UNIVERSITÉ DU QUÉBEC À MONTRÉAL

COMPARAISON BETWEEN A VEGAN AND AN OMNIVORE DIET ON DELAYED ONSET MUSCLE SORENESS IN YOUNG FEMALES

MÉMOIRE

PRÉSENTÉ(E)

COMME EXIGENCE PARTIELLE

DE LA MAÎTRISE EN SCIENCE DE L'ACTIVITÉ PHYSIQUE

PRÉSENTÉ PAR

PRESSILA NJEIM

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COMPARAISON ENTRE LES OMNIVORES ET VÉGÉTALIENNES SUR LA RÉCUPÉRATION RETARDÉE DES DOULEURS MUSCULAIRES CHEZ LES JEUNES FEMMES

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DOMS: Delayed-onset muscle soreness

1RM: 1 Maximal repetition

RANG: Relaxed elbow joint angle

FANG: Flexed elbow joint angle

EIMD: Exercise-induced muscle damage

PPT: Pressure-pain threshold

ROS: Reactive oxygen species

IL: Interleukin

IFN: interferons

TNF-α: Tumor necrosis factor alpha

NF-KB: Nuclear factor kappa B

WHO: World health organization

SAFA: Saturated fatty acids

(MCP)-1: monocyte chemotactic protein

CRP: C-reactive protein

CI: confidence interval

CK: creatine kinase

VAS: visual analog scale

DXA: dual energy X-ray absorptiometry

RÉSUMÉ

Contexte **:** L'exercice de résistance aiguë pourrait entraîner des douleurs musculaires d'apparition retardée (DOMS), qui en soi est une réponse inflammatoire. Il existe des évidences suggérant qu'un régime végétalien peut être associé à un profil d'inflammation plus faible. Ainsi, on peut affirmer qu'un régime végétalien peut entraîner une réponse inflammatoire plus faible après un exercice de résistance et, par conséquent, une baisse des niveaux de DOMS.

Objectif : Le but de notre étude est de comparer les niveaux de DOMS entre les végétaliennes et les omnivores suite à une séance d'entraînement en résistance de haute intensité.

Méthodologie : Notre population était composée de 54 femmes (27 végétaliennes depuis au moins 2 ans et 27 omnivores qui mangent de la viande au moins 3 fois par semaine) en bonne santé et âgée entre 18 et 35ans. Toutes les participantes étaient physiquement actives (>150 min/semaine) avec un IMC entre 18,5 et 24,9 kg/m2. Lors de la première séance, des mesures de base et un entraînement en résistance ciblant les muscles principaux étaient effectués. L'entraînement en résistance était composé de 4 séries de 10 répétitions des 4 exercices suivants ; développé couché, leg press, flexion des biceps et ischio jambiers. La charge représentera 80% de la force maximale de chaque participante. Deux questionnaires portant sur le bien-être, l'état d'anxiété, ainsi que l'échelle des sentiments et de l'excitation étaient utilisés pour étudier l'aspect psychologique des participantes. La circonférence musculaire et le seuil de point de pression, était utilisée pour la mesure des niveaux de DOMS. Un dynamomètre et un 1RM (chest press et leg press) était utilisé pour mesurer la force musculaire et l'endurance musculaire. La composition corporelle était mesurée avec un DXA scan et le profil alimentaire était mesuré par un journal alimentaire de 3 jours. Toutes les mesures étaient répétées 48 heures après la séance d'exercice.

Résultats : Aucun changement ou changement similaire n'a été constaté après un exercice de résistance aiguë pour le bien-être et les circonférences musculaires entre les groupes. Cependant, les changements de PPT étaient significativement meilleurs chez les végétaliens par rapport aux omnivores pour le biceps droit ($p = 0,002$), le vaste médial gauche ($p = 0,03$) et le vaste latéral droit ($p = 0,002$). Des changements favorables significatifs ont également été observés pour la force de préhension droite chez les végétaliens par rapport aux omnivores ($p = 0,04$).

Conclusion : Les végétaliennes étaient associées à de meilleurs changements dans les niveaux de DOMS après un exercice de résistance aiguë par rapport aux omnivores, ce qui pourrait suggérer de plus grandes améliorations de la récupération musculaire.

