The Short-Term Effects of Dry Cupping the Lumbar Paraspinal Muscles in Individuals with Non-specific Low Back Pain: A Single-Blind Randomized Trial

by

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Abstract

Introduction: Non-specific low back pain (NSLBP) is a leading cause of global disability, affecting millions of individuals and imposing significant personal and societal burdens. Current treatments (chiropractic or physiotherapy care, stretching exercises, maintaining a physically active lifestyle, and pharmacological interventions) often yield inconsistent results, highlighting the need for alternative therapies. Dry cupping, an ancient practice involving suction on the skin, has shown promise in improving pain and mobility, yet comprehensive evidence for its efficacy in NSLBP remains limited. This study investigated the short-term effects of dry cupping on lumbar paraspinal muscles in individuals with NSLBP, focusing on pain, range of motion (ROM), skin temperature (as a blood flow indicator), function, and perceived treatment effect.

Methods: Adults aged 18–55 (31 females and 21 males) with clinician-confirmed NSLBP were recruited to participate in a single-blind randomized clinical trial. Fifty-two participants (26 intervention, 26 placebo) received three sessions of either dry cupping or placebo cupping with approximately 48 hours in between each session. The intervention group received static cupping (10 minutes/session) at lumbar landmarks, based on indicated painful areas, using Hansol© cups. The placebo group received identical-appearing cups without suction. Measurements included ROM (Sit and Reach Test, dual inclinometry), pressure pain threshold (algometry), subjective pain (Numeric Pain Rating Scale; NPRS), skin temperature (laser thermometer), function (Roland-Morris Questionnaire), and perceived treatment effect (Patient Global Impression of Change Scale; PGICS). Data were analyzed using three-way and two-way mixed factorial ANOVAs and post-hoc tests.

Results: A three-way mixed factorial ANOVA revealed a nonsignificant interaction effect between the three variables (treatment group, session and time) $F(1.720, 26)=1.172$, $p=.309$, $\eta^2=.023$) but a significant two-way interaction effect between treatment group and session ($F(1.8949, 26)=29.603$, $p<.001$, $\eta^2=.372$) and between treatment group and time ($F(1, 26)=126.968$, $p<.001$, $\eta^2=.717$) on Sit and Reach scores.

A three-way mixed factorial ANOVA revealed a nonsignificant interaction effect between the three variables (treatment group, session and time) ($F(1.766, 26)=.206$, $p=.787$, $\eta^2=.004$), but a significant two-way interaction effect between treatment group and session ($F(1.558, 26)=25.207$, $p<.001$, $\eta^2=.335$) and between treatment group and time ($F(1, 26)=131.725$, $p<.001$, $\eta^2=.725$) on inclinometry scores.

A three-way mixed factorial ANOVA revealed a nonsignificant interaction effect between the three variables (treatment group, session and time) ($F(2, 26)=.361$, $p=.698$, $\eta^2=.007$), but a significant two-way interaction effect between treatment group and session ($F(2, 26)=13.694$, $p<.001$, $\eta^2=.215$) and between treatment group and time ($F(1, 26)=71.237$, $p<.001$, $\eta^2=.604$) on pressure pain threshold.

A three-way mixed factorial ANOVA revealed a nonsignificant interaction between the three variables (treatment group, session and time) ($F(1.593, 26)=.956$, $p=.371$, $\eta^2=.019$), but a significant two-way interaction effect between treatment group and session ($F(1.545,$

26)=11.640, $p<.001$, η^2 =.189) and between treatment group and time ($F(1, 26)=97.051$, $p<.001$, $\eta^2=.660$) on subjective pain perception.

A three-way mixed factorial ANOVA revealed a significant three-way interaction effect between treatment group, time, and session ($F(2, 26)=19.666$, $p<.001$, $\eta^2=.282$) on skin temperature.

A two-way mixed factorial ANOVA revealed a significant interaction effect between treatment group and session ($F(1.702, 26)=9.387$, $p<.001$, $\eta^2=.158$) on perceived treatment effect.

A three-way mixed factorial ANOVA revealed a nonsignificant interaction effect between the three variables (treatment group, session and time) ($F(2, 26)= 1.538$, $p=.220$, $\eta^2=.030$), but a significant two-way interaction effect between treatment group and session ($F(2, 26)=6.522$, $p=.002$, $\eta^2=.115$), between treatment group and time ($F(1, 26)=28.736$, $p<.001$, $\eta^2=.365$) and between session and time ($F(2, 26)=4.363$, $p=.015$, $\eta^2=.080$) on overall function.

Conclusion: This randomized clinical trial demonstrates that dry cupping therapy significantly improves short-term pain and ROM in individuals with NSLBP, with a modest effect on overall function. Compared to placebo, the intervention group showed clinically meaningful reductions in pain, increased ROM, elevated skin temperature, and significantly higher treatment satisfaction, leading to a greater understanding of the physiological mechanisms of treatment. Results highlight the importance of multiple treatment sessions for cumulative effects and demonstrate dry cupping is a viable non-pharmacological adjunct for NSLBP management. Further research is needed to explore the long-term sustainability of these effects and to establish optimal treatment protocols, including frequency and duration.

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List of Acronyms and Abbreviations

ANOVA – Analysis of Variance

C – Celsius

CM – Centimeters

CV – Coefficient of Variation

DEG – Degrees

F – Fahrenheit

GAQ – Get Active Questionnaire

LBP – Low Back Pain

MCID – Minimal Clinically Important Difference

MDC – Minimal Detectable Change

MIN – Minutes

MRI – Magnetic Resonance Imaging

N – Newton

NPRS – Numeric Pain Rating Scale

NSLBP – Non-specific Low Back Pain

ROM – Range of Motion

VAS – Visual Analogue Scale

Chapter 1 - Review of the Literature

Introduction

Background

Conditions affecting the lumbar spine comprise one of the most prevalent categories of impairment worldwide. On average, about 84% of the global population will encounter an episode of acute lower back pain (LBP) in their lifetime, and this condition is projected to burden 800 million individuals within the next 30 years (Centers for Disease Control and Prevention, 2022; Gill, 2023a). Assessing issues and injuries related to LBP is increasingly challenging due to the complex nature of these conditions and the anatomical area involved. The lumbar spine is comprised of various components, including bones, nerves, ligaments, blood vessels, and muscles, most notably the paraspinal muscles. Due to the essential function of the lumbar spine in human movements, the lumbar paraspinal muscles are often subjected to repetitive stress and strain, resulting in pain and tightness (Hoy et al., 2012).

Lower back pain can be categorized in various ways and is often very complex due to many contributing factors (Ferreira et al., 2023). One of the most common back pain diagnoses is non-specific low back pain (NSLBP; Savigny et al., 2009). Non-specific low back pain is categorized as an umbrella term for any pain in the lumbar spine that is not attributable to any other known cause or pathology. It describes a generalized discomfort that may be acute, subacute, or chronic, with varying degrees of intensity (Ferreira et al., 2023). The diagnosis of NSLBP involves a diagnosis of exclusion, meaning that other potential conditions (e.g., spondylolisthesis, spinal stenosis or intervertebral disc herniation) must be ruled out for the condition to be classified as NSLBP (Almeida et al., 2018; Physiopedia, 2024c). Clinical practitioners commonly use this classification of LBP to guide treatment practices, accounting

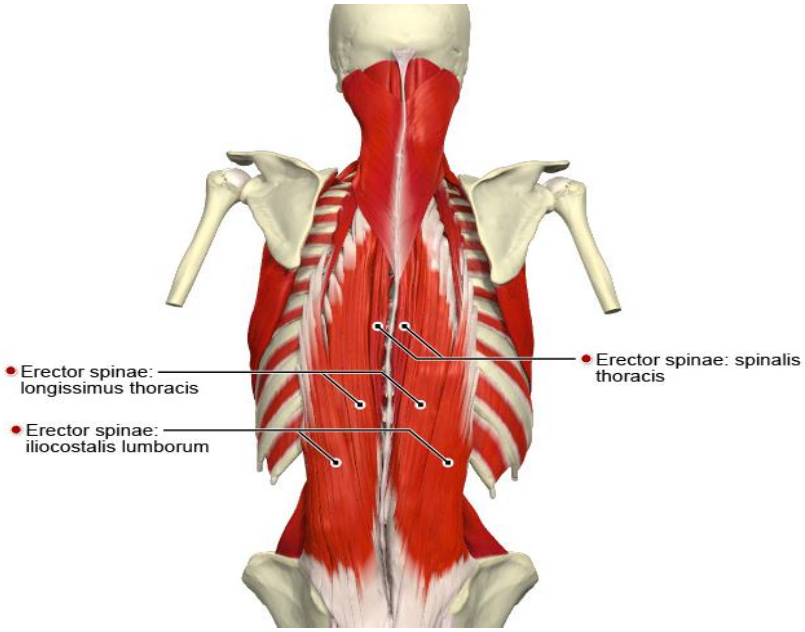
for 90% of patients seeking therapeutic care (Savigny et al., 2009). Due to the concerningly high prevalence of NSLBP, treatment methods continue to be widely researched (Centers for Disease Control and Prevention, 2022). Since such a large percentage of the population is affected by this condition, it is necessary that effective treatments be fully understood and implemented (Maher et al., 2017). To better understand potential treatment strategies, it is important to first consider the complex anatomy and function of the lumbar spine.

The Lumbar Spine

The lumbar spine includes bones that provide structure, blood vessels and nerves that perfuse and innervate the area, and ligaments and muscles that provide passive and dynamic support (Physiopedia, 2024b). The primary muscles covering the lumbar spine are the paraspinal muscles, including the iliocostalis, longissimus, and spinalis muscles, and these muscles function as primary movers in a great number of human movements. Since the core muscles and stabilizers such as the internal and external oblique muscles, multifidus, pelvic floor, diaphragm, and transverse abdominis are so involved in most functional tasks, these muscles play a critical role in the proper functioning of the spine and the entire body (Noonan & Brown, 2021). Various roles of these muscles include stabilizing and extending, flexing, side flexing, and rotating the spine, as well as maintaining proper posture (see Figure 1). The lumbar paraspinal muscles are commonly involved in conditions impairing the lower back (Hoy et al., 2012). For example, they may be injured directly, such as paraspinal muscle strain, or indirectly, as a result of an injury to another related area, such as spasm or restriction following a disc or ligament injury or maintaining a slumped seated posture for extended periods of time (Physiopedia, 2024b).

Figure 1

The Lumbar Paraspinal Muscles (Physiopedia, 2024b)



Performing everyday functional movements repetitively, such as bending, lifting, twisting, and simply maintaining posture in seated positions, impose a stretch on the lumbar paraspinals due to their prolonged or repeated flexed position. The essential engagement of these muscles in most body positions and movements and the heavy load that muscle tissues experience makes them easily prone to tightness and dysfunction (Noonan & Brown, 2021). This tightness can reduce the mobility of the lumbar spine, leading to a restriction in range of motion (ROM) and/or resulting in local or referred pain. Lumbar mobility restrictions can have widespread effects on the musculoskeletal system. These limitations may result in radiating symptoms into the lower extremities, including numbness or distal pain. Furthermore, individuals often develop compensatory movement patterns above and below the lumbar spine, potentially leading to altered biomechanics and total body involvement. (Prather & Van Dillen, 2019). Furthermore, the lumbar spine paraspinal muscles are critically involved in most known lower back conditions, including NSLBP (Noonan & Brown, 2021). Due to the repetitive nature

of functional tasks in which they are heavily involved (such as prolonged sitting when driving or working), the muscles may be subjected to prolonged or repeated stretching, resulting in restriction and even generalized pain (Noonan & Brown, 2021).

Lower Back Pain

Prevalence

The increasing incidence of LBP-related conditions has become a global health problem as it makes up the leading cause of disability worldwide (Hartvigsen et al., 2018; Ferreira et al., 2023). It accounts for the most common cause of pain in adults and the second most common reason for individuals to seek emergency ambulatory care, closely following infections (Laffont et al., 2016; Weiss & Jiang, 2021). This condition can be experienced at any age, however, there is an increased incidence in persons 50-55 years of age and a higher prevalence among women than men (Hartvigsen et al., 2018). Lower back pain may be acute (lasting less than three months) or chronic (lasting more than three months) in nature, and sometimes, individuals will experience a transition from acute to chronic pain, which may also be referred to as sub-acute, if the condition is not managed and treated appropriately (Henschke et al., 2009). The reported incidence of LBP is increasing as the population ages, and it continues to have a widespread impact on various individual and societal factors (Bone and Joint Canada, 2014).

Societal and Personal Impact

Beyond the physical strain, LBP conditions impose an important economic burden on society and the healthcare system. It is estimated that the cost of LBP in Canada is between $6 and $12 billion annually when considering medical resources and other direct and indirect costs such as disability payments (Bone and Joint Canada, 2014). The highest prevalence is documented among working age adults, leading to substantial economic losses due to decreased

productivity and increased health care and workplace disability costs (Hartvigsen et al., 2018). Evidence shows that the prevalence of LBP is increasing globally, particularly among low- and middle-income countries where healthcare resources are often limited (Hartvigsen et al., 2018). The increased incidence of LBP may result in significant implications such as time away from work, decreased productivity, and substantial financial resources allotted to treating these conditions, including physiotherapy and other allied health professional consultation and treatment, doctors' visits, imaging, and the use of prescription medications (Ferreira et al., 2023). Furthermore, it is estimated that 1 in every 25 individuals in the United States will need to change their careers or retire early due to disability related to LBP (Garofalo & Polatin, 1999). Living with LBP also often causes a significant impact on one's mental health and social well-being, with up to 25% of LBP patients also being diagnosed with depression (Hu et al., 2022). Beyond being limited in their ability to be physically active and engaged, individuals with LBP may struggle with maintaining a quality sleep schedule, often experience depressive mood symptoms, and generally have a lower quality of life (Ge et al., 2022). Being physically limited by their condition, in conjunction with depressive symptoms and frustration, may lead to social withdrawal (Ge et al., 2022). Consequently, the direct and indirect costs of LBP further support the need to address the high prevalence of LBP in the population. Given its widespread impact and economic burden, it is essential to understand the multifaceted nature of LBP and the various ways it can be classified.

Non-specific Low Back Pain

Pathology

Lower back pain can be categorized in various ways and is complex due to many contributing factors (e.g. biomechanical, psychosocial, lifestyle, structural; Ferreira et al., 2023).

Lower back conditions are often termed by their causes or most notable symptoms. Categorizations of conditions allow for a generalized understanding of the condition and a starting point for treatment. Specific LBP is pain that is caused by a certain disease or structural pathology (e.g., spondylolisthesis, spinal stenosis) in the spine or when the pain radiates from another part of the body (e.g., intervertebral disc herniation with compression of a nerve or the spinal cord/cauda equina; World Health Organization, 2023). However, one of the most common diagnoses of back pain is NSLBP. Non-specific low back pain is categorized as any pain that is not attributable to any other known cause or pathology (Ferreira et al., 2023). It describes a generalized discomfort in the lower back, with varying degrees of intensity (Casazza, 2012). Risk factors for this condition include low physical activity levels, smoking, obesity, or high occupational stress (such as lifting heavy loads or repetitive motions involving the lower back; Ferreira et al., 2023). Since the specific cause of the condition is unknown and often multifactorial, contributing factors vary on an individual basis (Ferreira et al., 2023). As previously stated, LBP often involves the lumbar paraspinal muscles and their pre-disposition to develop protective muscle spasms and tension. With the rising numbers and prevalence rates, it is not surprising that NSLBP has become a significant concern worldwide and that the trends and data suggest that the prevalence of this condition is continuing to increase (Casazza, 2012). As the global burden of NSLBP continues to grow, accurate identification and diagnosis become increasingly important.

Diagnosis

The assessment of NSLBP is a diagnosis of exclusion (Almeida et al., 2018; Physiopedia, 2024c). This approach means that the practitioner is required to rule out other potential pathoanatomical causes. This triage process aims to exclude specific causes, such as a vertebral

fracture, radiculopathy, spondylolisthesis, spinal stenosis, or other serious pathology, to diagnose NSLBP (Almeida et al., 2018; Physiopedia, 2024c).

The assessment, clinical reasoning, and diagnosing process often involves a comprehensive patient history and physical examination. Clinical reasoning refers to the cognitive and analytical processes clinicians use to assess patient information, formulate diagnoses, make treatment decisions, and evaluate outcomes within the context of individual patient needs. This may be followed by blood work or imaging such as radiography (X-ray) or magnetic resonance imaging (MRI) techniques or functional testing to rule out bone involvement or serious pathology, if it is suspected (Almeida et al., 2018; Physiopedia, 2024c). In the case of NSLBP, several lumbar structures are possible sources of pain (e.g., the intervertebral disc, the facet joints), but clinical tests or imaging do not reliably attribute the pain to those structures, and, therefore, it is labelled and deemed to be non-specific (Almeida et al., 2018; Physiopedia, 2024c).

Treatment

Clinical practitioners commonly use this classification of LBP to guide treatment practices (Savigny, 2009). Due to the concerningly high prevalence of NSLBP and the lack of consistent evidence to support the most effective treatment methods, these treatment practices continue to be widely researched. The large percentage of the population affected by this condition deems it necessary to explore further and examine effective treatment methods (Maher et al., 2017). A systemic review by Arnau et al. (2005) examined the quality of current guidelines for LBP treatment. Various treatment recommendations included the use of non-steroidal anti-inflammatory drugs, maintaining physical activity, and avoiding bed rest. However, results concluded that the evidence supporting the effectiveness of these methods requires further

investigation and that more rigorous guidelines should be set for LBP treatments (Arnau et al., 2005).

Furthermore, various systemic reviews from the Cochrane Library have examined effectiveness of various treatment methods, such as pharmaceuticals and exercise interventions on LBP (Cashin et al., 2023). It has been concluded that pharmaceuticals may provide little to no benefit in effectively managing LBP (Cashin et al., 2023). Exercise therapy has also been explored as a treatment method for acute and chronic LBP; however, a meta-analysis by Hayden and Van Tulder (2005) concluded that this treatment is not likely effective at reducing pain for NSLBP patients. Furthermore, a systemic review by Almeida et al. (2003) examined the use of the McKenzie Method® of Mechanical Diagnosis and Therapy (a system of diagnosis and treatment for spinal and extremity musculoskeletal disorders that emphasizes patient empowerment and self-treatment) on LBP patients (Werneke & Hart, 2004). This review compiled and appraised evidence from 12 randomized controlled trials (RCTs). It was concluded that this treatment approach likely provides little to no relief from pain in individuals with LBP (Almeida et al., 2003). Further, a systematic review of treatment guidelines by Corp et al. (2021) examined the evidence supporting the use of education, exercise, manipulation, and pharmaceuticals on LBP. Despite minimal positive findings for these methods, the overall evidence was appraised to be weak, and future examination and refinement of LBP treatment methods were recommended. A systemic review by Zaina et al. (2023) sought to identify evidence-based rehabilitation interventions for individuals with NSLBP and to develop recommendations from high-quality clinical practice guidelines based on the evidence. Their review of 12 articles indicated that future clinical practice guidelines should include patient education, multimodal therapy, including exercise and manual therapy and manipulation, non-

steroidal anti-inflammatory drugs, and interdisciplinary rehabilitation programs. However, it is emphasized that the quality of evidence supporting these recommendations varies from low to high, with evidence generally appraised as moderate (Zaina et al., 2023). Thus, it is a consistent finding that although various treatment practices have been adopted, the benefits appear minimal and inconsistent, and effective treatment methods require further investigation (Corp et al., 2021). Patient-centred care must be implemented in order to more effectively address the individualized problem of NSLBP. Practitioners must be cautious about over-simplifying the condition and neglecting to consider the true complexity of NSLBP (Diener, 2021).

The idiopathic nature of NSLBP causes the treatment focus to shift towards pain and symptom management (Maher et al., 2017). Treating pain-related conditions is very complex and requires a highly individualized approach, as symptoms may vary from person to person (Balagué et al., 2012). Common treatments for LBP may include education, manual therapies such as chiropractic or physiotherapy care, stretching exercises, maintaining a physically active lifestyle, and pharmacological interventions, including non-steroidal anti-inflammatory drugs, when necessary (Savigny, 2009). Treating practitioners must emphasize the importance of a multidisciplinary approach to LBP management, involving a range of healthcare professionals and the promotion of non-pharmacological treatments such as physical therapy, exercise, and patient education (Nicol et al., 2021). Despite these common treatment recommendations, research has indicated little evidence to support these therapies on NSLBP (Casazza, 2012). Furthermore, as pain is often linked with functional impairment and there has been limited treatment success with current Western practices, there is a need to examine alternative treatment strategies, and a potential method is dry cupping therapy (Wood et al., 2020).

Dry Cupping

History

Cupping is an ancient holistic treatment practice with roots in Ancient Egyptian and Chinese Medicine (Qureshi et al., 2017). It is one of the oldest documented traditional medicine procedures, dating back over 3500 years (Qureshi et al., 2017). Initially, this therapeutic intervention, known as wet cupping, was used to treat various ailments such as nausea, respiratory distress, rheumatic conditions, and multiple disabilities including paralysis and musculoskeletal impairments. It was also commonly used during surgical procedures to draw blood away from the surgical site and to balance bodily humors (preventing illness) by detoxifying the blood (Qureshi et al., 2017). Traditional cups were typically made of animal horns, bones, bamboo, or seashells, as these items could be modified to cause a suction effect on the skin (Qureshi et al., 2017). Wet cupping involved puncturing the skin and placing a suction cup over the punctured site to draw blood to the skin's surface. Due to its perceived effects, this treatment practice has continued to be implemented and evolved considerably over the past 3000 years. Cupping treatment has spread globally, and cupping practices are currently used worldwide. Over time, the practice has been modified to dry cupping, eliminating the risk associated with the traditional method involving the extraction of bodily fluids and blood while still proposing the same benefits (Qureshi et al., 2017).

Current Practice

While traditional techniques involve puncturing the skin to release blood and bodily fluids, modern cupping methods, known as dry cupping, use suction cups without puncturing the skin (Lempke et al., 2022). Dry cupping involves placing plastic, glass, or rubber suction cups on the skin, followed by the creation of negative pressure within the cup to generate suction (see

Figure 2; Markowski et al., 2014). Modern plastic cups typically employ a mechanical pump attached to a valve to evacuate air and create negative pressure. Alternatively, silicone or rubber cups are manually compressed prior to placement, and as they re-expand, a vacuum is formed (Markowski et al., 2014).

Figure 2

Plastic Cup Used for Dry Cupping (Denny & Denny, 2024)

Cupping can either occur statically, where the cups remain stationary, or dynamically, which involves moving the cups for a massaging effect (Stephens et al., 2022). There are various techniques practitioners may use during a cupping session, similar to the methods used in a manual massage. Beeswax or adhesive skin spray may be applied to prevent cup movement, especially in individuals with a lot of body hair (Kohlmeier, 2019). Cups typically remain on the skin for about 7-10 minutes (min) before the suction is released. Suction is released by allowing ambient air to re-enter the cup. In plastic cups with valves, this is typically achieved by unlocking the valve or gently lifting the rim of the cup. For glass cups, practitioners may tilt the cup or introduce air manually at the seal. In the case of flexible silicone cups, the suction is

released by compressing and peeling the cup away from the skin. This approach is the optimal time proposed for promoting treatment benefits, as shorter sessions may not allow for the suctioning mechanism to take full effect, while longer treatment sessions do not appear to increase benefits (Wang et al., 2020). This practice is most commonly used by healthcare providers such as physiotherapists, chiropractors, and massage therapists to reduce musculoskeletal-related stiffness and pain for their patients (Murry & Clarkson, 2019). Furthermore, this treatment is proposed to promote relaxation, increase circulation, and reduce inflammation (Markowski et al., 2014). Due to its relatively novel introduction to Western society and Westernized medicine, the physiology behind cupping practice's mechanisms and treatment benefits has yet to be thoroughly explored (Markowski et al., 2014).

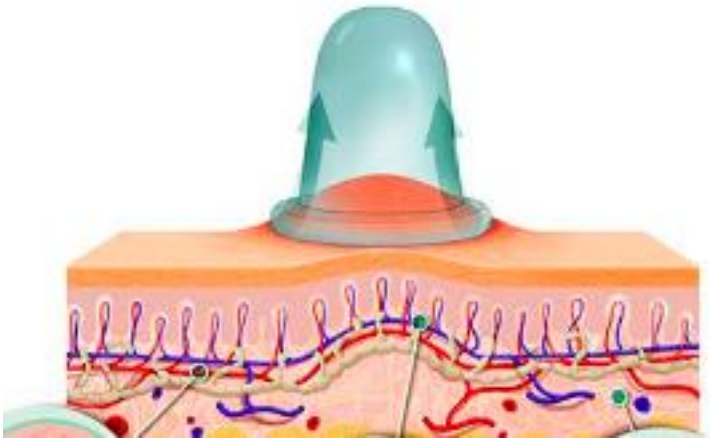
Physiological Effects of Cupping

The suction mechanism of cupping treatment is proposed to be responsible for the observed treatment effects (Markowski et al., 2014). The suction applied often results in hyperpigmentation, indicating increased blood flow to the treated area without the trauma associated with a regular bruise (Markowski et al., 2014). The negative pressure also causes vasodilation of the blood vessels local to the treatment zone and within the surrounding areas (Stephens et al., 2022). This process promotes oxygenated blood flow and lymphatic circulation, leading to a possible anti-inflammatory response through the nutrients carried within the bloodstream and the lymphatic system’s ability to reduce overall bodily inflammation. Furthermore, the healing properties of the blood and the associated nutrients and biological factors and markers are essential for promoting tissue repair and regeneration in instances involving pathologies such as infection or conditions such as NSLBP. In addition, cupping is proposed to create negative pressure on the skin, stretching both the skin and underlying tissue

(Stephens et al., 2022). This negative pressure may also be referred to as suction, and the force is proposed to lift the skin, underlying muscle tissue, and the fascia into the cup, which creates space for the underlying muscle to relax and reduce tension (Bentley, 2013; see Figure 3). The stretch within the deep muscle tissue allows the muscle to lengthen past its resting state, potentially leading to increased ROM and mobility, thereby reducing functional limitations and restriction (Markowski et al., 2014).

Figure 3

Negative Pressure Diagram (Revolve Physiotherapy, 2024)



Current Research on Dry Cupping

Range of Motion and Overall Function Effects

As previously mentioned, one of the most common uses for dry cupping therapy is to increase joint ROM (Markowski et al., 2014). Range of motion refers to a joint's ability to move through a plane without pain or restriction and is one of the most notable markers of an individual's physical function (Ratamess, 2021). Increased ROM has many benefits for an

individual, such as increasing mobility (Pedrosa et al., 2023). Increases in mobility may occur as the joint can move through a wider range, allowing for ease of movement and the ability to perform functional tasks with limited strain. Increased ROM has also been shown to reduce the risk of injury and improve overall movement efficiency and quality of life (Ratamess, 2021). Various factors can affect joint movement, such as muscular tension, swelling, or pain (Ratamess, 2021). Restrictions in ROM, especially in the lumbar spine, can cause significant functional limitations. Individuals may be impaired from engaging in their daily functional, occupational, or sport-related activities, and often, additional joints will become affected due to compensation strategies used (MacPherson, 2022). Furthermore, limited ROM can often lead to increased discomfort and pain and the risk of further injury (MacPherson, 2022).

Cupping treatments have been reported to increase joint ROM in various body regions (Markowski et al., 2014). The negative pressure within the cup has been reported to cause a neurophysiological stretch in the muscle, allowing it to lengthen following treatment (Chiu et al., 2020). Muscle stretching begins within the sarcomere, the contractile unit of muscle tissue. The sarcomeres are fully stretched when a muscle fibre is at its maximum resting length (Appleton, 1997). Cupping and the associated negative pressure are thought to create a gap in the muscle tissue, allowing the fibres to stretch beyond their resting length, potentially increasing ROM (Dunning, 2016). The proposed neurophysiological mechanism behind cupping and the associated ROM increase is similar to that of other soft tissue mobilization techniques (instrument-assisted soft tissue mobilization and myofascial release), as it creates a gap within the layer of soft tissue due to the suctioning effect of the cup (Cobb et al., 2022).

The majority of research examining the effect of dry cupping on ROM has been concentrated on the lower limbs. Murray and Clarkson (2019) examined the effects of hamstring

cupping on hip ROM. This study included a 15 min dynamic cupping intervention on 21 healthy individuals. Range of motion was measured using the Straight Leg Raise Test, pre-and post-treatment. The treatment resulted in an average 7% increase in ROM, as measured by the Straight Leg Raise Test; however, the results of this study are significantly limited by the low sample size and lack of a control group (Murray & Clarkson, 2019).

Another study by Yim et al. (2017) looked at the effects of static cupping on the cervical spine of 18 healthy individuals with an average age of 22.7 years, with a height of 166.58 centimetres (cm), and a body mass of 59.5 kilograms (kg). Inclusion criteria included participants who had no restrictions on the ROM of the neck, those without disc disorder, and no open wounds at the sites where the cupping therapy was applied. In this study, an 8 min dry cupping treatment was compared to a McKenzie Method® of Mechanical Diagnosis and Therapy to determine which was more effective at increasing ROM of the cervical spine. The crossover design allowed all 18 participants to engage in both treatment conditions (stretching versus cupping). Cervical spine ROM measurements were taken using a goniometer pre-and post-treatment under both conditions. An average 11% increase in ROM in all directions in the cupping condition was reported, which was more significant than the changes observed with the McKenzie Method® of Mechanical Diagnosis and Therapy (Yim et al., 2017). Therefore, using a dry cupping treatment may induce a more significant increase in ROM compared to other related methods. It is essential to recognize that this study was also limited by the small sample size of only 18 participants.

Markowski et al. (2014) conducted a pilot study focused on dry cupping of the lumbar spine in individuals with reported subacute or chronic mechanical LBP. This investigation represents one of the lone studies that has examined the use of dry cupping on the lumbar spine,

specifically in those experiencing LBP. Seventeen individuals experiencing subacute or chronic mechanical LBP received a 10 min cupping intervention. Four glass cups were placed on the lumbar paraspinal muscles at L2 and L4 during the treatment. Range of motion was measured using the Straight Leg Raise Test and inclinometry pre-and post-intervention. Subjective pain was measured using the Visual Analogue Scale (VAS) and pressure pain threshold. It was reported that the treatment effectively increased the mobility of the lumbar spine, with a 9° increase in lumbar spine flexion as measured by inclinometry and a 2° and 3° increase in Straight Leg Raise Test scores on the right and left sides, respectively (with significant improvements on the left), following the 10 min cupping intervention. A statistically significant decrease in pain was reported in both measures (VAS and pressure pain threshold), following the cupping intervention. It was concluded that dry cupping may be a low-risk therapy that can effectively increase ROM, reduce mobility limitations, and decrease pain for individuals experiencing LBP (Markowski et al., 2014).

Recently, more sophisticated study designs have been developed in efforts to determine the neurophysiological effects of dry cupping treatment. Specifically, Almeida Silva et al. (2019) examined the use of a dry cupping therapy on individuals with NSLBP. This prospectively registered randomized sham-controlled clinical trial assigned 90 participants to either an intervention or sham-control group prior to the beginning of the study. Participants were screened for eligibility, including the NSLBP diagnosis, by a physiotherapist prior to enrollment in the study. Each group received a 10 min dry cupping intervention once per week for eight weeks. The placebo group received cups with 2 mm holes punctured in them, which were secured on the skin using double-sided tape so as not to change the sensation for the participant (see Figure 4).

