participants were also free of serious spinal pathologies (fracture, spinal cord injury spinal disease resulting in increased inflammation, neurological disorder, cauda equina syndrome and tumour growths). Additionally, any participants with comorbidities known to elevate inflammatory systemic blood markers (hyperthyroidism, endometriosis, reactive arthritis and serious injuries to other parts of the musculoskeletal system

in the last 12 months) were also excluded (Klyne et al., 2016). Finally, female participants were all pre-menopausal, had a normal menstrual cycle and were tested within the first week of their cycle (days 1 and 7).

4.2 Study Design

Participants completed two sessions separated by a period of one week, of approximately six hours in length each day, at the University of Ottawa Human Movement Biomechanics Laboratory. In addition to the two main sessions, participants were asked to return 24 hours following the completion of each session for approximately 15 minutes to complete a follow up blood draw. Independent variables included loading condition (high force, low repetition (HFLR) and low force, high repetition (LFHR)) as well as time (Baseline, 0, 4 and 24 hours post-lifting task). Dependent variables included pro-inflammatory cytokine levels (Interleukin 6 and 8 (IL-6, IL-8)) (Human Luminex Performance Assay Base Kit, Panel A; R&D Systems, MN, USA). Other variables of interest included: 1) peak and cumulative spinal loading from VICON motion capture and force plate data, calculated using Visual 3D software (VICON Vantage V5, Vicon, UK; 2 Bertec FP4060 force plates; Visual 3D V5, C-motion, USA); 2) percentage of fat mass (%FM), quantified by DEXA (General Electric Lunar Prodigy, Madison, Wisconsin; software version 6.10.019); 3) psychological data collected from the Pain Catastrophizing Scales (PCS), Tampa Scale for Kinesiophobia (general population) questionnaires (TSK-G), pain/fatigue levels measured on a visual analogue scale (VAS) for participants 1-4, exertion levels via Borg CR-10 questionnaires for participants 5-12 and 4) sex (male and female). Participants 5-12 also completed the Short-Form International Physical Activity Questionnaire (Appendix D) for demographic information. Visual representation of timelines in each condition can be found in Figure 1. These time points and cytokines were chosen for all 12 participants based on pilot testing carried out on

the first four participants where a greater number of time points and physiological markers were studied to optimize the overall study design; results of which can be found in Appendix A.

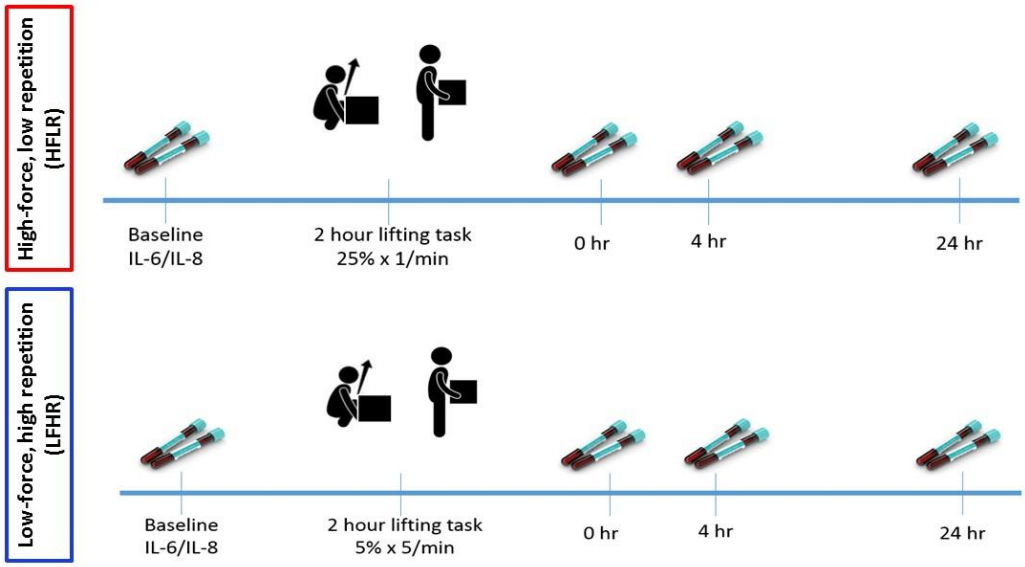

Figure 1: Methodological process for testing sessions. HFLR condition at 25% of the participant's maximal lifting strength, one lifting cycle per minute, and LFHR condition at 5% of the participant's maximal lifting strength, five lifting cycles per minute.

4.2.1 Physiological Instrumentation

Participants had a single-port, closed IV catheter (BD Nexiva™; Becton, Dickinson and Company) inserted in the antecubital area prior to the baseline blood draw, which was kept patent with semi-continuous infusions of 0.9% sodium chloride (BD PosiFlush XS™; Becton, Dickinson and Company). Each blood draw consisted of 6 mL of venous blood which was centrifuged at 2500 rpm for 15 minutes to allow separation of plasma, which was subsequently aliquoted in 450 µL quantities and placed in a freezer at -80°C for storage until time of analysis. DEXA scans were also carried out on each participant between the zero and four hour blood draws on the first experimental testing day (General Electric Lunar Prodigy, Madison, Wisconsin; software version 6.10.019).

4.2.2 Biomechanical Instrumentation

A uniaxial load cell (60001A500-1000, Sensortronics, NZ) was affixed to a handle to measure maximum lifting strength (outlined in section 4.3), of which the peak value measured was utilized to dictate the weight to be placed in a hollow box (25 cm x 25 cm x 25 cm with handles that are 2.5 cm in diameter (Mavor and Graham, 2015)) that participants lifted for the experimental trial (Mehta, Lavender & Jagacinski, 2014). The output from this was fed back to a power source (XP power, VCS70US24, USA) and an amplifier (VOCM-491-2, Intertechnology, USA), which was connected to an analogue-to-digital board (NI USB-6363, National Instruments, USA). The voltage data were then read by the computer at 100 Hz and converted to kilograms using custom LabVIEW software (LabVIEW 2013, National Instruments, USA), which was developed using the factory calibration documents. During the lifting trial, participants were outfitted with 22 single reflective markers (12.7 mm, B & L Engineering, USA) and 10 rigid-body clusters bilaterally (humerus, forearm, T_{10}-T_{12} vertebrae, sacrum, thigh and shank; Appendix E), to collect kinematic data throughout the lifting task (e.g. Ross et. al., 2015, Figure 2). Reflective markers were also placed on the box utilized throughout the lifting task. 3D position data of these markers were recorded at 60 Hz using 10 Vicon Vantage V5 cameras (Vicon Motion Systems, Oxford, UK). Participants also carried out the task while standing on two force platforms (FP-4060, Bertec, USA) positioned in parallel, directly beside each other, which provided kinetic data. The analogue ground reaction force (GRF) data were collected at 2040 Hz data from the force plates, and were synchronized with the kinematic data through a 64-channel analogue-to-digital converter (Lock+, Vicon, UK). In addition, surface electromyography was collected on 4 trunk muscles bilaterally (multifidus, lumbar erector spinae, thoracic erector spinae and latissimus dorsi), during the first and last ten minutes of the lifting task; however, these data are outside the scope of this thesis.

4.2.3 Psychological Instrumentation

A number of psychological assessment surveys were administered to participants, including a 13-item Pain Catastrophizing Scale (PCS), 17-item Tampa Scale for Kinesiophobia, and either the Visual Analogue Scale of pain/discomfort (VAS) (participants 1-4) or Borg CR-10 Scale (participants 5-12), evaluated at 4 half hour intervals throughout the lifting protocol (Appendices F, G, H and I, respectively). Participants 5-12 completed the Borg CR-10 scale in place of the VAS as it was more representative of effort, rather than pain or discomfort. The rationale for the decision to change questionnaires is discussed in more detail in Appendix A.

4.3 Experimental Protocol

Participants completed two experimental testing sessions, each consisting of 4 blood draws and a two hour lifting task designed to simulate an occupational setting. On both days, participants arrived in the biomechanics laboratory at 7:30 am, at which time they had the catheter inserted and their first blood draw completed (Baseline). Following this, they completed the maximum lifting strength trial. The maximum strength trial was completed on both days to mirror the work stress imposed, but only the value from the first day's test was used to calculate the box weight.

For each testing session, the box was weighted at either 25 or five percent of the participant's maximal lifting strength (in Newtons, converted to kilograms), with each load being administered in a randomized, which was counterbalanced across all participants. Once each load was determined, participants were then outfitted in a spandex suit and all passive reflective markers for motion capture were affixed. In both conditions, participants stood barefoot on the force plates and were instructed to lift the weighted box to a shelf placed at knuckle height when standing

upright next to a customised tower. One lift cycle consisted of a lift from the floor to the shelf, as well as lowering the box back to its original position (Figure 2).

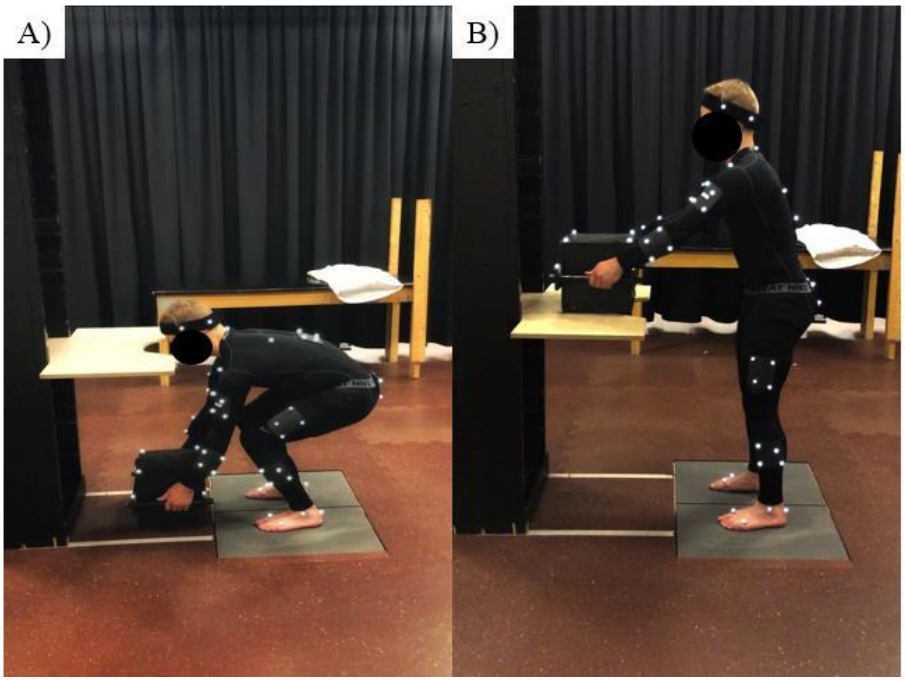

Figure 2: Experimental lifting task. Beginning on the floor directly in front of the participant, the box was lifted to a shelf in front of the participant on the first beat of the metronome, and then lowered from the shelf to the ground on the second beat.

In the 5% (LFHR) condition, participants completed five lift cycles per minute, while in the 25% (HFLR) condition, they completed one lift cycle per minute to the beat of a metronome, such that the external workload was consistent between conditions, as per equation one using a lifting height of 0.5 m and hypothetical loads of 25 kg (~250 N) and 5 kg (~50N), respectively:

Equation 1:

$$Total\ work = force\ \times frequency\ \times duration \times distance\ moved$$

$$\text{i.e. } Work\ (HFLR\ conditon) = 250\ N\ \times 1\frac{lift}{minute} \times 1m\ (lift\ and\ lower) \times 120\ minutes$$

$$= 30\ 000 \text{ Nm (Joules)}$$

$$i.e. Work\ (LFHR\ condition) = 50\ N\ \times 5\frac{lifts}{minute} \times 1m\ (lift\ and\ lower) \times 120\ minutes$$

$$= 30\ 000 \text{ Nm (Joules)}$$

Participants were given three to five minutes to familiarize themselves with the lifting task and to find the most comfortable foot position such that they were not reaching excessively to place the box on the shelf. Once they were comfortable, their foot position was outlined with chalk on the force plates and they were instructed to keep that position throughout the lifting task. They were not restricted as to their lifting strategy (i.e. stoop vs. squat), as long as they maintained their foot position.

Participants lifted to the beat of a metronome for a period of two hours, with a five minute break every half hour, during which they completed a VAS/Borg CR-10 evaluation. Following the two hour lifting protocol, they immediately had a follow-up blood draw at 0, 4 and 24 hours post lifting, in which the protocol was identical to the baseline draw (i.e. They completed the PCS, TSK-G and IPAQ questionnaires between the zero and four hour blood draws, as well as the DEXA scan).

Participants were fed a standardized breakfast, lunch, dinner and breakfast the following morning for the duration of the experimental period, in accordance with the Harris-Benedict equation to determine daily caloric intake on the basis of their Basal Metabolic Rate (BMR), with a multiplier for a moderate level of physical activity (1919);

Equation 2:

Women:
$BMR = 655 + 4.35W + 4.7S - 4.7A$

Men:
$BMR = 66 + 6.23\,W + 12.7S - 6.8A,$

where ‘W’ is equal to the participant’s weight in pounds, ‘S’ is equivalent to height in centimetres, and ‘A’ is equivalent to age in years. The Harris-Benedict equation determines the number of

calories needed to sustain a day in which an individual is lying down and not performing any physical activity. The BMR for each participant was multiplied by 1.76 (moderate activity level), to account for the two hour lifting task. Breakfast consisted of a combination of a Builder's Protein bar (Kirkland Signature, Costco Canada) and Ensure high-calorie meal replacement shake (number dependent on calculated caloric needs; Abbott Laboratories), while lunch and dinner was provided in the form of Swanson Skillet meal(s) (Swanson Skillet Meals, Pinnacle Foods Corporation).

Finally, participants were instructed to track all physical activity and food the day prior to the experimental task and to duplicate these on the day prior to their second session. They also refrained from partaking in any physical activity outside of the testing protocol within the 24 hour testing period to the lifting task itself, and refrained from consuming alcohol, tobacco and anti-inflammatory medications for the 24 hours prior to, as well as the duration of the testing period. This was done to ensure, to the best of the researcher's ability, that external confounding factors were controlled for, and both testing days were as comparable as possible.

4.4 Data Processing and Analysis

4.4.1 Physiological Data

Each blood sample was assayed for Interleukin 6 (IL-6) and Interleukin 8 (IL-8) using a 96-well, high sensitivity enzyme-linked immunosorbent assay kit (ELISA; R&D Systems, MN, USA). A total of 12 participants were used for analysis; however, two participants (4 and 6) were unable to provide a sample at 24 hours in the LFHR task.