Mots clés : Courbatures, endurance, performance, viande, résistance, douleur.

ABSTRACT

Background: Acute resistance exercise is associated with an elevated inflammation response, which could lead to delayed onset muscle soreness (DOMS). There is evidence that suggests that ingesting foods that have anti-inflammation properties may help reduce DOMS. A vegan diet has also been shown to be an anti-inflammatory diet which could in turn decrease DOMS.

Objective and hypothesis: The purpose of the present study was to compare markers of DOMS between vegans and omnivores after acute resistance exercise in young females. We hypothesize that vegans will have a better recovery of DOMS markers after a resistance exercise session compared to omnivores.

Methods: We recruited 27 vegans and 27 omnivores to participate in this study. All volunteers will follow either a vegan or an omnivore diet for at least 2 years. As for the inclusion criteria all subjects must not perform any resistance training or weight training, young healthy women (18-35 years old) with a normal weight (BMI: 18.5-24.9kg/m2) were recruited. Participants must be nonsmokers and should consume less than 2 alcoholic drinks per day. Anthropometric measurements, pressure pain threshold (PPT), body composition, muscle endurance and strength (leg and chest press), markers of DOMS (swelling, and pain) and dietary factors as well as a wellness and anxiety questionnaire were measured. All participants also performed an acute resistance session that consisted of 4 exercises with 4 sets of 10 repetitions to induce DOMS.

Results: No changes or similar changes were found after acute resistance exercise for wellness and muscle circumferences between groups. However, changes in PPT were significantly better in vegans compared to omnivores for the right biceps ($p = 0.002$), the left vastus medialis ($p = 0.03$) and the right vastus lateralis ($p = 0.002$). Significant favourable changes were also observed for right grip strength in vegans vs. omnivores ($p = 0.04$).

Conclusion: Vegans were associated with better changes in DOMS levels after acute resistance exercise compared to omnivores, which could suggest greater improvements in muscle recovery.

Keywords: Pain, muscle recovery, resistance training, muscle strengths, veganism

INTRODUCTION

Currently, nutrition and its effect on health are becoming more and more recognized among the population. People are showing more interest in plant-based diets because of its protective properties, health benefits and richness in anti-oxidants and vitamins (Menzel *et al.,* 2020). A plant-based diet is considered to be rich in whole-grain foods, vegetables, legumes, fruits and nuts which provides a high number of phytochemicals, vitamins, minerals anti-oxidants and dietary fibers (Benatar *et al.,* 2018). In fact, there is evidence that shows that a plant-based diet can protect against type 2 diabetes (Lee *et al.,* 2017), cancer (Dinu *et al.,* 2017) and heart diseases (Kahleova *et al.,* 2018) due to the high content in antioxidants and low intake in saturated fatty acids (SAFA) and cholesterol (Benatar *et al.,* 2018). A plant-based diet has progressively become popular due to increased environmental concerns, animal rights activism, moral and ethical values as well as personal preferences. Approximately 3.3% of Americans claim to be vegetarians, while 46% of these people identify as vegans. Six percent of individuals between 18 and 34 years old and 5% of high school students between 14- and 17-years old report being vegetarian or vegan, indicating that vegetarianism is expanding among this group of people (Vitale et Hueglin 2021). The potential health benefits of veganism and vegetarianism have pushed a considerable number of athletes to adapt these diets, making understanding the effects these diets have on exercise and recovery crucial. The prevalence of vegan athletes is increasing; however, the percentage of vegan and vegetarian athletes is not known (Vitale et Hueglin 2021). In 2010, it has been reported at the Delhi Commonwealth Game that 8% of athletes were vegetarians, and 1% among them were vegan (Pelly *et al.,* 2014).

Previous literature has shown that a vegan diet is not detrimental to performance in endurance and muscle strength exercises, on the contrary, according to Boutros *et al.,* (2020), females who follow a vegan diet showed better results in submaximal endurance tests compared to those who follow an omnivore diet. These results are contrary to the popularly belief that animal protein is essential for a better performance. Thus, the aforementioned study provides tantalizing evidence to further explore the effects of vegan versus omnivore diets on other aspects of exercise performance such as muscle recovery.