Figure 4

Placebo Cups with 2 mm Holes Punctured

Measurements were taken at baseline, after the first session, at four weeks, and at eight weeks (immediately following the final intervention session). Outcome measures included subjective pain measured using the Numeric Pain Rating Scale (NPRS), ROM using the Finger-to-Floor Test, physical function using the Time Up and Go Test, perception of effect using the Global Impression Scale, and overall quality of life using the Short-Form 36. Results revealed no significant differences between groups in outcome measures when comparing the intervention to the sham-control group. A notable difference in pain sensation was reported; however, it did not exceed the minimal clinically important pain intensity in LBP patients (Almeida Silva et al., 2022). This is the first high-quality RCT that compared the dry cupping intervention to a placebo condition in individuals with NSLBP.

Range of Motion Measurement. Range of motion can be measured using various tools and is commonly included in health care assessment and standard fitness testing procedures (Physiopedia, 2024a). Specifically related to the lumbar spine, methods such as inclinometry or the Sit and Reach Test are widely used for their simplicity and demonstrated reliability. They are the most often reported method of measuring lumbar spine ROM within the current literature,

but not the only methods that can be used (Physiopedia, 2024a). Inclinometry is considered the most reliable and accurate measurement method due to its ease of use and the ability to use multiple devices simultaneously, allowing for an average measurement (Nussbaumer et al., 2010). Dual inclinometry employs two inclinometers placed at various standardized landmarks. This tool has demonstrated excellent inter-rater (r=.88-.94), excellent intra-rater (r=.90-.91), and excellent test-retest (r=.91-.93) reliability for measuring thoracolumbar spine ROM in individuals with LBP, with an accuracy of ± 0.1 ° (Dimitriadis et al., 2022). This tool's minimal detectable change (MDC) is between 1.50° - 3.41° (Boyd, 2012). Minimal detectable change refers to the smallest amount of change in a measurement that reflects a true difference beyond the margin of measurement error or natural variability. If an observed change falls below this threshold it may not be considered a meaningful improvement as it could reflect random variation or measurement inaccuracy rather than a genuine change.

The Sit and Reach Test is also a reliable measure of lumbar spine flexibility with minimal variance and is a common standardized measure used in exercise physiological testing (Chung & Yuen, 1999). Though commonly used for testing ROM in the hamstring muscles, the lumbar flexion required by this test also deems it an appropriate measure for low back ROM (Chung & Yuen, 1999). This test has shown an excellent intra-class correlation coefficient (r=.92) and a moderate inter-class correlation coefficient (r=.74), with an 8.74% coefficient of variation (CV) demonstrating strong evidence of validity and reproducibility (Ayala et al., 2012; Lemmink et al., 2013). The MDC for the Sit and Reach Test is between 1.13 - 1.74 cm (Fang et al., 2020).

Overall Function Measurement. Range of motion restrictions are often accompanied by functional limitations. Reducing the ability of a joint to fully move will impair one's ability to effectively carry out certain tasks (MacPherson, 2022). For example, decreases in the ROM of

one's lower back may impair their ability to bend over to put their socks on or stand upright when getting up from a seated position, limiting their overall function (American Association of Neurological Surgeons, 2024). An individual's overall function is commonly measured based on their ability to perform daily tasks without limitations due to pain. Measuring functional ability is critical as functional impairments have the ability to negatively impact one's quality of life (MacPherson, 2022). In the context of treatment methods, functional status may be evaluated using self-report questionnaires, which allow the individual to appraise their own abilities, as well as to track changes over time and make comparisons (Sherman & Reuben, 1998). The Roland-Morris Questionnaire is a validated measure commonly used by practitioners to assess physical disability and functional limitations caused by LBP (Physiopedia, 2024d). It is a 24-item self-report questionnaire that is scored to obtain a functional score. The patient is asked to indicate when a statement applies to them on that specific day, and the end score is the sum of the ticked boxes. The score ranges from 0 (no disability) to 24 (maximum disability). This questionnaire is often used to track changes in function over time as it is easy to use and interpret. This tool has strong evidence of intra-rater reliability (r=.91), with moderate internal (r=.71) and external (r=.54) responsiveness. The MDC for this tool is 5 points (Physiopedia, 2024d).

Range of motion and function are important constructs to consider when determining the efficacy of dry cupping as a treatment for NSLBP. In addition to ROM and functional increases, a decrease in pain is one of the most commonly reported treatment outcomes of dry cupping therapy (Markowski et al., 2014). Given its frequent use for pain management, it is essential to examine how dry cupping influences not only physical outcomes but also subjective pain perception.

Subjective Pain Effects

Subjective pain perception is an individual's experience of an unpleasant sensory and emotional feeling associated with or resembling actual or potential tissue damage, and it is the most commonly reported patient symptom (Childs et al., 2005; International Association for the Study of Pain, 2020; Sweiboda et al., 2013). Pain perception and understanding are increasingly complex (Casazza, 2012). Since pain is such an individualized construct, it is hard to measure objectively within the population as it cannot be directly observed or evaluated. Therefore, researchers and practitioners must rely on an individual's subjective assessment to comprehensively understand their individual pain experience. Pain is often classified based on the region of the body involved (e.g., lumbar spine or referred pain from a visceral structure), the time domain associated with the pattern of occurrence (i.e., acute or chronic), the pain mechanism (i.e., nociceptive, neuropathic, nociplastic, and central sensitization), and the system that is the cause of the pain (i.e., nervous or musculoskeletal; Casazza, 2012).

The experience of pain can be modulated by various physical, emotional, cognitive, and environmental factors making it challenging for clinicians and researchers to understand and even more complex to classify (Peters, 2015). Firstly, an individual's pain experience can be impacted by physical factors such as the level of nerve stimulation, the type of fibre stimulation, and the stimulus's strength and physical appearance (e.g., sharp or pointed; Sweiboda et al., 2013). Also, one's hormones are crucial in determining pain sensation intensity. Especially for females, the decrease in estrogen during menstruation often causes females to experience pain more intensely, indicating potential sex and hormonal influences in pain experience and appraisal (Craft, 2007). Emotional factors also play a significant role in the pain experience. For example, pain may be perceived as more intense or severe if accompanied by anxiety,

depression, anger, or other negative emotions. Positive emotions such as joy or excitement have often been shown to decrease pain sensations (Peters, 2015).

Furthermore, cognitive engagement and processing may also impact the subjective pain experience (Sant'Anna et al., 2024). The level of attention or distraction, expectancy, and individual appraisal may significantly impact pain intensity. Finally, environmental factors such as the physical environment (i.e., the space in which the incident occurred), who was present at the time, familiarity with the environment, and previous pain experiences may heavily influence one's perceived pain intensity. Considering and appraising all potential factors in an individual's pain experience further complicates the assessment of pain (Sant'Anna et al., 2024).

As previously mentioned, NSLBP is often an idiopathic condition, and treatment is often focused on pain modulation rather than targeting the root cause of the condition (Ferreira et al., 2023). Most treatments for this condition are focused on reducing the individual's subjective pain experience. Despite the many treatment methods available for consideration for pain modulation in individuals with NSLBP, the reports of this symptom continue to persist in up to 90% of patients (Centers for Disease Control and Prevention, 2022).

In the context of cupping, along with increasing ROM, a decrease in pain is one of the most commonly reported effects of treatment (Markowski et al., 2014). As previously mentioned, most research in this area has been directed at assessing the effects of dry cupping on the lower limbs. However, as the intervention becomes more prevalent, high-quality research studies and designs with high-impact findings on the lower back continue to increase (Wood et al., 2020).

A systemic review conducted by Wood et al. (2020) examined 21 RCTs involving 1049 participants receiving cupping treatments for chronic LBP and neck pain. Primary outcome

measures included the VAS, NPRS, Short Form McGill Pain Questionnaire, and pressure pain threshold. Functional status was also measured using self-report questionnaires including the Short-Form 36, Neck Pain and Disability Index, Roland-Morris Disability Questionnaire, Oswestry Disability Index, and Western Ontario and McMaster Universities Arthritis Index (WOMAC). The systematic review indicated that trials pertaining to NSLBP often compared cupping therapy to routine care, such as chiropractic adjustments and massage and the use of medications. A significant decrease in LBP in favour of cupping was reported across all 21 RCTs (Wood et al., 2020). Furthermore, moderate evidence suggested that dry cupping may significantly improve functional status and pressure pain threshold in individuals with chronic low back or neck pain. Low evidence suggested that dry cupping treatments may improve ROM compared to controls. These results indicate that dry cupping may effectively reduce the intensity of pain, functional limitations, and ROM restrictions associated with LBP and neck pain conditions (Wood et al., 2020).

To further support these findings, a meta-analysis conducted by Wang et al. (2017) examined the results of six RCTs on the effects of dry cupping treatments on LBP. Findings indicated a significant reduction in patient-reported LBP following treatment across all studies. These conclusions are limited by the low to moderate appraisal of the evidence and suggest that the effect of dry cupping treatment on LBP be further examined (Wang et al., 2017).

De Melo Salemi et al. (2021) further examined the effect of dry cupping on subjective pain in patients with NSLBP. In one of the only RCTs to explore this specific effect to date, 37 individuals were recruited to participate in 5 consecutive treatment sessions of dry cupping, scheduled 3-4 days apart, with each session lasting 20 min. For the first 10 min, the cupping took place on the anterior surface of the abdomen to stimulate blood flow to various acupoints

associated with emotions and conditions such as depression and anxiety, followed by 10 min on the lumbar spine. Participants were randomly assigned to either a placebo or intervention group, and the study participant allocation and results were blinded to evaluators, participants, and statisticians. Subjective pain was measured using the VAS and the Oswestry Low Back Pain Disability questionnaire, Start Back Screening Tool, and a weekly pain diary. Measures were taken at baseline, immediately post-treatment, and follow-up four weeks after the final treatment. In each condition, 17 cups were used and pumped twice for moderate suction and consistency across all participants. The placebo group received cups with small holes drilled in them so that the pressure would immediately release upon application. Double-sided tape also ensured the cups stayed in place throughout the treatment. Results revealed that the dry cupping group reported a statistically significant decrease in subjective pain between the baseline and post-treatment period and between baseline and the four-week follow-up period, with a large effect size. There were no statistically significant differences in the pain intensity measured between the time points in the placebo group. These findings further support the likelihood that dry cupping may be an effective tool to manage pain-related symptoms in a population with NSLBP and that the effect of dry cupping treatment should continue to be explored (De Melo Salemi et al., 2021).

Subjective Pain Measurement. Due to the complexity of measuring pain and the individuality of the experience, practitioners often rely on subjective self-report methods (Breivik et al., 2008). Various self-report tools and outcome measures are employed, but the most commonly reported within studies on NLSBP are the NPRS and VAS. Both measures use a Likert-scaled measure, allowing for simplified treatment comparisons (Breivik et al., 2008). Practitioners rely on patient self-report outcome measures as they enable the individual to

quantify their experience. Also, they are a way for individuals to rate their pain relative to other experiences (pre- or post-treatment) and enable comparisons.

Numeric Pain Rating Scale. As previously mentioned, one of the most commonly used scales is the NPRS. It requires an individual to reflect on their pain experience and rate their pain on a scale from 0 (no pain) to 10 (worst possible pain). This tool has demonstrated excellent reliability (r=.99) for assessing musculoskeletal pain and a very high intraclass correlation coefficient (ICC=.95; Alghadir et al., 2018). The MDC for this tool is 1.33 points, and the minimum clinically significant difference (MCID) is 2.1 points (Gallasch & Alexandre, 2007). The 0-10 scale is chosen as it is easy for patients to understand. It is commonly used in a research or treatment settings as it is simple to interpret and allows for easy comparison between multiple survey responses at various intervals (Childs et al., 2005). Although scales cannot be directly compared across individuals due to the fact that pain is appraised differently by each person, they provide a general method of making interpersonal comparisons and are reliable for assessing treatment effects (Breivik et al., 2008). In researching therapeutic interventions, self-report scales are frequently used to measure pain perception changes following treatment (Wood et al., 2020).

Algometry. Another commonly employed method of measuring pain, specifically pressure pain threshold, is algometry. Pressure pain threshold refers to the amount of pressure applied over the skin when a feeling of pressure transitions into a feeling of pain. This is measured using a force gauge and provides a value in Newtons or kilopascals (N; kPa; Castien et al., 2021). This method requires the examiner to press on a landmark on the patient (e.g., lower back) perpendicular to the surface using the force gauge, and the patient must report when pain is induced. This tool has demonstrated good to excellent intra-rater (r=.75-.99) and good to

excellent inter-rater (r=.81-.99) reliability in measuring LBP, with an accuracy of ± 0.2% (Bhattacharyya et al., 2023; Wagner, 2024). The MDC for this tool is 47.2 kPa/0.472N and it is the gold standard for measuring an individual's pain level (Ibrahim et al., 2022; Salom-Moreno et al., 2024). Thus, pain is a critical construct to consider when determining the efficacy of cupping treatments on individuals with NSLBP.

Blood Flow and Skin Temperature Effects

In addition to the effects on ROM and pain perception, cupping has been shown to increase blood flow to the treated area, often reflected in increased skin temperature (Lowe, 2017). Blood flow is the amount of oxygenated blood that travels to the muscle at a given time (Cage et al., 2020). Muscles are highly vascularized and full of rich, oxygenated blood, but the flow of blood within muscles fluctuates with muscular contraction and relaxation (Joyner & Casey, 2015). During muscular contraction, the vasculature within the muscle is compressed, and there is a lower arterial inflow and higher venous outflow, resulting in less blood volume in the relaxed muscle (Joyner & Casey, 2015). The increased blood flow has many immediate and long-term benefits. Increases in muscle blood flow and venous return facilitate the delivery of oxygen, nutrients, and growth factors to the muscle. It also aids in removing chemical waste, similar to its function in other areas of the body (Lowe, 2017). In other words, this mechanism creates an environment that promotes cellular detoxification and healing, which is essential in a pathological population such as individuals suffering from NSLBP (Lowe, 2017).

Cupping is thought to increase the flow of oxygenated blood to the muscle due to the negative pressure within the cup, causing a suction effect on the skin and underlying tissue (Markowski et al., 2014). The negative pressure is caused by sucking air through the air pump used to apply the cups on the skin. It is what allows for the cups to stay in place and for the

proposed physiological mechanism of treatment to occur. This mechanism causes dilation of the blood vessels and promotes the flow of oxygenated blood to the treated area (Lowe, 2017). Increased flow of oxygenated blood has been proposed to produce both analgesic and anti-inflammatory healing properties. The nutrients carried within the bloodstream are essential for fostering the natural recovery process, and using a treatment for this mechanism may improve recovery times (Markowski et al., 2014). Specifically for individuals with NSLBP, whose treatment is often focused on pain management, this effect of cupping may be of particular interest and importance (Maher et al., 2017).

Minimal studies have sought to examine the specific relationship between muscular blood flow and a cupping intervention. Arce-Esquivel et al. (2017) sought to examine the specific effect on blood flow following a singular 10 min dry cupping treatment on 11 healthy individuals. Blood flow was measured using a finger digital thermal monitor of vascular reactivity to measure flow downstream of the cupping treatment, which occurred on the forearm. The results revealed a 36% increase in microvascular function following the treatment, indicating that cupping promotes increased circulation locally and within the surrounding areas (Arce-Esquivel et al., 2017). The lack of a control group and small sample size serve as limitations of this study which must be considered. Furthermore, the study was conducted on a healthy population, and comparisons cannot be made directly to someone experiencing LBP.

A similar study by Wei et al. (2013) examined blood flow to the cervical spine following a dry cupping treatment. Thirty healthy individuals were recruited, and blood flow measurements were recorded using a PeriCam© PSI blood flow monitoring video system of laser speckle. A laser speckle is a monitoring system used to analyze blood flow based on fluctuations in dynamic speckle pattern to detect the movement of particles, specifically red blood cells (Ponticorvo &

Dunn, 2010). The cupping intervention lasted 10 min and was conducted on the lumbar spine at various acupoints. The study occurred in a temperature-controlled environment at 25ºC with no significant air convection to prevent the possibility of temperature measurements being skewed by ambient temperature. Thermal images were taken pre-treatment, immediately post-treatment, and subsequently in 5 min intervals up to 30 min post-treatment. Results indicated a statistically significant increase in blood flow immediately after treatment was concluded, at the site of the cups. The blood flow decreased at every interval following treatment, ultimately returning to baseline, indicating that the increase in blood flow following cupping treatment is likely an immediate effect that is not sustained. It was concluded that the negative pressure on the skin induced by the cups likely caused the increase in cutaneous blood flow during and immediately after the treatment. This study was limited by the lack of a control group and the use of a healthy population as opposed to a pathological one. Considering the vital impact of adequate circulation in promoting healing, it is essential to examine the treatment effects on blood flow in a pathological population (Liu et al., 2022).

Due to the fact that blood flow measures are often complex and may require invasive or expensive equipment and procedures, various studies have examined skin temperature changes as an indicator of increased blood flow (Cage et al., 2020). This outcome was reported by Hertzman (1953), who reviewed the dynamic relationship between blood flow and skin temperature change. In this foundational review, he explained the intimate connection between changes in skin temperature as a result of increased cutaneous blood flow (Hertzman, 1953). This relationship is further supported by the understanding of human thermodynamics, and the concept that increases in blood flow cause an increase in overall body temperature and often result in sweating as a regulation mechanism (Kregel, 2021). Thus, it is understood that increases

in blood flow in the cutaneous surface vessels cause skin temperature adjustments (Vuksanovic et al., 2008). Based on this understanding and the complexity of obtaining blood flow measures, many researchers rely on skin temperature to indicate increased cutaneous blood flow (Cage et al., 2012). Skin temperature measures can be easier to obtain, less costly, and accurately reflect the examined relationship. As a result, skin temperature changes have often been used to indicate blood flow changes within the body (Cage et al., 2012).

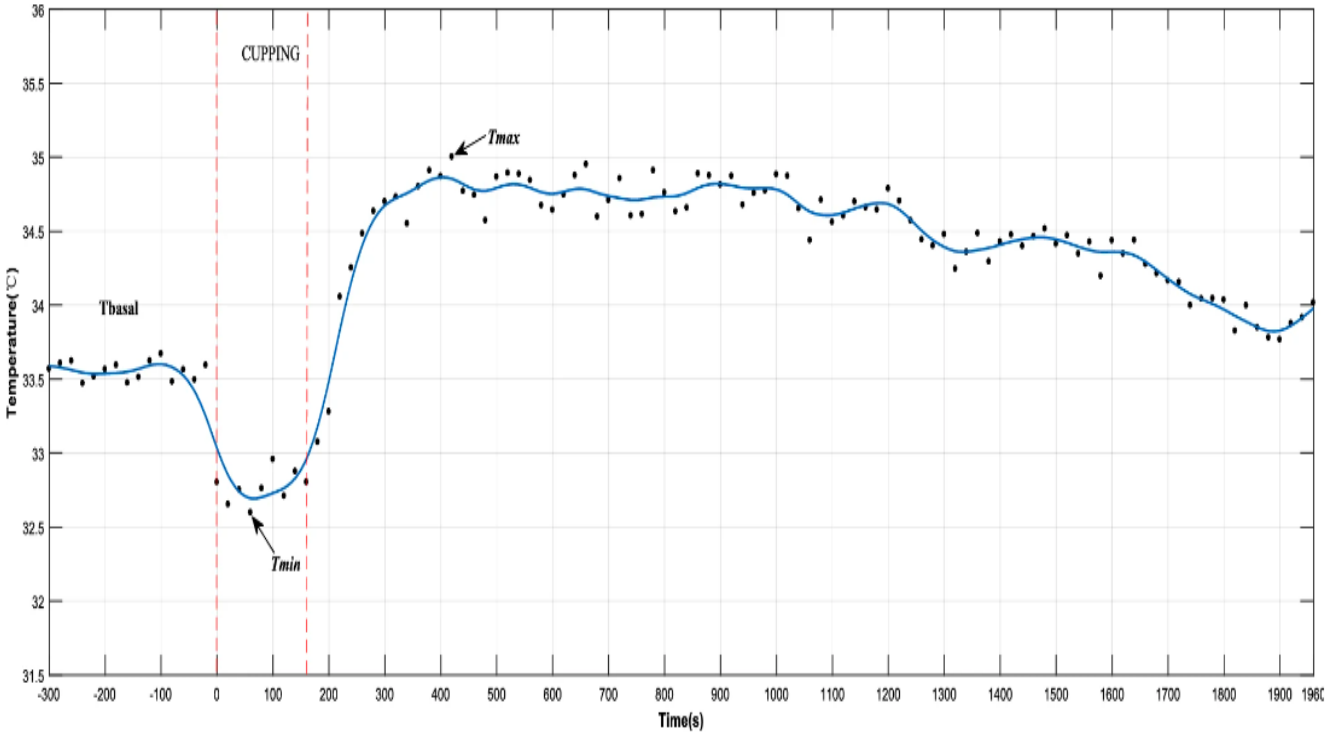
In the context of cupping, the use of an increase in skin temperature as an indicator of warm, oxygenated blood in the treatment area has been employed by various researchers (Cage et al., 2020). Cage et al. examined the relationship between a 15 min dry cupping treatment and the cutaneous temperature of 32 healthy individuals. The cupping intervention occurred on the forearm, and the cups remained static for the entire duration of the treatment. This study took place in a temperature-monitored room (70-75º Fahrenheit; F; 21.1-23.9º Celsius; C), and temperature measurements were taken using an infrared thermometer at the location of the cups. The cups were removed every 5 min throughout treatment for measurements to be taken and recorded, followed by a final measurement at 5 min post-treatment. The results indicated a statistically significant average skin temperature increase of 2º F (approximately 1.1º C) over treatment and an additional 1ºF (approximately .83ºC) 5 min post-treatment. Based on the significant increase in skin temperature during and following treatment, it was concluded that cupping likely leads to an increase in localized blood flow, which is reflected in a slight increase in skin temperature. Studies suggest that when skin temperature rises by approximately 9-13°C, local blood flow can increase by up to nine times its normal rate, although there is not a single definitive temperature threshold that guarantees changes in cutaneous circulation (Hao et al., 2016). The limitations of this study include the fact that it was conducted on a healthy population

and without a control group. Therefore, researchers cannot determine causation between treatment and effect (Cage et al., 2020).

A similar study by Liu et al. (2022) examined skin temperature changes on the forearm following a cupping treatment. The changes in skin temperature were examined as an indicator of increased cutaneous blood flow during and after treatment. Skin temperature measurements were recorded using infrared thermography on 22 healthy individuals. It is important to note that an electric cupping device, a battery-operated tool that automatically applies suction to the skin upon application, was used for the intervention and the results may not be directly comparable to those using standard cupping procedures. The study took place in a temperature-controlled environment with no significant air convection to prevent temperature measurements from being skewed by ambient temperature. The treatment lasted only 3 min and thermal images were taken pre-treatment and immediately post-treatment and, subsequently, in 5 min intervals up to 30 min post-treatment. The dynamic change in skin temperature induced by the negative pressure was divided into three stages to better understand the physiological response. Results indicated a non-linear skin temperature response during and after the cupping treatment (see Figure 5).

Figure 5

Time-dependent Skin Temperature Changes Induced by Cupping Treatment (Liu et al., 2022)



Following the treatment, the monitoring system measured an immediate significant increase in skin temperature (Liu et al., 2022). During the treatment, however, the temperature temporarily decreased which was attributed to the rapid increase in the negative pressure tightening the skin on the edge of the cup, resulting in a decrease of local blood flow and skin temperature. The maximum cutaneous temperature measure was taken almost immediately following the cupping treatment, indicating increased cutaneous blood flow following the treatment. Therefore, these findings further support the notion that skin temperature assessments can indicate increases in blood flow following a cupping treatment. Similar to most studies in this domain, this study was limited by the lack of a control group, which resulted in a limited ability to determine causation between the cupping treatment and the observed increase in skin temperature as an indicator of blood flow. This is important to determine because it allows

researchers to establish a direct effect of treatment. Furthermore, it is essential to note that this study was conducted on a healthy population and cannot be directly compared to a pathological population, such as those experiencing NSLBP. Considering the vital impact of adequate circulation in promoting healing, it is essential to examine this construct in a pathological population (Liu et al., 2022). The effect of dry cupping treatments on cutaneous blood flow increase should be further examined to better understand the specific neurophysiological effects of the treatment on a pathological population and with the use of a control group. Thus, skin temperature as an indicator of blood flow is an important construct to consider when determining the efficacy of dry cupping treatments on individuals with NSLBP. In addition to neurophysiological and physiological measures, when evaluating the effectiveness of physical therapy outcomes, it is crucial to consider the patient's perceived treatment effect throughout the process (Volpicelli Leonard, 2020).

Perceived Treatment Effects

The perceived effect of treatment is a subjective measure described by the impact of treatment on an individual, which can be measured in various forms and may either be qualitative or quantitative in nature (Volpicelli Leonard, 2020). This assessment method is becoming increasingly prevalent in healthcare and other related treatment settings to understand the quality of treatment and care. Understanding patients' perception of treatment effects is critical, as this cognitive appraisal can potentially influence treatment outcomes (Rosenthal & Shannon, 1997). With increased interest in providing patient-centred care, the importance of understanding this construct has also significantly increased (Sidani & Fox, 2020). Practitioners understand that individual perceptions play a critical role in the pursuit and outcomes of treatment interventions. It suggested that research should continue to examine the participants'

perceptions of the impact of the effectiveness of interventions, or lack thereof (Sidani & Fox, 2020).

Despite this universal understanding, limited research has sought to examine this relationship in a physical therapy context. A study by Takahashi et al. (2012) examined patient's attitudes and satisfaction with treatment regarding treatment outcomes for rheumatoid arthritis. This cross-sectional study investigated the perspectives of 220 individuals seeking treatment for rheumatoid arthritis. Self-report questionnaires were used to measure patient satisfaction and attitudes toward treatment, and functional outcomes were assessed using the Stanford Health Assessment Questionnaire. Current satisfaction with the disease state was scored on a 5-point Likert scale from "very satisfied" (1) to "very dissatisfied" (5). Overall, it was concluded that patient attitudes toward treatment were significantly correlated with treatment outcomes, with a large effect, supporting the understanding that patient perceptions may heavily influence physical treatment outcomes (Takahashi et al., 2012).

Another study by Volpicelli Leonard et al. (2020) examined the relationship between the perception of treatment and therapy outcomes in patients experiencing chronic pain-related health conditions. This cross-sectional study employed the use of a self-report questionnaire, which was completed by 1820 individuals with varying chronic health conditions. Electronic survey data was collected on 30 multiple-choice questions, which examined patient demographics, treatment journey, treatment satisfaction, and effectiveness. Satisfaction was measured on a 7-point Likert scale, similar to the Patient Global Impression of Change Scale (PGICS), where responses were rated from "not that effective" (1) to "extremely effective" (7). Results indicated that the perceived effect of treatment and overall satisfaction were highly correlated, suggesting that perceived effect significantly impacts overall patient outcomes

(Volpicelli Leonard et al., 2020). It is important to note that this measurement scale has not been validated, and the study results may not be reliable.

Improving patient outcomes is the goal of any intervention, and evaluating this variable as it relates to cupping therapy is vital in understanding the overall effects of treatment (Stephens, 2022). In the current research, the perceived effectiveness of treatment has primarily been examined from the practitioner's perspective in the context of dry cupping therapy, and still, the findings are limited (Stephens, 2022).

Stephens et al. (2022) investigated the clinical usage, application, and perceived effectiveness of cupping therapy among healthcare professionals in the United States. Through an online survey, healthcare providers were assessed on their cupping therapy usage, application, and effectiveness. Question-response types included multiple-choice, yes or no, select all that apply, numerical values, and heat maps of specific cup application sites. Relevant results indicated that the clinician's perceived benefits of cupping therapy had an average response of 6.85 ± 1.96, which corresponded with "moderately beneficial" to "very beneficial" on a 0 to 10 scale. Furthermore, the average clinician estimation of patient-perceived benefit was 8.18 ± 1.56, corresponding to "highly beneficial". Providers also indicated that the average patient return rate for additional cupping treatments was 82.46 ± 18.18%. It was concluded that healthcare providers perceived dry cupping treatments to improve musculoskeletal conditions (Stephens, 2022).

One study has examined patients' perspectives on the treatment effects of dry cupping. A previously discussed study by Almeida Silva et al. (2022) measured the perceived effect of cupping treatment in a placebo versus intervention cupping design. Semi-structured interviews were used to explore the general perceptions of participants in both groups. Generally, the

perceptions of participants from both groups were quite similar, with positive effects on pain and their overall condition. One significant difference reported between groups indicated that the intensity of pain symptoms remained lower for a longer time following treatment in the intervention group than in the placebo group. However, the majority of reported patient outcomes were similar across groups (Almeida Silva et al., 2022). Despite these findings, understanding the patient's perspective on outcomes must be further examined due to its high influence on positive intervention outcomes (Rosenthal & Shannon, 1997). Therefore, continuing to understand the patient's perspective of cupping therapy and its role in outcomes is critical, especially for individuals suffering from a pain-related condition such as NSLBP.

Perceived Treatment Effect Measurement. As previously discussed, quantifying a patient's appraisal of their condition is challenging due to its subjective nature (Breivik et al., 2008). Therefore, scales have been developed to understand the patient's perceived effectiveness of treatment in a way that can easily make comparisons between pre- and post-treatment changes. Furthermore, the use of a scale allows for simplified interpretation and the ability to quantify patient satisfaction (Breivik et al., 2008). The PGICS is a standard method of measuring intervention outcomes (Bobos et al., 2020). This 7-point Likert scale is a validated measure commonly used by practitioners and requires the patient to reflect on their overall status since the beginning of the treatment and rate it from "very much improved" (rated a 1) to "very much worse" (rated a 7; Guy, 1976). It is a standardized method of measuring patient report outcomes that has demonstrated strong evidence of test-retest reliability (ICC=.84) in patients with LBP and 87% accuracy in classifying patient status (Bobos et al., 2020; Farrar et al., 2001). The MCID for this tool is a 1-unit difference between assessments (Salaffi et al., 2004). Considering the perceived effect of treatment when evaluating an intervention is critical, as this variable has

demonstrated a strong association with the overall effect of treatment (Rosenthal & Shannon, 1997). Therefore, it is crucial to examine the construct of perceived treatment effect when evaluating the effectiveness of dry cupping therapy on individuals with NSLBP.

Dry Cupping Benefits for NSLBP

In summary, dry cupping is an ancient treatment practice with potential benefits for various conditions, including increasing ROM, reducing functional limitations and relieving pain (Markowski et al., 2014). More research is needed to understand its specific mechanisms and effects, especially in a pathological population. Given the prevalence of lower back issues, exploring the impact of dry cupping on the lumbar spine region is of clinical importance. Various studies have sought to examine the effects of dry cupping on various functional outcomes, though very few have done so with a specific focus on individuals experiencing NSLBP (Markowski et al., 2014). Based on previous research, cupping may be an effective strategy to increase ROM and reduce functional limitations experienced by individuals with NSLBP (Almeida Silva et al., 2022). However, the quantity of high-quality research in this domain is limited, and continuing to examine dry cupping treatment effects is crucial to potentially improve patient outcomes (De Melo Salemi et al., 2021).

Furthermore, along with a reduction in mobility and increased functional limitations, many individuals with NSLBP report a high level of pain related to their condition (Ferreira et al., 2023). As previously explained, individuals with NSLBP often seek out treatment that is focused on pain management due to the idiopathic cause of the condition. Based on previous research, cupping may be an effective strategy to reduce the intensity and occurrence of pain and related symptoms (Wood et al., 2020). Many previous findings in this area have been limited by their small sample size, lack of a control group, and the ability to attribute causation between

treatment and effect. Also, only two true RCTs have been conducted with individuals who experience NSLBP and sought to examine the effect of dry cupping on pain thus far (Almeida Silva et al., 2022). Randomized trials are critical in clinical research as they provide the highest level of evidence by minimizing bias, controlling for confounding factors, and establishing causal relationships between interventions and outcomes. Although the results show promise for this treatment, further investigation using this rigorous design is required.