4.4.2 Biomechanical Data (Kinetics)

Biomechanical data were analyzed in conjunction with inflammatory data in an effort to further explain changes seen in the systemic inflammatory profiles in each condition. Two main variables were analyzed: cumulative and peak moments at the low back. This was defined as pelvis-in-pelvis moment, created using the Anterior Superior Iliac Spine (ASIS) and Posterior Superior Iliac Spine (PSIS) markers to align their local coordinate systems (LCS). The tracking clusters used to calculate this were the low back rigid body cluster (T_{10}/T_{12}) and the pelvis cluster (sacrum). Visual 3D was used to calculate net reaction moments about the low back. All subsequent calculations (cumulative and peak moments) were performed using custom Matlab software (R2015b, The MathWorks Inc., USA).

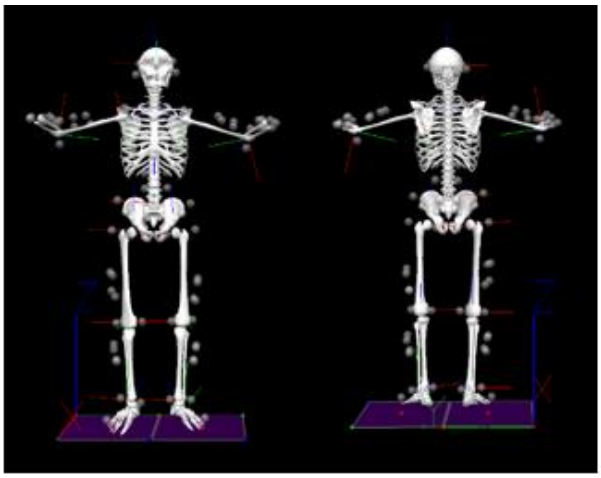

Figure 3: Biomechanical model from Visual 3D. This model was used for all calculations.

Moments were calculated for each lift during the first 10 minutes of the lifting task, and maximum, minimum and mean moments were identified for each participant. Cumulative loads were calculated by integrating the area under the curve for each lift cycle in the first 10 minutes, subsequently divided by the number of lifts in 10 minutes in each condition (HFLR-10; LFHR-50) to find a mean cumulative load for one lift. This average was then extrapolated across the full duration of the lifting task by multiplying by the total number of lifts performed (HFLR-120;

LFHR-600) to obtain an estimate of cumulative load over the full 2 hour lifting protocol. In addition, to further understand the forces acting on the spine, data from one participant was analyzed using a full-body lumbar spine model for lifting to look at the specific shear and compressive loading on the spine in OpenSim (SimTK, Stanford, USA) (Appendix J; Beaucage-Gauvreau et. al., 2018).

4.4.3 Psychological Data and Questionnaires

Data from the PCS questionnaire were compiled into an Excel (Microsoft, Redmond, WA, USA) spreadsheet and total scores were calculated. Furthermore, sub-scores were calculated according to Sullivan (1995), corresponding to Rumination, Magnification and Helplessness. Rumination, or the fixation on pain when it occurs, was calculated as the sum of scores on items 8, 9, 10 and 11. Magnification, or the concern that something serious may arise as a result of the pain, was the sum of items 6, 7 and 13. Finally, Helplessness, or the feeling that nothing can be done to resolve the pain, was calculated by summing items 1, 2, 3, 4, 5 and 12.

VAS scores were summed for participants 1-4, and scored from zero to a possible 10, with zero representing a complete lack of any pain or discomfort, and 10 being excruciating pain. Similarly, Borg CR-10 scores were summed for participants and reported in a range of 0-11, with zero representing little to no perceived exertion, and 11 being the hardest task the participants had ever had to do.

Total scores from the TSK-G questionnaire were summed, and participants were classified as either “high” or “low” kinesiophobic individuals, with high being classed as anything above a score of 37, while low was either equal to or less than 37 (Vlaeyen et al., 1995).

Finally, the IPAQ was reported according to four activity categories: Vigorous, Moderate, Walking and Sitting. Each category was reported according to number of days spent in each category in a typical week, and number of minutes on each of those days, on average. These values were then converted to metabolic equivalents (METS) using the following equations (Equation 3 a, b, c):

Equation 3:

a) Vigorous Physical Activity:
$$Vigorous\ METS = \ 9 \times d \times m$$

b) Moderate Physical Activity:
$$Moderate\ METS = 4 \times d \times m$$

c) Walking:
$$Walking\ METS = 3.3 \times d \times m,$$

where "d" is equivalent to the number of days in that category, and "m" is the number of minutes in that category (IPAQ Research Committee, 2005). Number of minutes spent sitting was reported for informational purposes only and was not converted to a MET value.

For categorization purposes, individuals were either classed as Category 1, 2 or 3. Category 1, or "Low Activity" refers to those individuals that the requirements to be placed in categories 2 or 3 were not met. Category 2, or "Moderately Active", included individuals who met one of 3 possible standards: three or more days of vigorous activity at 20 or more minutes per day; five or more days of moderate and/or walking at 30 minutes per day; or five or more days of any combination of walking, moderate and/or vigorous activity totalling 600 METS per week or more. Category 3, or "Highly Active" included those that met one of the following two standards: three or more days of vigorous activity, totalling 1500 Vigorous METS per week; or seven days of any combination of walking, moderate or vigorous and 3000 METS per week or more.

4.5 Statistical Analysis

A full table outlining all variables included in statistical analyses by participant can be found in Appendix K.

4.5.1 Physiological data

Two-way repeated measures ANOVAs were run for each inflammatory marker, utilizing within factors of load condition (HFLR and LFHR) and time (Baseline, 0, 4 and 24 hours) using SPSS 23 for Windows (SPSS Corporation, Chicago, IL, USA). Least significant difference post-hoc pairwise comparisons for IL-6 and IL-8 were performed. Each time point contained data from all twelve participants, with the exception of the 24-hour time point in the LFHR condition for two participants due to technical difficulties with sampling. These data were also split by sex to visually inspect differences.

4.5.2 Biomechanical Data

One-way repeated measures ANOVAs were run for both peak and cumulative moments to determine whether there was an effect of condition on loading in the low back. Two participants were excluded from analysis due to technical difficulties.

4.5.3 Comparative Analyses

Preliminary analyses of the complex relationships between demographic, anthropometric and psychological variables and inflammation responses as well as biomechanical variables were carried out using correlational analyses. Inflammatory cytokine concentrations were examined as raw values, percentage change from baseline levels and absolute changes (0, 4 and 24 hours). Biomechanical data (peak and cumulative spinal loading) were examined using raw values as well as normalized to weight and height, and weight only. Pearson correlation analyses were run with

respect to inflammation at each time point and body fat percentages by area of body, height, sex, weight, all psychological tests. The same was done with biomechanical loading variables in each condition.

CHAPTER 5: RESULTS

5.1 Physiological Data

IL-6 and IL-8 both demonstrated a significant main effect of time on concentration levels ($p = 0.009$, $\eta^2=0.480$ and $p = 0.030$, $\eta^2=0.261$ respectively with Huynh-Feldt corrections), with the most substantial differences at four hours post-lifting in both conditions, as demonstrated by post-hoc analyses (Tables 3 and 4). Both cytokines also exhibited significant load x time interaction effects (IL-6: $p = 0.048$, $\eta^2=0.298$; IL-8: $p = 0.029$, $\eta^2=0.296$). There was no significant main effect of load condition on either biomarker (IL-6: $p = 0.145$, $\eta^2=0.221$; IL-8: $p = 0.16$, $\eta^2=0.171$).

Table 2: Statistical Analysis of IL-8 and IL-6 systemic inflammation levels

		Type III Sum of Squares	F	p	η^2
IL-8	**Time**	108.270	3.88	0.030 *	0.261
	Load	25.8200	2.27	0.160	0.171
	Time*Load	106.650	4.62	0.029*	0.296
IL-6	**Time**	2279.60	8.30	0.009*	0.480
	Load	253.020	2.55	0.145	0.221
	Time*Load	599.760	3.83	0.048*	0.298

Two-way, repeated measures ANOVA statistical results for mean inflammation levels (SPSS 23).

Table 3: Post-hoc pairwise comparisons of IL-6 systemic inflammation levels

(I) time	(J) time	Mean Difference (I-J)	Std. Error	Sig.[b]
1	2	-4.89500*	1.466	.009
	3	-13.7730*	4.127	.009
	4	-1.53400	0.788	.083
2	1	4.89500*	1.466	.009
	3	-8.87800*	3.589	.035
	4	3.36100	1.781	.092
3	1	13.7730*	4.127	.009
	2	8.87800*	3.589	.035
	4	12.2390*	4.367	.021
4	1	1.53400	0.788	.083
	2	-3.36100	1.781	.092
	3	-12.2390*	4.367	.021

Il-6 concentration levels at Time 1 (baseline), 2 (Zero hours post-lifting), 3 (Four hours post-lifting) and 4 (24 hours post-lifting).

Table 4: Post-hoc pairwise comparisons of IL-8 systemic inflammation levels

(I) time	(J) time	Mean Difference (I-J)	Std. Error	Sig.[b]
1	2	-0.8780*	0.340	.025
	3	-2.9130*	1.018	.016
	4	-1.0140	0.743	.200
2	1	0.8780*	0.340	.025
	3	-2.0340*	0.901	.045
	4	-0.1360	0.805	.869
3	1	2.9130*	1.018	.016
	2	2.0340*	0.901	.045
	4	1.8990	1.218	.147
4	1	1.0140	0.743	.200
	2	0.1360	0.805	.869
	3	-1.8990	1.218	.147

IL-8 concentration levels at Time 1 (baseline), 2 (Zero hours post-lifting), 3 (Four hours post-lifting) and 4 (24 hours post-lifting).

Mean concentrations for each marker in both conditions are shown in Figure 4, with IL-6 (top) and IL-8 (below). Individual responses can be seen in Figures 5 and 6. In Figure 5, it is evident that the LFHR condition creates much more variability in response to the task, as four participants show marked increases in concentration levels of IL-8 at the four hour sampling point, while the HFLR condition demonstrates a much lower level of variability at the same point, as well as across all other time points. In Figure 6, with respect to IL-6 levels, the same trend is evident, as a number of participants show substantial increases at the four hour point, while those same participants display much less of a deviation from baseline.

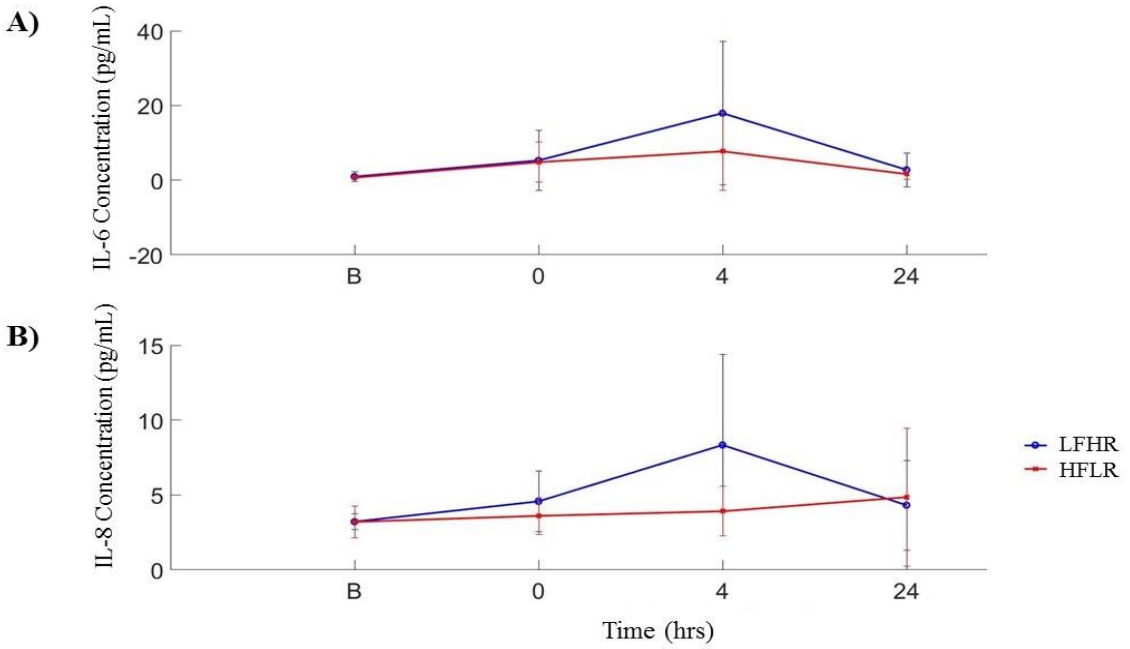

Figure 4: Mean Concentration levels across each condition (HFLR in red, LFHR in blue) with respect to A) IL-6, and B) IL-8.

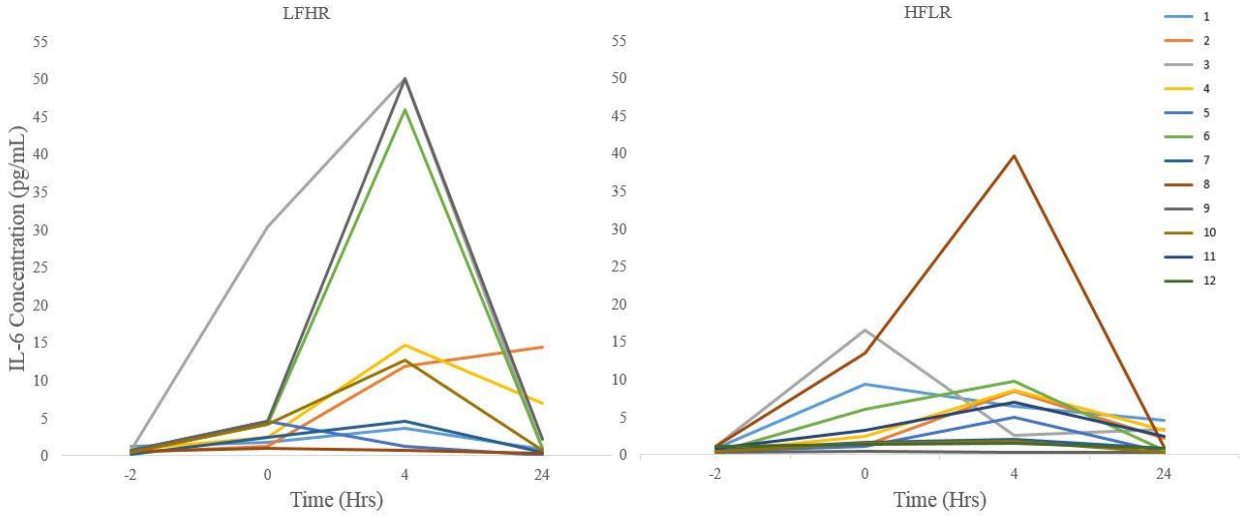

Figure 5: IL-6 plasma concentration levels by participant at baseline, 0, 4 and 24 hours post-lifting in LFHR (left) and HFLR (right) conditions.