Eccentric contraction that occurs during a resistance exercise is known to be one of the main reasons behind muscle damage within and among muscle fibers (Zainuddin *et al.,* 2005). This damage is generally felt few hours post exercise, reaching its peak between 24 and 72 hours later, and possibly lasting for several days (Al-Nakhli *et al.,* 2012). In a review of literature by Clarckson *et al.,* (2002) it has been shown that soreness usually subsides within 5 to 7 days after exercise. This process is defined as delayed onset muscle soreness (DOMS) and is associated with muscle soreness, pain, tenderness, stiffness and muscle inflammation. Particularly, DOMS is considered to be one of the symptoms of muscle damage that is induced by eccentric contractions. Previous studies have shown that exercise–induced muscle injuries can trigger inflammatory responses depending on the duration and intensity of the exercise (MacIntyre *et al.,* 1995). Upon injury or infection, plasma protein, fluids and leucocyte move into tissues to clear damaged tissue and repair them. This response is characterized as inflammation. One to two days after high force eccentric exercise, the accumulation of neutrophils peaks, followed by the buildup of monocytes and macrophages which in turn peak after several days (MacIntyre *el al.,* 1995).

New nutritional and behavioral strategies have been immerging to minimize the pain and inflammation that can lead to strength loss, fatigue, limited movement, and decreased quality of daily activities. Thus, alleviating DOMS could lead to less inflammation and thus a better muscle recovery. Accordingly, there is evidence that suggests that ingesting foods with anti-inflammation properties may help reduce DOMS (Kim *et al.,* 2014). It has been shown that individuals who follow a vegan diet have lower C-reactive protein (CRP) and interleukin-6 (IL-6) levels, both important indicators of inflammation and mediators of inflammatory response, than people who follow an omnivore diet (Ganie *et al.,* 2019). A plant-based diet has also been suggested to be an anti-inflammatory diet that ameliorates inflammatory processes and decreases levels of circulating biomarkers which could in turn decrease DOMS (Menzel *et al.,* 2020). Therefore, the purpose of this study will be to investigate DOMS levels between omnivores and vegans after a resistance exercise in young healthy females.

CHAPITRE 1

DELAYED ONSET MUSCLE SORENESS

1.1 Defining muscle soreness

After an unfamiliar or intense exercise, individuals can feel muscle pain for several days. This type of pain is characterized by muscle shortening, loss of strength, swelling and tenderness. It is described as a dull, agonizing pain that is typically experienced during an activity or when pressure is applied to the affected muscle (Connolly *et al.,* 2006). This sensation can range from mild muscle stiffness that subsides when performing daily tasks, to an intense pain that could restrict movement. This pain increases within the first 24 hours after exercise, peaks at 48 hours and decreases in 5 to 7 days after (Armstrong, 1990). Cleak et Eston (1992) also found that peak muscle soreness occurred at 24-48h post-exercise, with serum enzymes peaking at 8-24h after exercise.

1.1.1 Muscle soreness and type of exercise

The degree of muscle soreness after an exercise is defined by the intensity, the duration and the type of muscle contraction during this activity. Physical movements are characterized by the combination of eccentric, concentric and isometric muscle activity. Concentric contraction is characterized by the shortening and contraction of muscle fibers when performing a physical task. Isometric contractions are defined by the tightening and contraction of the muscle without changing its length. Eccentric contraction is defined by the elongation and the contraction of the muscle and is known to cause highest degree of discomfort and pain post-exercise (Gulick *et al.,* 1996). In a comparison between isometric, eccentric and concentric work, eccentric work resulted in a greater degree of DOMS than isometric work (Clarkson et *al.,* 1986). As for the concentric contraction, it showed that there was no significant increase in soreness compared to eccentric contraction (Cleak et Eston 1992). Talag (2013) conducted a study on the relationship between muscle soreness and the type of muscle activity (Figure 1.1). The authors observed that there was no significant difference between isometric and concentric muscle contractions; however, eccentric contractions showed a significant increase in soreness that peaked 48 hours post exercise.