The increased flow of oxygenated blood associated with cupping treatment may also be beneficial for those suffering from NSLBP (Markowski et al., 2014). Since blood carries various nutrients and hormones, stimulating blood flow is crucial in aiding the healing of various pathologies. Blood's natural healing properties, such as promoting cellular detoxification and regeneration, may improve NSLBP conditions (Liu et al., 2022). Further examining this association through skin temperature as an indicator of increased blood flow may be critically important for supporting cupping treatment in individuals with NSLBP.

Finally, limited current research has examined the patient's perspective on the overall treatment effect of cupping interventions (Almeida Silva et al., 2022). Although research has indicated that practitioners perceive the treatment as effective, further investigation of the patient's viewpoint is even more clinically significant. A patient's perceptions may significantly impact the overall effectiveness of an intervention and examining a patient's perspective is of high value and aligns with patient-specific and centred models of care (Stephens, 2022).

Purpose of Research

Non-specific low back pain is a condition that affects a large portion of the population and makes up the largest category of diagnosed back pain (Ferreira et al., 2023). Treating LBP is complex, especially when no known cause exists. Despite various reported modalities and

treatments to address this problem, patients still report persisting symptoms (Maher et al., 2017). Furthermore, with the projected increase in prevalence of musculoskeletal disorders from 494 million to 1060 million in the next 25 years, there is a critical need to address this issue (Gill, 2023a). Dry cupping may be an effective adjunct treatment strategy to decrease pain and increase mobility for those with NSLBP (Markowski et al., 2014). Despite the long history of cupping practice, its novel introduction to Western practice and medicine issues a requirement for further examination of specific effects, especially in a pathological population to better address the need for effective NSLBP treatment practices (Wood et al., 2020).

Objectives

This study aimed to determine the short-term effects of dry cupping the lumbar paraspinal muscles on lumbar spine ROM, pressure pain threshold, subjective pain perception, blood flow as indicated by skin temperature, perceived treatment effect, and overall function in individuals with NSLBP.

Research Questions

The following research questions were developed to guide this study:

1) What are the short-term effects of dry cupping the lumbar paraspinal muscles on lumbar spine ROM as measured by the Sit and Reach Test in individuals with NSLBP (ROM construct)?
2) What are the short-term effects of dry cupping the lumbar paraspinal muscles on lumbar spine ROM as measured by inclinometry in individuals with NSLBP (ROM construct)?
3) What are the short-term effects of dry cupping the lumbar paraspinal muscles on pressure pain threshold as measured by algometry in individuals with NSLBP (pain construct)?

4) What are the short-term effects of dry cupping the lumbar paraspinal muscles on subjective pain perception as measured by the NPRS in individuals with NSLBP (pain construct)?
5) What are the short-term effects of dry cupping the lumbar paraspinal muscles on blood flow to the paraspinals as indicated by a change in skin temperature and measured by a laser thermometer in individuals with NSLBP (skin temperature construct)?
6) What are the short-term perceived treatment effects of dry cupping the lumbar paraspinal muscles as measured by the PGICS in individuals with NSLBP (perceived treatment effect construct)?
7) What are the short-term effects of dry cupping the lumbar paraspinal muscles on overall function as measured by the Roland-Morris Questionnaire in individuals with NSLBP (function construct)?

Chapter 2 – Methods

The CONSORT guidelines were used to design and implement this randomized trial (Schulz et al., 2010).

Trial Design

This study had a parallel design with two groups including placebo and intervention, therefore, it was a parallel group randomized clinical trial. The allocation ratio was 1:1.

Participants

Recruitment

This project was submitted for ethical review to the Thunder Bay Regional Health Sciences Center Ethics Review Board; once ethics was approved, the study was registered as a single-blind randomized clinical trial on Clinicaltrials.gov (NCT06469762). After the registration was completed, prospective participant recruitment began.

The participants that were included in this study met the following criteria:

1. Males and females (based on sex at birth);
2. Between the ages of 18 - 55 years;
3. Experiencing NSLBP, confirmed by their care provider (chiropractor, physiotherapist, or medical physician); and
4. Otherwise healthy, and successful completion of the Get Active Questionnaire (GAQ) with no contraindications for physical activity.

Should the participant have been currently receiving treatment for NSLBP or for another musculoskeletal condition, a washout period of 2 days (48 hours) was ensured between their treatment and study participation (Bell, 2024).

Participants were excluded from the study if they met any of the following criteria:

1. Any individual with a specific low back or lower body condition (i.e., spondylolisthesis, spinal stenosis, osteoporosis, or intervertebral disk derangement);
2. Any individual with a previous or scheduled surgery to the lower body, which may affect their hip and/or knee ROM;
3. Any individual who was diagnosed with cancer;
4. Any individual who was experiencing referred leg symptoms;
5. Any individual who was confirmed or suspected to be pregnant; and
6. Any individual with a confirmed or suspected blood/blood clotting disorder (i.e., hemophiliac).

Sample Size

A total of 52 participants (26 in the placebo group and 26 in the intervention group) were recruited for this study. Based on an a priori power analysis using a sample size calculator for RCTs, this number was sufficient to detect a medium to large effect size with 80% power at α=.05 (EasyMedStat, 2022). The confidence interval was set to 95%, the margin of error was set to 5%, and the power was set to 80%. The number of groups was set to two (placebo versus intervention), and a conservative assumption of 20% dropout was implemented in the calculation. The primary variable used to compute sample size based on the priori power of analysis was pain (pressure pain threshold), therefore, the subsequent information was inputted based on the findings from the study conducted by Lauche et al. (2011), which stated a significant difference in pain measurements between a cupping intervention and control group, with a large effect size (d=1.4). The mean and standard deviation values for the intervention (M=26.1, SD=22.7) and control group (M=47.1, SD=19.8) were inputted, and the analysis stated that with an alpha level of .05, a sample size of 46 participants (23 per group) or more is needed

to have a confidence level of 95% in detecting statistical significance, therefore, the goal was set at 50, with maximum recruitment being optimal.

Participants were recruited using purposive and convenience sampling for access to a pathological population. Snowball sampling was also utilized as participants were encouraged to refer other individuals who met the inclusion criteria. Recruitment methods included recruitment posters, which were posted throughout Lakehead University and at various local chiropractic and physiotherapy clinics, as well as on social media including Instagram© and Facebook© pages. The poster included the study's title, purpose, procedures, and inclusion/exclusion criteria. The student researcher's contact information was also provided (see Appendix A).

Instrumentation and Equipment

The following instrumentation and equipment were used for data collection:

Examination Table

An examination table was used during the cupping treatment. The participants lay prone on the table for 10 min while the cups remained on their lumbar spine.

Hansol Professional Cupping© Therapy Equipment Set

The cups used were made of high-quality transparent plastic. This allowed the student researcher to monitor changes to the skin through the clear plastic throughout treatment. The suction within the pumps was increased using a hand pump. Each cup was pumped three full times for consistency across all participants. Four cups were used on each participant and placed superior and inferior to the participant's identified problem areas (P1 and P2), which will be later described (see Appendix B). The student researcher was trained and certified to provide cupping treatment by Cupping Canada© Inc. (see Appendix C).

Canon™ Sports Skin Adhesive Spray

The Canon™ Sports skin adhesive spray is a soft tissue lubricant that was used to increase the seal between the cups and the surface of the skin. This was used to improve the degree of suction and adherence to the skin. It also ensured that the cups remained suctioned to the skin in the placebo condition (see Appendix D).

Sit and Reach Device

The Sit and Reach Device was used as a pre-and post-treatment measurement method of lumbar spine flexibility. The lumbar spine flexion ROM was measured in cm before and immediately after the cupping treatment.

Maximum™ (Model N08064) Laser Thermometer

The Maximum™ (Model N08064) Laser Thermometer was used to measure lumbar spine skin temperature pre- and post-treatment. This was measured in degrees (deg) ºC before and immediately after the cupping treatment at the locations of the participant's identified problem areas (P1 and P2), which will be later described. The mean of the measurements was taken and recorded. This tool has an accuracy of ±1 to ±2 ºC (±2 to ±4 ºF; Gill, 2023b).

Numeric Pain Rating Scale

The NPRS is a validated self-report pain questionnaire commonly used in treatment. It is simple to interpret and allows for easy comparison between multiple values, such as pre- and post-treatment (see Appendix E). It requires the participant to rate their subjective pain experience from 0 (no pain) to 10 (worst possible pain). It was used to measure subjective pain perception in written form in real-time, both pre-and post-treatment. Reliability and validity discussed on page 37.

Patient Global Impression of Change Scale

The PGICS is a validated self-report questionnaire commonly used by practitioners to assess a patient's treatment experience (see Appendix F). This 7-point Likert scale requires the patient to reflect on their overall status since the beginning of the study/treatment and rate it from "very much improved" (1) to "very much worse" (7). It was used in the post-treatment analysis to assess a patient's overall perceived effectiveness of the treatment. Reliability and validity discussed on page 48.

Wagner Force One™ Digital Force Gauge

The Wagner Force One™ Digital Force Gauge was used to measure the pressure pain threshold (algometry). It is considered the gold standard for measuring pain (Salom-Moreno et al., 2024). The pressure pain threshold was first measured in a non-painful area identified by the participant (e.g. deltoid) to establish a baseline, which was recorded. Next, it was measured at the participant's identified problem areas (P1 and P2; which will be later described) and an average of the two measurements was taken and recorded, both pre- and post-intervention.

Rolland-Morris Questionnaire

The Roland-Morris Questionnaire is a validated measure commonly used by practitioners to assess physical disability caused by LBP (see Appendix G). It is a self-report questionnaire that is scored to obtain a functional score. The participant was asked to indicate when a statement applied to them that specific day, making it possible to follow changes in time. The end score was the sum of the ticked boxes. The score ranged from 0 (no disability) to 24 (maximum disability).

Get Active Questionnaire

The GAQ is a screening tool developed by the Canadian Society for Exercise Physiology© (CSEP©; see Appendix H). This tool aims to assess individual health status and related medical information that may prevent them from safely engaging in physical activity. It is a self-administered questionnaire applicable to all age groups and physical activity levels, which was used to clear participants for study involvement. Upon completing the questionnaire, the student researcher reviewed the forms to ensure it was safe for the participant to engage in the study.

Tyenaza© Digital Inclinometers

The Tyenaza© digital inclinometer is a device used to measure joint angles in deg (º). Two of these devices were used to measure the deg of lumbar spine flexion the participant achieved prior to and immediately following the cupping treatment. The placement of the inclinometers was 3 cm on either side of the L1 and L5 vertebrae (see Appendix I).

Measuring Tape

A measuring tape was used to find the location 3 cm on either side of the L1 and L5 vertebrae to determine the placement of the inclinometers.

Hydrogen Peroxide Solution

A 3% hydrogen peroxide solution was used to safely clean the plastic cups following each participant. This solution was created by combining one part 35% hydrogen peroxide with 11 parts water.

Procedures

A detailed information letter was provided after potential participants contacted the student researcher regarding their interest in the study. The information letter included details pertaining to the study, including the purpose, procedures, duration, potential session availabilities, and the location at which the research took place (see Appendix J). If the prospective participant continued to demonstrate an interest in engaging in the study, they arranged an appropriate time to meet with the student researcher for data collection. Three sessions were scheduled, each approximately 48 hours apart (e.g., Monday, Wednesday, and Friday). Each session lasted about 30 min and took place at Lakehead University in the School of Kinesiology Sanders Building in room SB-1025.

Randomization

Randomization involves randomly assigning each participant in the study to a certain group (National Cancer Institute's Division of Cancer Prevention, 2024). This process is intended to ensure that all potential confounding variables are equally distributed among groups, as well as to ensure homogeneity of variance across differing groups (Faltin et al., 2018). Various methods may be used to randomize participant assignment, such as simple randomization, block randomization, or stratified randomization (Faltin et al., 2018). One standard method is asymptotic maximal randomization, which was used in the current study. When using this technique each participant is randomly assigned to a treatment group, typically using a random number generator, with consideration for the number of participants already assigned to each group (National Cancer Institute's Division of Cancer Prevention, 2024). The goal of asymptotic maximal randomization is to achieve a balance between treatment groups in a study, even as the sample size becomes very large. This approach ensures that the treatment groups are comparable,

which is crucial for the validity of the study's conclusions (National Cancer Institute's Division of Cancer Prevention, 2024).

Sequence Generation. In the context of this study, participants were randomly assigned to either a placebo or intervention group, which was decided prior to the session. This was done using a clinical randomization tool developed by the National Cancer Institute's Division of Cancer Prevention (https://ctrandomization.cancer.gov; 2024). Values were inputted based on the target participant count (50) and the number of groups (intervention versus placebo). Asymptotic maximal randomization was used, which means the probability of group assignment depended on the imbalance between the group sizes. The asymptotic maximal procedure used fixed allocation probabilities set within the online generator. The maximum tolerated imbalance was set at two, meaning that the difference in the number of participants between groups never exceeded two. The sequence was stratified by sex to maintain a balance between males and females in each group (National Cancer Institute's Division of Cancer Prevention, 2024).

Following the randomization of the participant assignment sequence, individuals were appropriately allocated to their respective groups.

Allocation

Allocation involves a technique that chooses individuals for treatment groups and control groups or placebo groups (National Cancer Institute's Division of Cancer Prevention, 2024). It employs a specific technique to generate a sequence that specifies how participants will be assigned to their respective groups (Dettori, 2010). The allocation process is essential to ensure that each participant has an equal chance of being assigned to each possible group option, thereby reducing the risk of selection bias (Faltin et al., 2018). The allocation process may be subdivided into two separate procedures: concealment and implementation (Dettori, 2010).

Concealment is the process of hiding the randomization sequence from those assigning the participants to groups, in order to prevent the possibility of selection bias (Friedman et al., 2010). This technique is commonly done using a computer program that assigns participants to groups without the sequence being known to the researcher. The sequence is then placed in sealed opaque envelopes, numbered sequentially, with one participant assignment per envelope. This is done by a third party so that the researcher remains blind to the assignment until the session begins, thus supporting a single-blind design (Friedman et al., 2010). Implementation involves assigning participants to each group based on the pre-determined random sequence without deviation (Dettori, 2010).

Concealment Mechanism. In the context of this study, allocation was accomplished using the same tool that the researchers used for randomization. A generated output file indicating participant assignment was produced and used to determine participant grouping as enrollment occurred (National Cancer Institute's Division of Cancer Prevention, 2024). The sequence was then separated and placed into opaque envelopes by a third party, with one assignment per envelope.

Implementation. In each initial session, after informed consent was obtained, the researcher opened one envelope to indicate the participant's group assignment. This was done sequentially, and there was no deviation from the pre-determined generated sequence.

Blinding. The participants remained blinded to their group assignment for the duration of the study, including all three treatment sessions. At the outset of the study, should the participants have been in the placebo group, they were offered the opportunity to receive treatment upon the completion of the final data collection session.

Following all data collection, data was analyzed using intention-to-treat analysis.

Intention-to-Treat Analysis

Intention-to-treat analysis is a principle used in the analysis of randomized clinical trials that involves analyzing the data based on the initial treatment assignment and not on the treatment eventually received (Balakrishnan, 2014). This means that all participants are included in the group they were initially randomized to, regardless of whether they completed the treatment, adhered to the protocol, or switched to a different treatment. This type of analysis intends to maintain the benefits of randomization by preserving the initial group assignment, regardless of protocol deviance or dropouts, thereby ensuring limited risk of bias (Brody, 2016). Including all participants in the intention-to-treat analysis minimizes selection bias and attrition bias, making the results more generalizable (Balakrishnan, 2014). Furthermore, this type of analysis includes a procedure for handling missing data or participant dropout, which is estimated to be approximately 20% (Gupta, 2011; EasyMedStat, 2022). A common strategy for this scenario, known as the Expectation-Maximization Algorithm, uses a mathematical algorithm to accurately estimate the missing value with a limited risk of bias (Murphy, 2012). Ultimately, this allows all participants to remain in their original assigned group and provides a more realistic estimate of the treatment effect. It includes all participants and reflects the practical challenges of treatment adherence and protocol deviations in clinical practice (McCoy, 2017).

Intention-to-treat analysis was used to analyze the participants within this randomized clinical trial. The participants were analyzed according to the groups to which they were originally assigned in order to provide a more accurate and unbiased analysis of treatment outcomes (McCoy, 2017). Should the participant have missed one or more of the subsequent treatment sessions, their data from the missed sessions would have been replaced by using an algorithm that alternates between estimating the missing data and updating the model's

parameters based on those estimates until the parameters converge to the best fit for the data (Murphy, 2012). In the case of dropout, the same procedure would have been followed for each respective treatment session. However, should the participant have dropped out and requested that their data be removed from the study, this wish would have been honoured. Throughout this study, no sessions were missed and there was a 0% dropout rate, therefore, the procedure for missing data was not required nor employed.

Interventions

Consent and Demographics. The procedures remained the same for both the individuals in the intervention and placebo conditions. However, those in the placebo condition received cups with two 2 mm holes drilled in either side of them so that the suction was immediately released upon application. In the initial session, the potential participant reviewed and signed the provided consent form (see Appendix K). The student researcher also explained the ability to withdraw from the study at any time without penalty. After informed consent had been given, the researcher opened an opaque envelope to indicate the participant's group assignment as previously described, and the participant remained blind to the assignment. At this point, the participant completed the GAQ (see Appendix H) and a Participant Demographic form, including their gender, sex, and age. Height and body mass were also measured and recorded (see Appendix L). Should the participant have responded "Yes" to any question on the GAQ, they would have been required to obtain clearance from their medical provider prior to participation. No participants were required to obtain medical clearance.

Landmarks. At this point, the intervention began, and the participant was asked to lie prone on the examination table with their lumbar spine exposed. The student researcher landmarked the L1 and L5 vertebrae and marked these locations with a skin-safe marker. This

was located by palpating the iliac crests and following them directly inward to landmark the spinous processes of L4 (Duniec et al., 2013). From there, L5 was marked one thumb-width downward from the spinous process of L4, and L1 was marked three thumb-widths up the spine (Duniec et al., 2013). Next, the student researcher measured 3 cm on each side of the landmarked spinous processes of L1 and L5 using the measuring tape. This was done to determine where the inclinometers were placed, and all four locations were marked using a marker. Next, the participant was asked to identify their primary location of LBP (by pointing to the area; e.g., right side of L3), this area was marked using a marker and represented problem area one (P1). The participant was then asked to name their secondary location of LBP (by pointing to the area; e.g., left side of L4), this area was marked using a marker and represented problem area two (P2).

Skin Temperature. After the locations had been marked, baseline measurements were taken. The skin temperature of the lumbar spine was taken using the Maximum™ Laser Thermometer at P1 and P2, and the mean skin temperature was calculated and recorded to the nearest tenth of a deg (with no cups on the skin).

Pressure Pain Threshold. Following that, the pressure pain threshold was measured using the Wagner Force One™ Digital Force Gauge. Firstly, the participant was asked to identify an area of no pain (e.g., the deltoid, triceps, or gastrocnemius muscle), and the location was marked with a washable skin-safe marker. The pressure pain threshold was measured at the indicated location by slowly applying pressure to the marked area using the gauge, perpendicular to the surface. The participant was instructed to indicate when the feeling of pressure transitioned to a feeling of pain. At this point, the result indicated on the gauge was recorded to the nearest tenth of a N and the pressure was released. This was done to establish a baseline in an area of no

pain and to familiarize the participant with the measurement tool. The identified baseline area remained the same throughout all three sessions. Next, measurements were taken at P1 and P2, and the two measurements were recorded to the nearest tenth of a N. The average of the two values (P1 and P2) was also taken and recorded.

Dual Inclinometry. Next, the participant was asked to stand, and two inclinometers were placed on the L1 and L5 landmarks on the right side of the spine. The participant was instructed to flex forward as far as comfortably possible trying to reach for the ground, maintain a very slight bend in the knees. The mean of the two values measured by the inclinometers was recorded to the nearest tenth of a deg. This was completed again with the inclinometers on the left side of the spine, and the mean of both the L1 and L5 values was recorded to the nearest tenth of a deg. Following the measurements on both sides of the spine, the mean of the right and left side measurements were recorded.

Sit and Reach Test. Finally, the participant completed the Sit and Reach Test using the Sit and Reach Device. The Sit and Reach Test was conducted by instructing the participant to remove their shoes and sit on the floor with their back against a wall and legs out straight in long sitting (Mayorga-Vega et al., 2014). The feet were placed into the foot pedals, and the participant was asked to clasp their hands resting on the metal measuring piece. The participant was asked to keep their legs flat, and feet pressed against the pedals. They were then asked to reach forward as far as possible, pushing the metal measuring piece with their fingertips. After three warm-up trials, the participant held the fourth trial for 3 sec, and the measurement was recorded to the nearest tenth of a cm.

NPRS and Roland-Morris Questionnaire. The participant completed the NPRS and was asked to indicate their overall current LBP (considering both P1 and P2 together) on a scale

from 0 to 10. Finally, the participant completed the Roland-Morris Questionnaire, to assess their overall function.

Cupping Treatment. Following the baseline measurements, the cupping treatment began. Once again, the participant was asked to lie prone on the examination table. The student researcher applied a light layer of Canon™ Sports skin adhesive spray to the participant's lumbar spine at the four cupping locations. This was used to improve suction. Four medium-sized Hansol© plastic cups were placed superior and inferior to P1 and P2 (i.e., superior to P1, inferior to P1, superior to P2, inferior to P2). Each cup was pumped three times using the hand pump for consistent suction (465 mmHg of pressure; Lee et al., 2021). The cups were then left in a static position for a total of 10 min. After the treatment was concluded, the suction was released, and the cups were removed and placed into a bin to be later disinfected by the hydrogen peroxide solution.

Repeating Baseline Measures. Immediately following the cupping intervention, after the cups had been removed, the skin temperature of P1 and P2 were retaken using the Maximum™ (Model N08064) Laser Thermometer, and the mean was recorded. The pressure pain threshold was once again measured using the Wagner Force One™ Digital Force Gauge first at the non-painful site, followed by P1 and P2 and the dual inclinometry lumbar flexion and Sit and Reach Test were also repeated. The post-intervention results were recorded as described previously and in the same order. The participant also completed the NPRS once again and was asked to indicate their current LBP on a scale from 0 to 10. Next, they completed the Roland-Morris Questionnaire, to assess their overall function, and finally, they completed the PGICS and were asked to reflect on their treatment experience and indicate if their condition was "very much improved" (rated a 1) to "very much worse" (rated a 7).

Final Procedures. Following the completion of the final test, the participant was thanked for their involvement and offered to receive a copy of the results at the completion of the study. If the participant wished to receive the information, their email address was recorded to forward the results at a later date. Once the participant left, the student researcher disinfected the table, inclinometers, and Sit and Reach Device using a disinfectant spray. The cups were washed in a bin of warm water with dish detergent. After they were rinsed, they were dried with a paper towel and placed into the pre-mixed 3% hydrogen peroxide solution for 10 min. After 10 min, the cups were removed and set aside to dry before being used on the next participant (Kohlmeier, 2018).

Second and Third Sessions. In the second and third sessions (approximately 48 and 96 hours following the initial sessions, respectively), the procedures were repeated as previously described, with the exclusion of the consent form, GAQ and Patient Demographic Form. Following the final data collection session, those in the placebo group were offered an opportunity to receive the cupping treatment. The participants were then thanked for their involvement, and a copy of the results were emailed to them at a later date, if requested.

Outcomes

The primary outcome measure was pain, which was assessed using the NPRS and pressure pain threshold at six time points (pre-intervention and post-intervention in sessions 1, 2, and 3).

The secondary outcome measures included ROM measured using inclinometry and the Sit and Reach Test, skin temperature as an indicator of blood flow measured using a laser infrared thermometer, perceived treatment effect measured using the PGICS, and overall function measured using the Roland-Morris Questionnaire. These measures were also assessed at

six time points (pre-intervention and immediately post-intervention in sessions 1, 2, and 3), with the exception of perceived treatment effect which was only assessed three times (post-treatment in sessions 1, 2, and 3).

Data Analysis

For the purpose of data analysis, all raw data obtained from the Sit and Reach Test, Tyenaza© Inclinometers, Maximum™ (Model N08064) Laser Thermometer, Wagner Force One™ Digital Force Gage and self-report scales was inputted into a Microsoft® Excel® spreadsheet to allow for the proper management of data.

Statistical Analysis

Statistical analysis was conducted using IBM® SPSS® Statistics 28. Descriptive statistics were used to determine the mean and standard deviation values for the variables of interest and inferential statistics were analyzed with the alpha level set at .05.

To answer the research questions 1, 2, 3, 4, 5, and 7, a three-way mixed factorial analysis of variance (ANOVA) was used for each question individually. This statistical test was conducted to compare the interaction effect of the independent variables treatment group (intervention versus placebo), session (treatment 1, treatment 2, and treatment 3), and time (pre-intervention versus post-intervention) on the dependent variables of interest, respectively (lumbar ROM as measured by the Sit and Reach Test (cm), lumbar ROM as measured by inclinometry (°), pressure pain threshold as measured by algometry (N), skin temperature as measured by a laser thermometer (°C), subjective pain as measured by the NPRS, and overall function as measured by the Roland-Morris Questionnaire).

If the analysis revealed a statistically significant interaction effect among the three independent variables, two-way ANOVAs were conducted to help explain the interaction by

examining the effect of group and time across treatment sessions. If the three-way interaction was not significant then individual two-way interactions were examined between the independent variables (session and treatment group, treatment group and time, and time and session). One-way ANOVAS for repeated measures, t-tests for independent and repeated measures were conducted to help explain main effects and interactions.

To answer research question 6, a two-way mixed factorial analysis of variance (ANOVA) was used. This statistical test was conducted to compare the interaction effect of the independent variables: treatment group (intervention versus placebo) and session (treatment 1, treatment 2, and treatment 3), on the dependent variable of interest, perceived treatment effect (as measured by the PGICS). For this statistical test, the alpha level was set at .05.

If the analysis revealed a statistically significant interaction effect between the independent variables, multiple one-way repeated measures ANOVAs were performed to examine the simple main effects and identify differences between the sessions for each treatment group, respectively. Bonferroni's post hoc was used for pairwise comparisons across the three sessions.

Chapter 3 – Results

The results of this study provide evidence that dry cupping the lumbar paraspinal muscles may have short-term effects on lumbar spine ROM (Sit and Reach Test), lumbar flexion (inclinometry), pressure pain threshold (algometry), subjective pain perception (NPRS), skin temperature (laser thermometer), perceived treatment effect (PGICS), and overall function (Roland-Morris Questionnaire) in individuals with NSLBP, comparing outcomes between intervention and placebo groups across three treatment sessions.

Demographic Information and Participant Flow

A total of 52 participants completed this study and were randomly assigned to their respective groups (26 in the placebo group and 26 in the intervention group). An analysis of demographic variables was conducted at baseline; there were no differences between groups. Participant demographic data is presented in Table 1.

Table 1.

Participant Demographics

	Number of Participants	**Mean Height (cm)**	**Mean Body Mass (kg)**	**Mean Age**
Male	21	180.2 (11.4)	83.5 (11.6)	27.9 (14.2)
Female	31	164.1 (10.8)	66.0 (15.4)	33.0 (11.)
Total	52	170.6 (11.0)	73.3 (13.9)	31.3 (13.1)

Missing Data, Recruitment, Baseline Data, and Numbers Analyzed

There was no missing data to report. Recruitment began following ethical approval in November of 2024 and continued for 6 months until April of 2025 as 6 months is standard procedure for Randomized Clinical Trials. Baseline data is included in the graphs for each research question, with one graph for both groups (intervention versus placebo). Each group had

26 participants included in analysis and the analysis was conducted based on original assigned groups as previously described.

Outcomes and Estimation

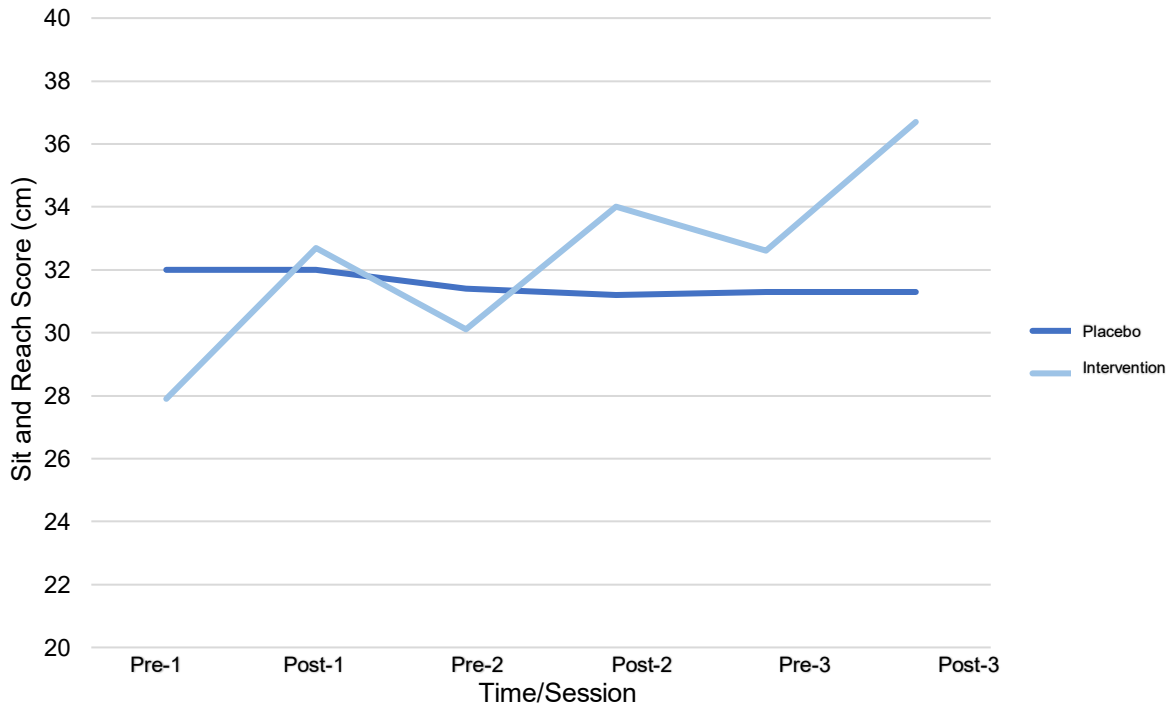
Research Question 1: What are the short-term effects of dry cupping the lumbar paraspinal muscles on lumbar spine ROM as measured by the Sit and Reach Test in individuals with NSLBP?

Descriptive statistics revealed that individuals in the placebo group had a mean Sit and Reach score of 31.9 cm (SD=8.0) pre-intervention in session 1, which decreased to 31.3 cm (SD=10.0) post-intervention in session 3, indicating a decrease of 0.6 cm across the 3 sessions (see Figure 6). Individuals in the intervention group had a mean Sit and Reach score of 28.0 cm (SD=8.0) pre-intervention in session 1, which increased to 36.8 cm (SD=10.0) post-intervention in session 3, indicating an increase of 8.8 cm across the 3 sessions (see Figure 6). An increase in Sit and Reach Test scores indicates an increase in range of motion.