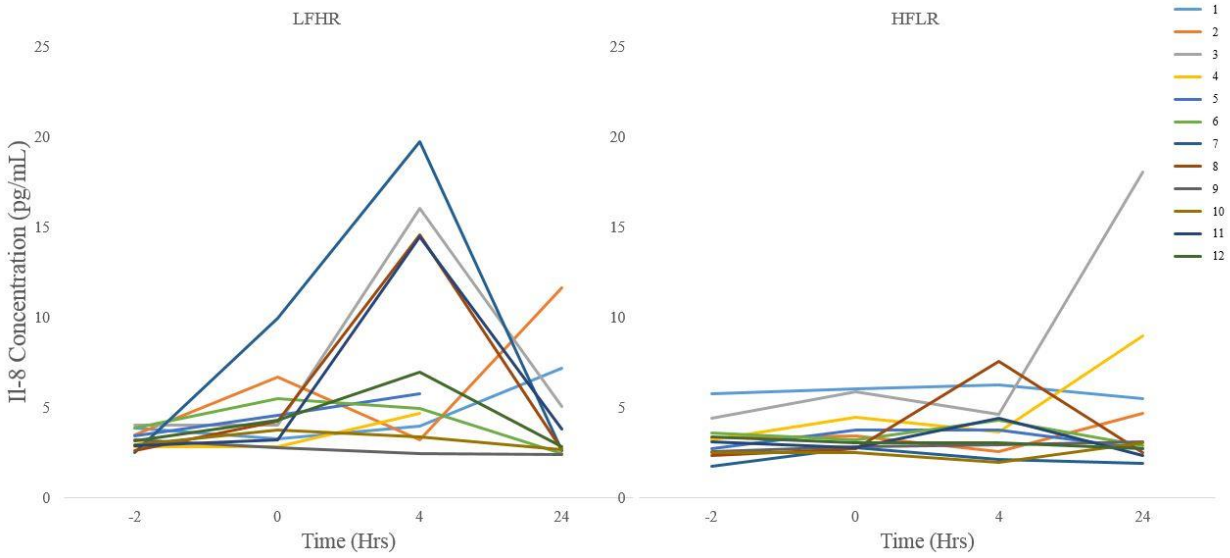

Figure 6: IL-8 concentration levels at baseline, 0, 4 and 24 hours post-lifting in LFHR (left) and HFLR (right) conditions.

Mean responses to each loading condition on the basis of sex are shown in Figure 7. With respect to both cytokines, their general profile is similar in the LFHR task, with females demonstrating slightly higher levels of inflammation across all time points, especially with regards to IL-6 levels (top left). In the HFLR condition, females are driving the majority of the increase in mean levels at the four-hour point, most notably in IL-6 concentrations. IL-8, in contrast, sees males retaining concentration levels significantly elevated above baseline levels at the 24-hour point, while females generally return to baseline levels.

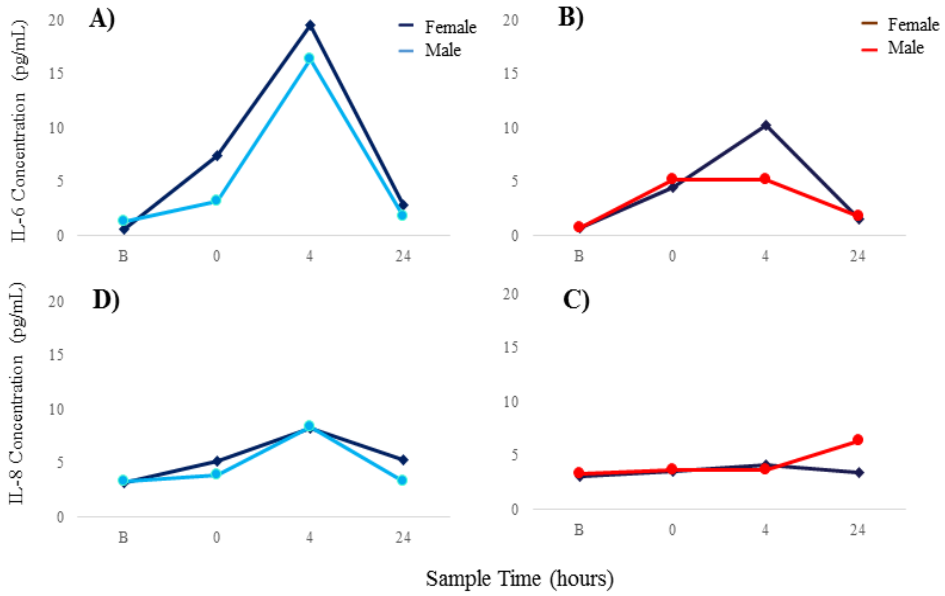

Figure 7: Mean response to each loading condition for IL-6 and IL-8, separated by sex. Clockwise from top left: A) LFHR IL-6, B) HFLR IL-6, C) HFLR IL-8, D) LFHR IL-8.

5.2 Biomechanical Data

Both peak and cumulative spinal loads were significantly different with respect to the HFLR and LFHR conditions ($p = 0.014$, $\eta^2 = 0.589$ and $p = 0.002$, $\eta^2 = 0.681$, respectively, Table 5). With respect to peak loads, the LFHR condition produced, on average, spinal loads of 189.16 Nm (SD=64.38), while the HFLR condition averaged 234.65 Nm (SD=99.1). Consequently, while

the peak loads were significantly greater in the HFLR condition due to the heavy load, the mean cumulative load in the LFHR condition was greater, averaging 312 205 Nm•s (SD=112 251), whereas the HFLR condition's cumulative spinal loads were 188 545 Nm•s (SD=39 099).

Table 5: Cumulative and Peak Spinal Loads

Moment	F	df	p	η^2
Cumulative	19.24	9	0.002*	0.681
Peak	9.329	9	0.014*	0.509

*One-way ANOVA with repeated measures for peak and cumulative loading, as calculated in SPSS 23, where "t" = critical t value, "df" = degrees of freedom, "p" = significance and "η^2" = partial eta squared. Note: * = statistically significant at 0.05 alpha level.*

Peak and cumulative spinal loads by participant can be seen in Figures 8 a) and b), respectively.

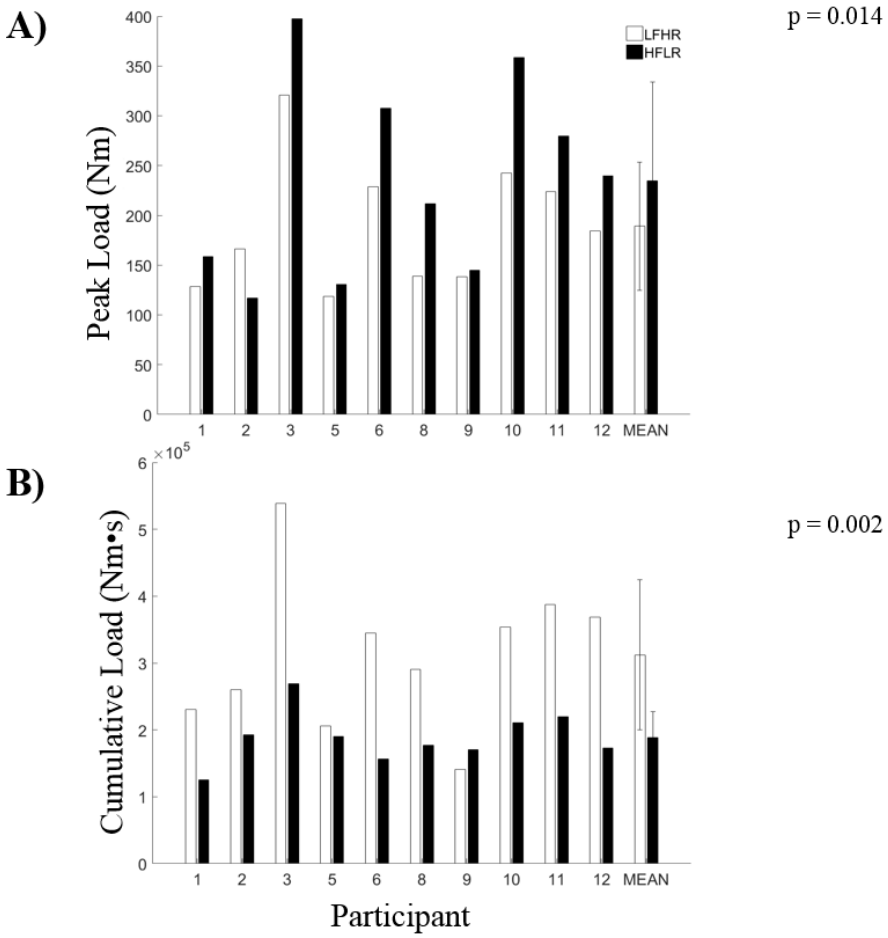

Figure 8: A) Average peak spinal load for each participant during the first 10 minutes of the lifting task. B) Cumulative spinal loads were calculated using the average integrated area under the curve of each lift in the first 10 minutes, multiplied by the total number of lifts in each condition.

5.3 Psychological

Firstly, with respect to the PCS, all 12 participants completed the questionnaire. PCS total scores ranged from 0-14, out of a possible 52, with the highest score falling in the 35th percentile (Appendix L). The average total score was 7.4 (SD 4.4), which corresponds to the 18th percentile. Full results by category can be found in Table 6.

Table 6: PCS Scores by Participant

	1	2	3	4	6	7	8	9	10	11	12	13	All
Total	13 (34)	0 (1)	1 (3)	13 (34)	7 (17)	7 (17)	8 (19)	14 (35)	5 (11)	8 (19)	3 (6)	10 (24)	7.4 (18)
Rumination	4 (26)	0 (2)	0 (6)	6 (38)	2 (13)	4 (26)	2 (13)	3 (19)	2 (13)	4 (26)	0 (2)	4 (26)	2.7 (17)
Magnification	4 (63)	0 (14)	0 (14)	3 (50)	4 (63)	1 (27)	3 (50)	4 (63)	2 (42)	4 (63)	1 (27)	4 (63)	2.5 (45)
Helplessness	5 (36)	0 (6)	0 (6)	4 (29)	1 (10)	2 (16)	3 (22)	7 (47)	1 (10)	0 (6)	2 (16)	2 (16)	2.3 (18)

Participants' raw scores for Pain Catastrophizing, followed by the corresponding percentile "raw score (percentile)" (Sullivan, 2009).

All 12 participants also completed the Tampa Scale for Kinesiophobia for the General Population, translated from its original Dutch format. Scores ranged from 28 to 42 out of a possible 68. The average score for this scale was 36.6 (SD=3.97), with men exhibiting slightly higher mean scores as compared to women (37.16, SD=3.53 and 36.16, SD=4.3, respectively). Full results by participant can be found in Appendix M.

With respect to the scales of exertion, the first four participants completed a VAS scale, as previously mentioned, while the remaining eight participants completed the Borg CR-10 scale. Among those that completed the VAS, the average score was 2 across each half hour interval in the HFLR condition, and 2.25 in the LFHR condition, demonstrating little change between conditions, likely due to its measurement of pain and discomfort as opposed to exertion. The Borg CR-10 scale was able to ascertain slightly greater differences in perceived exertion across the two

conditions, averaging 3.2 and 3.7 out of a possible 11 in the HFLR and LFHR conditions, respectively. When separated by sex, males demonstrated much less variation between the two conditions, averaging 3.4 and 3.7 in the HFLR and LFHR conditions, while females reported an average rating of 2.9 in the heavier condition and 3.6 in the lighter, more frequent task.

5.4 Comparative Analyses

5.4.1 Physiological Comparisons

The LFHR condition demonstrated greater relationships between IL-8 levels and other psychological and anthropometrical variables, especially with respect to body fat percentages. Total body fat and leg body fat percentage exhibited a positive correlational relationship with IL-8 levels immediately following the lifting task at the zero hour time point ($r = 0.589$, $p = 0.044$; $r = 0.607$, $p = 0.036$, respectively). The percentage of body fat participants possessed in their arms was also positively correlated with IL-8 levels, specifically when examining levels as a percentage of change from baseline at 24 hours post-lifting ($r = 0.663$, $p = 0.037$). While not statistically significant, the complementary relationship between IL-8 levels at zero and 24 hours post-lifting and trunk, leg and arm body fat percentages demonstrated positive correlational values from 0.4 to 0.6 for those measures that were not statistically significant (i.e. zero hours and trunk, arm body fat percentage; 24 hours and legs, trunk, total body fat percentage). With respect to inflammatory responses and their relationship to biomechanical loading, average peak moment was positively correlated with IL-8 levels at four hours post-lifting ($r = 0.668$, $p = 0.035$). Although not statistically significant, when examining absolute changes from baseline of IL-6 levels at zero, four and 24 hours, moderate METS were positively correlated with zero and four hours, while it was negatively correlated with 24 hour levels ($r = 0.539$; $r = 0.604$; $r = -0.548$; zero to 24 hours, respectively).

In the HFLR condition, PCS scores for helplessness were positively related to IL-6 and IL-8 levels at 4 hours post-lifting ($r = 0.723$, $p = 0.025$; $r = 0.736$, $p = 0.006$, respectively). In addition, percentage of change from baseline at 24 hours post-lifting was positively correlated to the average cumulative moment, both raw and normalized to height and weight ($r = 0.664$, $p = 0.036$ in both cases).

5.4.2 Biomechanical Comparisons

Peak and cumulative loads were significantly correlated with sex for raw, weight-normalized and height/weight normalized values in the LFHR condition, while these were statistically significant for weight normalized values in the HFLR condition. In addition, total body fat was significantly correlated in a positive direction with peak weight- and height-normalized moments in the HFLR condition ($r = 0.632$, $p = 0.05$), and positively although not significantly, correlated with peak and cumulative weight-normalized loading in the same condition ($r = 0.611$, $p = 0.061$; $r = 0.629$, $p = 0.051$; respectively).

CHAPTER 6: GENERAL DISCUSSION

The purpose of this investigation was to evaluate the acute systemic inflammatory effects of altering frequency and magnitude during a symmetrical lifting task with identical external task demands, as one might expect to find in an occupational setting (e.g. automotive assembly plant, construction, food service industry). This was done to examine whether a worker's potential choice of methodology in completing a task could increase the stress they place on their body and subsequently increase their potential for developing acute musculoskeletal disorders, and in particular, LBDs. It was hypothesized that the greater loads in the HFLR condition would induce greater peak stresses on the low back region, and thus cause greater micro-damage to tissues in that region, creating the potential to develop a greater systemic inflammatory response as the body attempts to rectify this damage over the course of the 24 hour testing period.