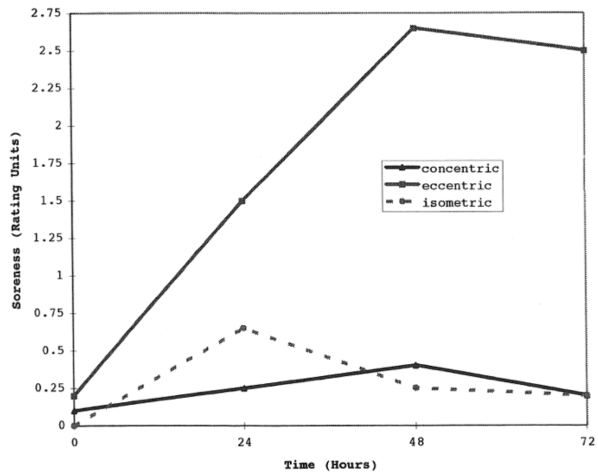
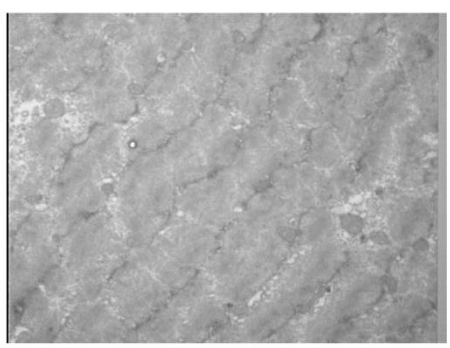


Figure 1 — The effect of various types of muscle activity on muscle soreness over time (62).

Figure 1.1 The effect of each type of muscle contraction on soreness.

1.1.2 Proposed mechanisms of DOMS

The primary mechanism underlying speculations on the pathophysiology of DOMS is based on the microdamage done to the muscle due to unfamiliar or eccentric activity. According to a biopsy investigation of eccentrically strained muscle tissue, there is a loss of myofibrillar integrity with Z-band streaming and sarcomere disruption in the myofibrils (Beaton *et al.,* 2002; Friden *et al.,* 1984) that causes further protein degradation, apoptosis and local inflammatory response (Nahon *et al.,* 2021) (Figure 1.2).



► **Fig. 1** Z-disk disintegration and myofilament disarrangement as sign of ultrastructural damage was evaluated by electron microscopy of biopsies of human vastus lateralis 24 h after strenuous resistance exercise for 70 s time under tension leading to DOMS.

Figure 1.2 Muscle damage in vastus lateralis muscle after a leg biopsy (Hotfiel et al., 2019).

The literature exploring the exact detailed theory of DOMS is large. Researchers have been studying DOMS for more than 120 years (Hotfiel *et al.,* 2019). Several hypotheses have been proposed to explain the mechanisms that are causing DOMS including: inflammation, lactic acid, muscle spasm, muscle damage, enzyme efflux theories and connective tissue damage. Until now, there has been no clear explanation for DOMS, thus, it may occur from the combination of the several proposed hypotheses and concepts. The mechanisms of DOMS will not be further discussed since this is not the objective of the present study. However, in sport science, inflammation is referred to as the cellular, molecular and physiological changes occurring in injured tissues (Scott *et al.,* 2004). In the past, inflammation within the muscles that occurs after a DOMS has occasionally been seen as a negative process linked to muscle damage, pain, and slowed recovery (Toumi et Best 2003). It is now becoming widely accepted that inflammation is a crucial mechanism underlying muscular repair and regeneration. (Chazaud, 2016; Tidball *et al.,* 2014).

1.2 Markers of DOMS

Understanding DOMS and its effect on the body has been challenging throughout the years. Assessing pain has been difficult due to its subjective nature. Multiple questionnaires and visual scales have been created to quantify this pain in a subjective way, nevertheless, new tests are being conducted in order to further aid in quantifying this sensation. As mentioned before DOMS is characterized by symptoms of muscle damage such as muscle pain, loss of muscle strength, stiffness, swelling and perception of decreased well-being. Figure 1.3 shows how these symptoms are quantified with their indirect markers. It is measured by quantifying loss of muscle strength represented by a decrease in 1 repetition maximum (1RM), handgrip and endurance strength. Increase in muscle pain may be assessed by an algometer a device that quantifies pain in Newton after exerting pressure on the muscle. As for muscle swelling, the circumference of the muscle may be used as an indirect measurement using a measuring tape. The perception of well-being could be measured using questionnaires.