The observed Sit and Reach Test score increase in the intervention group also exceeded the MDC of 1.13 - 1.74 cm for the Sit and Reach Device, indicating that the application of dry cupping resulted in clinically significant improvements in lumbar spine range of motion. The Sit and Reach score decrease in the placebo group did not exceed this value, suggesting the application of the placebo intervention did not affect lumbar spine range of motion.

Figure 6

Pre-Intervention Versus Post-Intervention Sit and Reach Scores Across all Three Sessions for the Placebo Group and Intervention Group



Z-scores and boxplot inspection revealed no outliers in either treatment group. Prior to further analysis, Mauchly's Test of Sphericity was used to ensure equal variance between both groups. Since this assumption was violated, the Greenhouse-Geisser correction was applied. A three-way mixed factorial ANOVA was used to compare the interaction effect between the three independent variables (treatment group, time, and session) on Sit and Reach Test scores (see Figure 6). The analysis revealed no statistically significant interaction effect between the three variables (treatment group, session and time; $F(1.720, 26)=1.172$, $p=.309$, $\eta^2=.023$) on Sit and Reach scores, with a small effect size. Further analysis revealed statistically significant two-way interactions between session and treatment group, ($F(1.8949, 26)=29.603$, $p<.001$, $\eta^2=.372$) as

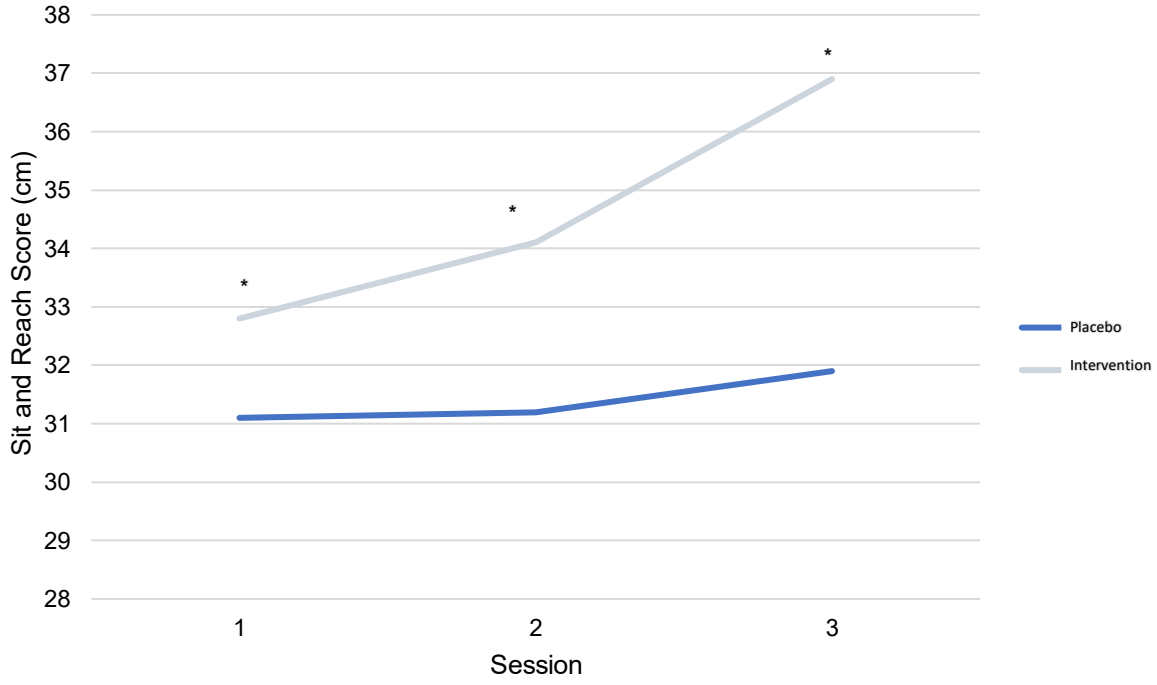
shown in Figure 7 and treatment group and time, ($F(1, 26)=126.968$, $p<.001$, $\eta^2=.717$), with a large effect size as shown in Figure 8, but no statistically significant two-way interaction between session and time, ($F(1.720, 26)=2.266$, $p=.117$, $\eta^2=.043$), with a small effect size.

To help explain the two-way ANOVA interaction in Figure 7, multiple one-way repeated measures ANOVAs were performed to examine the simple main effects and identify differences between the sessions (1, 2, and 3) for each treatment group (placebo versus intervention). The analysis revealed a significant difference between the mean Sit and Reach scores across the three sessions for individuals in the intervention group ($F(1.588, 26)=36.580$, $p=<.001$, $\eta^2=.594$), with a large effect size, but a no statistically significant differences between mean Sit and Reach scores across the three sessions for individuals in the placebo group ($F(1.559, 26)=1.803$, $p=.184$, $\eta^2=.067$), with a medium effect size.

A Bonferroni pair mean comparison analysis revealed significant differences between sessions 1 and 2 ($p<.001$, CI: [-2.142, -.397]), sessions 2 and 3 ($p<.001$, CI: [-4.122, -1.417]) and sessions 1 and 3 ($p<.001$, CI: [-5.458, -2.619]) for the intervention group (see Figure 7 and Table 2 in Appendix N). There were no statistically significant differences observed for the placebo group.

Figure 7

Sit and Reach Scores for Each Treatment Group (Placebo Versus Intervention) Compared Across Sessions One, Two, and Three

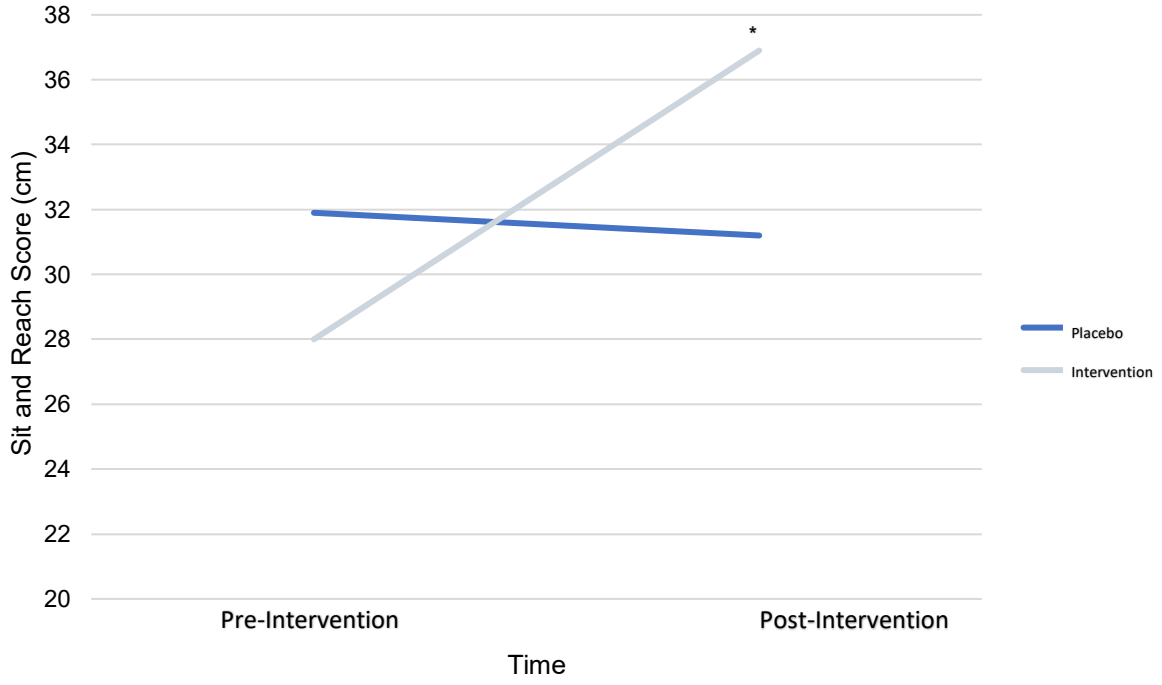


Note: * denotes statistical significance

To help explain the two-way ANOVA interaction in Figure 8, multiple t-tests for the independent measures were performed to identify differences between each treatment group (placebo versus intervention) for the two time intervals (pre-and post-intervention), respectively. A significant difference was revealed between the two treatment groups for the post-intervention scores ($t(26)=-2.114$, $p=0.04$, $d=-0.586$, CI[-10.87616, -.27769]), with a medium effect size, but not the pre-intervention scores ($t(26)=1.686$, $p=0.098$, $d=0.468$, CI[-.75804, 8.68111]; see Figure 8), with a medium effect size.

Figure 8

Sit and Reach Scores for Each Treatment Group (Placebo Versus Intervention) Compared Across Time (Pre- and Post-Intervention)



Note: * denotes statistical significance

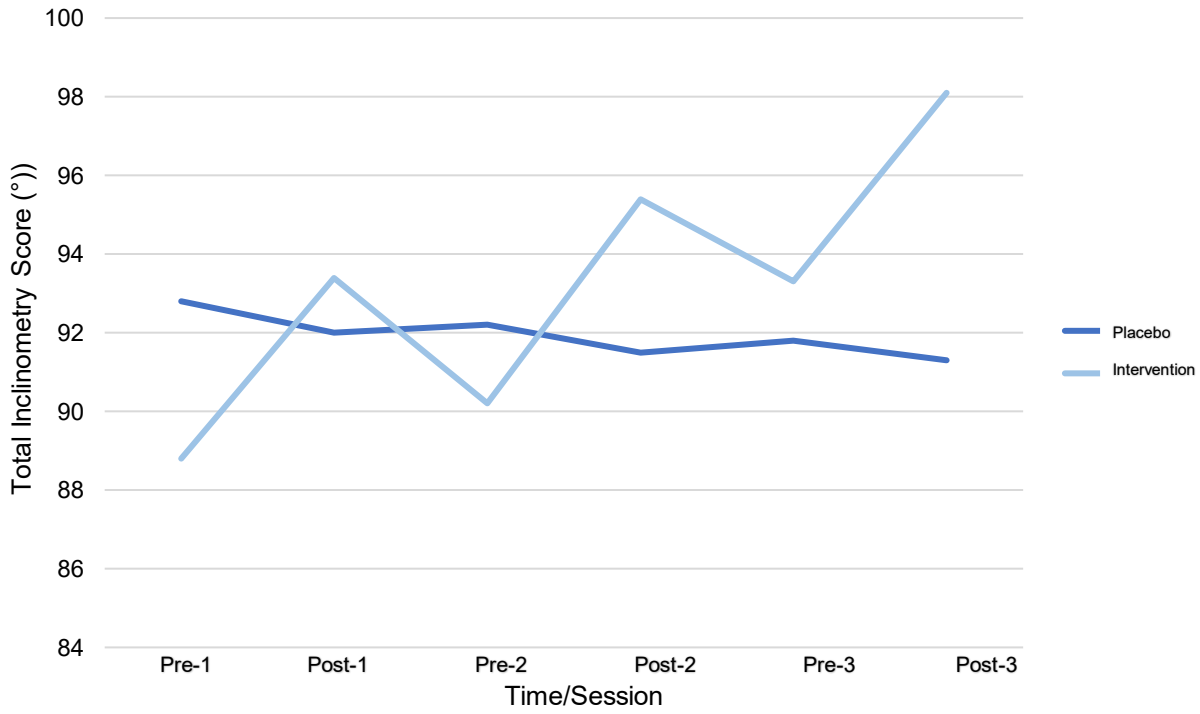
Research Question 2: What are the short-term effects of dry cupping the lumbar paraspinal muscles on lumbar spine ROM as measured by inclinometry in individuals with NSLBP?

Descriptive statistics revealed that individuals in the placebo group had a mean inclinometry score of 92.5° (SD=8.0) pre-intervention in session 1, which decreased to 91.2° (SD=8.0) post-intervention in session 3, indicating a decrease of 1.3° across the 3 sessions (see Figure 9). Descriptive statistics indicated that individuals in the intervention group had a mean inclinometry score of 88.8° (SD=7.0) pre-intervention in session 1, which increased to 98.3° (SD=8.0) post-intervention in session 3, indicating an increase of 9.5° across the 3 sessions (see Figure 9). An increased inclinometry score indicates an increase in ROM of the lumbar spine.

The observed inclinometry score increase in the intervention group exceeded the MDC of 1.50° - 3.41° for the inclinometers, indicating that dry cupping resulted in clinically significant changes in lumbar spine ROM. The inclinometry score decrease in the placebo group did not exceed this value, indicating that lumbar spine ROM did not change with the application of the placebo intervention.

Figure 9

Pre-Intervention Versus Post-Intervention Total Lumbar Flexion Inclinometry Scores Across all Three Sessions for the Placebo Group and Intervention Group



Z-scores and boxplot inspection revealed no outliers in either treatment group. Prior to further analysis, Mauchly's Test of Sphericity was used to ensure equal variance between both groups. Since this assumption was violated, the Greenhouse-Geisser correction was applied. A

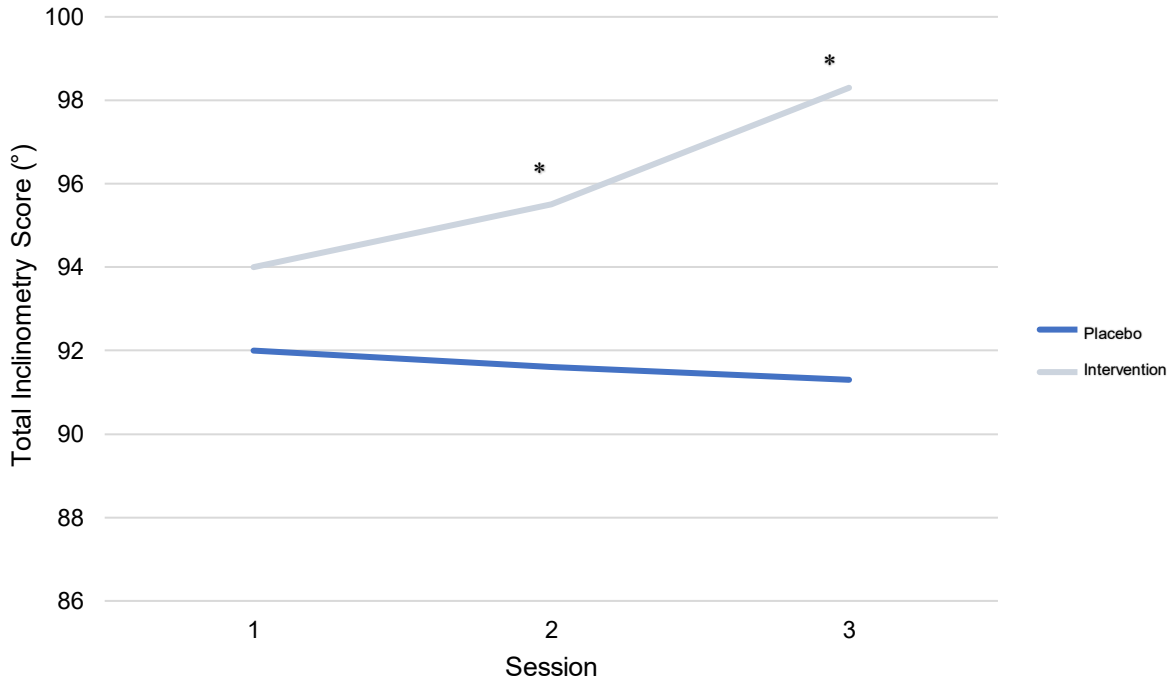
three-way mixed factorial ANOVA was used to compare the interaction effect between the three independent variables (treatment group, time, and session) on inclinometry scores. The analysis revealed no statistically significant interaction effect between the three variables (treatment group, session and time; $F(1.766, 26)=.206$, $p=.787$, $\eta^2=.004$) on inclinometry scores, with a small effect size. Further analysis revealed a statistically significant two-way interaction between session and treatment group, ($F(1.558, 26)=25.207$, $p<.001$, $\eta^2=.335$) and treatment group and time, ($F(1, 26)=131.725$, $p<.001$, $\eta^2=.725$), with a large effect size, but not for session and time, ($F(1.766, 26)=.014$, $p=.978$, $\eta^2=.000$), with a small effect size.

Multiple one-way repeated measures ANOVAs were performed to examine the simple main effects and identify differences between the sessions (1, 2, and 3) for each treatment group (placebo versus intervention). The analysis revealed a statistically significant difference between mean inclinometry scores across the three sessions for individuals in the intervention group ($F(1.498, 26)=27.242$, $p=<.001$ $\eta^2=.521$), with a large effect size, but no statistically significant differences between mean inclinometry scores across the three sessions for individuals in the placebo group ($F(1.579, 26)=1.309$, $p=.276$, $\eta^2=.050$), with a medium effect size.

A statistically significant difference was revealed between sessions 1 and 3 ($p<.001$, CI: [-6.038, -2.462), sessions 2 and 3 ($p<.001$, CI: [3.733, -1.729) but not sessions 1 and 2 ($p=.064$, CI: [-5.458, -2.619]) for the intervention group (see Figure 10 below and Table 3 in Appendix O). There were no statistically significant differences observed for the placebo group.

Figure 10

Inclinometry for Each Treatment Group (Placebo Versus Intervention) Compared Across Sessions One, Two, and Three

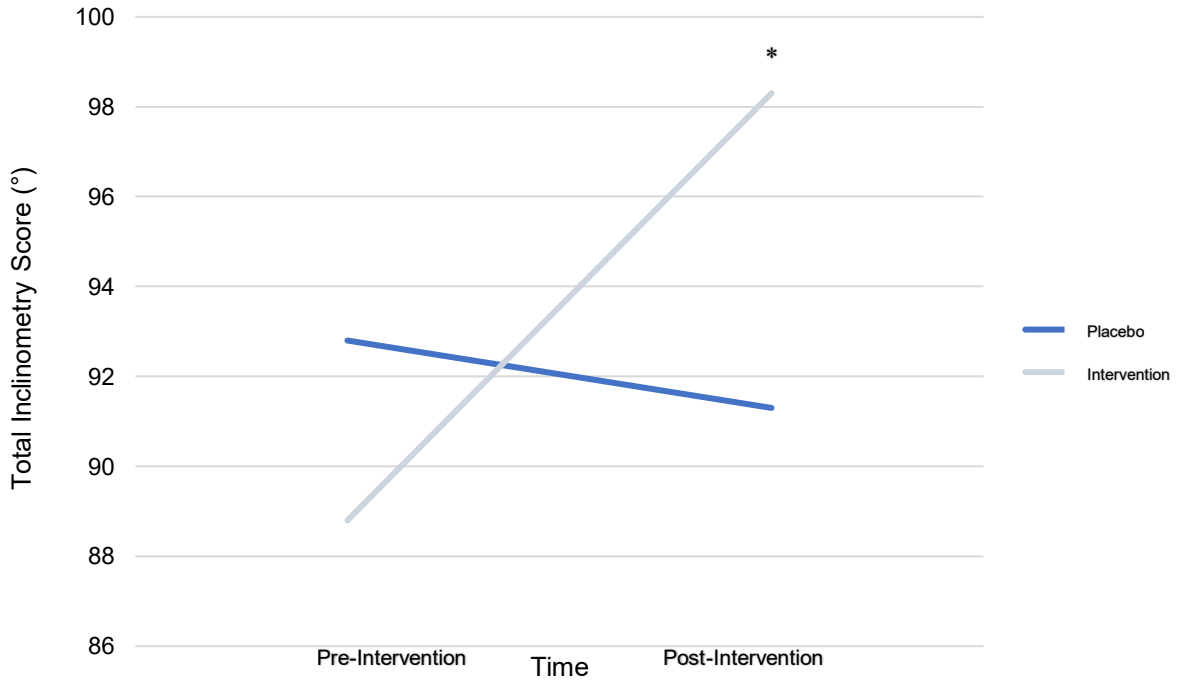


Note: * denotes statistical significance

Multiple t-tests for independent measures were performed to examine the simple main effects and identify differences between each treatment group (placebo versus intervention) for the two-time intervals (pre- and post-intervention). A statistically significant difference was revealed between the two treatment groups for the post-intervention scores ($t(26)=-3.083$, $p=0.03$, $d=-0.855$, CI[-11.68763, -2.46621]), with a large effect size, but not the pre-intervention scores ($t(26)=1.841$, $p=0.071$, $d=0.511$, CI[-.34373, 7.92065]; see Figure 11), with a medium effect size.

Figure 11

Inclinometry Scores for Each Treatment Group (Placebo Versus Intervention) Compared Across Time (Pre- and Post-Intervention)



Note: * denotes statistical significance

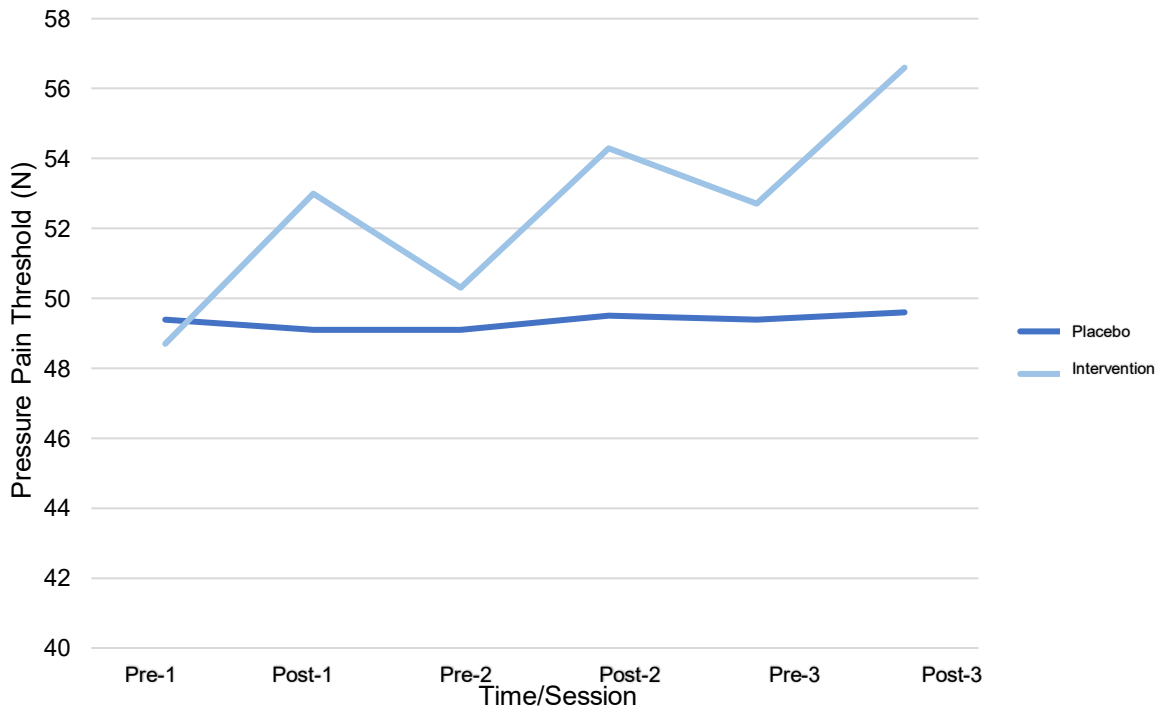
Research Question 3: What are the short-term effects of dry cupping the lumbar paraspinal muscles on pressure pain threshold as measured by algometry in individuals with NSLBP?

Descriptive statistics indicated that individuals in the placebo group had a mean pressure pain threshold of 48.8 N (SD=7.0) pre-intervention in session 1, which increased to 48.9 N (SD=7.0) post-intervention in session 3, indicating an increase of 0.1 N across the 3 sessions (see Figure 12). Individuals in the intervention group had a mean pressure pain threshold of 48.9 N (SD=9.0) pre-intervention in session 1, which increased to 56.8 N (SD=8.0) post-intervention in session 3, indicating an increase of 7.9 N across the 3 sessions (see Figure 12).

The observed pain reduction in the intervention group exceeded the MDC of 47.2 kPa/0.472 N for pressure pain threshold, indicating that dry cupping provided clinically significant relief (Ibrahim et al., 2022). The increase in pressure pain threshold within the intervention group indicates an increase in pain tolerance and, therefore, a decrease in overall pain. The observed pain increase in the placebo group did not exceed this value, indicating that the placebo intervention did not affect the participant's level of pain.

Figure 12

Pre-Intervention Versus Post-Intervention Pressure Pain Threshold Values Across all Three Sessions for the Placebo Group and Intervention Group



Z-scores and boxplot inspection revealed no outliers in either treatment group. Prior to further analysis, Mauchly's Test of Sphericity was used to ensure equal variance between both groups. Once this assumption was validated, the analyses proceeded. A three-way mixed

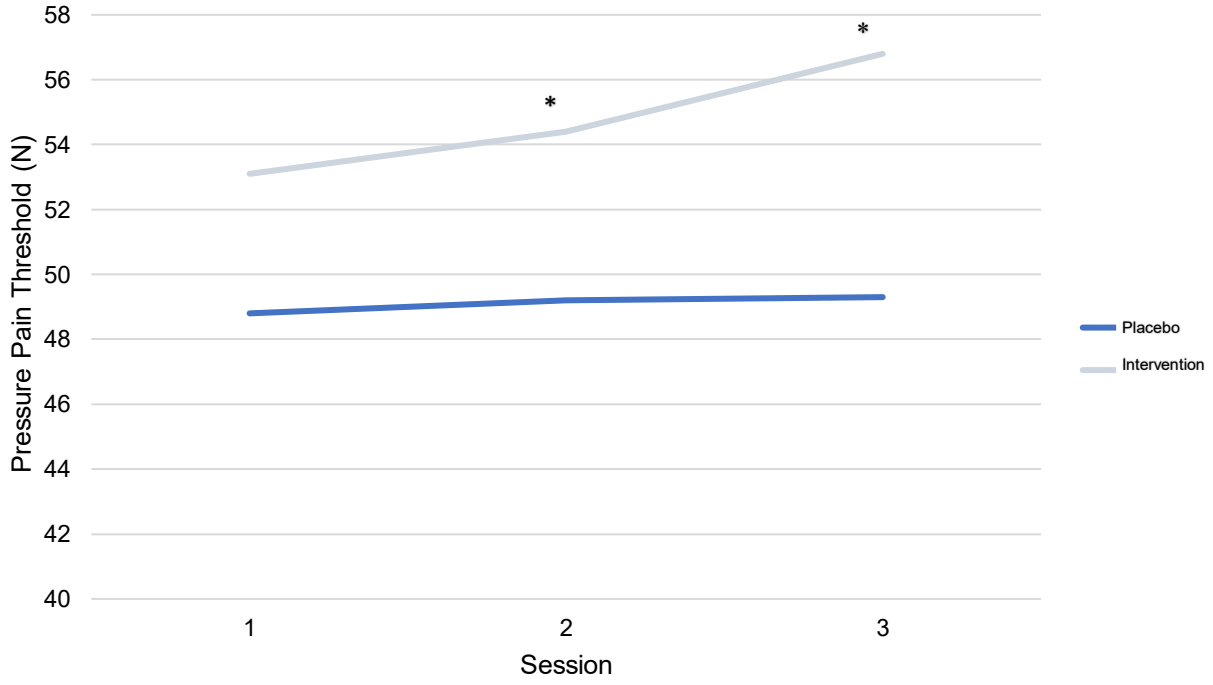
factorial ANOVA was used to compare the interaction effect between the three independent variables (treatment group, time, and session) on pressure pain threshold. The analysis revealed no statistically significant interaction effect between the three variables (treatment group, session and time; $F(2, 26)=.361$, $p=.698$ $\eta^2=.007$) on pressure pain threshold, with a small effect size. Further analysis revealed a statistically significant two-way interaction effect between session and treatment group, ($F(2, 26)=13.694$, $p<.001$, $\eta^2=.215$) and treatment group and time, ($F(1, 26)=71.237$, $p<.001$, $\eta^2=.604$), with a large effect size, but not session and time, ($F(2, 26)=.305$, $p=.738$, $\eta^2=.006$), with a small effect size.

Multiple one-way repeated measures ANOVAs were performed to examine the simple main effects and identify differences between the sessions (1, 2, and 3) for each treatment group (placebo versus intervention). The analysis revealed a statistically significant difference between mean pressure pain threshold scores across the three sessions for individuals in the intervention group ($F(2, 26)=14.737$, $p=<.001$ $\eta^2=.371$), with a large effect size, but no statistically significant difference between mean pressure pain threshold scores across the three sessions for individuals in the placebo group ($F1.312, 26)=.997$, $p=.348$, $\eta^2=.038$), with a medium effect size.

A statistically significant difference was revealed between sessions 1 and 3 ($p<.001$, CI: [-5.737, -1.694), sessions 2 and 3 ($p<.001$, CI: [-4.066, -.711) but not sessions 1 and 2 ($p=.135$, CI: [-2.941, .268]) for the intervention group (see Figure 13 below and Table 4 in Appendix P). There were no statistically significant differences observed for the placebo group.

Figure 13

Pressure Pain Threshold Scores for Each Treatment Group (Placebo Versus Intervention) Compared Across Sessions One, Two, and Three

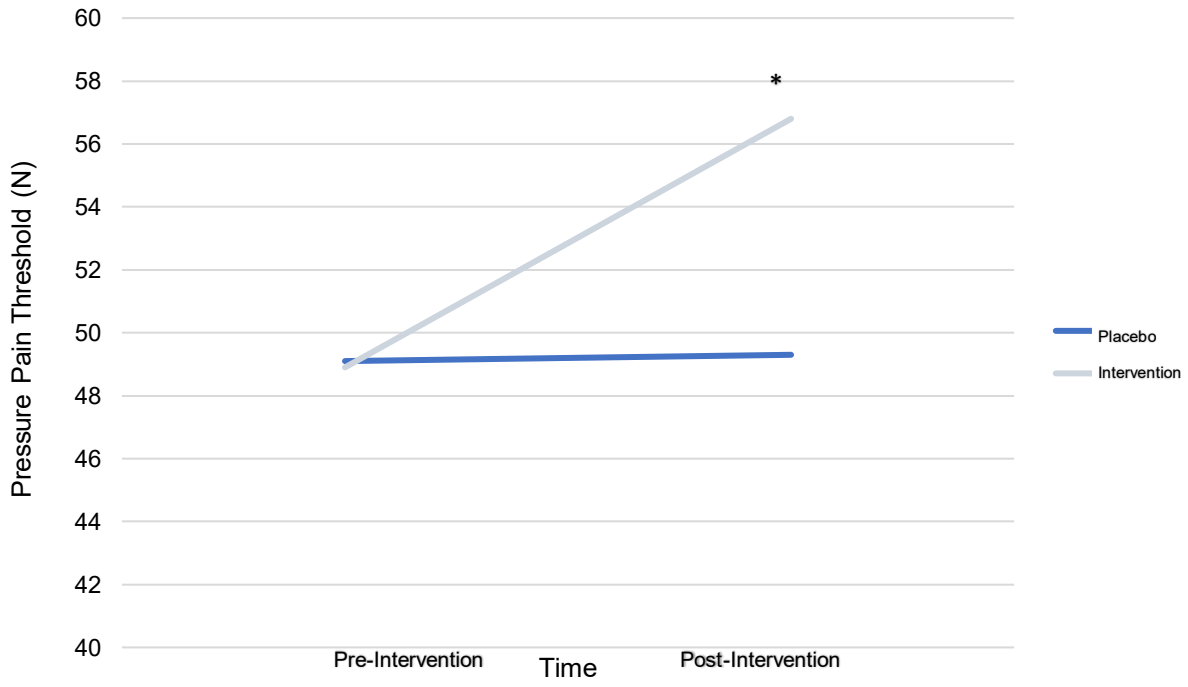


Note: * denotes statistical significance

Multiple t-tests for independent measures were performed to examine the simple main effects and identify differences between each treatment group (placebo versus intervention) for the two time intervals (pre- and post-intervention). A statistically significant difference was revealed between the two treatment groups for the post-intervention scores ($t(26)=-3.630$, $p<.001$, $d=-1.007$, CI[-12.29479, -3.53598]), with a large effects size, but not the pre-intervention scores ($t(26)=-.069$, $p=0.945$, $d=-.019$, CI[-4.99464, 4.66387]; see Figure 14), with a small effect size.