Although external load task demands were equivalent between the HFLR and LFHR condition, it appears that the frequency and magnitude in which that external load is lifted does exert differential physiological and biomechanical effects on individuals. While the HFLR condition might exert greater peak spinal loads on a lift-by-lift basis, over the course of the two hour task, lifting a lighter load more frequently exerts a much greater cumulative spinal load (Figure 8b), and consequently, induces a greater inflammatory response following the lifting task (Figures 4, 5 and 6). In contrast, the HFLR condition remains relatively stable across the duration of the 24 hour, although with respect to IL-8, the profile does trend towards an increasing rather than decreasing profile. This may suggest that had more time points been included beyond the 24 hour testing period, the presence of greater levels of systemic IL-8 may have become evident. It is reasonable to assume that these effects would be magnified had the participants completed a full eight hour workday, as would be the case in a typical shift in an occupational setting. Several

researchers have identified that extended durations of repetitive lifting tasks at relatively large magnitudes are a significant risk factor for spinal column damage and thus place individuals at a much greater risk of developing LBDs (Gooyers et al., 2015; King et al., 2009).

There was not a significant effect of load with respect to either IL-6 ($p = 0.145$, $\beta = 0.62$), or IL-8 ($p = 0.16$, $\beta = 0.48$), likely due to the almost identical mean values at baseline and 24 hours post-lifting. Post-hoc analyses of statistical power (G-Power 3.1) indicate that we can be confident in the assumption that the two conditions were not significantly different from each other. However, IL-6 and IL-8 did show a significant effect of time ($p = 0.009$, $\eta^2=0.480$ and $p = 0.030$, $\eta^2=0.261$), as well as time x load condition interactions (IL-6: $p = 0.048$, $\eta^2=0.298$; IL-8: $p = 0.029$, $\eta^2=0.296$). The LFHR condition did produce greater responses over time (especially at four hours post-lifting) in the case of both interleukins, as indicated by the significant interaction. Therefore, we can reject the hypothesis that the HFLR condition created significantly more inflammation systemically than the LFHR condition.

There was, however, a significant difference in mechanical loading between the LFHR and HFLR condition with respect to both peak and cumulative loading ($p = 0.014$ and $p = 0.002$, respectively). Peak spinal loads in the HFLR condition were significantly greater due to the increased external weight of each lift, while the cumulative load was 1.7 times greater in the LFHR condition over the course of the two-hour lifting task. This was likely due to the increased stress of lifting and lowering the individual's torso weight each time they bent to pick up and release the box, an effect which would undoubtedly exert a much more magnified effect given an eight-hour workday. This may also explain the greater level of systemic inflammation seen in the LFHR condition, as metabolically, the more movement that occurs, the greater the physiological stress,

irrespective of the external weight imposed. That is to say, that while the external load was controlled for, the internal metabolic strain between the two conditions was likely much greater in the LFHR condition. This was further supported by the greater perceived exertion levels demonstrated by the Borg CR-10 scores in the LFHR condition (3.7) as compared to the HFLR condition (3.2).

When separated on the basis of sex, visually, the inflammation results tell an interesting story (Figure 7). With respect to IL-6, the general profile over the 24-hour testing period is similar between the two sexes; however, females exhibit marginally higher mean values across all time points, with the exception of the baseline measure in the LFHR condition. However, in the HFLR condition females drove the majority of the increase in the inflammatory profile, particularly at the four-hour testing point. The opposite is true when examining IL-8 in the HFLR condition, in which males demonstrate a marked upwards trend at the 24-hour point, with systemic levels reaching of 1.8 times above baseline. This suggests that pro-inflammatory responses to the heavier lifting task may be amplified if testing occurs beyond the 24-hour time point (due to delayed onset muscle soreness, etc.); an important consideration for future studies. For our purposes, we chose the 24-hour as a limit for testing on the principle that workers who would benefit from the current investigation are mainly shift-workers, and therefore would be commencing their next shift within 24 hours following the completion of the previous one. With this in mind, any inflammation that remained at the last testing point would be present at the start of their next shift and would lead to cumulative damage over time. These workers are subjected to these types of stresses on an ongoing, consecutive basis, often up to five days per week and thus it is important to note that these effects demonstrated both in the inflammatory and mechanical domains would be amplified

over the course of the week. Longer-term investigations are recommended to more accurately estimate the physiological and mechanical stresses of either condition on workers.

The current investigation expands on work previously carried out by Yang, Marras and Best in 2011, as well as Splittstoesser and colleagues in 2012 who also examined immune responses to acute lifting tasks. By modifying the task to control for total external biomechanical work, we were able to untangle some of the effects of magnitude and frequency of lifting in the LFHR and HFLR conditions and examine the physiological responses on an equivalent level between the two. In addition, two main study design modifications were made that created the opportunity to examine the immune responses from a multidisciplinary perspective. Firstly, we were able to investigate the effect that adiposity and psychology may exert on the acute inflammatory response to these tasks by utilizing questionnaires and DEXA scans. Adiposity has been implicated as significantly correlated with increased inflammation, especially in chronic pain patients (Park et al., 2005), as have negative psychological states (Dowlati et al., 2010; Picavet et al., 2002), so the simultaneous evaluation of these variables in conjunction with inflammation and mechanical variables lend a particularly relevant additional layer to the evaluation of potentially risky lifting conditions. Secondly, by testing both males and females, we were able to begin to ascertain sex-effects on immune responses to lifting tasks, as well as tailor the tasks to more subject-specific demands by standardizing the tasks as a percentage of strength capabilities as opposed to weight.

For the psychological variables, the PCS did not reveal high levels of catastrophizing among participants, with all scores ranking below the 50th percentile, with the exception of three participant's magnification scores. However, PCS scores, specifically in the Helplessness domain, were significantly correlated in a positive manner with IL-6 and IL-8 levels at 4 hours post lifting.

Although IL-6 does have the potential to be both pro- and anti-inflammatory, four hours post-exercise a very acute sampling time and significant correlations occur in both IL-6 and IL-8. Due to the fact that IL-8 has strictly pro-inflammatory properties, it is likely that the relationship between PCS and IL-6 levels can be attributed to its pro-inflammatory properties. It is also of interest to note that seven of the twelve participants were classed as "Highly Kinesiophobic" on the Tampa Scale, defined as having an overall score greater than 37 (Swinkels-Meewisse et al., 2003). As previously mentioned, researchers have shown a greater incidence of highly kinesiophobic individuals with chronic LBDs as compared to individuals with low Kinesiophobia. (Swinkels-Meewisse et al., 2006; Vlaeyen et al., 1995; Vlaeyen and Linton, 2000). This is a particularly relevant detail, because it represents the fact that the current sample is psychologically diverse, and thus increases the external validity of the investigation. Due to the fact that approximately half of the sample possesses a psychological disposition which is common in LBDs, conclusions about inflammatory and biomechanical responses are more representative of a wide range of individuals, some of whom may be at a greater risk of developing LBDs (Picavet et al., 2002).

By utilizing a DEXA scan, we were able to obtain estimates of body fat percentages by region of the body, with some interesting relationships observed when examining these in conjunction with inflammation, specifically IL-8 levels in the LFHR condition. While total body and leg fat percentage was most strongly related to the immediate response of IL-8 after the LFHR task ($r = 0.589$, $p = 0.044$; $r = 0.607$, $p = 0.036$, respectively), arm body fat percentage most significantly related to the percentage change in IL-8 levels at 24 hours following the HFLR task ($r = 0.663$, $p = 0.037$). In complementary fashion, the body fat percentages by region that were not statistically significant did demonstrate positive correlational relationships for the zero and 24 hour

time points. This may be simply a result of the small sample size, but there is a high potential for anthropometry to exhibit a closely intertwined relationship with the scale of inflammatory responses following a lifting task, and subsequently risk of injury as a result. Trunk body fat, for example, exhibited an r^2 value of 0.31 ($p = 0.056$) with IL-8 levels at 0 hours post-LFHR task, meaning that fat carried in the trunk region can explain approximately 30% of the variance in IL-8 levels immediately after a highly repetitive lifting task. As there are several such relationships, the continued investigation of anthropometrical effects on inflammation levels resulting from occupational tasks is an important future research direction.

Inflammatory effects, as hypothesized, did bear some relationship to peak and cumulative loading. Average peak moment was positively correlated with IL-8 levels at four hours post-lifting in the LFHR condition ($r = 0.668$, $p = 0.035$), while average cumulative load was more strongly related to the HFLR condition levels of IL-8 at 24 hours post-lifting as a percentage of change from baseline. This is supported based on anecdotal feedback from participants; the HFLR condition was generally perceived as being fairly easy, and thus although the weight per lift was higher for each lift, it was likely not enough for the peak loading to directly impact pro-inflammatory levels. The cumulative effect of this higher load per lift, however, clearly does affect recovery time as greater cumulative loads are indicative of greater levels of pro-inflammatory levels at 24 hours following the lifting task. Peak moments in the LFHR task, however, were more strongly related to the IL-8 inflammation levels at four hours, which is still in the very acute physiological response stage. Therefore, greater moments with each lift, based on the sheer number of repetitions in this condition, were more likely to elicit a greater immediate inflammatory response. It is possible that this task was not long enough to demonstrate a statistically significant relationship with cumulative moments in this task.

One limitation to the current investigation includes the participant demographics with respect to activity level, as indicated by IPAQ scores. The eight participants in Phase II of the study were all classed as either moderately or highly physically active individuals. Due to the fact that the relationship between adiposity and chronic inflammatory levels is well-documented (Park, 2005), the relatively high activity level of the participants undoubtedly had an effect on the diversity of the body morphologies included. However, there were some promising relationships that emerged from this questionnaire with respect to inflammatory levels to the lifting task in spite of this. It was found that moderate METS exhibited a positive relationship with absolute changes from baseline IL-6 at zero and four hours post-lifting in the LFHR condition, while the relationship was negative at 24 hours post-lifting. The directional change is potentially a result of IL-6's dual pro- and anti-inflammatory properties; the initial period directly following the lifting task is potentially "good inflammation" and thus the more moderate activity an individual typically does, the greater the quick inflammatory action of Il-6 immediately following the lifting task. In contrast, IL-6 should typically be contained to the localized site of damage to act most effectively and increase muscle repair by 24 hours post-lifting, as persistent IL-6 levels in the circulating plasma have been associated with deleterious effects on muscle content (Muñoz-Cánoves et. Al., 2013).

Finally, biomechanical variables measured (i.e. peak and cumulative moments) demonstrated significant sex differences across conditions, which is likely related to differences in lifting strategies (Plamondon et al., 2014), which can affect the loading of the spine during these lifting tasks. In addition, total body fat demonstrated a positive association with peak moments (weight- and height-normalized) in the HFLR condition. Total body fat likely had an effect on peak moment due to the increased mass of relative body segment that were being moved with each lift.

CHAPTER 7: CONCLUSION

This thesis began to investigate the complex interaction of biochemical and biomechanical responses to occupational tasks, specifically lifting tasks of various frequencies and magnitudes. Both IL-6 and IL-8 increased in response to both lifting tasks; however, the LFHR task caused a greater increase in systemic inflammation and also induced a greater cumulative load on the low back than the HFLR condition. This suggests that cumulative load may be a better indicator of the level of physiological stress occurring in response to an occupational task, and that repetition may be a more relevant factor than magnitude (provided peak loads are still below injurious thresholds) when designing tasks in the workplace if the goal is to reduce the risk of developing LBD among workers. Significant relationships existed between anthropometric variables (total, arm and leg body fat percentages) and IL-8 levels in the LFHR condition, and a generally positive trend was associated with those variables that were not statistically significant and IL-8 levels in the same condition. The positive relationship of systemic inflammation following acute work stress and increased body fat percentage adds another layer of understanding of moderating factors on the body's acute physiological response, one which is modifiable and may decrease risk of injury if reduced. Emergent relationships between peak and cumulative moments indicate that biomechanical variables do indeed affect systemic inflammation levels, and vice versa. Follow-up analyses to this investigation include examining changes in tissue properties (i.e. stiffness) pre- and post-lifting from shear wave ultrasound images to evaluate whether any visible changes occurred in conjunction with inflammation profiles.

In summary, the present results enhance our understanding of the acute response to lifting tasks from a more holistic rather than purely mechanical perspective and begin to add to our

understanding of the potential risk factors which may lead to LBDs both in the chronic and acute sense.

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Appendix A

Pilot Testing

A.1 Specific Methodologies

All methodological procedures were identical to those discussed in Chapter 3 with the exception of the differences outlined below.

Physiologically, participants one through four were tested at two additional time points (2 and 6 hours post-lifting), and each sample was tested for the presence of Creatine Kinase (CK), Tumour Necrosis Factor-alpha (TNF-α) and Cortisol.

Psychologically, participants in this phase completed a Visual Analogue Scale, which was replaced with the Borg CR-10 scale for participants 5-12.

A.1.1 Statistics

Two-way repeated measures ANOVAs were run for each inflammatory marker, utilizing a within factor of load condition (HFLR and LFHR) and time (Baseline, 0, 2, 4, 6 and 24 hours) using SPSS 23 for Windows (SPSS Corporation, Chicago, IL, USA). Each time point contained data from all four participants, with the exception of the 24-hour time point in the LFHR condition for one participant due to technical difficulties with sampling.

A.2 Results

All statistical results are summarized in Table A.1. Il-6 showed a significant effect of time on concentration levels ($p = 0.024$, $\eta^2 = 0.683$) and CK showed a significant effect of load ($p = 0.011$, $\eta^2 = 0.450$). All other inflammatory markers were not statistically significant. Although not statistically significant, there was a moderate effect ($\eta^2 = 0.455$) for load*time interaction on Il-6 concentration. Thus, in this sample, IL-6 exhibited the greatest sensitivity to the lifting task, most

notably at four hours post-lifting. Mean data for all inflammatory markers are shown in Figure A.1. Overall, IL-8 and IL-6 exhibited the greatest change from baseline concentrations at the 24 hour sampling point, remaining elevated from mean baseline levels on average by 5.13 and 2.5 pg/mL, respectively, for the 25% condition, and 4.4 and 5.51 pg/mL for the 5% condition.

Table A.1: *ANOVA results by cytokine (Participants 1-4)*

Marker	Time	Load Condition	Time*Load Condition
IL-6	0.024 (η^2 = 0.68)	0.625 (η^2 = 0.12)	0.230 (η^2 = 0.46)
IL8	0.441 (η^2 = 0.34)	0.393 (η^2 = 0.37)	0.595 (η^2 = 0.28)
CK	0.290 (η^2 = 0.45)	0.011 (η^2 = 0.978)	0.699 (η^2 = 259)
TNF-α	0.517 (η^2 = 0.31)	0.148 (η^2 = 0.73)	0.859 (η^2 = 0.16)
Cortisol	0. 122 (η^2 = 0.54)	0.532 (η^2 = 0.22)	0.459 (η^2 = 0.34)

2-way repeated-measures ANOVA results (p-value (partial-eta squared)) for each cytokine, including main effects of Time and Load Condition, and interaction effects.