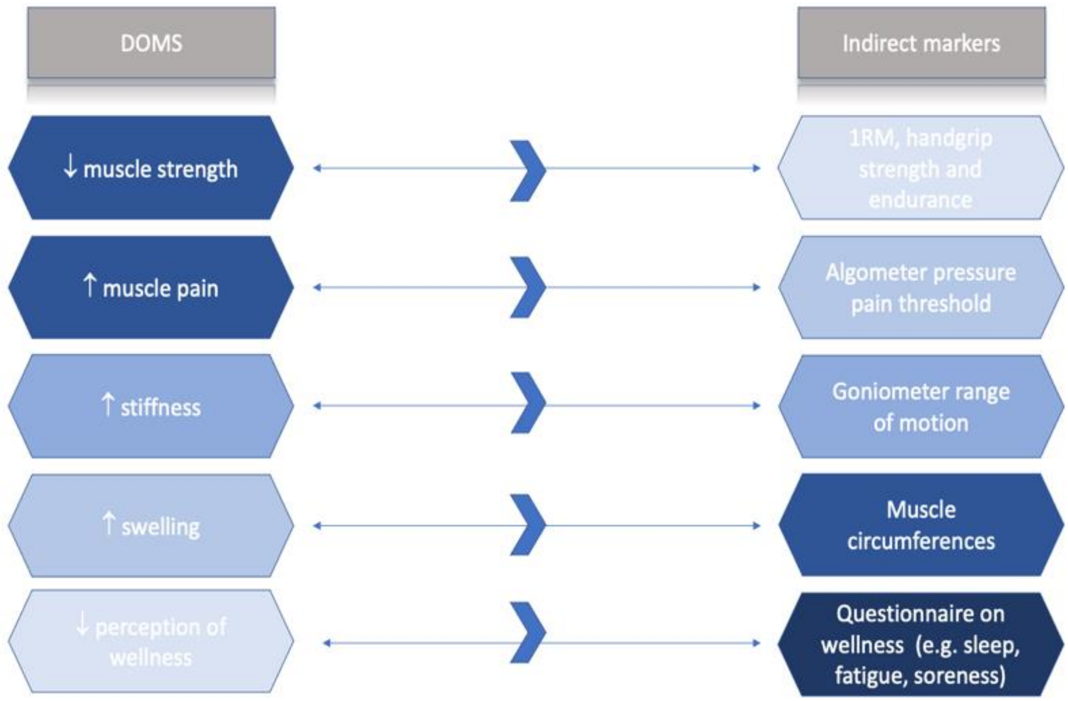


Figure 1.3 Measurement of each symptom of DOMS by indirect markers.

1.2.1 DOMS and muscle strength

Loss of muscle strength may occur immediately after unaccustomed eccentric exercise and could remain for 14 days or more (Clarkson *et al.,* 2002; Howell *et al.,* 1993). For example, the study of Clarckson *et al.,* (1992) showed that when DOMS was induced by eccentric exercise there was a significant loss of muscle strength by 50% immediately after exercise. In another study by Howell *et al.,* (1993), there was a loss of 35% of muscle strength after eccentric exercise of elbow flexors. Likewise, Komi *et al.,* (1977) reported 35% loss of muscle strength after eccentric exercise of knee flexors. According to Clarkson *et al.,* (1992) force loss may be caused by overstretched sarcomeres in which the overlap between actin and myosin filaments is reduced causing a decrease in force production, whereas, Faulkner *et al.,* in 1993 suggested that some sarcomeres may maintain their length during eccentric activity, but others may be harmed when they are stretched past the point of overlap, which will cause a mechanical injury. According to Raastad *et al.,* (2010), myofibrillar disruptions especially at the Z disk (the most vulnerable fiber structure to eccentric exercise induced injury), correlated with the extent of force loss after eccentric contractions.

1.2.2 DOMS and swelling

One of DOMS most known characteristics is swelling of the muscle which is measured by muscle circumference. This was observed by several studies who showed a significant increase in the muscle circumference of the mid-belly and distal junction of the bicep (Cleak et Eston 1992). The mean of the circumference was higher by 1 to 1.8 cm after eccentric-exercise. Intramuscular oedema has been proposed to explain the swelling of the muscle after eccentric exercise (Crenshaw *et al.,* 1944).