Figure 14

Pressure Pain Threshold Scores for Each Treatment Group (Placebo Versus Intervention) Compared Across Time (Pre- and Post-Intervention)



Note: * denotes statistical significance

Research Question 4: What are the short-term effects of dry cupping the lumbar paraspinal muscles on subjective pain perception as measured by the NPRS in individuals with NSLBP?

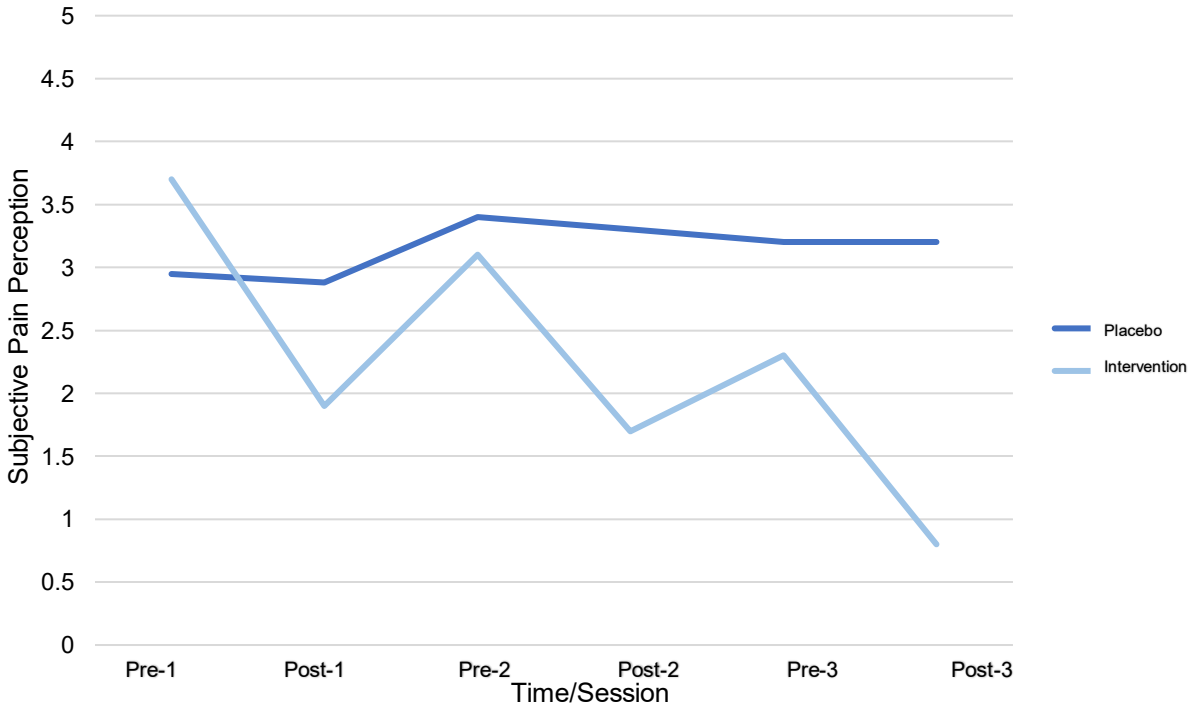
Descriptive statistics indicated that individuals in the placebo group had a subjective pain perception of 3.0 points (=1.00) pre-intervention in session 1, which increased to 3.3 points (SD=1.0) post-intervention in session 3, indicating an increase of 0.3 points across the 3 sessions (see Figure 15). Individuals in the intervention group had a subjective pain perception of 3.7 (SD=1.0) pre-intervention in session 1, which decreased to .8 (SD=1.0) post-intervention in session 3, indicating a decrease of 2.9 across the 3 sessions (see Figure 15). Subjective pain

scores were measured on a 0-10 scale, with lower scores indicating less pain and higher scores indicating more intense pain.

The observed pain reduction in the intervention group exceeded the MDC of 1.33 points and MCID of 2.1 points for the NPRS, indicating that dry cupping provided clinically significant relief in pain. The observed pain increase in the placebo group did not exceed these values, indicating that the placebo did not affect pain.

Figure 15

Pre-Intervention Versus Post-Intervention Numeric Pain Rating Scale Scores Across all Three Sessions for the Placebo Group and Intervention Group



Z-scores and boxplot inspection revealed no outliers in either treatment group. Prior to further analysis, Mauchly's Test of Sphericity was used to ensure equal variance between both groups. Since this assumption was violated, the Greenhouse-Geisser correction was applied. A three-way mixed factorial ANOVA was used to compare the interaction effect between the three

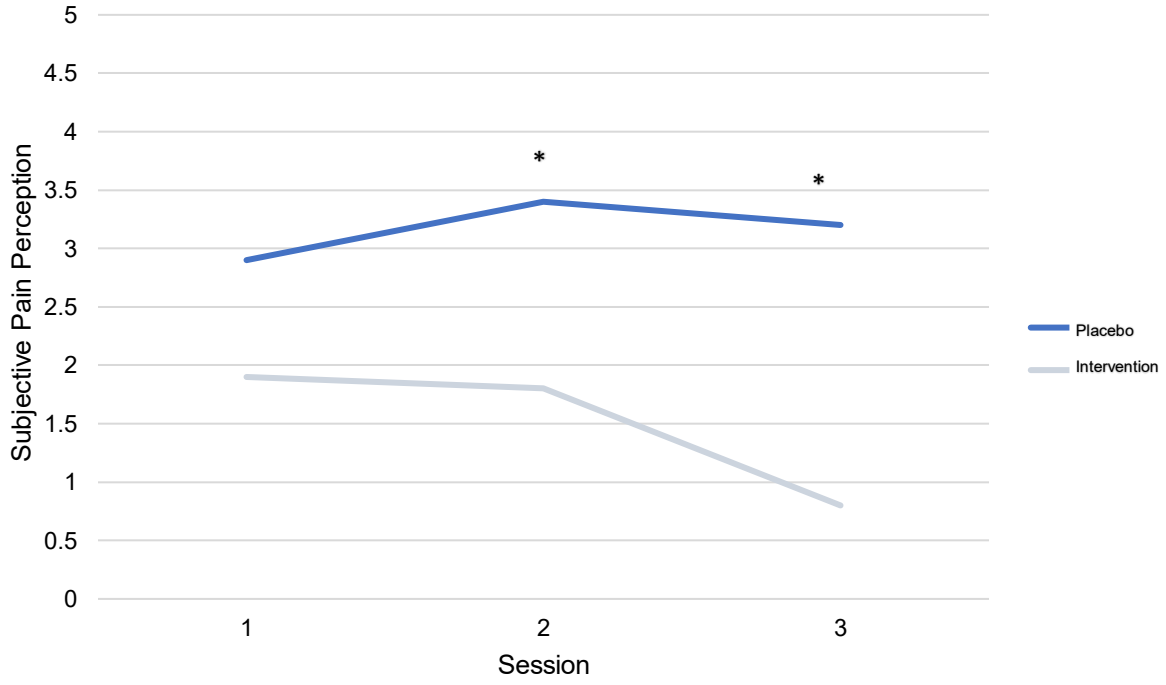
independent variables (treatment group, time, and session) on subjective pain perception. The analysis revealed no statistically significant interaction effect between the three variables (treatment group, session and time; $F(1.593, 26)=.956$, $p=.371$, $\eta^2=.019$) on subjective pain perception, with a small effect size. Further analysis revealed a statistically significant two-way interaction effect between session and treatment group, ($F(1.545, 26)=11.640$ $p<.001$, $\eta^2=.189$) and treatment group and time, ($F(1, 26)=97.051$, $p<.001$, $\eta^2=.660$), with a large effect size, but not session and time, ($F(1.593, 26)=1.928$, $p=.160$, $\eta^2=.037$), with a small effect size.

Multiple one-way repeated measures ANOVAs were performed to examine the simple main effects and identify differences between the sessions (1, 2, and 3) for each treatment group (placebo versus intervention). The analysis revealed a statistically significant difference between mean subjective pain perception scores across the three sessions for individuals in the intervention group ($F(2, 26)=13.221$, $p=<.001$ $\eta^2=.346$), with a large effect size, but no statistically significant differences between subjective pain perception scores across the three sessions for individuals in the placebo group ($F(1.203, 26)=1.784$, $p=.192$ $\eta^2=.067$), with a medium effect size.

A statistically significant difference was revealed between sessions 1 and 3 ($p<.001$, CI: [.413, 1.779) and sessions 2 and 3 ($p<.001$, CI: [.401, 1.407) but not sessions 1 and 2 ($p=1.000$, CI: [-.359, .744]) for the intervention group (see Figure 16 below and Table 5 in Appendix Q). There were no statistically significant differences observed for the placebo group.

Figure 16

Subjective Pain Perception for Each Treatment Group (Placebo Versus Intervention) Compared Across Sessions One, Two, and Three

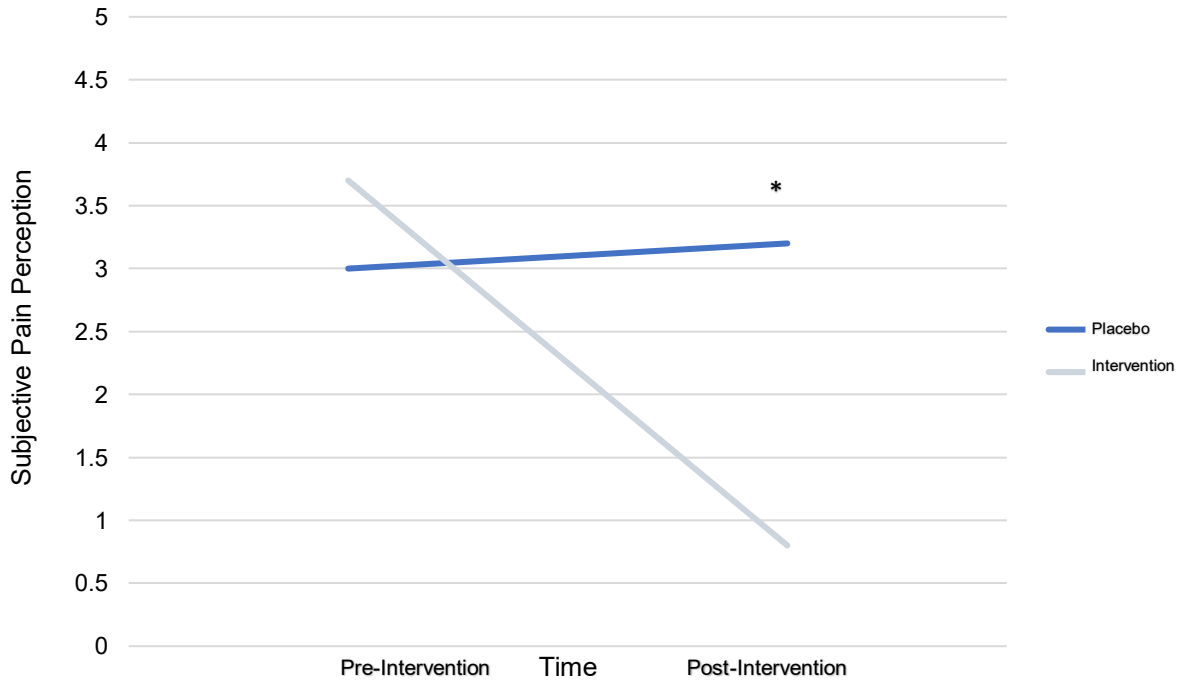


Note: * denotes statistical significance

Multiple t-tests for independent measures were performed to examine the simple main effects and identify differences between each treatment group (placebo versus intervention) for the two-time intervals (pre- and post-intervention). A statistically significant difference was revealed between the two treatment groups for the post-intervention scores ($t(26)=-6.662$, $p<.001$, $d=-1.848$, CI[1.69248, 3.15367]), with a large effect size, but not the pre-intervention scores ($t(26)=-1.516$, $p=0.136$, $d=-.421$, CI[-1.56456, .21841]; see Figure 17), with a small effect size.

Figure 17

Subjective Pain Perception for Each Treatment Group (Placebo Versus Intervention) Compared Across Time (Pre- and Post-Intervention)



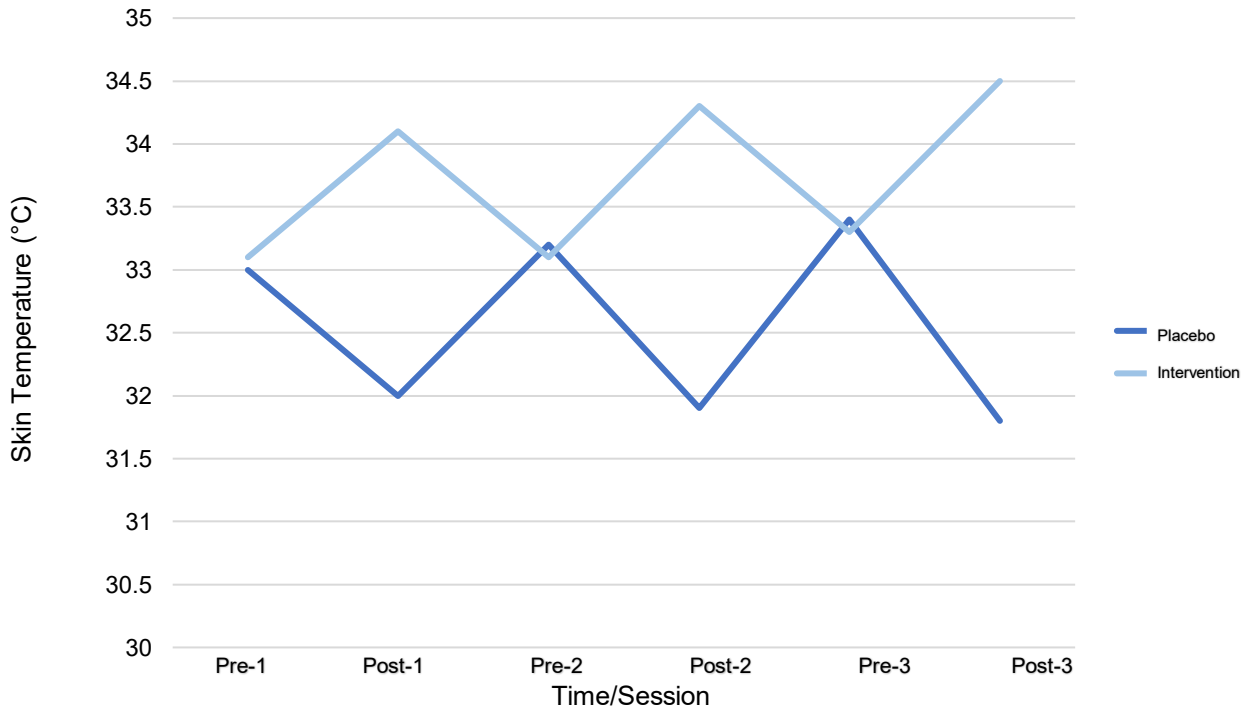
Note: * denotes statistical significance

Research Question 5: What are the short-term effects of dry cupping the lumbar paraspinal muscles on blood flow to the paraspinals as indicated by a change in skin temperature and measured by a laser thermometer in individuals with NSLBP?

Descriptive statistics indicated that individuals in the placebo group had a lumbar spine skin temperature of 33.0° (SD=1.0) pre-intervention in session 1, which decreased to 31.8° (SD=1.0) post-intervention in session 3, indicating a decrease of 1.2° across the 3 sessions (see Figure 18). Individuals in the intervention group had a lumbar spine skin temperature of 33.1° (SD=1.0) pre-intervention in session 1, which increased to 34.5° (SD=1.0) post-intervention in session 3, indicating an increase of 1.4° across the 3 sessions (see Figure 18).

Figure 18

Pre-Intervention Versus Post-Intervention Lumbar Spine Skin Temperature Across all Three Sessions for the Placebo Group and Intervention Group



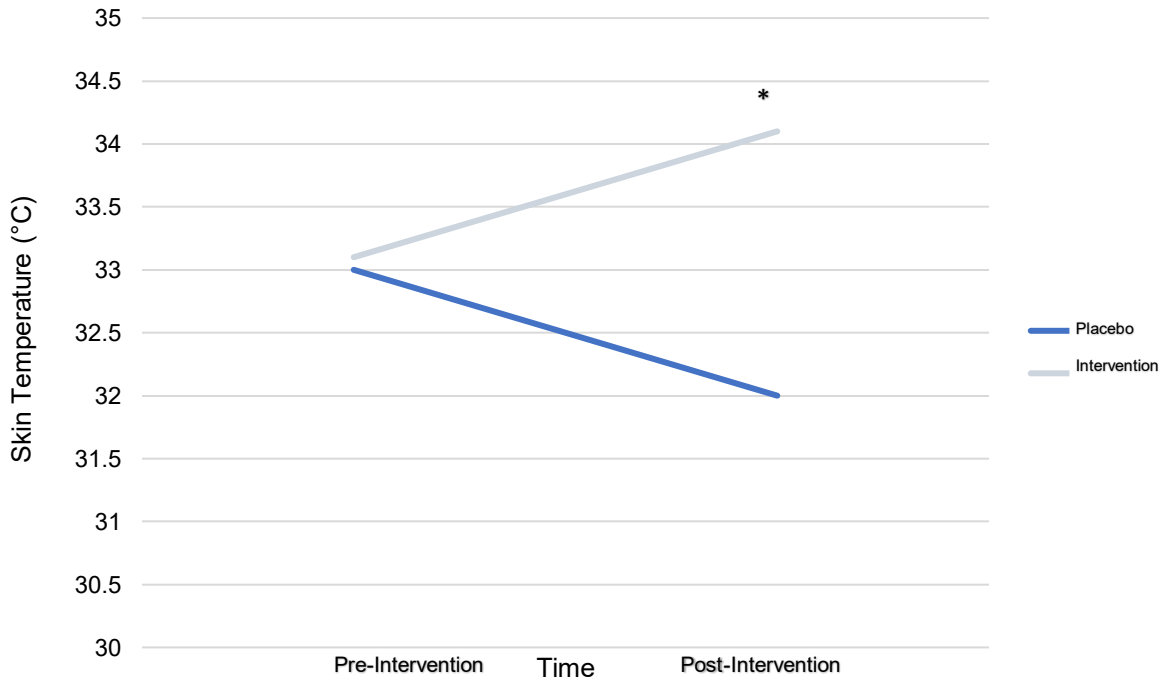
Z-scores and boxplot inspection revealed no outliers in either treatment group. Prior to further analysis, Mauchly's Test of Sphericity was used to ensure equal variance between both groups. Once this assumption was validated, the analyses proceeded. A three-way mixed factorial ANOVA was used to compare the interaction effect between the three independent variables (treatment group, time, and session) on skin temperature. Analysis revealed a statistically significant interaction effect between the three variables (treatment group, session and time; $F(2, 26)= 19.666$, $p<.001$, $\eta^2=.282$) on skin temperature, with a large effect size.

Multiple two-way mixed factorial ANOVAs were performed to examine the simple main effects and identify differences across time (pre- and post) and treatment group (placebo versus intervention) for each session (1, 2, and 3). The analysis revealed a statistically significant

difference between mean skin temperature values across time (pre- and post-intervention) between groups (intervention versus placebo) in session 1 ($F(2, 26)=50.551$, $p<.001$, $\eta^2=.503$; see Figure 19 below and Table 6 in Appendix R), with a large effect size.

Figure 19

Lumbar Spine Skin Temperature Across Time (Pre- and Post-Intervention) in Session 1 for Each Treatment Group (Placebo Versus Intervention)



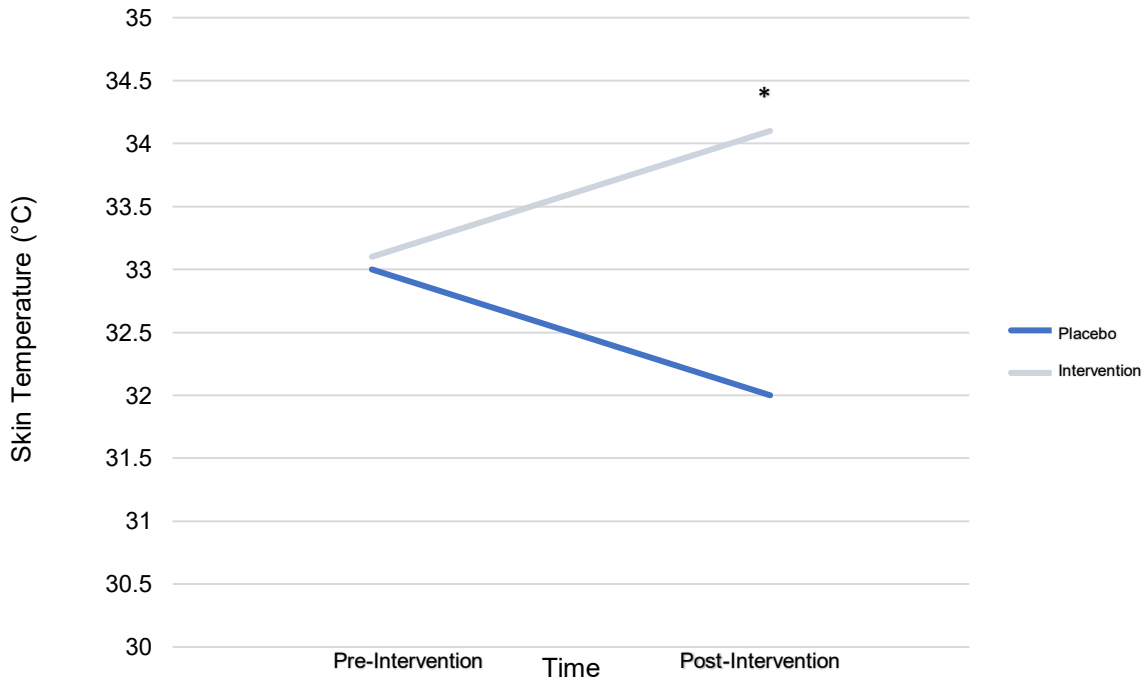
Note: * denotes statistical significance

Multiple t-tests for independent measures were performed to identify differences between each treatment group (placebo versus intervention) for the two time intervals (pre- and post-intervention). A statistically significant difference was revealed between the two treatment groups for the post-intervention values ($t(50)=-7.030$, $p<.001$, $d=-1.950$, CI[-2.607, -1.279]), with a large effects size, but not the pre-intervention scores ($t(50)=-.542$, $p=0.590$, $d=-.150$, CI[-.694, .395]) with a small effect size.

The analysis revealed a statistically significant difference between mean skin temperature values across time (pre- and post-intervention) between groups (intervention versus placebo) in session 2 ($F(2, 26)=78.043$, $p<.001$, $\eta^2=.610$; see Figure 20 below and Table 6 in Appendix R), with a large effect size.

Figure 20

Lumbar Spine Skin Temperature Across Time (Pre- and Post-Intervention) in Session 2 for Each Treatment Group (Placebo Versus Intervention)



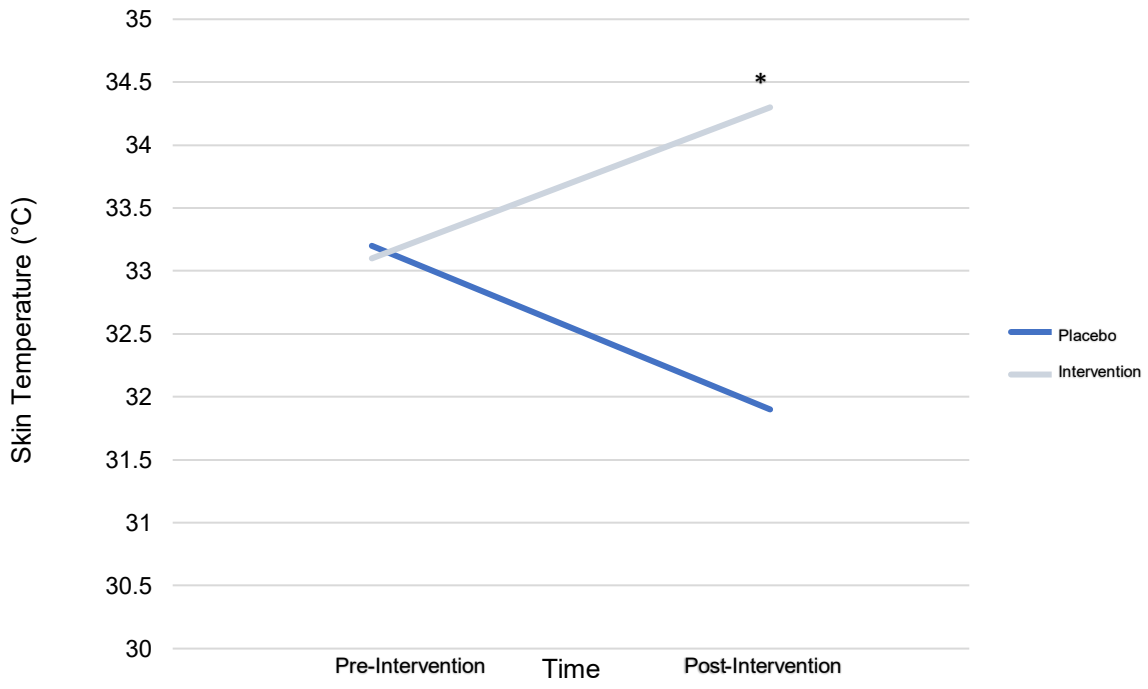
Multiple t-tests for independent measures were performed to identify differences between each treatment group (placebo versus intervention) for the two time intervals (pre- and post-intervention). A statistically significant difference was revealed between the two treatment groups for the post-intervention scores ($t(50)=-9.066$ $p<.001$, $d=-2.514$, CI[-3.240, -1.774]), with a large effects size, but not the pre-intervention scores ($t(50)=-.039$, $p=0.969$, $d=-.011$, CI[-.554, .533]) with a small effect size.

Note: * denotes statistical significance

The analysis revealed a statistically significant difference between mean skin temperature values across time (pre- and post-intervention) between groups (intervention versus placebo) in session 3 ($F(2, 26)=108.003$, $p<.001$, $\eta^2=.684$; see Figure 21 below and Table 6 in Appendix R), with a large effect size.

Figure 21

Lumbar Spine Skin Temperature Across Time (Pre- and Post-Intervention) in Session 3 for Each Treatment Group (Placebo Versus Intervention)



Note: * denotes statistical significance

Multiple t-tests for independent measures were performed to identify differences between each treatment group (placebo versus intervention) for the two time intervals (pre- and post-intervention). A statistically significant difference was revealed between the two treatment groups for the post-intervention scores ($t(50)=-10.795$, $p<.001$, $d=-2.994$, CI[-3.785, -2.188]),

with a large effects size, but not the pre-intervention scores ($t(50)=1.165$, $p=0.249$, $d=.323$, CI[-.226, .869]), with a small effect size.

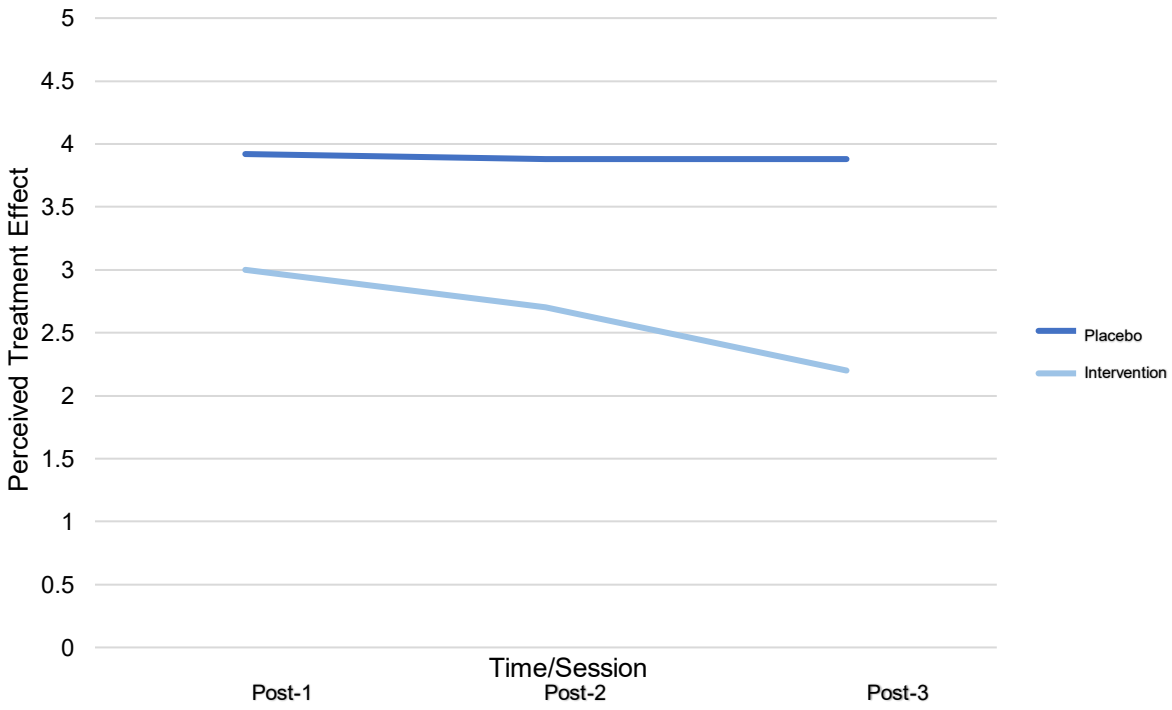
Research Question 6: What are the short-term perceived treatment effects of dry cupping the lumbar paraspinal muscles as measured by the PGICS in individuals with NSLBP?

Descriptive statistics indicated that individuals in the placebo group had a perceived treatment effect of 3.9 (SD=1.0), indicating "no change" following all 3 sessions (see Figure 22). Individuals in the intervention group had a perceived treatment effect of 2.2 (SD=1.0), indicating "much improved" following all 3 sessions (see Figure 22). Patient perception of treatment effect was measured on a 1-7 Likert scale, with lower numbers indicating a greater improvement in condition, a score of 4 corresponding to no change, and higher numbers indicating a worsening of the condition.

The patient perception of treatment in the intervention group did not exceed the MCID of a 1-unit difference between assessments for the PGICS (though nearing this value with a .8-point increase), indicating that dry cupping provided clinically insignificant relief. The patient perception of treatment in the placebo group also did not exceed this value, indicating no clinically significant changes.

Figure 22

Post-Intervention Perceived Treatment Effect Across all Three Sessions for the Placebo Group and Intervention Group



Z-scores and boxplot inspection revealed no outliers in either treatment group. Prior to further analysis, Mauchly's Test of Sphericity was used to ensure equal variance between both groups. Since this assumption was violated, the Greenhouse-Geisser correction was applied. A two-way mixed factorial ANOVA was used. This statistical test was used to compare the interaction effect between the two independent variables (treatment group and session) on perceived treatment effect. Analysis revealed a statistically significant interaction effect between the two variables ($F(1.702, 26)= 9.387$, $p<.001$, $\eta^2=.158$) on perceived treatment effect, with a large effect size.