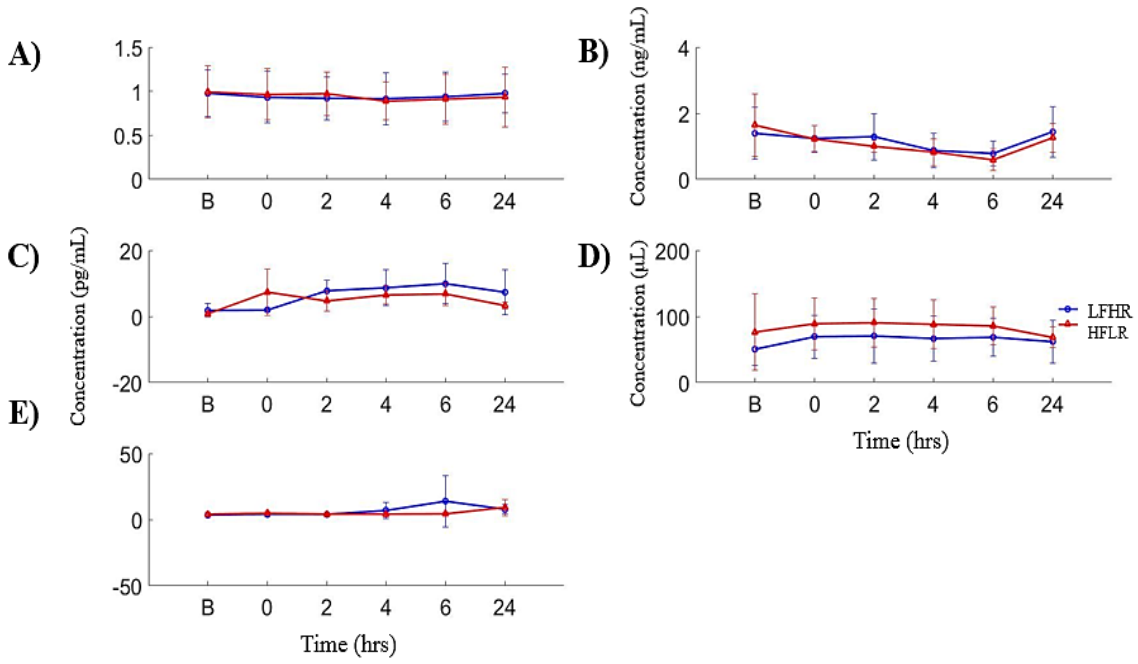


Figure A.1:Mean systemic concentration of A) IL-6, pg/mL, B) IL-8, pg/mL, C) TNF-α, pg/mL, D) Cortisol, ng/mL and E) CK, µL at baseline, 0, 2,4, 6 and 24 hours post-lifting. HFLR and LFHR conditions depicted in red and blue, respectively.

Individual responses by participant are shown in Figures A.2 and A.3 for LFHR and HFLR tasks, respectively.

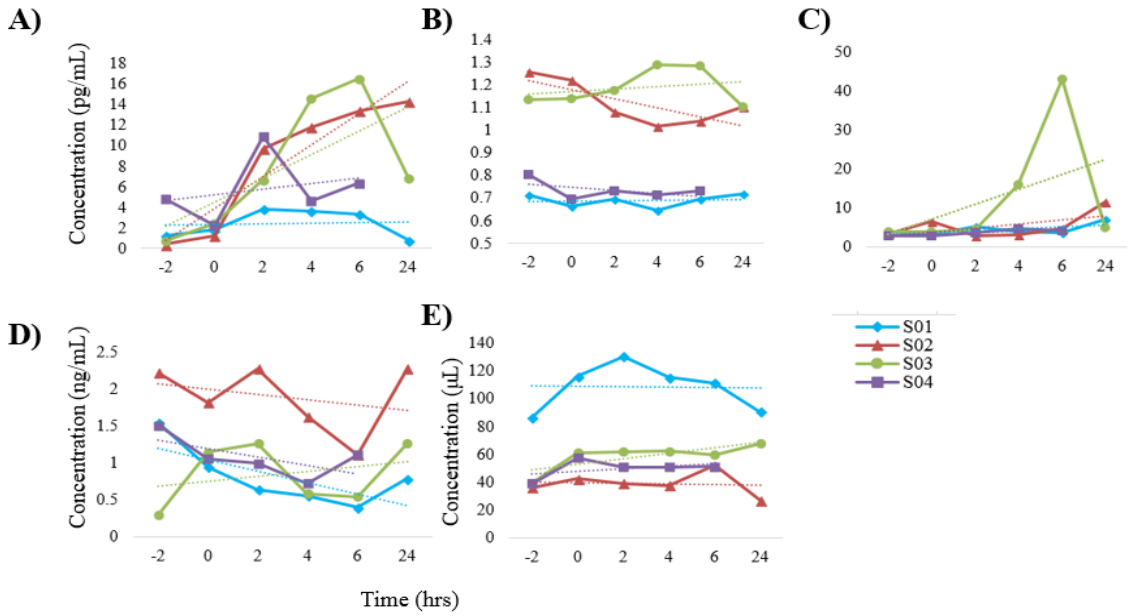


Figure A.2: Individual responses to the LFHR task, with time on the x-axis in hours and concentration on the y-axis. A) IL-6, B) TNF-α, C) IL-8, D) Cortisol, E) CK. Note "-2" is baseline concentration.

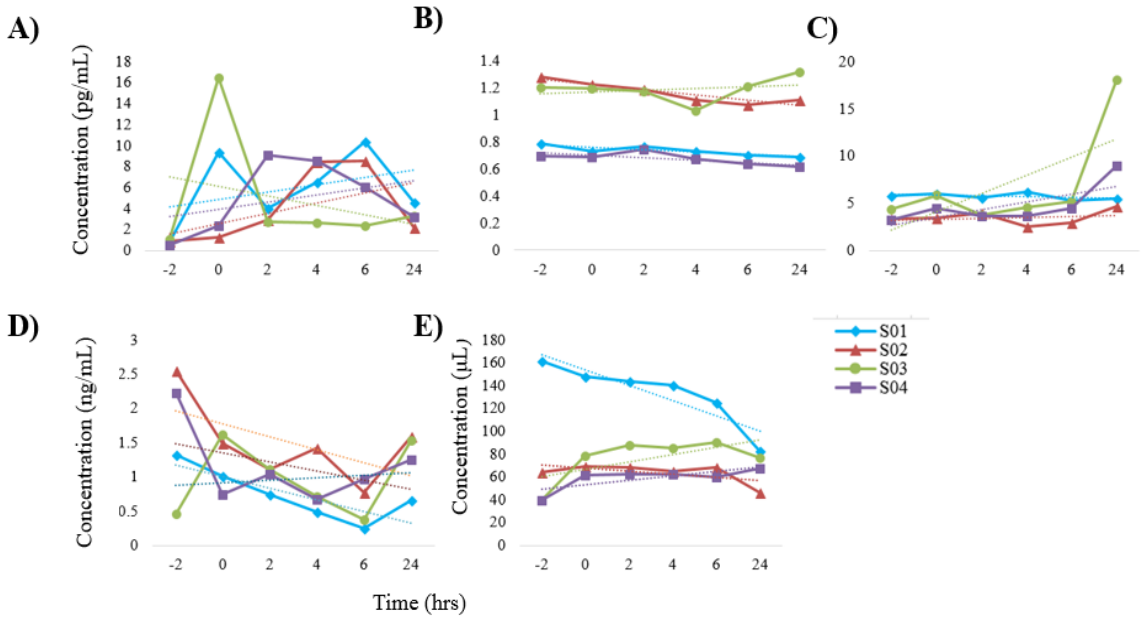


Figure A.3: Individual responses to the HFLR task, with time on the x-axis and concentration on the y-axis. A) IL-6, B) TNF-α, C) IL-8, D) Cortisol, E) CK.Note, "-2" is the baseline measure.

A.3 Discussion

TNF-α and CK, two inflammatory factors commonly implicated in chronic disorders (Johnson et al., 2015; Le Maitre et al., 2007a; Risbud and Shapiro, 2014; Wang et al., 2008), returned near their baseline levels by the 24 hour sampling point, and remained relatively stable across all testing points. While CK exhibited a significant effect of loading condition, the effect of time was not significant, and its profile remained close to the same levels across all sampling points, even at baseline. These results indicate that the experimental task was not arduous enough to elicit an inflammatory response strong enough to significantly elevate chronic markers, and thus, these markers were not included in Phase II of the investigation.

Cortisol, while deviating from baseline levels in a fairly substantial manner, exhibited nearly identical patterns in both the HFLR and LFHR condition. Commonly known as the "stress hormone" (Stark et al., 2006), cortisol was originally included to quantify differences in perception of difficulty and effort between the two conditions. The typical diurnal variation for cortisol tends to display a negative slope, peaking in the morning and then tapering off into the evening (Dowd et al., 2009). The findings from this investigation are in accordance with the typical diurnal profile, and thus, similar to TNF-α and CK, the experimental tasks were not enough to elicit a variant time course in systemic levels.

In contrast, IL-6 showed a substantial increase across all time points and thus was the most responsive to an acute task such as the one in the experiment. This is an important finding, as increased levels of IL-6 have been identified in LBP patients (Heffner et al., 2012), and thus may also lend some predictive capabilities in terms of risk of chronic pain development. In addition, IL-6 has also been identified as a pleiotropic myokine, meaning that it generally is produced and

secreted by skeletal muscle rather than circulatory white blood cells (Pal et al., 2014). Further adding to the intrigue of this cytokine is its ability to contribute to both pro- and anti-inflammatory processes, dependent on its activation pathway. Through the traditional signalling pathway, the cytokine primarily initiates anti-inflammatory processes (Scheller et al., 2011), while the trans-signalling pathway induces a more long-term pro-inflammatory cascade via soluble forms of the cytokine as opposed to membrane-bound (Scheller et al., 2011). The presence of IL-6 above baseline levels remaining in the systemic circulatory system at 24 hours following the lifting task may indicate that its role had crossed over from the initial anti-inflammatory pathway to pro-inflammatory, and over time, could lead to a chronically inflamed state (Gabay, 2006). Acute inflammation is typically transient, and in limited amounts, can be beneficial. After 24 to 48 hours, the main profile of secondarily recruited immune cells switches from primarily neutrophilic to monophilic, a hallmark of chronic inflammatory states (Gabay, 2006).

Alternately, IL-8 is primarily produced in the circulatory system by a number of immune cells, including monocytes, neutrophils, fibroblasts and tumour cells (Baggiolini and Clark-Lewis, 1992). This cytokine has a solely pro-inflammatory role (Harada et al., 1994), and thus the discovery that it too remained elevated above baseline levels at the 24 hour draw further strengthened the hypothesis that the lifting task, and in particular, the LFHR condition, was inducing some negative inflammation. Thus, this cytokine retains an important role in confirming findings in subsequent portions of this study. If IL-6 remains elevated at 24 hours in conjunction with IL-8, it can be fairly certainly ascertained that IL-6 is acting in a pro-inflammatory capacity. Having a purely pro-inflammatory cytokine is, therefore, a very relevant checkpoint when examining IL-6 levels in order to interpret results accurately.

A.4 Conclusion

In summary, IL-6 and IL-8 were the most responsive inflammatory markers to the lifting task in both the HFLR and LFHR condition, remaining elevated above baseline levels at 24 hours post-lifting. In selecting the most appropriate markers to measure in the second phase of this study, IL-6 and IL-8 were deemed the most appropriate, as their roles complement each other in many ways. The four hour sampling point was the most responsive across both tasks and both cytokines, so this point was retained for participants 5-12, as well as the baseline, 0, and 24 hour points. The two and six hour sampling points were omitted from the second phase due to the fact that any large changes in concentration were able to be picked up by the four hour time point.

Appendix B: Participant Activity Levels

Participant	*Vigorous METs*	*Moderate METs*	*Minutes Sitting*	*Total*
5	2430	80	360	3896
6	270	240	480	2589
7	540	360	420	1824
8	2430	1680	480	6882
9	540	720	420	2184
10	5400	720	90	6219
11	4050	160	240	4606
12	1215	1200	600	2415

Appendix C: DEXA Results by Participant

					Bone Mineral Density (BMD, g/cm²)								
Participant ID	**Sex**	**Height (cm)**	**Weight (kg)**	**Age**	**Head**	**Arms**	**Legs**	**Trunk**	**Ribs**	**Pelvis**	**Spine**	**Total**	**Age-Matched Z-Score**
1	F	165	59.7	27.3	2.25	0.979	1.437	0.993	0.688	1.281	1.118	1.261	1.7
2	F	158.5	66.3	23.6	2.267	1.034	1.393	0.9	0.681	1.171	0.958	1.218	1.2
3	M	180	77	23.2	2.39	0.93	1.366	0.981	0.767	1.247	1.101	1.219	0
4	M	172.5	68.6	22.1	1.995	0.952	1.439	0.987	0.725	1.287	1.049	1.219	0
6	F	156.5	55.2	23	2.088	0.827	1.273	0.98	0.661	1.287	1.166	1.174	0.6
7	M	184	78.2	24.3	2.096	1.088	1.536	1.019	0.765	1.365	1.142	1.297	1
8	F	165.5	62.5	26.5	1.894	0.763	1.107	0.844	0.611	1.089	0.934	1.025	-1.2
9	F	174.5	72.1	19.7	2.2	0.868	1.306	0.962	0.69	1.211	1.113	1.175	N/A
10	F	170	59.1	19.7	2.154	0.827	1.281	0.843	0.617	1.11	0.905	1.115	N/A
11	M	179.5	78.3	20.1	2.131	1.093	1.552	1.088	0.772	1.449	1.282	1.323	1.3
12	M	178	66.9	38.3	2.812	1.008	1.626	1.028	0.683	1.319	1.272	1.381	2
13	M	169	70.6	25.6	1.965	0.926	1.576	0.958	0.707	1.24	1.073	1.264	0.5