1.2.3 DOMS and pain

Soreness is one of the main indication of DOMS. Soreness is the painful sensation that is felt after practicing an unaccustomed exercise training. It can be felt immediately after the exercise and persist up to 7 days post exercise. PPT have been used to measure pain inflicted by DOMS in previous studies (Naderi et *al.,* 2020). For example, in a study by Pearcey *et al.,* in 2015, PPT was measured using an algometer and it was defined as the pain felt after exerting a minimal amount of pressure. In another study by Zainnudin *et al.,* (2005), PPT was measured by palpating the brachialis by the investigator and pain was reported using a visual analog scale that quantifies pain sensation. It has been shown that this pain could be due to mechanical strains in the muscles that may cause muscle inflammation to the muscle fibers and trigger pain responses (Gibson *et al.,* 2009).

CHAPITRE 2

NUTRITIONAL STRATEGIES THAT REDUCE DOMS

2.1 Oxidative stress, inflammation and DOMS

DOMS is considered to be caused by a mechanical stress which triggers a physiological response that initiates a cascade of inflammatory responses and oxidative stress (Drobnic *et al.,* 2014). Oxidative stress is the result of increased levels of free radicals and low levels of antioxidants in the body. This is caused by an imbalance of reactive oxygen species (ROS) and the body's ability to eliminate these products through antioxidants (Szczepanski *et al.,* 2022). When the equilibrium between these free radicals and the endogenous antioxidant is not reached, muscle damage could occur and this may delay muscle recovery (Saranya *et al.,* 2021) (Figure 2.1).

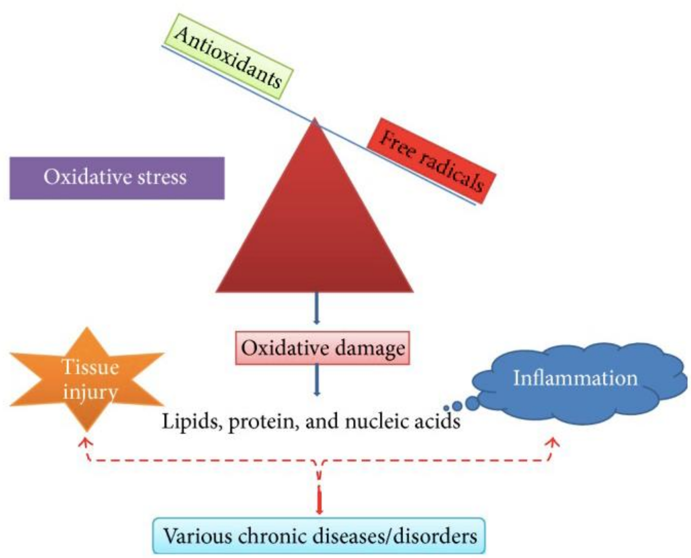


Figure 2.1 Mechanisms that result in tissue injury and inflammation (Saranya *et al.,* 2021).

2.2 Effects of plant-based foods on DOMS

Flavonoids and polyphenols that are usually found in plant-based foods, not only have antioxidant properties, but they also work well as anti-inflammatory agents (Arulselvan *et al.,* 2016). All these types of antioxidants are found in the human diet especially in fruits, vegetables, herbal products and plants. Therefore, consuming plant-based foods may be a good strategy in counteracting the inflammatory response of DOMS.

Interestingly, several interventions studies have examined the effect of certain plant-based foods on DOMS. For example, Sarnaya *et al.,* (2021) reported a decrease in CRP levels and the perception of muscle soreness when participants consumed 200 ml of beetroot, pineapple and turmeric juice for 10 days compared to the control group after performing resistance exercises. This decrease in inflammation could be due to the high content of vitamins and phytochemicals such as beta-carotene, flavonoids and phenols that relieve pain and inflammation, and alleviate DOMS. It has also been shown that pineapple decreases muscle injury and fatigue due to its content in bromelain, an enzyme that reduces soreness and injury by its anti-inflammatory and analgesic properties (Shing *et al.,* 2016).