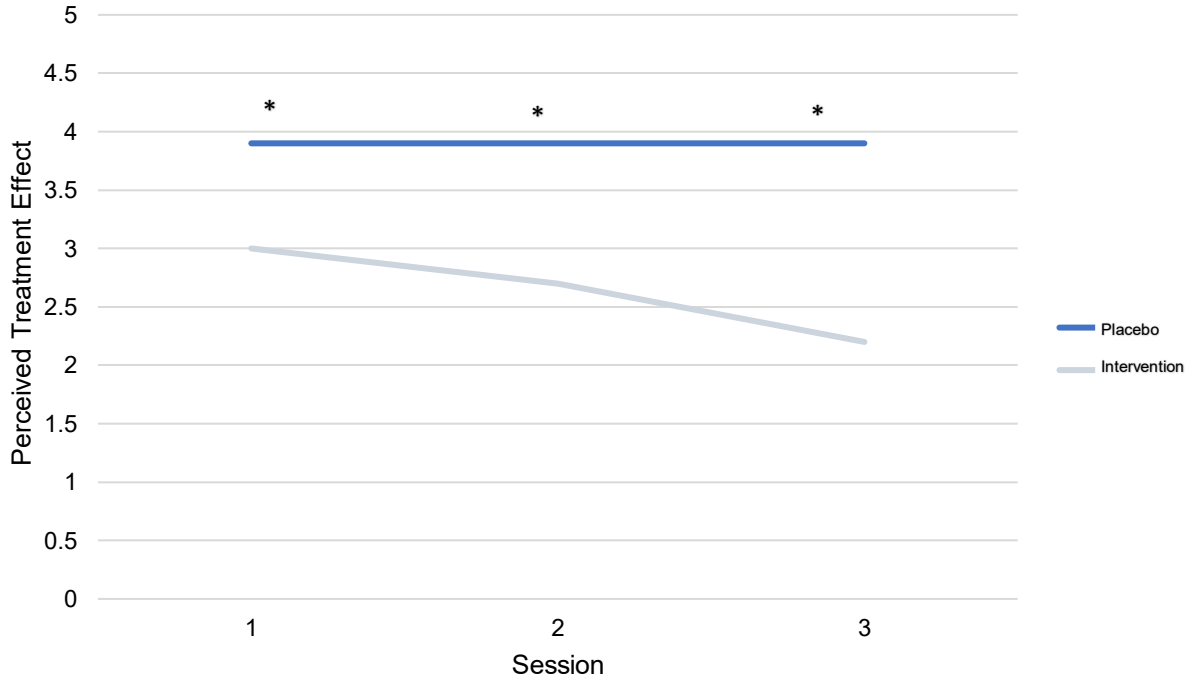
To help explain the interaction, multiple one-way repeated measures ANOVAs were performed to examine the simple main effects and identify differences between the sessions (1,

2, and 3) for each treatment group (placebo versus intervention), respectively. The analysis revealed a statistically significant difference between mean perceived treatment effect scores across the three sessions for individuals in the intervention group ($F(1.777, 26)=30.488$, $p<.001$, $\eta^2=.549$), with a large effect size, but no statistically significant differences between perceived treatment effect scores across the three sessions for individuals in the placebo group ($F(1.558, 26)=0.64$, $p=.898$, $\eta^2=.003$), with a small effect size.

A statistically significant difference was revealed between sessions 1 and 3 ($p<.001$, CI: [.412, 1.127) and sessions 2 and 3 ($p<.001$, CI: [.213, .864) but not sessions 1 and 2 ($p=.093$ CI: [-.023, .490]) for the intervention group (see Figure 23 below and Table 7 in Appendix S). There were no statistically significant differences observed for the placebo group.

Figure 23

Perceived Treatment Effect for Each Treatment Group (Placebo Versus Intervention) Compared Across Sessions One, Two, and Three



Note: * denotes statistical significance

Research Question 7: What are the short-term effects of dry cupping the lumbar paraspinal muscles on overall function as measured by the Roland-Morris Questionnaire in individuals with NSLBP?

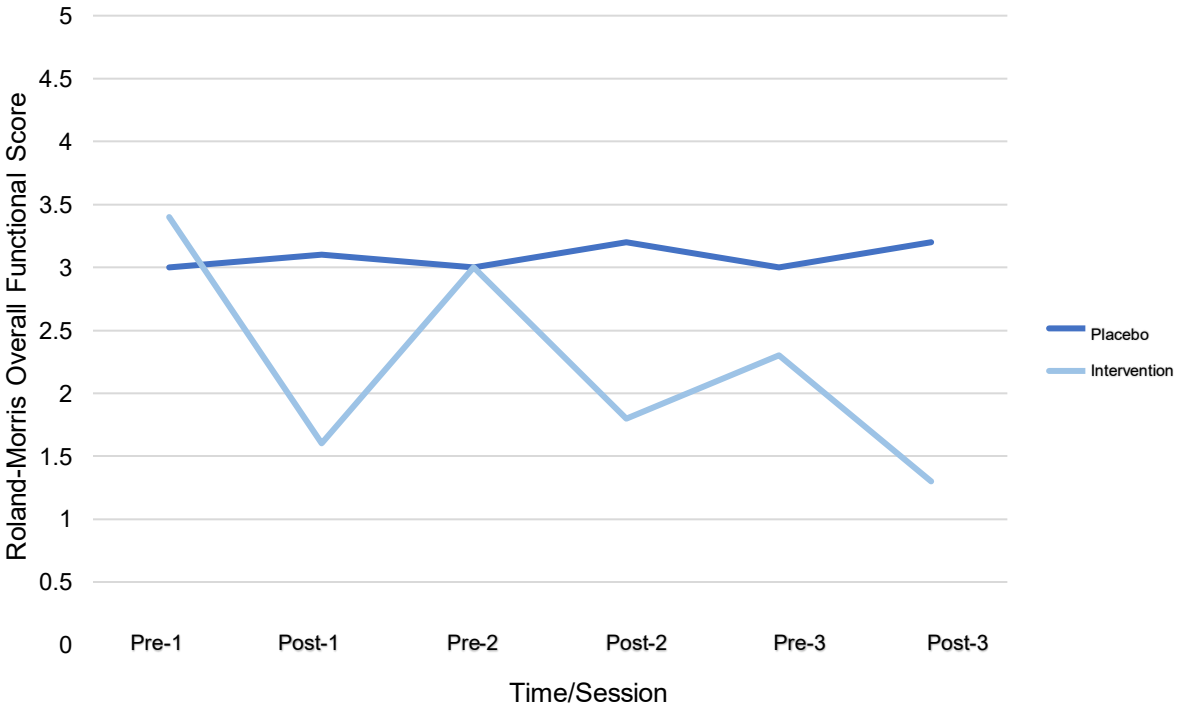
Descriptive statistics indicated that individuals in the placebo group had an overall functional score of 3.1 points (SD=3.0) pre-intervention in session 1, which increased to 3.2 points (SD=3.0) post-intervention in session 3, indicating an increase of 0.1 points across the 3 sessions (see Figure 24). Individuals in the intervention group had an overall functional score of 3.5 (SD=2.0) pre-intervention in session 1, which decreased to 1.3 (SD=1.0) post-intervention in session 3, indicating a decrease of 2.2 across the 3 sessions (see Figure 24). Overall function was

measured using the Roland-Morris Questionnaire in which the total score ranged from 0-24, with lower scores indicating less disability and higher scores indicating greater disability.

The observed overall functional improvement in the intervention group did not exceed the MDC of 5 points for the Roland-Morris Questionnaire, indicating that dry cupping did not result in clinically significant changes in function. The overall functional decline in the placebo group also did not exceed this value, indicating clinically insignificant changes.

Figure 24

Pre-Intervention Versus Post-Intervention Roland-Morris Overall Functional Scores Across all Three Sessions for the Placebo Group and Intervention Group



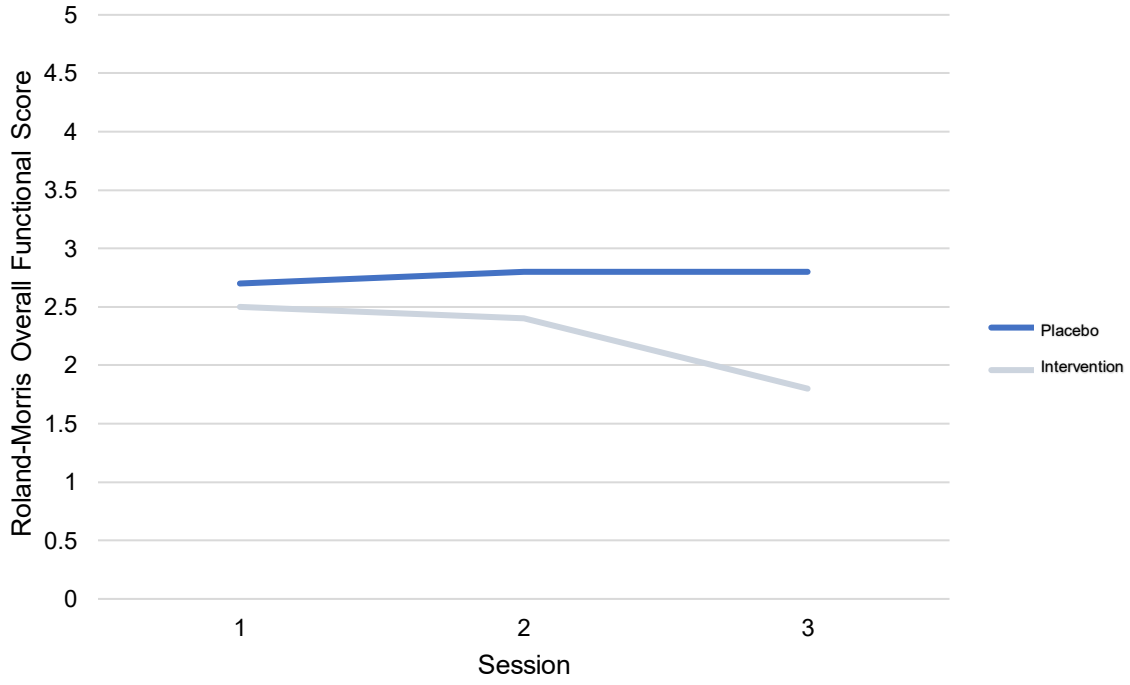
Z-scores and boxplot inspection revealed no outliers in either treatment group. Prior to further analysis, Mauchly's Test of Sphericity was used to ensure equal variance between both groups. Once this assumption was validated, the analyses proceeded. A three-way mixed factorial ANOVA was used to compare the interaction effect between the three independent

variables (treatment group, time, and session) on overall function. The analysis revealed no statistically significant interaction effect between the three variables (treatment group, session and time; $F(2, 26)= 1.538$, $p=.220$, $\eta^2=.030$) on overall function, with a small effect size. Further analysis revealed a statistically significant two-way interaction effect between session and treatment group, ($F(2, 26)=6.522$, $p=.002$, $\eta^2=.115$), treatment group and time, ($F(1, 26)=28.736$, $p<.001$, $\eta^2=.365$), with a large effect size and session and time, ($F(2, 26)=4.363$, $p=.015$, $\eta^2=.080$) on overall function, with a medium effect size.

To help explain the interaction between group and session, multiple one-way repeated measures ANOVAs were performed to examine the simple main effects and identify differences between the sessions (1, 2, and 3) for each treatment group (placebo versus intervention), respectively. The analysis revealed no statistically significant differences between mean overall functional scores across the three sessions for individuals in the intervention group ($F(2, 26)=2.067$, $p=.137$, $\eta^2=.076$), with a medium effect size, and individuals in the placebo group ($F(2, 26)=.584$, $p=.561$, $\eta^2=.023$; see Figure 25 below and Table 8 in Appendix T), with a small effect size.

Figure 25

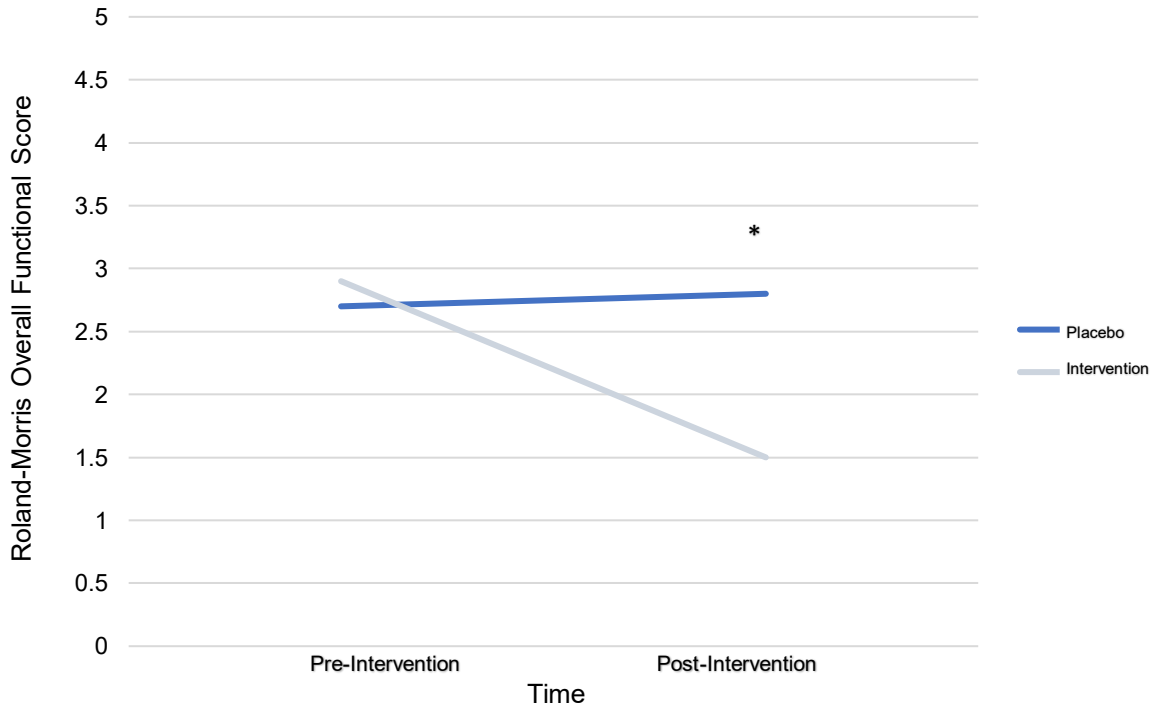
Roland-Morris Overall Functional Scores for Each Treatment Group (Placebo Versus Intervention) Compared Across Sessions One, Two, and Three



To help explain the interaction between group and time, multiple t-tests for independent measures were performed to examine differences between each treatment group (placebo versus intervention) at time intervals (pre- and post-intervention). A statistically significant difference was revealed between the two treatment groups for the post-intervention scores ($t(26)=2.928$ $p=.005$, $d=.812$, CI[.61593, 3.30715]), with a large effect size, but not the pre-intervention scores ($t(26)=-.518$, $p=0.607$, $d=-.144$, CI[-1.87588, 1.10665]; see Figure 26), with a small effect size.

Figure 26

Roland-Morris Overall Functional Scores for Each Treatment Group (Placebo Versus Intervention) Compared Across Time (Pre- and Post-Intervention)



Note: * denotes statistical significance

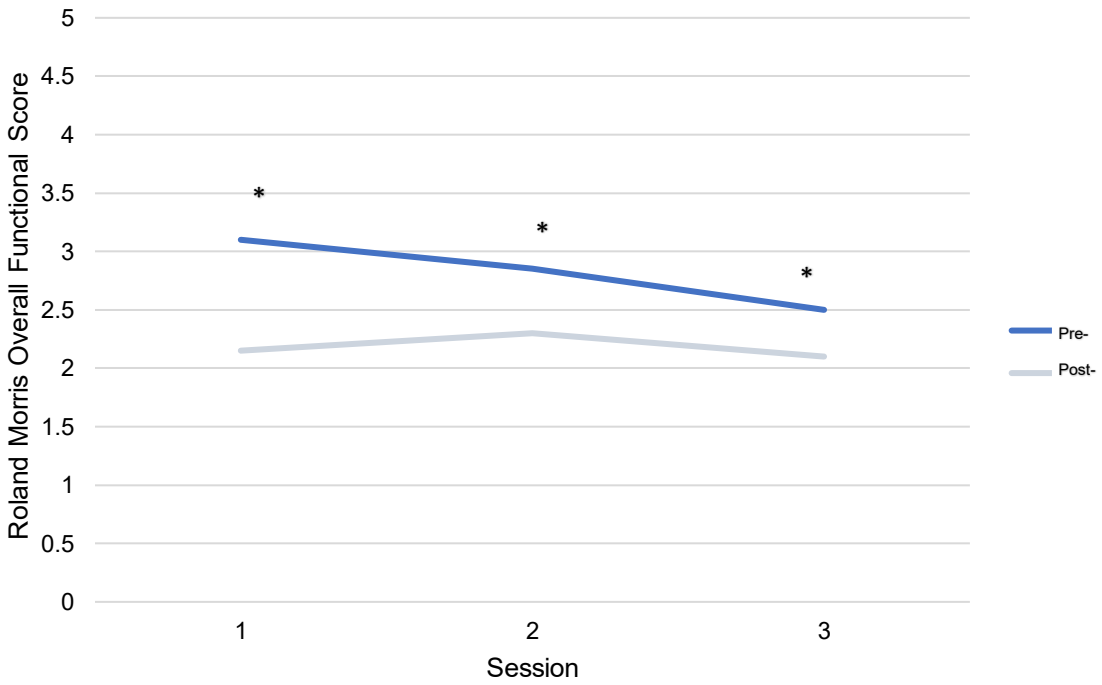
To help explain the interaction between time and session, multiple one-way repeated measures ANOVAs were performed to examine the simple main effects and identify differences of each time intervals (pre- and post-intervention), respectively across sessions (1, 2, and 3). The analysis revealed a statistically significant difference between mean pre-intervention overall functional scores across the three sessions ($F(2, 26)=8.029$, $p=<.001$ $\eta^2=.136$), with a large effect size, but no statistically significant difference between post-intervention overall functional scores across the three sessions ($F(2, 26)=.938$, $p=.395$, $\eta^2=.018$), with a small effect size.

A statistically significant difference was revealed between sessions 1 and 3 ($p=.004$, CI: [.161, .992]) and 2 and 3 ($p=.041$, CI: [.010, .644]), but not 1 and 2 ($p=.205$, CI: [-.082 .582]), for

the pre-intervention measurements (see Figure 27 and Table 9 in Appendix T). There were no statistically significant differences observed for the post-intervention measurements.

Figure 27

Roland-Morris Overall Functional Scores for Each Treatment Session (One, Two, and Three) Compared Across Time (Pre- and Post-Intervention)



Note: * denotes statistical significance

Ancillary Analysis and Harms

No additional analysis was performed, and no harms or unintended effects occurred throughout the duration of this study.

Chapter 4 – Discussion

The purpose of this study was to investigate the short-term effects of dry cupping on pain, ROM, skin temperature as an indicator of blood flow, overall function, and perceived treatment effect in individuals with NSLBP. Previous literature has highlighted the potential benefits of this treatment for low back musculoskeletal stiffness, pain relief, ROM, and functional limitations, however, limited research has sought to examine the specific effects in a pathological population (Almeida Silva et al., 2022; Ferreira et al., 2023; Markowski et al., 2014). These findings not only reinforce the potential benefits but also provide novel insights into the cumulative nature of treatment effects across multiple sessions. The findings contribute to the growing body of evidence supporting adjunct non-pharmacological interventions for NSLBP and related conditions that can be used with other treatments such as education and exercise, for example. The following section will discuss the results within the context of existing literature for each research question, examine methodological strengths and limitations, and explore implications for clinical practice and future research.

Research Questions 1 and 2: What are the short-term effects of dry cupping the lumbar paraspinal muscles on lumbar spine ROM as measured by the Sit and Reach Test in individuals with NSLBP? What are the short-term effects of dry cupping the lumbar paraspinal muscles on lumbar spine ROM as measured by inclinometry in individuals with NSLBP?

Dry cupping significantly improved lumbar flexibility, as measured by the Sit and Reach Test (increased by 8.8 cm) and lumbar spine flexion measured by inclinometry (increased by 9.5°). These improvements are particularly noteworthy as they exceed both the MDC and MCID, suggesting the changes are both statistically significant and clinically meaningful (Boyd, 2012;

Mayorga-Vega et al., 2014). These results align with the broader literature emphasizing dry cupping's role in enhancing joint ROM, which is a critical marker of physical function linked to improved mobility, injury prevention, and quality of life (MacPherson, 2022; Ratamess, 2021). Analysis revealed both statistically and clinically significant differences between the intervention and placebo groups in post-intervention measurements for both Sit and Reach and lumbar spine flexion measured by inclinometry, with medium to large effect sizes. In contrast, the placebo group showed non-significant decreases in both measures (decreased by 0.6 cm and decreased 1.3°, respectively). The gains observed in the intervention group likely reflect the mechanical effects of negative pressure, which stretches muscle fibres and fascia, reducing stiffness and adhesions (Markowski et al., 2014).

The progressive improvement across sessions and significant differences between sessions for the intervention group suggest cumulative benefits, possibly due to mechanical deformation of the fascia or neural adaptation (Markowski et al., 2014). This cumulative effect pattern has not been consistently demonstrated in previous studies and represents an important contribution to understanding the dose-response relationship in cupping therapy. Post-hoc analysis confirmed statistically significant improvements between sessions 1 and 2, sessions 1 and 3, and sessions 2 and 3 for the Sit and Reach Test, while lumbar spine flexion measured by inclinometry revealed statistically significant improvements between sessions 1 and 3 and sessions 2 and 3. This pattern of improvement may suggest that cupping's effects on tissue extensibility may involve both immediate mechanical changes and longer-term adaptations in connective tissue properties (e.g., modification of the collagen or reductions in fascial restrictions).

The clinical relevance of these ROM changes warrants further examination. A 9.5° increase in lumbar spine flexion exceeds the MDC (3.41°; Boyd, 2012), but its impact on functional tasks (e.g., lifting, bending) remains unclear. This highlights the multifactorial nature of disability in NSLBP, where psychological factors may mediate self-reported function independently of physical improvements (Hu et al., 2022). This means that even with improvements in physical symptoms, psychological and emotional factors may continue to influence an individual's perceived ability to function.

Biomechanical research offers additional insights into the mechanisms underlying ROM improvements. Markowski et al. (2014) demonstrated that negative pressure application altered fascial hydration and the viscoelastic properties of the underlying tissue, potentially explaining the sustained flexibility gains observed across sessions. Likewise, Wang et al. (2017) found that cupping reduced myofascial trigger point activity, which may contribute to improved movement capacity by decreasing protective muscle guarding. These mechanistic findings complement this study's clinical observations, providing a physiological basis for the ROM improvements documented.

The current findings align with and expand upon existing literature, demonstrating both consistencies and variations in cupping therapy's effects across studies. A notable similarity lies in treatment duration, with the present study employing a 10 min static cupping protocol, mirroring the approach of Markowski et al. (2014), who utilized a single 10 min intervention in individuals with subacute and chronic mechanical LBP and reported a 9° increase in lumbar spine flexion and 2-3° improvement in the Straight Leg Raise Test. This study was also conducted on a pathological population, with individuals experiencing subacute LBP, and, therefore, is comparable to the current findings. This consistency suggests that even brief

cupping applications may elicit measurable improvements in ROM specifically for individuals experiencing LBP. Furthermore, the observed improvements in lumbar mobility correspond with Yim et al.'s (2017) findings regarding cervical spine ROM enhancements (11% increase), following an 8 min cupping intervention, further supporting the hypothesis that mechanical and neurophysiological effects of dry cupping may generalize across spinal regions due to shared anatomical and functional characteristics. These findings support the use of cupping as an effective method to increase ROM across both a healthy and pathological population. Furthermore, the treatment durations of 8-10 min show consistent improvements, and support the optimal recommended treatment time of 7-10 min from a dosage perspective (Wang et al., 2020).

Contrasts emerge when examining treatment location and methodology. While the current study and Markowski et al. (2014) focused on the lumbar spine, Murray and Clarkson (2019) investigated dynamic cupping applied to the hip, reporting more modest ROM improvements (7% increases in hip flexion). This discrepancy suggests that spinal regions, due to their integral role in postural control and load transfer, may respond more significantly to cupping than peripheral joints. Furthermore, this study was conducted on a healthy population, which may have influenced the smaller increase in ROM observed, as a pathological population may present with greater ROM limitations, allowing them to respond more effectively to cupping treatments. This trend is not consistent across the available literature as some studies such as the previously discussed study by Yim et. al (2017) reported large ROM increases in healthy individuals. Additionally, the use of static cupping in the present study differs from Murray and Clarkson's dynamic approach, indicating that treatment technique may influence outcome magnitude. Static approaches may have also allowed for more consistent treatments across participants, contributing to the consistently higher ROM gains in this study. Unlike dynamic

cupping, where cup movement introduces variability in pressure and application, static cupping provides consistent mechanical stimulation across participants. Methodological variations in outcome reporting, such as percentage improvements versus absolute values, further highlight the need for standardized metrics in cupping research to facilitate direct comparisons.

These comparisons reinforce the importance of considering and clearly reporting the anatomical region, treatment parameters and dosages, and population characteristics when reporting and interpreting the effects of cupping. The convergence of findings across studies strengthens the evidence for the efficacy of cupping in enhancing spinal mobility, particularly in symptomatic populations. The present study contributes to the growing body of evidence supporting cupping's therapeutic potential while emphasizing the need for tailored intervention strategies based on a clinical context.

Despite these findings, methodological inconsistencies across studies impair the ability to make direct comparisons. Almeida Silva et al. (2019) found no significant ROM differences (via the Finger-to-Floor Test) between cupping and placebo groups in NSLBP patients after eight total sessions (scheduled once per week), despite using a similar placebo design. This discrepancy may stem from differences in outcome measures (the Finger-to-Floor Test versus lumbar spine flexion measured by inclinometry and the Sit and Reach Test) or treatment frequency (once a week for eight weeks versus three sessions in one week). Furthermore, Lauche et al. (2011) employed different application protocols (duration of treatment was dependent on skin appearance, where cups were removed when hyperpigmentation was observed by the researchers) and reported negligible ROM improvements, emphasizing potential dose-dependent responses, indicating a longer treatment time may be necessary to see benefits. These discrepancies highlight a critical need for standardized protocols and comprehensive reporting of

application parameters (e.g., negative pressure intensity, treatment duration) to facilitate meaningful clinical understanding and comparison across studies. The heterogeneity in outcomes also highlights the potential influence of participant characteristics, as individuals with more significant baseline impairment or specific tissue restrictions may respond differently to mechanical deformation induced by cupping therapy.

These comparative findings highlight the complexity of cupping therapy's effects on lumbar ROM, demonstrating the interaction between treatment parameters, anatomical considerations, and population characteristics. While the current study demonstrates clinically significant improvements that align with previous research on spinal applications, the inconsistencies across literature, regarding treatment protocols, measurement approaches, and reported outcomes, emphasize the need for greater methodological standardization and reporting. The more significant response observed in individuals with NSLBP compared to healthy populations suggests that cupping may be particularly effective for addressing pathological restrictions, potentially through combined mechanisms of fascial deformation, altered tissue hydration, and neurophysiological modulation of protective muscle guarding (Markowski et al., 2014; Wang et al., 2017).

Research Questions 3 and 4: What are the short-term effects of dry cupping the lumbar paraspinal muscles on pressure pain threshold as measured by algometry in individuals with NSLBP? What are the short-term effects of dry cupping the lumbar paraspinal muscles on subjective pain perception as measured by the NPRS in individuals with NSLBP?

The construct of pain was explored using two complementary measures including self-reported subjective pain perception (NPRS) and pressure pain threshold (algometry). The intervention group demonstrated statistically and clinically significant reductions in subjective

pain (2.9 points) and increased pressure pain thresholds (7.9 N) across all three sessions, with statistically significant differences between sessions 1 and 3 and sessions 2 and 3, but not between sessions 1 and 2 for both measures. This delayed pain relief pattern suggests that dry cupping may require multiple sessions to achieve optimal analgesic effects, possibly due to the time needed for neurophysiological adaptations or tissue remodeling. These findings align with prior studies demonstrating cupping's analgesic effects and pose critical questions about the physiological and psychological mechanisms underlying these outcomes (De Melo Salemi et al., 2021; Wood et al., 2020).

Various proposed mechanisms may explain the observed decrease in pain. The concurrent 1.4°C increase in skin temperature suggests enhanced blood flow, which may reduce inflammation and improve tissue oxygen delivery (Liu et al., 2022; Lowe, 2017; Wang et al., 2020). This increased blood flow could reduce ischemia-related pain by improving oxygen delivery to hypoxic tissues while simultaneously promoting the clearance of inflammatory mediators (Liu et al., 2022; Lowe, 2017). The improved microcirculation may be particularly relevant in NSLBP, where chronic muscle tension often leads to localized hypoxia and accumulation of pain-inducing metabolites (Wang et al., 2020). Such physiological responses support previous findings that cupping induces circulatory changes which may contribute to analgesia (Lowe, 2017).

Muscle relaxation represents another potential mechanism, as the mechanical stretch induced by cupping's negative pressure may reduce hypertonicity, alleviating nociceptive input from the tense paraspinal muscles (Markowski et al., 2014). The substantial increases in pressure pain threshold (7.9 N) supports this mechanism, as decreased muscle tension would allow for greater tolerance to mechanical pressure (Markowski et al., 2014). Cupping's negative pressure is

thought to create a mechanical stretch that reduces muscle hypertonicity, thereby decreasing compression on nociceptors and surrounding tissues (Lowe, 2017; Wood et al., 2020). When muscles are hypertonic, they compress blood vessels and nerve endings, leading to localized ischemia and sensitization of pain receptors (Noonan & Brown, 2021). By alleviating this tension, cupping may improve microcirculation and reduce the accumulation of inflammatory mediators that activate nociceptors (Joyner & Casey, 2015; Wei et al., 2013). This biomechanical decompression allows tissues to tolerate greater external pressure before pain is perceived, possibly explaining the 7.9 N increase in pressure pain threshold.

The observed pain reduction exceeded the MCID for NPRS (≥2.1 points; Gallasch & Alexandre, 2007), indicating that dry cupping provided clinically meaningful relief. This aligns with a meta-analysis by Wang et al. (2017), which synthesized six RCTs and found significant reductions in patient-reported LBP following dry cupping (mean NPRS reduction: 1.8 points). However, this study documented a larger pain reduction (2.9 points), potentially due to stricter protocol standardization (e.g., fixed 465 mmHg pressure) compared to the variable methods in their included trials. Furthermore, a systematic review of 21 RCTs comparing cupping therapy to routine care (e.g., chiropractic adjustments, massage, and medications), reported significant reductions in LBP favouring cupping (Wood et al., 2020). Evidence from this review highlighted dry cupping's efficacy in improving functional status and pressure pain thresholds in the chronic low back or neck pain populations, further supporting the findings of this study (Wood et al., 2020).

The placebo group exhibited minimal pain changes (NPRS increased by 0.3 points), while the intervention group had a 2.9-point reduction in NPRS scores, suggesting a treatment-specific effect. The lack of significant baseline differences reinforces this distinction. This

mirrors De Melo Salemi et al. (2021), who reported a 2.2-point VAS decrease versus a 0.6-point placebo change following 5 consecutive cupping treatments in individuals with NSLBP, further reinforcing cupping's neurophysiological mechanisms. Given that expectation effects often contribute to placebo responses, the significant between-group differences suggest that dry cupping exerted analgesic effects beyond the psychological expectation alone (Almeida Silva et al., 2022). This aligns with previous studies demonstrating that cupping engages neurophysiological pathways rather than relying solely on the patient's beliefs (De Melo Salemi et al., 2021; Wood et al., 2020). While these mechanisms have been examined, other potential pathways, such as neurological effects (e.g., pain modulation via gate control theory or pain mechanism) or local cellular responses (e.g., inflammatory responses), may also contribute to the observed treatment response.