	ID	1	2	3	4	6	7	8	9	10	11	12	13
% Fat	Left Arm	27.6	36.1	15.1	5.7	30.07	6.6	28.2	27.4	17.1	6	4.3	8.7
	Left Leg	31.5	45.5	29.4	11.5	37.7	19.7	42.4	32.6	31.1	14.9	9.9	22.2
	Left Trunk	22.6	37.8	27.5	10.2	34.4	21.2	31.5	33	22.7	17.8	9.8	26
	Left Total	26.1	39.4	25.9	10	34.1	18.5	34.6	31.3	25.1	14.9	9.1	22
	Right Arm	27.7	36.1	15.1	5.6	30.7	6.6	28.2	27.4	17	6	4.3	8.6
	Right Leg	31.5	45.5	29.4	11.5	47.7	19.7	42.4	32.6	31.2	14.9	9.9	22.3
	Right Trunk	22.6	37.9	27.5	10.2	34.4	21.2	31.5	33	22.7	17.8	9.8	26
	Right Total	26.1	39.7	25.9	9.9	33.9	18.3	34.6	31.6	24.9	14.7	9.1	21.9
	Arms	27.7	36.1	15.1	5.7	30.7	6.6	28.2	27.4	17.1	6	4.3	8.7
	Legs	31.5	45.5	29.4	11.5	37.7	19.7	42.4	32.6	31.2	14.9	9.9	22.2
	Trunk	22.6	37.9	27.5	10.2	34.4	21.2	31.5	33	22.7	17.8	9.8	26
	Total	26.1	39.6	25.9	9.9	34	18.4	34.6	31.4	25	14.8	9.1	22
Tissue Amount (g)	Left Arm	3167	3683	4274	3806	2364	4193	2817	3447	2739	4688	3438	3600
	Left Leg	10713	11987	12911	11714	9485	12973	11644	13286	11224	13169	1151	11164
	Left Trunk	12305	14572	17444	15537	12588	18622	13933	16026	12430	17486	15076	16400
	Left Total	27922	32167	36890	33046	26220	37863	30292	34835	27840	37218	32092	33042
	Right Arm	3353	3797	4189	4032	2491	4332	2844	3399	2695	4805	3571	4059
	Right Leg	11296	12586	13156	11643	9851	13482	11665	12913	11563	13735	11660	11491
	Right Trunk	12236	12970	17214	15879	11637	16818	12837	16379	12211	17168	14721	17172
	Right Total	28755	31134	36926	33574	26083	36820	29280	33978	28661	38190	31969	34769
	Arms	6520	7481	8463	7838	4855	8524	5661	6846	5433	9493	7009	7659
	Legs	22009	24573	26066	23357	19336	26455	23309	26199	22787	26904	23161	22654
	Trunk	24541	27542	34658	31415	24225	35440	26771	32405	24641	34655	29797	33571
	Total	56678	63301	73816	66619	52304	74683	59572	68814	56501	75408	64060	67811
Fat (g)	Left Arm	876	1330	645	216	726	277	794	944	469	280	146	314
	Left Leg	3376	5449	3792	1343	3573	2561	4939	4330	3496	1968	1139	2482
	Left Trunk	2777	5515	4805	1578	4331	3947	4394	5281	2824	3112	1478	4267
	Left Total	7279	12687	9558	3291	8942	7017	10467	10887	6984	5528	2921	7280
	Right Arm	928	1370	631	228	765	288	801	931	458	289	153	350
	Right Leg	3562	5723	3865	1335	3709	2657	4947	4210	3611	2046	1152	2558

	Right Trunk	2762	4916	4740	1613	4005	3562	4050	5401	2772	3053	1443	4465
	Right Total	7519	12375	9567	3333	8845	6749	10143	10748	7135	5610	2901	7608
	Arms	1803	2700	1276	443	1492	565	1596	1875	927	570	299	664
	Legs	6938	11172	7657	2678	7282	5219	9887	8540	7107	4013	2291	5040
	Trunk	5539	10431	9545	3191	8336	7508	8444	10682	5596	6165	2921	8732
	Total	14798	25061	19125	6624	17787	13766	20610	21636	14120	11138	5822	14888
Lean (g)	**Left Arm**	2292	2353	3629	3590	1638	3915	2023	2503	2270	4408	3292	3286
	Left Leg	7337	6538	9119	10371	5912	10412	6705	8956	7728	11202	10362	8682
	Left Trunk	9528	9057	12639	13959	8257	14675	9540	10745	9606	14375	13598	12132
	Left Total	20644	19480	27332	29755	17278	30846	19825	23948	20855	31690	29171	25762
	Right Arm	2425	2427	3558	3804	1726	4044	2042	2469	2237	4515	3418	3710
	Right Leg	7735	6863	9291	10308	6142	10825	6718	8703	7952	11689	10508	8933
	Right Trunk	9474	8054	12474	14266	7633	13256	8787	10978	9439	14115	13278	12707
	Right Total	21236	18759	27359	30241	17239	30070	19136	23230	21526	32580	29068	27161
	Arms	4717	4781	7187	7395	3364	7959	4065	4971	4506	8923	6710	6995
	Legs	15072	13401	18409	20679	12054	21236	13423	17659	15680	22891	20870	17615
	Trunk	19002	17111	25113	28224	15889	27931	18327	21723	19045	28490	26876	24840
	Total	41880	38240	54691	59995	34517	60916	38962	47178	42381	64270	58239	52923

Appendix D: International Physical Activity Questionnaire

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 E: Marker Placement

Segment	Placement	Name	Use
Head	Front right	RFHD	Calibrate/Track Head
	Front left	LFHD	Calibrate/Track Head
	Back right	RBHD	Calibrate/Track Head
	Back left	LBHD	Calibrate/Track Head
Upper Arm (Bilateral)	Humerus Lateral Epicondyle	LELBL/RELBL	Calibrate Upper arm and Forearm width
	Humerus Medial Epicondyle	LELBM/RELBM	Calibrate Upper arm and Forearm width
	Cluster: Middle, lateral	LUAPP, LUAPA, LUADA, LUADP/ RUAPP, RUAPA, RUADA, RUADP	Track upper arm segment
Forearm (Bilateral)	Ulna	LULN	Calibrate Forearm width
	Radius	LRAD	Calibrate Forearm width
	Cluster: Middle, Lateral	LFAPP, LFAPA, LFADA, LFADP/ RFAPP, RFAPA, RFADA, RFADP	Track forearm segment
Trunk	Sternal Notch	SN	Calibrate Trunk Depth
	Xiphoid	XP	Calibrate Trunk Depth
	Left Acromion	LAC	Calibrate Trunk Depth/ Track Upper Back
	Right Acromion	RAC	Calibrate Trunk Depth/ Track Upper Back
	Left Scapula	LSCAP	Calibrate Trunk Depth/ Track Upper Back
	Right Scapula	RSCAP	Calibrate Trunk Depth/ Track Upper Back
	C7	C7	Track Upper Back
	Cluster: T10/T12 vertebrae	LBUL, LBUR, LBLL, LBLR	Track Low Back segment
Pelvis	Left ASIS	LASI	Calibrate Pelvis width/depth
	Right ASIS	RASI	Calibrate Pelvis width/depth
	Left PSIS	LPSI	Calibrate Pelvis width/depth
	Right PSIS	RPSI	Calibrate Pelvis width/depth
	Left Iliac Crest	LIC	Calibrate Trunk width
	Right Iliac Crest	RIC	Calibrate Trunk width
	Cluster: Sacrum	PVUL, PVUR, PVLL, PVLR	Track Pelvis
Thigh (Bilateral)	Greater Trochanter	LGT/RGT	Calibrate Thigh width, length
	Lateral Femur Epicondyle	LKNL/RKNL	Calibrate Thigh/Shank width, length
	Medial Femur Epicondyle	LKNM/RKNM	Calibrate Thigh/Shank width, length
	Cluster: Middle; lateral side	LTHPA, LTHPP, LTHDA, LTHDP/ RTHPA, RTHPP, RTHDA, RTHDP	Track Thigh
Shank (Bilateral)	Cluster: Middle; lateral side	LSHPA, LSHPP, LSHDA, LSHDP/ RSHPA, RSHPP, RSHDA, RSHDP	Track Shank
Foot (Bilateral)	Lateral Malleolus	LANL/RANL	Calibrate Shank width, length/Foot width/Track Foot
	Medial Malleolus	LANM/RANM	Calibrate Shank width, length/Foot width
	1st Metatarsophalangeal joint	LM1/RM1	Calibrate Foot width, length/ Track foot
	5th Metatarsophalangeal joint	LM5/RM5	Calibrate Foot width, length/ Track foot
	Calcaneus	LHEE/RHEE	Calibrate Foot length/ Track foot

Appendix F: Pain Catastrophizing Scale

PCS

Client No.: _____ Age: _____ Sex: M(__) F(__) Date: _____

Everyone experiences painful situations at some point in their lives. Such experiences may include headaches, tooth pain, joint or muscle pain. People are often exposed to situations that may cause pain such as illness, injury, dental procedures or surgery.

We are interested in the types of thoughts and feelings that you have when you are in pain. Listed below are thirteen statements describing different thoughts and feelings that may be associated with pain. Using the following scale, please indicate the degree to which you have these thoughts and feelings when you are experiencing pain.

0 – not at all **1** – to a slight degree **2** – to a moderate degree **3** – to a great degree **4** – all the time

When I'm in pain …

1. ☐ I worry all the time about whether the pain will end.
2. ☐ I feel I can't go on.
3. ☐ It's terrible and I think it's never going to get any better.
4. ☐ It's awful and I feel that it overwhelms me.
5. ☐ I feel I can't stand it anymore.
6. ☐ I become afraid that the pain will get worse.
7. ☐ I keep thinking of other painful events.
8. ☐ I anxiously want the pain to go away.
9. ☐ I can't seem to keep it out of my mind.
10. ☐ I keep thinking about how much it hurts.
11. ☐ I keep thinking about how badly I want the pain to stop.
12. ☐ There's nothing I can do to reduce the intensity of the pain.
13. ☐ I wonder whether something serious may happen.

… Total

Appendix G: Tampa Scale for Kinesiophobia (General)

Tampa Scale for Kinesiophobia (General)

Translated from TSK-G (Vlaeyen & Crombez, 1998)

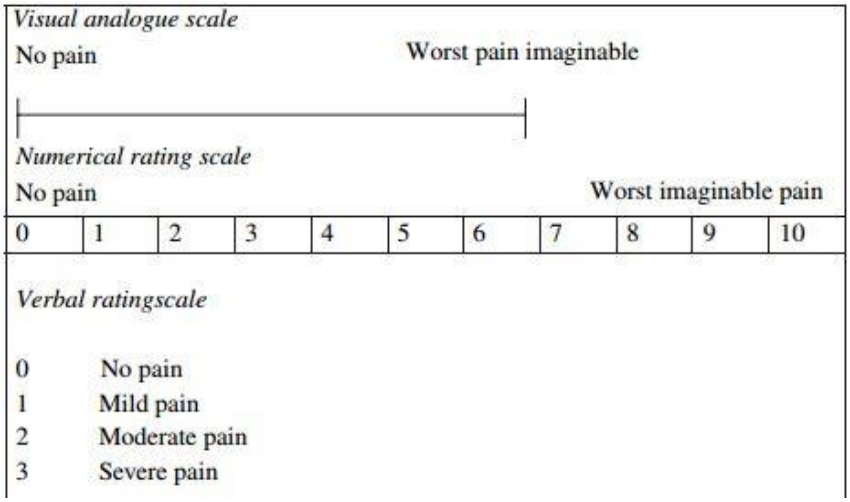
1 = strongly disagree
2 = disagree
3 = agree
4 = strongly agree

1. Sometimes I am afraid to injure/damage/harm myself when I do physical activity.	1	2	3	4
2. If I had back pain and I were to try and overcome the pain, the pain would likely worsen	1	2	3	4
3. Back pain means that something is seriously wrong with the body	1	2	3	4
4. If present, back pain would be relieved if I stayed physically active	1	2	3	4
5. My health status is not taken seriously enough by others	1	2	3	4
6. If I had long-term back pain, I would be at risk for the rest of my life	1	2	3	4
7. Back pain always means there is an injury	1	2	3	4
8. If back pain worsens with physical activity, it does not mean that the activity is dangerous	1	2	3	4
9. I am afraid to accidentally injure myself	1	2	3	4
10. Simply being careful that no unnecessary movements are made is the safest thing to prevent back pain from worsening	1	2	3	4
11. There might be less back pain if there weren't something potentially dangerous going on in my body	1	2	3	4
12. If I had back pain, I would be better off if I remained physically active.	1	2	3	4
13. Back pain lets me know when to stop exercising to prevent an injury/damage to the body	1	2	3	4
14. For someone with back complaints, physical activity is discouraged	1	2	3	4
15. I can't do everything that normal people do because I can easily get back issues	1	2	3	4
16. Even if something induces a lot of back pain, I don't immediately believe it's dangerous	1	2	3	4
17. I should not have to do any physical exercises if I have back pain	1	2	3	4

The modified Tampa Scale for Kinesiophobia for use in a non-pain population

JW Vlaeyen, G Crombez - Unpublished authorised Dutch/Flemish version, 1998

Appendix H: Visual Analogue Scale (Participants 1-4)



Appendix I: Borg CR-10 Scale

Borg CR10 Scale® (2010)[20]

0	Nothing at all	
0.3		
0.5	Extremely weak	Just noticeable
0.7		
1	Very weak	
1.5		
2	Weak	Light
2.5		
3	Moderate	
4		
5	Strong	Heavy
6		
7	Very strong	
8		
9		
10	Extremely strong	"Maximal"
11		
∫		
•	Absolute maximum	Highest possible

Borg CR10 Scale ® from Borg Perception, Rädisvägen 124, S-16573, Hässelby, Sweden.

Appendix J: OpenSim Results Participant 3

LFHR Condition, Minutes 1-10

	Average Dorsiflexion (°)	Peak Dorsiflexion (°)	Average Knee Flexion (°)	Peak Knee Flexion (°)	Average Hip Flexion (°)	Peak Hip Flexion (°)	Average Spine Flexion (°)	Peak Spine Flexion (°)	Average Spine Flex. Moment (Nm)	Peak Spine Flexion Moment (Nm)	Cumulative Spine Flex. Moment/lift (Nm•s)
Aver	14.14	49.47	23.27	142.77	1.42	90.34	31.89	94.40	29.97	124.16	340.83
Std	1.99	4.67	5.52	14.19	3.50	17.63	4.49	5.66	3.71	8.80	46.95

Total Cumulative Spine Load / 10 minutes **17041.71** Nm s

Total Cumulative Peaks / 10 minutes **6207.807** N

HFLR Condition, Minutes 1-10

	Average Dorsiflexion (°)	Peak Dorsiflexion (°)	Average Knee Flexion (°)	Peak Knee Flexion (°)	Average Hip Flexion (°)	Peak Hip Flexion (°)	Average Spine Flexion (°)	Peak Spine Flexion (°)	Average Spine Flex. Moment (Nm)	Peak Spine Flexion Moment (Nm)	Cumulative Spine Flex. Moment/lift (Nm•s)
Aver	6.90	44.13	2.42	142.64	1.76	145.24	3.05	80.16	8.99	244.29	534.42
Std	0.59	1.41	1.65	1.11	1.60	2.81	1.45	4.69	1.59	24.87	92.56

Total Cumulative Spine Load / 10 minutes **4563.759** Nm s

Total Cumulative Peaks / 10 minutes **2442.905** N

Appendix K: Data by Participant

Participant	Physiological Data	Biomechanical Data	TSK	PCS	Borg CR-10	VAS
1	Yes	Yes	Yes	Yes	No	Yes
2	Yes	Yes	Yes	Yes	No	Yes
3	Yes	Yes	Yes	Yes	No	Yes
4	Yes, no 24 hour LFHR	No	Yes	Yes	No	Yes
5	Difficulty sampling , participant excluded from all analyses					
6*	Yes, No 24 hour LFHR	Yes	Yes	Yes	Yes	No
7	Yes	Yes	Yes	Yes	Yes	No
8	Yes	No	Yes	Yes	Yes	No
9	Yes	Yes	Yes	Yes	Yes	No
10	Yes	Yes	Yes	Yes	Yes	No
11	Yes	Yes	Yes	Yes	Yes	No
12	Yes	Yes	Yes	Yes	Yes	No
13	Yes	Yes	Yes	Yes	Yes	No

**Participant 6-13 renumbered as 5-12 in all figures/references in-text.*

Appendix L: PCS Scores

		PCS												
	Sex	F	F	M	M	F	M	F	F	F	M	M	M	
		1	2	3	4	6	7	8	9	10	11	12	13	TOTAL Average
Item Number	1	2	0	0	2	1	1	2	1	0	0	1	2	
	2	0	0	0	0	0	0	0	2	0	0	0	0	
	3	1	0	0	1	0	0	0	1	0	0	0	0	
	4	0	0	0	0	0	0	0	1	0	0	0	0	
	5	1	0	0	0	0	1	0	1	1	0	1	0	
	6	1	0	0	1	2	1	1	1	2	2	1	2	
	7	1	0	0	0	0	0	0	1	0	0	0	1	
	8	1	0	0	1	1	1	0	0	0	1	0	1	
	9	1	0	1	2	0	1	1	1	1	1	0	1	
	10	1	0	0	2	1	1	1	1	1	1	0	1	
	11	1	0	0	1	0	1	0	1	0	1	0	1	
	12	1	0	0	1	0	0	1	1	0	0	0	0	
	13	2	0	0	2	2	0	2	2	0	2	0	1	
	TOTAL	13	0	1	13	7	7	8	14	5	8	3	10	
	Rumination	4	0	1	6	2	4	2	3	2	4	0	4	2.545455
	Magnification	4	0	0	3	4	1	3	4	2	4	1	4	2.363636
	Helplessness	5	0	0	4	1	2	3	7	1	0	2	2	2.454545
	Percentile	34	1	3	34	17	17	19	35	11	19	6	24	18.27273
	Rumination	26	2	6	38	13	26	13	19	13	26	2	26	16.72727
	Magnification	63	14	14	50	63	27	50	63	42	63	27	63	43.27273
	Helplessness	36	6	6	29	10	16	22	47	10	6	16	16	19.45455

Appendix M: TSK-G Scores

		TSK												
	Sex	F	F	M	M	F	M	F	F	F	M	M	M	
	ID	**S01**	**S02**	**S03**	**S04**	**S06**	**S07**	**S08**	**S09**	**S10**	**S11**	**S12**	**S13**	
Item Number	1	2	1	3	1	3	3	3	2	2	1	1	3	2.083333
	2	2	2	2	2	4	2	2	1	2	3	2	3	2.25
	3	1	2	2	2	2	2	2	1	2	1	2	3	1.833333
	4	3	3	4	4	3	3	3	1	3	2	3	3	2.916667
	5	1	2	1	2	1	2	1	1	2	1	2	1	1.416667
	6	3	2	2	1	3	2	2	2	2	4	3	3	2.416667
	7	1	2	1	2	1	2	2	1	2	2	2	2	1.666667
	8	4	3	4	2	4	3	2	3	2	1	3	3	2.833333
	9	1	2	1	1	2	3	3	2	2	2	2	3	2
	10	1	3	2	2	2	3	3	2	2	3	2	2	2.25
	11	1	2	1	1	3	2	2	1	2	4	2	3	2
	12	4	4	3	3	2	4	3	4	3	3	3	3	3.25
	13	2	2	2	3	3	3	3	1	3	1	2	3	2.333333
	14	1	2	1	2	2	1	2	1	2	1	2	2	1.583333
	15	2	2	1	2	1	2	2	1	2	1	2	1	1.583333
	16	3	3	4	2	2	3	2	3	3	2	3	2	2.666667
	17	1	2	2	1	2	1	2	1	2	1	2	2	1.583333
	TOTAL	33	39	36	33	40	41	39	28	38	33	38	42	36.66667
	CLASS (Vlaeyen Cutoff '95)	LOW	HIGH	LOW	LOW	HIGH	HIGH	HIGH	LOW	HIGH	LOW	HIGH	HIGH	

Appendix N: Thesis Consent Form (English)

uOttawa

Université d'Ottawa
Faculté des sciences de la santé

École des sciences de l'activité physique

University of Ottawa
Faculty of Health Sciences

School of Human Kinetics

200 Lees Ave. (E020)
Ottawa ON K1N 6N5 Canada

www.uOttawa.ca

Research Consent Form

Research Project Title: PHYSIOLOGICAL CHARACTERISTICS AND INFLAMMATORY RESPONSES TO ACUTE SPINAL LOADING

Investigateurs principale:
Tianna Beharriell
Dr. Ryan Graham (Supervisor)
Co-Investigators:
Wantuir Junior
Dr. Pascal Imbeault

University of Ottawa
Faculty of Health Sciences
Department of Human Kinetics
200 Lees Ave (E020)
Ottawa, ON K1N6N5

Background and Purpose of the Study:
Dynamic movements require the cooperation of complex interactions between multiple systems of the body to stabilize the spine and prevent low back disorders (LBD). It is important to understand how different factors affect these interactions and contribute to spinal stability so that conditions can be optimized and prevent LBDs. The goals of this study are:
1) To assess how an individual's tissue stiffness can affect stability of the spine during a dynamic flexion task, which will be evaluated using a local dynamic stability analysis and shear wave ultrasound.
2) To assess the relationship between pro-inflammatory blood markers and psychological states of individuals during two different lifting conditions.

Description of Study Procedures:
You are invited to participate in a two-day investigation (testing days shall be one week apart) for approximately 7 hours each day at the University of Ottawa Human Movement Biomechanics Laboratory (200 Lees Avenue, E020). The study protocol consists of completion of a repetitive lifting task under different conditions, as well as the measurement of body composition, tissue stiffness, psychological perceptions towards pain and pro-inflammatory blood markers. The lifting task includes two hours of lifting and lowering a loaded box from the floor to waist height and back to the floor. More specifically, one of the testing days will involve lifting a box weighted at 25% of your maximum strength at a rate of once per minute, while the other day will be performed at 5% of your maximum strength at a rate of 5 times per minute. Further

instructions will be given prior to completion of the trial. These conditions will be completed in a randomized order.

Before the procedure, you will be asked to complete 3 psychological surveys which will ask you about your current level of pain and discomfort (if any) as well as your attitudes towards pain and how it affects your daily activities. Your height, weight and waist/hip circumference will also be taken using a measuring tape, as well as your body composition using a DEXA scanning machine which analyzes bone density, percent fat and percent lean body mass. You will have to lie on an examination table, wearing a hospital gown, while a low-intensity x-ray will scan your entire body. The measurement takes approximately 20 minutes. The only risk is a minimal x-ray exposure of less than 0.0003 mSv. This exposure is less than the natural exposure to sunlight during the course of a day.

Baseline measures of pro-inflammatory cytokines will be taken by trained personnel via a catheter (small flexible plastic tube) inserted into a vein in your forearm. 6 mL (less than a tablespoon) of blood will be obtained to test for inflammatory markers. Tissue stiffness will be tested using a small, handheld shear-wave ultrasound machine, which will require ultrasound gel to be applied over the low back to obtain an image of good quality. This will be measured twice, pre- and post-lifting. Next, you will be asked to change into form-fitting spandex clothing before the lifting task. Reflective markers will be placed on anatomical landmarks with double sided tape. Marker clusters will be attached to the lower back and pelvis with tape around your trunk and waist, and a heart rate monitor will be attached with tape as well in order to gain insight into effort being expended. Scales on feelings of level of exertion will also be administered at 30 minute intervals throughout the lifting task.

Following the lifting protocol, you will be asked to fill out a follow-up questionnaire regarding any pain or fatigue experienced during the protocol, as well as complete follow-up blood sampling at 0, 4 and 24 hours after the completion of the lifting protocol. You will be asked to remain at the lab between the 0 and 4 hour draws, but you may leave and return to the lab again for the 24-hour draw. Finally, you will be asked to limit physical activity to your daily tasks and avoid exercise bouts throughout the duration of the testing days, as well as 24 hours prior to visiting the lab on both days.

DURATION OF EACH EXPERIMENTAL SESSION: 6-7 hours

Inclusion/Exclusion Criteria:

- Male or female, 18-55 years of age with a BMI between 18.5 and 40 (can be determined by the research personnel if unknown)
- Not currently be in receipt of an active worker's compensation claim for any injury, nor have incurred a LBD or other musculoskeletal injury in the last year
- Not have a known serious spinal pathology (fracture, spinal disease causing inflammation, neurological disorders, cauda equine syndrome and tumour growths)
- No comorbidities known to elevate inflammatory systemic blood markers (hyperthyroidism, chronic obstructive pulmonary disease, hypertension, cardiovascular disease, diabetes, endometriosis, reactive arthritis and serious injuries to other body parts in the last 12 months)

- Not be taking any anticoagulants, analgesics, anticonvulsants, antidepressants or anti-inflammatory medications
- Females:
    - Have a normal menstrual cycle
    - Willing to disclose their cycle information to researchers; females will be tested in the first week of their cycle (Day 1-7)
    - Pre-menopausal
    - Can be on contraceptive measures given that no known interruptions to their regular cycle occur
- Willing to abstain from exercise and caffeine and/or alcohol in the 24 hours preceding an experimental session (including anti-inflammatory medications such as ibuprofen and aspirin) and throughout the duration of the experimental protocol, including follow up blood draws where you must return to the lab for final testing

Possible Risks and Discomforts:

This project is of low risk. The testing procedures will be explained to you in detail by the researchers before you participate in any aspect of the study.

Lifting Protocol
You may experience some muscle soreness in your muscles during, and for several hours after the experiment due to the nature and repetition of the activity. This muscle soreness, which is typical of any physical exertion study, will be equivalent to a bout of moderately strenuous exercise and should not persist beyond 48 hours. Although muscle soreness is a possibility, it is a very common sensation for people after exerting brief maximal and submaximal efforts. To help relieve the muscle soreness, the investigators will teach you how to stretch your trunk muscles. You will be free to withdraw from the experiment at any time should you feel excessive discomfort. Additionally, although very rare, you may experience a temporary reaction to the adhesive from the reflective markers and heart rate monitor.

DEXA
Measures of body fat (DEXA) present minimal risks. One of the risks of this test is the level of exposure to X-ray by the DEXA. The DEXA machine exposes you to minimal radiation 0.0003 mSv, which is below the natural ambient exposure for a day and below the maximum dose allowed per year, which is 20 mSv.

Blood Sampling
The blood sampling poses low risks ranging from simple redness of the skin to a local inflammation of the vein. To minimize such risks, the skin will be sterilized with alcohol and the blood sampling will be performed by a qualified personnel according to standard procedures.

Should you experience any major discomfort, please tell us immediately and seek primary care from a medical professional on campus (100 Marie Curie, Ottawa, Tel.: 613-564-3950) or a medical professional of your choosing.

Possible Benefits:
You will not directly benefit from participating in this study. However, the results of this study (DEXA results, results from the analysis as well as microscope picture of the collected cells) will be provided to you free of charge. This information could be used to estimate the risk of developing health problems. The results from this study will greatly add to our knowledge of how differential lifting conditions can contribute to an increased risk of developing LBD by reducing both mechanical tissue tolerance and dynamic stability of the spine. Ultimately, these results could be utilized in the development of more comprehensive ergonomic lifting guidelines to be implemented in the workplace.

Voluntary Participation:
You are not obliged to participate in this study; participation in this study is voluntary. You may also withdraw from the study at any time with no penalty or coercion.

Confidentiality:
All personal information is kept confidential. Information gained from this study will be stored electronically and will need a password to access. Paper study records are stored in a locked cabinet and will be destroyed after 5 years; electronic records will be deleted and paper records will be shredded. You will not be identified by name in any reports of the completed study. Your anonymity will be strictly maintained – you will not be identified by your name, but will be determined by an independent study number.

Compensation:
Participants will be compensated $60 for each session, for a total of $120 if the entire study is completed. All participants will be compensated for each session they complete; that is, if you choose to withdraw from the study at any point after the mid-point of the first day, you will still receive compensation for that session.

Questions about the Study:

You are free to ask questions at any time; you can contact the principal investigators by email: Tianna Beharriell, Wantuir Junior and/or Dr. Ryan Graham/Dr. Pascal Imbeault. This project is funded by the Natural Sciences and Engineering Research Council of Canada. The ethics of this protocol have been approved by the University of Ottawa research ethics board. If you have any questions regarding the ethical conduct of this study, you may contact the Protocol Officer for Ethics in Research, University of Ottawa, Tabaret Hall, 550 Cumberland Street, Room 154, Ottawa ON, K1N 6N5. Tel.: (613) 562-5387 Email: ethics@uottawa.ca

Research Project Title: **PHYSIOLOGICAL CHARACTERISTICS AND INFLAMMATORY RESPONSES TO ACUTE SPINAL LOADING**

Consent:

I have read this consent form, and I agree to participate in the procedures of this study.

_____
Printed Name of Participant

_____ _____
Signature of Participant Date

Investigator Statement (or Person Explaining the Consent):
I have carefully explained to the research participant the nature of the above research study. To the best of my knowledge, the research participant signing this consent form understands the nature, demands, risks and benefits involved in participating in this study. I acknowledge my responsibility for the care and well-being of the above research participant, to respect the rights and wishes of the research participant, and to conduct the study according to applicable Good Clinical Practice guidelines and regulations.

_____
Name of Investigator/Delegate (printed)

_____ _____
Signature of Investigator/Delegate Date

Informed Consent to have Pictures Taken:
I consent to have side view pictures taken of myself completing the experiment, and understand that no pictures will be taken at any point without me knowing. I also understand that if any of these pictures are used in a subsequent presentation or publication, that my face and any other identifiers will be blurred. You can still participate in the research study without consenting to have pictures taken.

_____ _____
Name Date

_____
Signature

_____ _____
Witness Name Witness Signature

Future Participation:

- ☐ I am interested in being contacted to participate in future research performed by this laboratory (your email information will be saved in a password protected file).