The observed reduction in pain relief between sessions highlights the transient nature of cupping's analgesic effects, challenging its long-term sustainability without regular treatment. Statistical analysis revealed significant differences between sessions 1 and 3 and sessions 2 and 3 but not between sessions 1 and 2, suggesting that cumulative benefits may require multiple treatments. For instance, Almeida Silva et al. (2022) reported diminishing analgesic effects in individuals with NSLBP after cupping sessions once a week for eight weeks, highlighting the need for repeated sessions to maintain benefits. Such findings suggest that dry cupping may be most effective when incorporated into periodic treatment regimens as an adjunct intervention rather than as a standalone solution for pain management.

The classification of LBP into acute, subacute, and chronic phases guides clinical decision-making, yet the absence of consistently effective treatments for NSLBP remains a pressing concern (Savigny, 2009; Maher et al., 2017). Systematic reviews highlight the

limitations of current interventions where pharmaceuticals, exercise therapy, and even various stretching techniques such as the McKenzie Method® yield little pain relief (Almeida et al., 2003; Cashin et al., 2023; Hayden & Van Tulder, 2005). While clinical guidelines advocate multimodal strategies, (such as combining education, exercise, manual therapy, and interdisciplinary rehabilitation), the evidence supporting these recommendations is often weak or moderate (based on the Appraisal of Guidelines for Research and Evaluation II Guidelines; Corp et al., 2021; Zaina et al., 2023). This inconsistency highlights the need to explore alternative therapies, such as dry cupping, particularly given its potential mechanisms for pain modulation (Wood et al., 2020). A phased treatment approach may be effective as cupping could serve as an adjunct during acute/subacute stages to facilitate engagement in active therapies.

While this study supports cupping's short-term efficacy, it is important to consider contradictions in the literature, which may be explained by differences in protocol, study design and methodological differences (Corp et al., 2021). Systematic reviews of LBP treatments consistently report weak or minimal benefits for manual therapies, pharmaceuticals, and exercise therapy in chronic stages (Almeida et al., 2003; Cashin et al., 2023; Corp et al., 2021). This suggests that LBP may require multimodal, active strategies such as the interdisciplinary rehabilitation programs recommended by Zaina et al. (2023) rather than passive modalities alone. These discrepancies reinforce the need for standardized protocols based on pain chronicity, severity, and psychosocial factors.

Research Question 5: What are the short-term effects of dry cupping the lumbar paraspinal muscles on blood flow to the paraspinals as indicated by a change in skin temperature and measured by a laser thermometer in individuals with NSLBP?

The intervention group exhibited a statistically significant 1.4°C increase in skin temperature post-treatment, while the placebo group had a 1.2°C decrease, reinforcing cupping's capacity to possibly induce localized cutaneous temperature changes. Analysis revealed a significant three-way interaction between treatment group, time, and session with statistically significant simple main effects across all three sessions. The consistency of these temperature changes across all three sessions provides strong evidence for the reliability of cupping's hemodynamic effects. This thermal response likely reflects localized vasodilation and enhanced blood flow (Cage et al., 2020). The observed 1.4°C temperature increase aligns with the proposed mechanism whereby the negative pressure induced by cupping dilates blood vessels, enhancing microvascular perfusion and oxygenated blood flow to treated tissues (Lowe, 2017; Markowski et al., 2014). The thermal response observed in this study supports previous findings, suggesting that cupping induces meaningful hemodynamic effects in the treated tissues (Arce-Esquivel et al., 2017). For example, Arce-Esquivel et al. (2017) reported a 36% rise in microvascular function (blood vessel activity and responsiveness) in healthy individuals after 10 min forearm cupping, while Wei et al. (2013) documented cervical spine blood flow increases following a 10 min treatment, though both studies lacked control groups and focused on a healthy population. Similarly, Cage et al. (2020) observed a 2°F (approximately 1.1º C) skin temperature increase during forearm cupping in healthy participants, attributing this to localized vasodilation. It is critical to consider that most previous research has focused on a healthy population and is not directly comparable to individuals experiencing NSLBP or the participants

in this study, though the effects of increased cutaneous temperature and potentially blood flow increases may be crucially important for this population. Such circulatory improvements may contribute to accelerated tissue healing, enhanced nutrient delivery, and improved metabolic waste removal, all of which could contribute to the observed clinical benefits and be critically important for a pathological population (Lowe, 2017).

The transient nature of these temperature changes, returning to baseline within 30 mins in prior studies, highlights the potential need for repeated sessions to sustain hemodynamic benefits (Wei et al., 2013). This temporal dissociation suggests that while acute hemodynamic effects may initiate healing processes, sustained benefits likely depend on cumulative treatment effects or secondary physiological adaptations. This study's design, featuring three treatment sessions, begins to address this need for repeated interventions, but longer treatment courses may be necessary to induce lasting circulatory changes.

While skin temperature is often used as an indicator of blood flow, its clinical utility must be considered. This study's lack of parallel increase between temperature changes and functional outcomes parallels Wei et al.'s (2013) findings, suggesting that hemodynamic effects may be secondary to neuromodulatory mechanisms in producing clinical benefits. For example, pain relief may reduce sympathetic nervous system activity. The sympathetic nervous system plays a key role in regulating vascular tone. When pain activates the sympathetic nervous system, it can trigger peripheral vasoconstriction, which may compromise local tissue perfusion by restricting blood flow to affected areas (Kregel, 2021). By alleviating pain, interventions like cupping therapy may downregulate this heightened sympathetic nervous system response. The analgesic effects of cupping therapy, therefore, may help mitigate sympathetically mediated vasoconstriction, promoting vasodilation. This vasodilatory effect may improve regional blood

flow and enhance tissue oxygenation and nutrient delivery, ultimately supporting tissue healing and recovery. The complex connection between pain perception, autonomic function, and local hemodynamics highlights the multifactorial nature of cupping's effects.

Research Question 6: What are the short-term perceived treatment effects of dry cupping the lumbar paraspinal muscles as measured by the PGICS in individuals with NSLBP?

Intervention group participants rated their condition following dry cupping as "much improved" (PGICS: 2.2/7), contrasting with the placebo group's "no change" (3.9/7). No adverse effects or negative outcomes were reported by participants in either the cupping intervention or placebo control groups throughout the study duration. Statistical analysis showed statistically significant improvements across sessions for the intervention group, while the placebo group showed no statistically significant changes. Statistically significant improvements were found between sessions 1 and 3 and sessions 2 and 3 for the intervention group. The progressive improvement in PGICS scores across sessions (with the largest change occurring between sessions 2 and 3) mirrors the pattern seen in objective measures, providing compelling evidence for the validity of patient-reported outcomes.

The intervention group’s positive treatment perceptions may stem from several factors beyond the measured outcomes. The tangible sensations associated with cupping (i.e., pressure, warmth, and tissue release) may enhance perceived legitimacy compared to other passive therapies (e.g., ultrasound therapy), where sensory feedback is minimal (Stephens et al., 2022). Additionally, cupping's cultural resonance and historical roots in Traditional Chinese Medicine may align with patient preferences for holistic care approaches, potentially enhancing perceived benefit through cultural congruence and treatment credibility (Qureshi et al., 2017). This means that therapies with longstanding traditions and use may be perceived as more credible or

effective, not just due to their physical mechanisms, but because they align with one's beliefs about treatment. This marked difference in perceived benefit suggests that cupping's effects extend beyond expectancy alone, reflecting genuine neurophysiological and physiological changes as documented in the objective outcome measures. The consistent pattern between subjective ratings and objective improvements strengthens the case for cupping's clinical use, as patient perception often drives treatment adherence and satisfaction in clinical settings (Stephens et al., 2022).

The placebo group's essentially unchanged ratings suggest blinding was successful, reducing bias from expectancy effects. Although minimal research has been conducted in this realm, this contrasts with previous studies where placebo controls failed to mitigate positive expectations, resulting in more minor between-group differences (Almeida Silva et al., 2022). For example, Almeida Silva et al. (2019) examined the use of a dry cupping therapy on individuals with NSLBP and results revealed no significant differences between groups in outcome measures when comparing the intervention to the sham-control group. The current study's successful blinding strengthens confidence in the specificity of cupping's effects, suggesting genuine neurophysiological and physiological mechanisms beyond placebo responses.

Though very limited research has sought to understand an individual's perceptions of cupping treatment, the findings support broader evidence emphasizing the critical role of patient perceptions in treatment outcomes. This is demonstrated by Takahashi et al. (2012), who found that patient attitudes toward therapy are significantly correlated with functional improvements in patients with rheumatoid arthritis. Similarly, Volpicelli Leonard et al. (2020) found that perceived treatment effectiveness was strongly correlated to satisfaction in chronic pain patients.

However, their use of an unvalidated scale makes it difficult to compare their results with the PGICS outcomes in this study. The consistent connection between patient perception and overall functional outcomes highlights the critical importance of patient attitudes in clinical practice. This is further supported by the findings in this study, where those in the intervention group perceived their condition to be “much improved”, which is objectively reflected in significant changes in other outcome measures (ROM and pain). This also emphasizes a potential connection between subjective and objective treatment outcome measures.

Furthermore Stephens et al. (2022) conducted a survey of healthcare providers, where clinicians rated cupping as moderately to very beneficial (6.85/10) and estimated high patient-perceived efficacy (8.18/10) on a 0 to 10 Likert scale (with higher numbers indicating a more favoured outcome). Direct patient-reported PGICS scores (2.2/7 intervention versus 3.9/7 placebo) may provide more nuanced insights into the patient’s experience of treatment, though the provider’s perspective provides valuable insights into potential prevalence of treatment in practice. In addition, Almeida Silva et al. (2022)’s semi-structured interviews revealed overlapping positive perceptions between cupping and placebo groups, contrasting with the observed significant PGICS differences in this study. This discrepancy may stem from methodological distinctions such as the qualitative approach capturing broad satisfaction, while this study focused on isolated treatment-specific perceptions. Such contrasts highlight the value of multimodal assessment in capturing the complexity of patient experiences.

These findings indicate that dry cupping leads to significant patient-reported improvements ("much improved" on the PGICS) supported by objective measures, while the placebo group showed no change, suggesting genuine therapeutic effects beyond placebo effects. Previously established connections between patient perceptions and treatment outcomes

highlight the importance of understanding this construct. The intervention group's positive perceptions may stem from cupping's tangible sensory feedback and cultural resonance, enhancing treatment credibility. Successful blinding in this study contrasts with prior research, where placebo effects obscured treatment benefits, highlighting the importance of methodology (Almeida Silva et al., 2019). Together, these findings support cupping as a potentially effective intervention while emphasizing the need for further research in this under-explored area to better understand patient perceptions in diverse clinical contexts.

Research Question 7: What are the short-term effects of dry cupping the lumbar paraspinal muscles on overall function as measured by the Roland-Morris Questionnaire in individuals with NSLBP?

The Roland-Morris Questionnaire scores improved by 2.2 points in the intervention group while remaining essentially unchanged in the placebo group (increased by 0.1 points), with statistically significant between-group differences post-intervention (large effect size). While this change fell short of the 5-point MDC, the positive trend across all sessions suggests that functional benefits may require more extended treatment periods to reach full clinical significance (Physiopedia, 2024d). This aligns with rehabilitation models emphasizing that functional recovery often follows a nonlinear trajectory, particularly in conditions like NSLBP (Hu et al., 2022). Within the intervention group, differences across sessions did not reach statistical significance (Physiopedia, 2024d). Though statistically insignificant, participant reports of enhanced ease in activities like bending and sitting was evident. This discrepancy between objective functional measures and patient reports may reflect the limitations of the Roland-Morris Questionnaire in capturing subtle but meaningful functional changes that patients experience in daily activities. Furthermore, it is important to consider the potential for a floor

effect, where baseline scores may have been too low to detect further decline (e.g., minimal disability at enrollment) or to allow for statistical significance to be reached (the scale would have needed to enter negative numbers, based on participant baseline mean score of 3.2). Despite significant pain reduction and improved ROM, functional measures only improved partially. This further highlights the complex relationship between impairment and disability in NSLBP and the various factors that contribute to the overall condition.

The lack of statistically significant improvement across sessions warrants further examination. This phenomenon may reflect the complex nature of functional adaptation, which often requires both physical improvement and behavioural relearning (Hu et al., 2022). This lag effect was more pronounced in the current study compared to Wood et al.'s (2020) findings, potentially because the meta-analysis included studies with built-in behavioral components (e.g., exercise combined with cupping), whereas this study's intervention focused solely on passive therapy. Participants may have experienced reduced physical limitations but continued to employ compensatory movement patterns established during periods of pain, creating a lag between physiological recovery and actual functional improvement. Neuroplastic changes associated with chronic pain may also contribute to this delay, as the nervous system gradually adapts to new movement patterns (Hu et al., 2022).

The discrepancy between ROM gains and functional scores reinforces the complexity of disability in NSLBP, where psychosocial factors (e.g., catastrophizing, depression) often mediate self-reported limitations (Diener, 2021; Hu et al., 2022). This pattern is consistent with broader pain research, which demonstrates that functional recovery often lags behind pain reduction, particularly when long-standing movement avoidance or fear beliefs have developed (Diener,

2021; Hu et al., 2022). Clinically, this suggests that addressing fear-avoidance behaviors early in treatment could accelerate functional gains (Hu et al., 2022).

When contrasting these findings with prior work, contradictory patterns are evident. A systemic review by Wood et al. (2020) reported significant functional improvements in groups of patients receiving cupping versus no treatment across four trials and 191 participants. This suggests that cupping interventions likely have a positive impact on an individual's self-reported functional status measured using various validated self-reported functional ability questionnaires (i.e., Short Form 36, Neck Disability Index, Roland-Morris Questionnaire, Oswestry Disability Index and WOMAC). Furthermore, heterogeneity in cupping protocols (e.g., duration, frequency, and technique) across studies may contribute to inconsistent findings (Wood et al., 2020). Almeida Silva et al. (2019) found no functional differences between the cupping and the placebo groups in NSLBP patients after eight weekly sessions, despite using the same questionnaire (Short From 36) as previously mentioned, emphasizing the challenge of translating short-term ROM and pain improvements into functional gains. The discrepancy between objective ROM improvements (increase of 9.5° flexion and 8.8 cm on the Sit and Reach) and modest functional gains parallels findings in broader NSLBP research, where psychosocial factors like fear-avoidance beliefs and movement catastrophizing often mediated self-reported disability (Diener, 2021; Hu et al., 2022). This means that although the treatment may promote ROM increases, due to psychological factors, individuals may still perceive functional tasks to be challenging or be overly cautious due to fear of certain motions developed because of their condition. Integrating cognitive-behavioral strategies with physical therapies could help bridge this gap between physical capacity and functional performance (Hu et al., 2022).

These discrepancies suggest that this study's short-term design may have limited insight into functional adaptation. Based on this study's findings and previous research, dry cupping of the lumbar paraspinal muscles in individuals with NLSBP likely leads to modest improvements in functional status, particularly when administered over multiple sessions, though the clinical relevance of these gains may require further long-term evaluation. The gradual nature of behavioural change likely requires extended intervention periods to manifest fully in standardized outcome measures, even when underlying physical improvements occur more rapidly.

Limitations

Various limitations must be acknowledged when interpreting this study's findings. Firstly, although previous relationships have been identified between blood flow and skin temperature, the use of skin temperature as an indicator of blood flow limits the ability to make definitive statements about the potential blood flow mechanisms of cupping treatment. While the observed 1.4°C increase in skin temperature post-treatment aligns with prior research linking cupping to localized vasodilation, skin temperature is an indirect measure and may not fully capture underlying hemodynamic changes (Cage et al., 2020; Liu et al., 2022). Factors such as ambient temperature, individual variations in skin thickness, and baseline vascular tone can influence surface temperature readings, introducing variability and reducing precision (Gill, 2023). This study's short-term focus presents another limitation. Immediate post-treatment measurements capture acute effects but overlook long-term adaptation, which is crucial for determining clinical utility. Finally, the lack of a control group (no treatment at all) limits the ability to completely isolate the effect of the intervention itself from the placebo effect and other potential confounding factors.

Delimitations

This study was designed with specific boundaries to ensure internal validity and focus on the immediate effects of dry cupping in a well-defined population. By including adults aged 18–55 years with NSLBP and excluding specific pathologies (e.g., disc herniation, spinal stenosis), the study minimized confounding variables and ensured diagnostic clarity. This approach and research design aligns with the broader NSLBP literature, which emphasizes the importance of distinguishing non-specific from specific causes of LBP (Almeida et al., 2018; Ferreira et al., 2023). The age range was selected to target individuals most likely to benefit from short-term interventions, as younger adults typically exhibit greater tissue plasticity and responsiveness to mechanical therapies like cupping (Ferreira et al., 2023; Markowski et al., 2014).

The study's design as a true randomized trial with a placebo group represents a significant methodological strength. The use of placebo cups with 2 mm holes controlled for nonspecific effects, such as placebo responses or participant expectations, enhancing the validity of the findings (Almeida Silva et al., 2022). This rigorous design aligns with recommendations from systematic reviews, emphasizing the need for high-quality randomized trials to evaluate non-pharmacological therapies (Corp et al., 2021). Additionally, the focus on immediate effects over three sessions provided valuable insights into the short-term therapeutic potential of dry cupping, offering a foundation for future longitudinal studies to explore sustained effects and optimal treatment frequency.

The use of validated outcome measures, such as the NPRS, inclinometry, and the Roland-Morris Questionnaire, further strengthened the study's internal validity. These tools are widely recognized for their reliability and validity in assessing pain, mobility, and functional limitations in NSLBP populations (Boyd, 2012; Gallasch & Alexandre, 2007). By adhering to standardized

protocols, the study ensured consistency and comparability with prior research, facilitating a meaningful interpretation of the results.

Future Research

Future research may examine the effectiveness of dry cupping treatment from a longitudinal perspective. Longitudinal investigations are essential to evaluate the sustainability of dry cupping's effects over weeks, months, or years and establish evidence-based protocols for treatment frequency. Such studies could clarify whether repeated sessions yield cumulative benefits or if diminishing returns occur, informing clinical guidelines for maintenance therapy.

Furthermore, the use of a Doppler ultrasound to examine the specific effect of treatment on blood flow may improve the overall understanding of treatment mechanisms (Wang et al., 2020). By examining the specific impact of dry cupping on blood flow and tissue perfusion, researchers can uncover more detailed mechanisms of action, potentially clarifying its physiological effects and helping to establish a scientific foundation for its use.

Finally, integrating qualitative methodologies such as semi-structured interviews or patient diaries would contextualize quantitative outcomes by capturing lived experiences, including perceived barriers to adherence, cultural attitudes toward cupping, or unexpected benefits like improved sleep or mood. These perspectives could enrich the body of evidence surrounding dry cupping and provide healthcare professionals with a more comprehensive understanding of the treatment's acceptability and effectiveness in diverse populations.

Chapter 5 – Conclusion

This study demonstrates that dry cupping produces statistically significant improvements in pain, ROM, and perceived treatment effect in individuals with NSLBP, with more modest effects on functional measures as well as clinically meaningful effects on ROM and pain. These benefits may result from specific neurophysiological and physiological mechanisms rather than expectancy effects alone, as evidenced by the significant differences between intervention and placebo groups across multiple outcome measures. The placebo cupping procedure controlled for contextual and psychological factors while eliminating the mechanical tissue deformation and circulatory effects hypothesized to drive therapeutic outcomes. The significant difference in response between groups supports the theory that cupping's effects stem from genuine neurophysiological processes rather than purely psychosocial factors.

When evaluating dry cupping within the broader landscape of non-pharmacological interventions for NSLBP, various comparisons can be considered. The 2.9-point reduction in pain intensity (NPRS) and 7.9 N increase in pressure pain threshold observed in this study aligns with outcomes reported in previous research (De Melo Salemi et al., 2021; Wood et al., 2020). However, the functional outcomes literature suggests that active approaches may lead to superior improvements in disability measures, with greater Roland-Morris score changes than the 2.2-point improvement observed in this study (Hu et al., 2022). This suggests that while cupping may offer meaningful analgesic benefits comparable to other passive modalities, integration as an adjunct treatment used at the appropriate phase of healing with active rehabilitation strategies and education might optimize functional recovery. Due to the limited risk associated with cupping treatment, it may be favoured over pharmacological approaches (Ferreira et al., 2023). This favourable risk-benefit ratio, combined with the observed immediate effects on pain and

ROM, emphasizes cupping as a valuable intervention for individuals experiencing NSLBP (Almeida Silva et al., 2022).

Data analysis revealed that while some participants experienced immediate relief after the first session, the magnitude and stability of improvements generally increased with subsequent applications. By the third session, 87% of intervention participants reported at least a 30% reduction in pain intensity, compared to just 35% after the initial treatment. This pattern suggests clinicians should consider recommending a series of treatments rather than isolated applications when implementing cupping therapy.

The significant increases in skin temperature in the intervention group after each session (1.4° C) suggest localized vasodilation and enhanced blood flow, a finding consistent with prior research. While these hemodynamic effects may support tissue healing and metabolic waste removal, which are critical for a pathological population such as those with NSLBP, their transient nature implies that repeated sessions are needed to sustain benefits.

Furthermore, patient perceptions of treatment effectiveness were overwhelmingly positive among intervention participants, with 92% reporting satisfaction with outcomes compared to 45% in the placebo group. These satisfaction ratings suggest that patients can accurately perceive meaningful clinical change, which is critically important in clinical practice.

The complex relationship between physical improvements and functional outcomes emphasizes the multidimensional nature of NSLBP and suggests that comprehensive management approaches may be necessary to maximize recovery. Cumulative improvements across sessions suggest that physiological adaptations require iterative stimulation, reinforcing the importance of dosage in clinical protocols. While three sessions yielded meaningful short-

term outcomes, optimal treatment frequency and long-term sustainability remain critical areas for further investigation.

These findings provide evidence for dry cupping as an effective intervention for NSLBP, with benefits extending beyond expectancy effects to produce meaningful clinical improvements. The findings contribute significantly to the growing evidence base for non-pharmacological pain management approaches and offer clinicians additional tools for addressing this prevalent and challenging condition. As research continues to refine the understanding of optimal application parameters and integration strategies, cupping therapy holds promise as a valuable component in contemporary approaches to musculoskeletal care.

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Appendix A
Recruitment Poster

Figure 28. Recruitment Poster used at Lakehead University as well as local chiropractic and physiotherapy clinics and on social media.

Appendix B

Hansol Professional Cupping© Therapy Equipment Set

Figure 29. Hansol Professional Cupping© Therapy Equipment Set used for cupping treatments in both intervention and placebo groups.

Appendix C
Cupping Canada© Certificate

Figure 30. Cupping certificate for the Student Researcher who performed the interventions.

Appendix D

Canon™ Sports Skin Adhesive Spray

Figure 31. Skin Adhesive Spray to be applied to the lumbar spine of all participants prior to the cupping treatment to improve suction and ensure that the cups remain in place for the duration of the treatment.

Appendix E

Numeric Pain Rating Scale

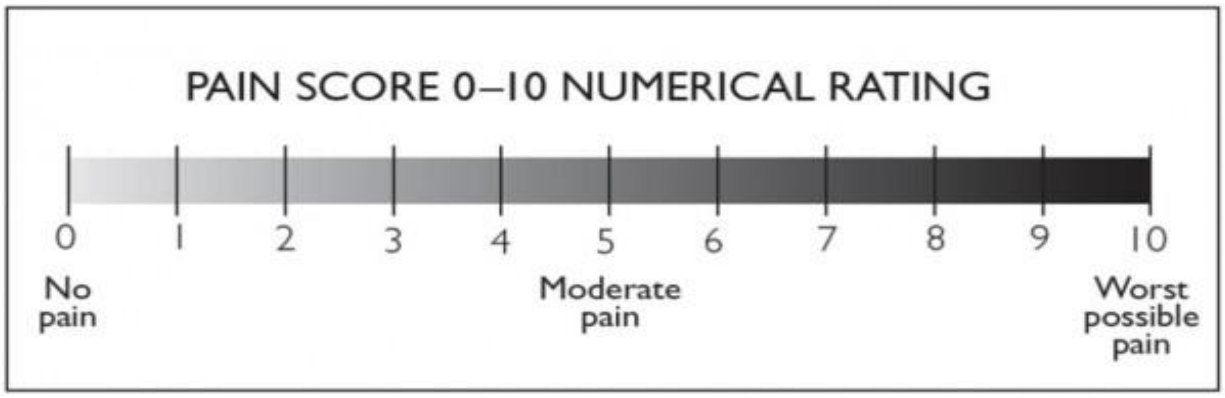


Figure 32. Numeric Pain Rating Scale used to assess subjective pain perception.

Appendix F

Patient Global Impression of Change Scale

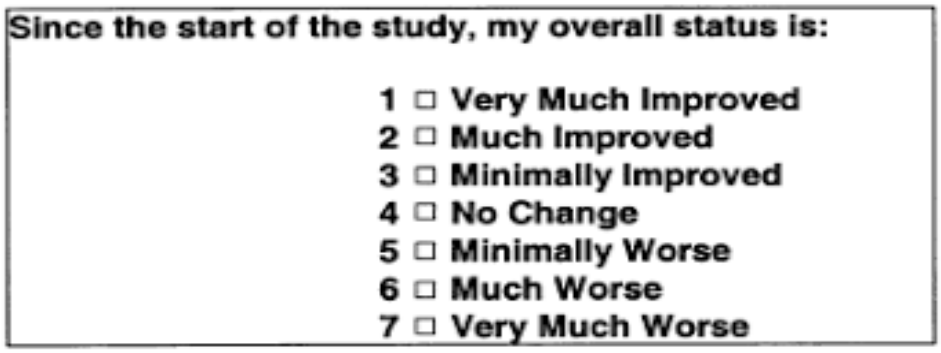


Figure 33. Patient Global Impression of Change Scale used to assess overall perceived treatment effect.

Appendix G
Roland-Morris Questionnaire

Please read instructions: When your back hurts, you may find it difficult to do some of the things you normally do. Mark only the sentences that describe you today.

- ☐ I stay at home most of the time because of my back.
- ☐ I change position frequently to try to get my back comfortable.
- ☐ I walk more slowly than usual because of my back.
- ☐ Because of my back, I am not doing any jobs that I usually do around the house.
- ☐ Because of my back, I use a handrail to get upstairs.
- ☐ Because of my back, I lie down to rest more often.
- ☐ Because of my back, I have to hold on to something to get out of an easy chair.
- ☐ Because of my back, I try to get other people to do things for me.
- ☐ I get dressed more slowly than usual because of my back.
- ☐ I only stand up for short periods of time because of my back.
- ☐ Because of my back, I try not to bend or kneel down.
- ☐ I find it difficult to get out of a chair because of my back.
- ☐ My back is painful almost all of the time.
- ☐ I find it difficult to turn over in bed because of my back.
- ☐ My appetite is not very good because of my back.
- ☐ I have trouble putting on my sock (or stockings) because of the pain in my back.
- ☐ I can only walk short distances because of my back pain.
- ☐ I sleep less well because of my back.
- ☐ Because of my back pain, I get dressed with the help of someone else.
- ☐ I sit down for most of the day because of my back.
- ☐ I avoid heavy jobs around the house because of my back.
- ☐ Because of back pain, I am more irritable and bad tempered with people than usual.
- ☐ Because of my back, I go upstairs more slowly than usual.
- ☐ I stay in bed most of the time because of my back.

Figure 34. Roland Morris Questionnaire used to assess overall function.

Appendix H

Get Active Questionnaire (GAQ)

CSEP | SCPE
THE GOLD STANDARD IN EXERCISE SCIENCE AND PERSONAL TRAINING

Get Active Questionnaire

CANADIAN SOCIETY FOR EXERCISE PHYSIOLOGY –
PHYSICAL ACTIVITY TRAINING FOR HEALTH (CSEP-PATH®)

Physical activity improves your physical and mental health. Even small amounts of physical activity are good, and more is better.

For almost everyone, the benefits of physical activity far outweigh any risks. For some individuals, specific advice from a Qualified Exercise Professional (QEP – has post-secondary education in exercise sciences and an advanced certification in the area – see csep.ca/certifications) or health care provider is advisable. **This questionnaire is intended for all ages – to help move you along the path to becoming more physically active.**

☐ I am completing this questionnaire for myself.

☐ I am completing this questionnaire for my child/dependent as parent/guardian.

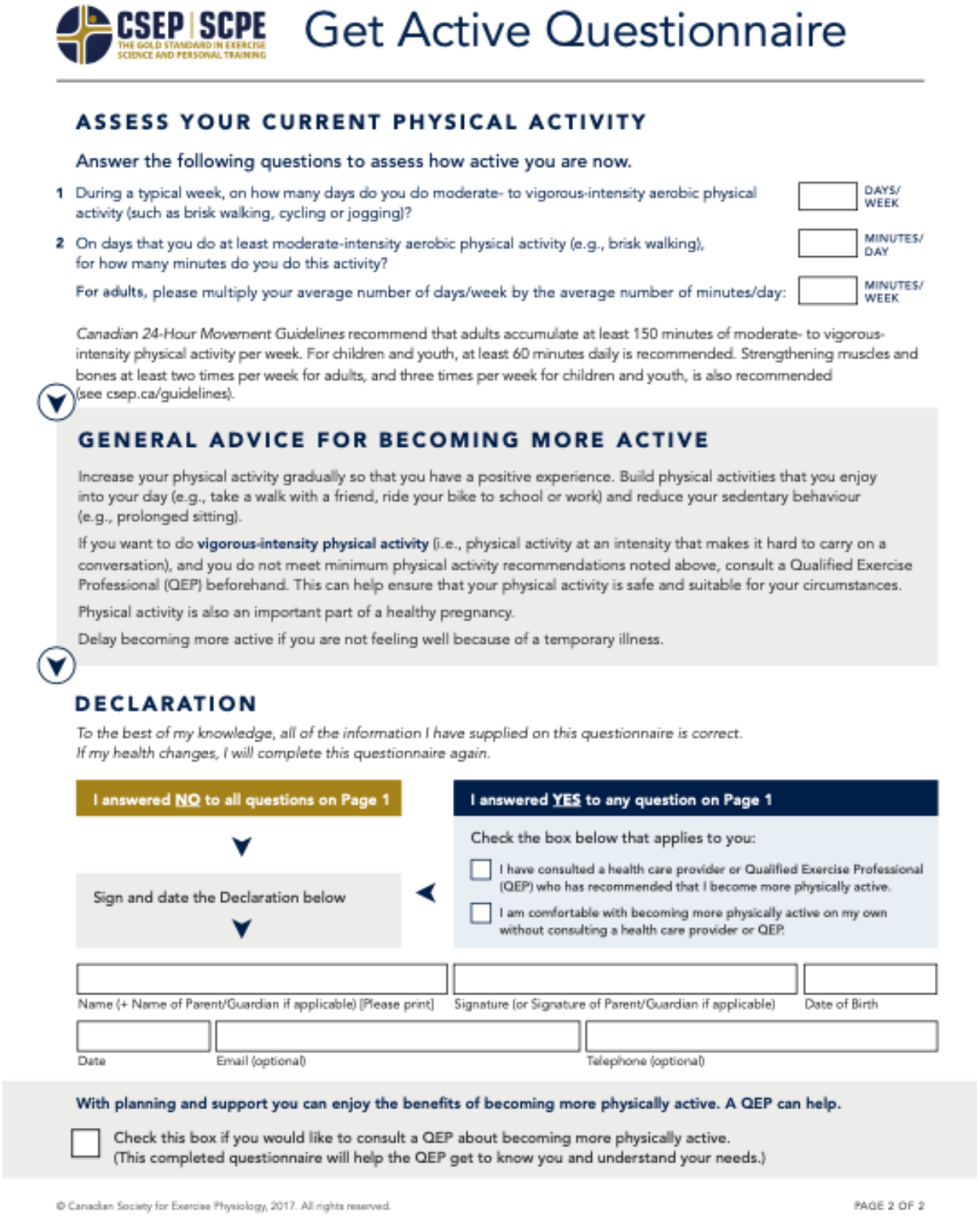
PREPARE TO BECOME MORE ACTIVE

The following questions will help to ensure that you have a safe physical activity experience. Please answer YES or NO to each question before you become more physically active. If you are unsure about any question, answer YES.