Appendix O: Consent Form (French)

Formulaire de consentement à la recherche

Titre du projet de recherche: CARACTÉRISTIQUES PHYSIOLOGIQUES ET RÉPONSES INFLAMMATOIRES À LA CHARGE SPINALE AIGUË

Université d'Ottawa
Faculté des sciences de la santé

École des sciences de l'activité physique

University of Ottawa
Faculty of Health Sciences

School of Human Kinetics

Investigateurs principale:
Tianna Beharriell
Dr. Ryan Graham (Superviseur)
Co-Chercheurs:
Wantuir Junior
Dr. Pascal Imbeault

Université d'Ottawa
Faculté des sciences de la santé
Département des sciences de l'activité physique
200 avenue Lees (E020)
Ottawa, ON K1N6N5

Contexte et objectif de l'étude:
Les mouvements dynamiques nécessitent la coopération d'interactions complexes entre plusieurs systèmes du corps pour stabiliser la colonne vertébrale et prévenir les troubles du bas du dos. Il est important de comprendre comment différents facteurs influent sur ces interactions et contribuent à la stabilité de la colonne vertébrale afin d'optimiser les conditions et de prévenir les LBD. Les objectifs de cette étude sont les suivants:
1) Évaluer comment la rigidité des tissus d'un individu peut affecter la stabilité de la colonne vertébrale au cours d'une tâche de flexion dynamique, qui sera évaluée à l'aide d'une analyse de stabilité dynamique locale et d'une échographie par ondes de cisaillement.
2) Evaluer la relation entre les marqueurs sanguins pro-inflammatoires et les états psychologiques des individus lors de deux conditions de levage différentes.

Description des procédures d'étude:
Vous êtes invité à participer à une enquête de deux jours (les jours d'essai doivent être espacés d'une semaine) pendant environ 7 heures chaque jour au laboratoire de biomécanique du mouvement humain de l'Université d'Ottawa (200, avenue Lees, E020). Le protocole de l'étude consiste à compléter une tâche de levage répétitive dans différentes conditions, ainsi qu'à mesurer la composition corporelle, la rigidité des tissus, les perceptions psychologiques envers la douleur et

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les marqueurs sanguins pro-inflammatoires. La tâche de levage comprend deux heures de levage et d'abaissement d'une boîte chargée
le sol à hauteur de la taille et le dos au sol. Plus précisément, une des journées de test consistera à soulever une boîte pesée à 25% de votre force maximale à raison d'une fois par minute, tandis que l'autre jour sera effectuée à 5% de votre force maximale à un taux de 5 fois par minute. minute. Des instructions supplémentaires seront données avant la fin du procès. Ces conditions seront remplies dans un ordre aléatoire.

Avant la procédure, il vous sera demandé de remplir 3 enquêtes psychologiques qui vous interrogeront sur votre niveau actuel de douleur et d'inconfort (le cas échéant), ainsi que sur votre attitude face à la douleur et son impact sur vos activités quotidiennes. Votre taille, votre poids et votre tour de taille / hanches seront également pris en utilisant un ruban à mesurer, ainsi que votre composition corporelle à l'aide d'un scanner DEXA qui analyse la densité osseuse, le pourcentage de graisse et le pourcentage de masse maigre. Vous devrez vous allonger sur une table d'examen et porter une blouse d'hôpital, tandis qu'une radiographie de faible intensité permettra de scanner votre corps tout entier. La mesure prend environ 20 minutes. Le seul risque est une exposition minimale aux rayons X inférieure à 0,0003 mSv. Cette exposition est inférieure à l'exposition naturelle au soleil au cours d'une journée.

Les mesures de base des cytokines pro-inflammatoires seront prises par un personnel qualifié via un cathéter (petit tube en plastique souple) inséré dans une veine de votre avant-bras. 6 mL (moins d'une cuillère à soupe) de sang seront prélevés pour détecter les marqueurs inflammatoires. La rigidité des tissus sera testée à l'aide d'un petit appareil à ultrasons manuel à ondes de cisaillement, qui nécessitera l'application d'un gel à ultrasons sur le bas du dos pour obtenir une image de bonne qualité. Cela sera mesuré deux fois, avant et après le levage. Ensuite, il vous sera demandé de changer de vêtements en élasthanne avant la tâche de levage. Des marqueurs réfléchissants seront placés sur des repères anatomiques avec du ruban adhésif double face. Des groupes de marqueurs seront attachés au bas du dos et au bassin avec du ruban adhésif autour du tronc et de la taille, et un cardiofréquencemètre sera fixé avec du ruban adhésif afin de mieux comprendre les efforts déployés. Des échelles sur le niveau d'effort seront également administrées à intervalles de 30 minutes tout au long de la tâche de levage.

Suivant le protocole de levage, il vous sera demandé de remplir un questionnaire de suivi concernant toute douleur ou fatigue ressentie pendant le protocole, ainsi que des prélèvements sanguins de suivi complets à 0, 4 et 24 heures après la fin du protocole de levage. . On vous demandera de rester au laboratoire entre les tirages de 0 et 4 heures, mais vous pourrez repartir et retourner au laboratoire pour le tirage au sort de 24 heures. Enfin, il vous sera demandé de limiter l’activité physique à vos tâches quotidiennes et d’éviter les séances d’exercices pendant toute la durée des journées d’essai, ainsi que 24 heures avant la visite du laboratoire les deux jours.

DURÉE DE CHAQUE SÉANCE EXPÉRIMENTALE: 6-7 heures

Critères d'inclusion / exclusion:

- Homme ou femme de 18 à 55 ans avec un IMC compris entre 18,5 et 40 ans (peut être déterminé par le personnel de recherche s'il est inconnu)
- Vous ne recevez pas actuellement de demande d'indemnisation du travailleur actif pour toute blessure, et vous n'avez pas été victime d'une lésion lombaire ou d'une autre blessure musculo-squelettique au cours de la dernière année.
- Ne pas avoir de pathologie rachidienne grave connue (fracture, maladie rachidienne causant une inflammation, troubles neurologiques, syndrome de la queue de cheval et croissance tumorale)
- Aucune comorbidité connue pour élever les marqueurs sanguins systémiques inflammatoires (hyperthyroïdie, bronchopneumopathie chronique obstructive, hypertension, maladie cardiovasculaire, diabète, endométriose, arthrite réactive et blessures graves à d'autres parties du corps au cours des 12 derniers mois).
- Ne prend pas des anticoagulants, analgésiques, anticonvulsivants, antidépresseurs ou des médicaments anti-inflammatoires
- Femmes :
    - Aient un cycle menstruelle
    - Prêt à divulguer leurs informations de cycle aux chercheurs; les femelles seront testées la première semaine de leur cycle (jour 1-7)
    - Pre-menopause
    - Peuvent prendre des mesures de contraception permit qu'il n'y a aucun interruptions dans leur cycle menstruel régulier
- Prêt à éviter l'exercice, la caféine, et/ou l'alcool pendant les 24 heures précédant chaque session d'expérimentation (incluant les médicaments anti-inflammatoires incluant ibuprofène et l'aspirine) et pendant la durée du protocole expérimentale, incluant les suivis des prélèvements sanguins quand vous devez retourner au laboratoire lors de la dernière expérimentation

Risques et inconforts possibles :

Ce projet a un risque minimal. Les procédures d'expérimentations seront expliqués en détail par les investigateurs avant que vous participé à l'étude.

Protocole de levage

Vous pourriez suffi un peu de douleur musculaire dans vos muscles pendant et pour quelques heures suivant l'expérimentation en conséquence de la nature et répétition de l'activité. Cette douleur musculaire, qui et typique pour n'importe quel étude d'activité physique sera l'équivalent à la douleur musculaire acquise lors de l'exercice d'intensité modéré et ne devrait pas persister plus de 48 heures. Bien que les courbatures soient une possibilité, c'est une sensation très courante chez les personnes qui font des efforts brefs et sous-maximaux. Pour aider à soulager les douleurs musculaires, les investigateurs vous apprendront comment étirer vos muscles du tronc. Vous serez libre de vous retirer de l'expérience à tout moment si vous ressentez un inconfort excessif. De plus, bien que cela soit très rare, vous pourriez ressentir une réaction temporaire à l'adhésif par les marqueurs réfléchissants et le moniteur de fréquence cardiaque.

DEXA

Les mesures de la graisse corporelle (DEXA) présentent des risques minimes. L'un des risques de ce test est le niveau d'exposition aux rayons X par le DEXA. La machine DEXA vous expose à une radiation minimale de 0,0003 mSv, inférieure à l'exposition ambiante naturelle pour une journée et inférieure à la dose maximale autorisée par an, soit 20 mSv.

Prélèvement sanguin

Les prélèvements sanguins présentent de faibles risques allant de la simple rougeur de la peau à une inflammation locale de la veine. Pour minimiser ces risques, la peau sera stérilisée avec de l'alcool et le prélèvement sanguin sera effectué par un personnel qualifié conformément aux procédures standard.

Si vous ressentez un inconfort majeur, veuillez nous en informer immédiatement et solliciter des soins primaires auprès d'un professionnel de la santé sur le campus (100 Marie Curie, Ottawa, Tél.: 613-564-3950) ou auprès d'un médecin de votre choix.

Avantages possibles:

Vous ne bénéficierez pas directement de votre participation à cette étude. Cependant, les résultats de cette étude (résultats de la DEXA, résultats de l'analyse ainsi que photo microscopique des cellules collectées) vous seront fournis gratuitement. Cette information pourrait être utilisée pour estimer le risque de développer des problèmes de santé. Les résultats de cette étude contribueront grandement à notre connaissance de la façon dont les conditions de levage différentielles peuvent contribuer à augmenter le risque de développer une DBL en réduisant à la fois la tolérance mécanique des tissus et la stabilité dynamique de la colonne vertébrale. En fin de compte, ces résultats pourraient être utilisés dans le développement de directives de levage ergonomiques plus complètes à mettre en œuvre sur le lieu de travail.

Participation volontaire:

Vous n'êtes pas obligé de participer à cette étude; la participation à cette étude est volontaire. Vous pouvez également vous retirer de l'étude à tout moment sans pénalité ni contrainte.

Confidentialité:

Toutes les informations personnelles sont confidentielles. Les informations obtenues grâce à cette étude seront stockées électroniquement et nécessiteront un mot de passe pour y accéder. Les dossiers d'étude sur papier sont stockés dans une armoire verrouillée et seront détruits après 5 ans; les dossiers électroniques seront supprimés et les dossiers papier seront déchiquetés. Vous ne serez identifié par aucun nom dans aucun des rapports de l'étude terminée. Votre anonymat sera strictement maintenu - vous ne serez pas identifié par votre nom, mais sera déterminé par un numéro d'étude indépendant.

Compensation:

Les participants recevront une indemnité de 60 dollars pour chaque session, pour un total de 120 dollars si l'étude est terminée. Tous les participants seront indemnisés pour chaque session qu'ils complètent; En d'autres termes, si vous choisissez de vous retirer de l'étude à tout moment après le milieu du premier jour, vous recevrez toujours une compensation pour cette session.

Questions sur l'étude:

Vous êtes libre de poser des questions à tout moment; vous pouvez contacter les investigateurs principaux par courriel: Tianna Beharriell, Wantuir Junior et / ou le Dr Ryan Graham/ Dr Pascal Imbeault). Ce projet est financé par le Conseil de recherches en sciences naturelles et en génie du Canada. L'éthique de ce protocole a été approuvée par le comité d'éthique de la recherche de l'Université d'Ottawa. Si vous avez des questions concernant la conduite éthique de cette étude, vous pouvez contacter l'agent du protocole pour l'éthique de la recherche, Université d'Ottawa, pavillon Tabaret, 550, rue Cumberland, pièce 154, Ottawa ON, K1N 6N5. Tél.: (613) 562-5387 Courriel: ethics@uottawa.ca

Titre du projet de recherche: **CARACTÉRISTIQUES PHYSIOLOGIQUES ET RÉPONSES INFLAMMATOIRES AU SPINAL AIGU CHARGEMENT**

Consentement:

J'ai lu ce formulaire de consentement et j'accepte de participer aux procédures de cette étude.

_____

Nom du participant:

_____ _____

Signature du participant: Date

Déclaration de l'investigateur (ou personne expliquant le consentement):

J'ai soigneusement expliqué aux participants à la recherche la nature de l'étude ci-dessus. À ma connaissance, le participant à la recherche qui signe ce formulaire de consentement comprend la nature, les exigences, les risques et les avantages liés à la participation à cette étude. Je reconnais ma responsabilité pour le soin et le bien-être du participant de recherche ci-dessus, pour respecter les droits et les souhaits du participant à la recherche et pour mener l'étude conformément aux directives et règlements applicables en matière de bonnes pratiques cliniques.

_____

Nom du chercheur

_____ _____

Signature du chercheur Date

Consentement informé à la prise de photos:

Je consens à prendre des photos de mon côté en train de terminer l'expérience et à comprendre qu'aucune photo ne sera prise à aucun moment sans que je le sache. Je comprends également que si l'une de ces images est utilisée dans une présentation ou une publication ultérieure, mon visage et tous les autres identificateurs seront flous. Vous pouvez toujours participer à l'étude de recherche sans consentir à des photos prises.

_____ _____

Nom Date

_____

Signature

_____ _____

Nom du témoin Signature du témoin

Participation future:

☐ Je suis intéressé à être contacté pour participer aux futures recherches effectuées par ce laboratoire (vos informations de courrier électronique seront enregistrées dans un fichier protégé par mot de passe).

Appendix P: Ethics Approval (University of Ottawa)

File Number: H08-17-02 **Date (mm/dd/yyyy):** 09/22/2017

Université d'Ottawa
Bureau d'éthique et d'intégrité de la recherche

University of Ottawa
Office of Research Ethics and Integrity

Ethics Approval Notice

Health Sciences and Science REB

Principal Investigator / Supervisor / Co-investigator(s) / Student(s)

First Name	Last Name	Affiliation	Role
Ryan	Graham	Health Sciences / Human Kinetics	Supervisor
Pascal	Imbeault	Health Sciences / Human Kinetics	Co-investigator
Tianna	Beharriell	Health Sciences / Human Kinetics	Student Researcher
Jean-François	Mauger	Health Sciences / Human Kinetics	Research Assistant
Wantuir Carlos	Ramos Junior	Health Sciences / Human Kinetics	Research Assistant

File Number: H08-17-02

Type of Project: Master's Thesis

Title: Physiological characteristics and inflammatory responses to acute spinal loading

Approval Date (mm/dd/yyyy)	Expiry Date (mm/dd/yyyy)	Approval Type
09/22/2017	09/21/2018	Renewal

Special Conditions / Comments:
N/A