YES	NO	
		1 Have you experienced **ANY** of the following (A to F) **within the past six months**?
		A A diagnosis of/treatment for heart disease or stroke, or pain/discomfort/pressure in your chest during activities of daily living or during physical activity?
		B A diagnosis of/treatment for high blood pressure (BP), or a resting BP of 160/90 mmHg or higher?
		C Dizziness or lightheadedness during physical activity?
		D Shortness of breath at rest?
		E Loss of consciousness/fainting for any reason?
		F Concussion?
		2 Do you currently have pain or swelling in any part of your body (such as from an injury, acute flare-up of arthritis, or back pain) that affects your ability to be physically active?
		3 Has a health care provider told you that you should avoid or modify certain types of physical activity?
		4 Do you have any other medical or physical condition (such as diabetes, cancer, osteoporosis, asthma, spinal cord injury) that may affect your ability to be physically active?

NO to all questions: go to Page 2 – ASSESS YOUR CURRENT PHYSICAL ACTIVITY

YES to any question: go to Reference Document – ADVICE ON WHAT TO DO IF YOU HAVE A YES RESPONSE



CSEP | SCPE
THE GOLD STANDARD IN EXERCISE SCIENCE AND PERSONAL TRAINING

Get Active Questionnaire

ASSESS YOUR CURRENT PHYSICAL ACTIVITY

Answer the following questions to assess how active you are now.

1 During a typical week, on how many days do you do moderate- to vigorous-intensity aerobic physical activity (such as brisk walking, cycling or jogging)? ☐ DAYS/WEEK

2 On days that you do at least moderate-intensity aerobic physical activity (e.g., brisk walking), for how many minutes do you do this activity? ☐ MINUTES/DAY

For adults, please multiply your average number of days/week by the average number of minutes/day: ☐ MINUTES/WEEK

Canadian 24-Hour Movement Guidelines recommend that adults accumulate at least 150 minutes of moderate- to vigorous-intensity physical activity per week. For children and youth, at least 60 minutes daily is recommended. Strengthening muscles and bones at least two times per week for adults, and three times per week for children and youth, is also recommended (see csep.ca/guidelines).

GENERAL ADVICE FOR BECOMING MORE ACTIVE

Increase your physical activity gradually so that you have a positive experience. Build physical activities that you enjoy into your day (e.g., take a walk with a friend, ride your bike to school or work) and reduce your sedentary behaviour (e.g., prolonged sitting).

If you want to do **vigorous-intensity physical activity** (i.e., physical activity at an intensity that makes it hard to carry on a conversation), and you do not meet minimum physical activity recommendations noted above, consult a Qualified Exercise Professional (QEP) beforehand. This can help ensure that your physical activity is safe and suitable for your circumstances.

Physical activity is also an important part of a healthy pregnancy.

Delay becoming more active if you are not feeling well because of a temporary illness.

DECLARATION

To the best of my knowledge, all of the information I have supplied on this questionnaire is correct.
If my health changes, I will complete this questionnaire again.

I answered NO to all questions on Page 1

Sign and date the Declaration below

I answered YES to any question on Page 1

Check the box below that applies to you:

☐ I have consulted a health care provider or Qualified Exercise Professional (QEP) who has recommended that I become more physically active.

☐ I am comfortable with becoming more physically active on my own without consulting a health care provider or QEP.

Name (+ Name of Parent/Guardian if applicable) (Please print) | Signature (or Signature of Parent/Guardian if applicable) | Date of Birth

Date | Email (optional) | Telephone (optional)

With planning and support you can enjoy the benefits of becoming more physically active. A QEP can help.

☐ Check this box if you would like to consult a QEP about becoming more physically active.
(This completed questionnaire will help the QEP get to know you and understand your needs.)

Figure 35. GAQ used to assess eligibility to participate in the study.

Appendix I
Inclinometry Method

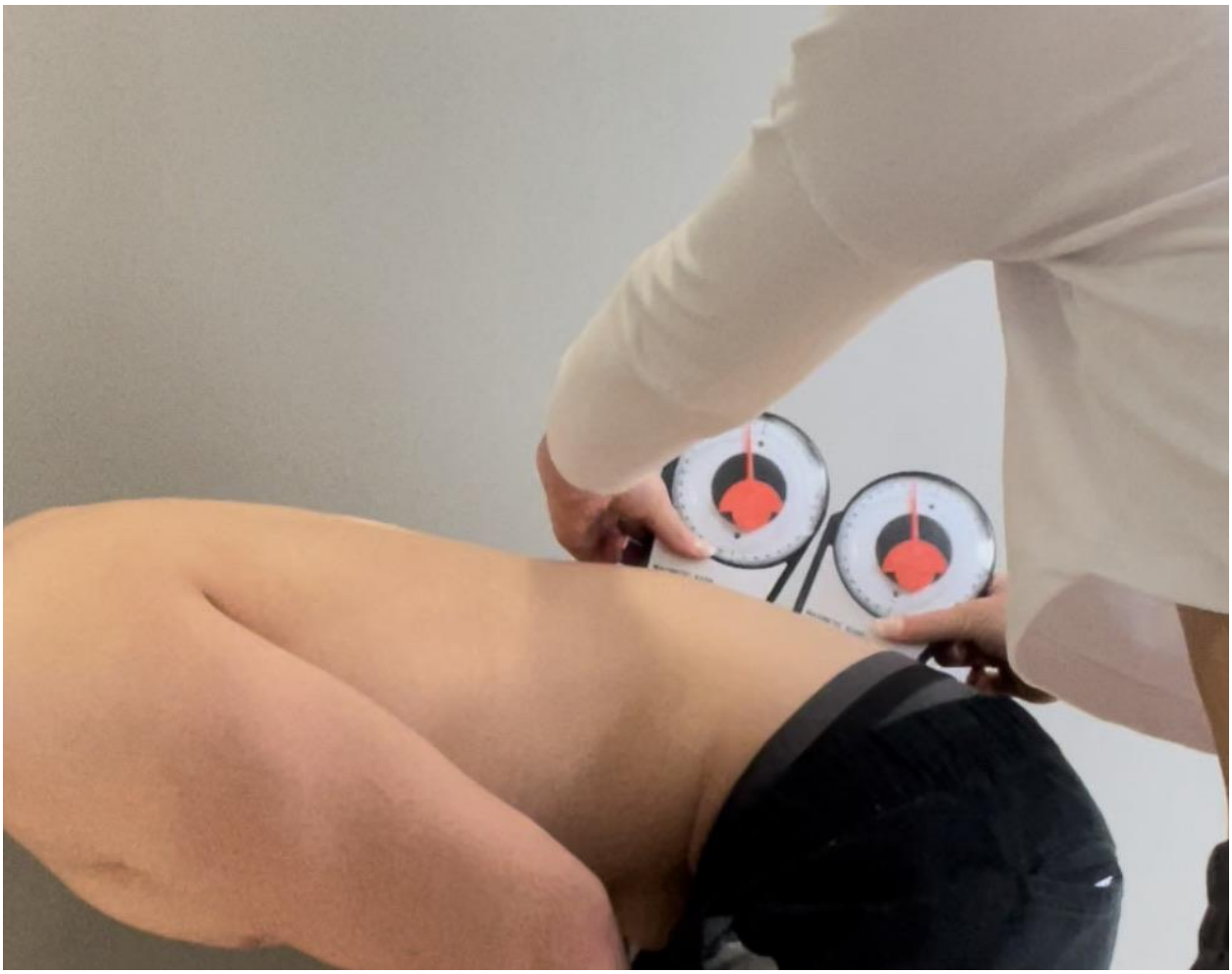


Figure 36. The Tyenaza © Inclinometers will be used to measure the lumbar spine ROM using a dual inclinometry method. The inclinometers will be placed on the right side at L1 and L5. The participant will be instructed to move into forward flexion. At the end of range, both measurements will be recorded, and the procedure will be repeated on the left side.

Appendix J
Information Letter

The Short-Term Effects of Dry Cupping the Lumbar Paraspinal Muscles in Individuals with Non-specific Low Back Pain: A Single-Blind Randomized Trial

Principal Investigator:	Dr. Paolo Sanzo Associate Professor, NOSMU and Lakehead University, School of Kinesiology (807) 343-8010 ext. 8647
Co-Investigators:	Ms. Natasha Scavarelli Graduate Student, Lakehead University (807) 632-8970
Research Team:	N/A
Funding provided by:	N/A

Dear Potential Participant:

You are being invited to take part in a research pilot study that has been designed to examine the effects of dry cupping the lumbar paraspinal muscles on the range of motion of the lumbar spine and changes in blood flow as indicated by skin temperature immediately following the intervention as well as to understand changes in the participant's pain, perception of treatment, and overall function.

Taking part in this pilot study is voluntary. You may refuse to take part, or stop taking part at any time.

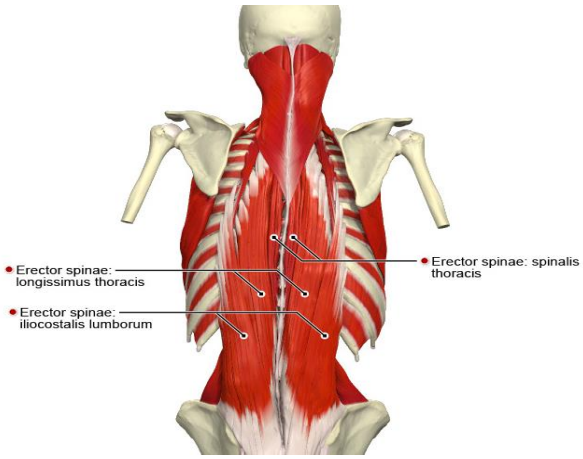
Before you decide whether or not you would like to take part in this pilot study, please read this letter carefully to understand what is involved. After you have read the letter, please ask any questions you may have.

This information and consent form has been reviewed and approved by the Research Ethics Board at TBRHSC.

What is the purpose of this study?

The purpose of this pilot study is to determine the short-term effects of dry cupping the lumbar paraspinal muscles on lumbar spine range of motion, subjective pain perception, blood flow as indicated by skin temperature, perceived treatment effect, and overall function in individuals with Non-specific low back pain. Non-specific low back pain is

categorized as an umbrella term for any low back pain that is not attributable to any other known cause or pathology. To measure lumbar spine flexion range of motion, the Sit and Reach Test as well as dual inclinometry will be used. To measure subjective pain, pressure pain threshold via algometry as well as the Numeric Pain Rating Scale will be used. To measure blood flow, as indicated by skin temperature changes, an infrared thermometer will be used. To understand perceived experience, the Patient Global Impression of Change Scale will be used. To measure function, the Roland-Morris Questionnaire will be used. The investigator leading this project is Dr. Paolo Sanzo, Associate Professor in the School of Kinesiology and a Registered Physiotherapist with the College of Physiotherapy in Ontario, who will be assisted by Natasha Scavarelli, Graduate Kinesiology student, who have completed a cupping course offered by Cupping Canada©.



The Lumbar Paraspinal Muscles (Physiopedia, 2024)

Dry Cups For Treatment Sessions

<u>Who can participate in this study?</u>

Individuals between the ages of 18-55 years, who are experiencing Non-specific low back pain (confirmed by a care provider such as a chiropractor, physiotherapist, medical physician or other regulated health professional with permission to diagnose), are otherwise healthy are encouraged to participate. Any individual with a previous or scheduled surgery to the lower body which may affect their hip and/or knee range of motion, previously experienced trauma to the low back area, are diagnosed with a specific low back or lower body condition (i.e., spondylolisthesis, spinal stenosis, osteoporosis, intervertebral disk derangement), are diagnosed with cancer, are experiencing referred leg symptoms, are confirmed or suspected to be pregnant, or with a confirmed or suspected blood/blood clotting disorder (i.e., hemophiliac), will be excluded from participation. Our goal is to invite 60 people to take part in the pilot study (30 per group).

What will participation involve from me?

The entire duration of the study period will be 6 months. Your participation will be completed in three, 30-60-minute sessions, scheduled approximately 48 hours apart (e.g. Monday, Wednesday, Friday). You will either be placed into an intervention, or placebo group, which will be randomly assigned once consent is obtained to participate prior to the data collection session, and ongoing consent will be maintained throughout the treatment sessions. You have equal probability of being assigned to either group, as the assignment will be done randomly. You will not be aware of your group assignment until all data collection has been completed. Should you be in the placebo group and wish to receive treatment, you will be offered this opportunity upon the completion of the data collection sessions. In the first session, after completing the required paperwork (Get Active Questionnaire, demographic questions, and consent form), you will be given the opportunity to ask any questions or withdraw if you no longer wish to participate. Collected information will include information pertaining to your eligibility to participate physical activity, your current low back pain, your overall function based on your ability to perform daily tasks, and personal information (age, height, weight, gender, sex, birthdate). If you respond "Yes", to any question on the Get Active Questionnaire, you must be cleared by your medical provider prior to participation. If you wish to proceed, you will be asked to change into a loose-fitting shirt, or one that exposes the lumbar spine. The pre-intervention testing will then begin.

Lying face down on the examination table, the investigator will mark the location of your L1 and L5 vertebrae on both the right and the left sides of the spine, using a washable marker. These marks will signify the location for the inclinometers (a device used to measure the angle of your spine when you bend forward). Next, you will be asked to identify the primary location of your low back pain (by pointing), this area will be marked and referred to as P1. You will then be asked to identify the secondary location of your low back pain (by pointing), this area will be marked and referred to as P2. These marked locations will indicate cup placement (above and below) as well as where temperature and pressure pain threshold measurements will be taken. Following that, the investigator will begin by taking the skin temperature using a laser thermometer at P1 and P2 and record the result. Next, the pressure pain threshold will be measured using the algometer's force gauge (a tool that is used to measure the amount of pressure applied to the specified area). This will be done by applying the tip of the force gauge perpendicular to the indicated area and applying a gradually increasing amount of pressure. You will be asked to indicate when the pressure sensation on the area transitions to a sensation of pain. At this point, the value indicated on the algometer will be recorded and the pressure will be removed. Measurements will be taken at P1 and P2, and the two measurements will be recorded. You will then be asked to complete the Sit and Reach Test using the Sit and Reach Device. For this test, you will be asked to long sit on the ground with your legs extended and feet placed against the device pedals. You will then be asked to bend forward with your arms reaching in front of you with your fingertips pushing the metal measuring piece on the device as far as you are able to. Once you have reached the end of range, the measurement will be recorded. Then, you will be asked to stand, and the inclinometers will be placed on the right side of the landmarked

locations of your back. You will be asked to bend forward as far as you can reaching to touch your toes, if possible. At the end of range, the two inclinometer readings will be averaged and recorded. This process will be repeated with the devices placed on the left side of your lumbar spine. You will then be asked to lay prone on the examination table and once again expose the landmarked locations. Next, you will complete the Numeric Pain Rating Scale, indicating your current low back pain on a scale from 0-10. Finally, you will complete the Roland-Morris Questionnaire, to assess your overall function. This questionnaire consists of 24 items, and you will be asked to indicate which of those items apply to your current condition. The questionnaire will be scored by the investigator and the result will be recorded. At this point, a light layer of a skin adhesive spray will be applied to the lumbar spine at the four cupping locations. The plastic cups will then be placed on the marked locations with three pumps of suction and remain there for 10 minutes. After the treatment is completed, the cups will be removed, and the skin temperature will be taken immediately and P1 and P2. The pressure pain threshold will be measured again using the force gauge at P1 and P2 as well as the non-painful site. You will then be asked to complete the Sit and Reach and dual inclinometry tests once again to measure your lumbar spine range of motion, and the Numeric Pain Rating Scale as well as Roland-Morris Questionnaire as described previously. Finally, you will complete the Patient Global Impression of Change Scale, by reflecting on your treatment experience and indicating if your condition is “very much improved (rated a 1) to “very much worse” (rated a 7).

In the second and third sessions, the procedures will be repeated as previously described, with the exclusion of the consent form, GAQ and Patient Demographic Form.

As a participant, you will be asked to perform the above listed procedures to the best of your ability. If questions persist, ask for clarification from the investigator at any time.

Statistical analysis will be conducted using IBM® SPSS® Statistics 28. The information obtained from this pilot study shall be disseminated through publication of a manuscript in a peer-reviewed journal and presentation at local scientific conferences such as the Northern Health Research Conference, Northern Constellations, and/or Showcase of Healthcare Research or other national or international conferences. Your information will remain confidential.

How long will I be involved in the study?

This research project will be completed in three, 30-60-minute sessions, scheduled approximately 48 hours apart (e.g., Monday, Wednesday, and Friday) at Lakehead University.

What are the alternatives to taking part?

If you choose not to participate, you will be thanked for your time and consideration as your decision to take part in this pilot study is completely voluntary.

Are there any benefits to being in this study?

While there is no direct benefit to you as a potential participant in the study, you may experience an increase in lumbar spine range of motion or a decrease in lower back pain immediately following the cupping intervention.

Clinicians can benefit from this pilot study as it will provide information on the short-term effects of cupping on the range of motion of lumbar spine in individuals experiencing non-specific low back pain and the associated functional limitations. Furthermore, it will increase the current knowledge on the potential reduction in pain associated with treatment. As well, patients may benefit from the research as this may provide a method of treatment for non-specific low back pain conditions and provide some education on the use of this modality in the future, to improve patient outcomes.

Are there any potential harms involved with participating?

As a participant, minimal physical risk is associated with participating in this pilot study. You may experience circular marks on the skin where the cups were. This is referred to as hyperpigmentation and is not associated with any trauma to the skin. The risk of these injuries will be minimized by constantly monitoring any discomfort and lessening the suction, if requested by you. You may also stop treatment or testing at any point during the study.

Confidentiality:

Your privacy is very important to us. All information derived from this pilot study will be kept strictly confidential. During your participation in this pilot study, the research team will not consult your health records to obtain data in order to conduct the study. Personal health information is information that could be used to identify you. It includes information such as your name, address, telephone number, date of birth, new and existing medical records, and results of tests and procedures. All personal health information will be kept confidential.

To protect your identity, you will be assigned a unique ID number for this research study. The ID number will be used on any research related forms. The link between your personal information and ID number will be only available to qualified members of the research team. The TBRHSC Research Ethics Board may require access to your study-related records to monitor the conduct of the research. No identifiable information will be copied or taken from our office.

Participation and Withdrawal:

It is important for you to know that participation is entirely **voluntary**. You may refuse to participate, refuse to answer questions, or choose to withdraw from the pilot study at any time. You do not waive any legal rights by signing this consent form.

Withdrawing from this pilot study will not result in any penalty, or compromise your medical care, or cause you to lose any benefits to which you are otherwise entitled. If you wish to withdraw from the pilot study, please call Dr. Paolo Sanzo at 807-343-8010 ext. 8647 or research team at 807-632-8970. Study information may be retracted if you withdraw, upon your request.

Costs:

You will not be paid for being in this research study.

In case of injury:

If you suffer injury as a result of taking part in this pilot study, you will be provided necessary information related to treatment options and providers. You will not receive any other financial compensation.

Conflicts of Interest:

There are no conflicts of interest to declare.

Commercialization:

There is no direct potential for commercialization in this pilot study.

Copy of Information Letter and Consent Form:

You will be given a copy of this signed consent form to keep.

Questions:

If you have any questions about this pilot study you are encouraged to contact the person in charge of this study, Dr. Paolo Sanzo at 807-343-8010 ext. 8647 or the research team at 807-632-8970. If you have any concerns regarding you rights as a research participant, or wish to speak to someone other than a research team member about this research project, you are welcome to contact:

Chair, Research Ethics Board
Thunder Bay Regional Health Sciences Centre
Phone: 807-684-6422
Email: TBRHSC.REO@tbh.net

We thank you for your time,

Dr. Paolo Sanzo and Ms. Natasha Scavarelli

Appendix K
Consent Form

The Short-Term Effects of Dry Cupping the Lumbar Paraspinal Muscles in Individuals with Non-specific Low Back Pain: A Single-Blind Randomized Trial

Research Participant's Consent

I have read the consent form and have had the details of the study explained to me.

All of my questions have been answered satisfactorily. I understand that I am free now, and in the future, to ask any questions about the study.

I agree to participate in this study.

I agree that my personal health and study information may be used as described in the consent form.

I understand that I am free to withdraw at any time without any affect to my current or future health care at the TBRHSC.

I understand the requirements of participating in this research study

I have been informed of the risks and benefits, if any, of participating in this research study

I have been informed of the rights of research participants

_____	_____	____/_____/____
Name of Research Participant *(print)*	Signature of Research Participant	Day Month Year

Signature of Person Obtaining Consent

I have explained the terms of this information and consent form to the research participant and I have answered the questions he/she asked me.

I will give a copy of this signed and dated document to the participant

_____	_____	____/_____/____
Name of Person Obtaining Consent *(print)*	Signature of Person Obtaining Consent	Day Month Year

Appendix L

Participant Demographic/Data Collection Sheet

Gender:_____

Sex: Male Female

Age:_____

Body Mass:_____

Height:_____

	Treatment 1 Pre	**Treatment 1 Post**	**Treatment 2 Pre**	**Treatment 2 Post**	**Treatment 3 Pre**	**Treatment 3 Post**
						Range of Motion Measurements
Sit & Reach Measurement						
Right-Side Lumbar Flexion Measurement						
Left-Side Lumbar Flexion Measurement						
Total Lumbar Flexion Measurement						
						Skin Temperature Measurements
Skin Temperature (Blood Flow Indicator)						
						Pain Measurements
Pressure Pain Threshold (Algometry)						
Pressure Pain Threshold Baseline (In non-painful area)	Body Part Indicated: Measured Value:	Body Part Indicated: Measured Value:	Body Part Indicated: Measured Value:	Body Part Indicated: Measured Value:	Body Part Indicated: Measured Value:	Body Part Indicated: Measured Value:
Pain (Numeric Pain Rating Scale)						
						Overall Perception of Experience
Overall Perception of Experience (Patient Global Impression of Change Scale						
						Function
Function (Roland-Morris Questionnaire)						

Appendix M
Sit and Reach Device

Figure 37. Sit and Reach Device used for the Sit and Reach Test.

Appendix N

Research Question 1 - Pairwise Comparison Tables

Table 2

Estimated Marginal Means – Post Hoc for Multiple Comparisons: Bonferroni, Sit and Reach, Treatment Group and Session

Treatment Group	(I)Session	(J)Session	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
Placebo	1	2	.731	.501	.471	-.555	2.016
		3	.615	.412	.442	-.441	1.672
	2	1	-.731	.501	.471	-2.016	.555
		3	-.115	.305	1.000	-.899	.668
	3	1	-.615	.412	.442	-1.672	.441
		2	.115	.305	1.000	-.668	.899
Intervention	1	2	-1.269*	.340	.003	-2.142	-.397
		3	-4.038*	.553	<.001	-5.458	-2.619
	2	1	1.269*	.340	.003	.397	2.142
		3	-2.769*	.527	<.001	-4.122	-1.417
	3	1	4.038*	.553	<.001	2.619	5.458
		2	2.769*	.527	<.001	1.417	4.122

Note. Based on estimated marginal means. *. The mean difference is significant at the .05 level.
b. Adjustment for multiple comparisons: Bonferroni.

Appendix O

Research Question 2 - Pairwise Comparison Tables

Table 3

Estimated Marginal Means – Post Hoc for Multiple Comparisons: Bonferroni, Total Inclinometry, Treatment Group and Session

Treatment Group	(I)Session	(J)Session	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
Placebo	1	2	.423	.494	1.000	-.843	1.690
		3	.731	.522	.521	-.609	2.070
	2	1	-.423	.494	1.000	-1.690	.843
		3	.308	.318	1.000	-.507	1.122
	3	1	-.731	.522	.521	-2.070	.609
		2	-.308	.318	1.000	-1.122	.507
Intervention	1	2	-1.519	.619	.064	-3.108	.070
		3	-4.250*	.697	<.001	-6.038	-2.462
	2	1	1.519	.619	.064	-.070	3.108
		3	-2.731*	.390	<.001	-3.733	-1.729
	3	1	4.250*	.697	<.001	2.462	6.038
		2	2.731*	.390	<.001	1.720	3.733

Note. Based on estimated marginal means. *. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Appendix P

Research Question 3 - Pairwise Comparison Tables

Table 4

Estimated Marginal Means – Post Hoc for Multiple Comparisons: Bonferroni, Pressure Pain Threshold, Treatment Group and Session

Treatment Group	(I)Session	(J)Session	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
Placebo	1	2	-.390	.385	.961	-1.378	.597
		3	-.421	.391	.875	-1.424	.582
	2	1	.390	.385	.961	-.597	1.378
		3	-.031	.175	1.000	-.479	.418
	3	1	.421	.391	.875	-.582	1.424
		2	.031	.175	1.000	-.418	.479
Intervention	1	2	-1.327	.629	.135	-2.941	.287
		3	-3.715*	.788	<.001	-5.737	-1.694
	2	1	1.327	.629	.135	-.287	2.941
		3	-2.388*	.654	.004	-4.066	-.711
	3	1	3.715*	.788	<.001	1.694	5.737
		2	2.388*	.654	.004	.711	4.066

Note. Based on estimated marginal means. *. The mean difference is significant at the .05 level.
b. Adjustment for multiple comparisons: Bonferroni.

Appendix Q

Research Question 4 - Pairwise Comparison Tables

Table 5

Estimated Marginal Means – Post Hoc for Multiple Comparisons: Bonferroni, Subjective Pain Perception, Treatment Group and Session

Treatment Group	(I)Session	(J)Session	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
Placebo	1	2	-.423	.267	.377	-1.108	.262
		3	-.308	.282	.855	-1.030	.415
	2	1	.423	.267	.377	-.262	1.108
		3	.115	.101	.795	-.144	.375
	3	1	.308	.282	.855	-.415	1.030
		2	-.115	.101	.795	-.375	.144
Intervention	1	2	.192	.215	1.000	-.359	.744
		3	1.096*	.266	<.001	.413	1.779
	2	1	-.192*	.215	1.000	-.744	.359
		3	.904*	.196	<.001	.401	1.407
	3	1	-1.096*	.266	<.001	-1.779	-.413
		2	-.904*	.196	<.001	-1.407	-.401

Note. Based on estimated marginal means. *. The mean difference is significant at the .05 level.
b. Adjustment for multiple comparisons: Bonferroni.

Appendix R
Research Question 5 - Pairwise Comparison Tables

Table 6

Estimated Marginal Means – Post Hoc for Multiple Comparisons: Bonferroni, Lumbar Spine Skin Temperature, Treatment Group and Session

Session	Condition	(I)Time	(J)Time	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
1	Placebo	Pre-	Post-	1.077*	.204	<.001	.667	1.486
		Post-	Pre-	-1.077*	.204	<.001	-1.486	-.667
	Intervention	Pre-	Post-	-.973*	.204	<.001	-1.383	-.564
		Post-	Pre-	.973*	.204	<.001	.564	1.383
2	Placebo	Pre-	Post-	1.281*	.193	<.001	.893	1.668
		Post-	Pre-	-1.281*	.193	<.001	-1.668	-.893
	Intervention	Pre-	Post-	-1.131*	.193	<.001	-1.518	-.743
		Post-	Pre-	1.131*	.193	<.001	.743	1.518
3	Placebo	Pre-	Post-	1.677*	.200	<.001	1.276	2.078
		Post-	Pre-	-1.677*	.200	<.001	-2.078	-1.276
	Intervention	Pre-	Post-	-1.258*	.200	<.001	-1.659	-.857
		Post-	Pre-	1.258*	.200	<.001	.857	1.659

Note. Based on estimated marginal means. *. The mean difference is significant at the .05 level.
b. Adjustment for multiple comparisons: Bonferroni.

Appendix S
Research Question 6 - Pairwise Comparison Tables

Table 7

Estimated Marginal Means – Post Hoc for Multiple Comparisons: Bonferroni, Perceived Treatment Effect, Treatment Group and Session

Treatment Group	(I)Session	(J)Session	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
Placebo	1	2	.038	.087	1.000	-.186	.263
		3	.038	.130	1.000	-.295	.372
	2	1	-.038	.087	1.000	-.263	.186
		3	.000	.147	1.000	-.377	.377
	3	1	-.038	.130	1.000	-.372	.295
		2	.000	.147	1.000	-.377	.377
Intervention	1	2	.231	.101	.019	-.028	.490
		3	.769*	.139	<.001	.412	1.127
	2	1	-.231	.101	.019	-.490	.028
		3	.538*	.127	<.001	.213	.864
	3	1	-.769*	.139	<.001	-1.127	-.412
		2	-.538*	.127	<.001	-.864	-.213

Note. Based on estimated marginal means. *. The mean difference is significant at the .05 level.
b. Adjustment for multiple comparisons: Bonferroni.

Appendix T
Research Question 7 - Pairwise Comparison Tables

Table 8

Estimated Marginal Means – Post Hoc for Multiple Comparisons: Bonferroni, Roland Morris Overall Functional Scores, Treatment Group and Session

Treatment Group	(I)Session	(J)Session	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
Placebo	1	2	-.115	.169	1.000	-.550	.319
		3	-.192	.200	1.000	-.706	.321
	2	1	.115	.169	1.000	-.319	.550
		3	-.077	.166	1.000	-.502	.348
	3	1	.192	.200	1.000	-.321	.708
		2	.077	.166	1.000	-.348	.502
Intervention	1	2	-.154	.190	1.000	-.641	.333
		3	.346	.260	.584	.321	1.013
	2	1	.154	.190	1.000	-.333	.641
		3	.500	.295	.307	.257	1.257
	3	1	-.346	.260	.584	-1.013	.321
		2	-.500	.295	.307	-1.257	.257

Note. Based on estimated marginal means. *. The mean difference is significant at the .05 level.
b. Adjustment for multiple comparisons: Bonferroni.

Table 9

Estimated Marginal Means – Post Hoc for Multiple Comparisons: Bonferroni, Roland Morris Overall Functional Scores, Time and Session

Time	(I)Session	(J)Session	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
Pre-	1	2	.250	.134	.205	-.082	.582
		3	.577*	.168	.004	.161	.992
	2	1	-.250	.134	.205	-.582	.082
		3	.327*	.128	.041	.010	.644
	3	1	-.577*	.168	.004	-.992	-.161
		2	-.327*	.128	.041	-.644	-.010

Post-	1	2	-.135	.126	.870	-.446	.177
		3	.077	.167	1.000	-.336	.490
	2	1	.135	.126	.870	-.177	.446
		3	.212	.172	.675	-.215	.638
	3	1	-.077	.167	1.000	-.490	.336
		2	-.212	.172	.675	-.638	.215

Note. Based on estimated marginal means. *. The mean difference is significant at the .05 level.
b. Adjustment for multiple comparisons: Bonferroni.