2.2.1 DOMS and curcumin:

According to numerous research, taking curcumin supplementation pre and post exercise reduces DOMS. In a study conducted by Nicol *et al.,* (2015), 17 healthy men consumed 5 g of curcumin two days before and three days after exercise. The supplement not only decreased DOMS, but it also improved performance, indicating that DOMS attenuation improves performance and speeds up recovery. In another study, 28 men were given 450 mg of curcumin to take before and after resistance exercise, and they found that the curcumin supplementation group experienced considerably less DOMS than the placebo group 48 and 72 hours after exercise in the lower limb (Mallard *et al.,* 2021). Drobnic *et al., (2014)* also found that ingesting 200 mg of curcumin twice daily beginning two days before exercise and finishing 24 hours after exercise, significantly decreased DOMS in the lower limbs after downhill running in men. Curcumin's primary physiological effects include anti-inflammatory and antioxidant properties (Tanabe *et al.*, 2019a). Furthermore, according to a systematic review of curcumin consumption in active people, curcumin could improve muscle performance, exhibit an anti-inflammatory effect by regulating pro-inflammatory cytokines, and decrease the perception of muscle pain (Hossain *et al.,* 2015).

2.2.2 DOMS and Quercetin:

One of the most prevalent flavonoids in the human diet is quercetin, which is found in apples, onions, berries, tomatoes, shallots, red grapes, leafy greens, and tea (Rojano-Ortega *et al.,* 2023). In two double-blind crossover studies, Bazzucchi *et al.,* (2019) and Patrizio *et al.,* (2018) randomly supplemented 12 young males with 1g/day of quercetin and placebo supplementation for 14 days. After exercise, the quercetin group showed a lower decrease in elbow flexor strength and an enhanced relaxed elbow angle. Patrizio *et al.,* (2018) showed less strength loss in the lower knee extensors after supplementing 10 young males with 1 g of quercetin 3 hours prior to exercise. Four other studies used a 10-cm visual analogue scale (VAS) to assess muscle soreness. In inactive to moderately active young men, quercetin supplementation resulted in a considerable reduction of muscular soreness 24-48 hours after exercise. Moreover, Bazzucchi et *al.,* (2019) and Sgro *et al.,* (2021) showed that in sedentary to physically active young men, quercetin supplementation reduced creatine kinase (CK) levels which is an indicator of muscle damage, 24-48 hours after exercise. Additionally, they demonstrated that compared to other dietary supplements, quercetin consumption appeared to be more effective at lowering CK levels. Furthermore, Overman *et al.,* (2011) reported that quercetin reduced the expression of the inflammatory cytokines tumor necrosis factor(TNF), interferon (IFN) , IL-6, and IL-1 transcripts in cultured human macrophages, when utilizing in vitro models and that, according to a review paper published in 2023 by Rojano-Ortega *et al.,* quercetin supplementation could improve antioxidant activity after exercise, which lead to reduced oxidative stress markers.

2.2.3 DOMS and Black currant:

Blackcurrant is a berry plant that is significantly high in antioxidants and vitamins. It appears to have an effect on the indirect markers of muscle damage such as CK. In a study by Lyall *et al.,* (2009), 5 males and 5 females with moderate activity levels were supplemented with 48g of blackcurrant before and after exercise. Blackcurrant supplementation significantly reduced the elevation in CK caused by a 30-min rowing exercise at 80% of maximum oxygen consumption maximal oxygen uptake VO2max compared to the placebo group. In 2016, a study by Hutchison *et al.,* confirmed that supplementation with 473ml of blackcurrant juice twice a day before exercise decreased CK levels 48 and 96 hours post exercise in healthy subjects after maximal eccentric exercise session.

2.2.4 DOMS and Tart cherry juice:

Tart juice is a juice made from cherry and is rich in anthocyanins which exhibit antioxidant and anti-inflammatory properties (Harty *et al.,* 2019). In a randomized controlled trial by Connolly *et al.,* (2006) where 14 young male students were given 14 oz of cherry tart juice or placebo 48 hours after exercise, twice a day for eight days, results showed a lower strength loss and lower pain perception 96 hours after maximal eccentric elbow flexors in the cherry juice group versus placebo group. In a similar study by Bowtell *et al.,* (2011) ten active males consumed cherry juice concentrate for 7 days 48 hours before and after exercise. Results showed an improvement with muscular strength after performing 10 x 10 knee extensions at 80% of one maximal repetition. It has also been demonstrated that the consumption of 480mg/day of tart cherry powder 48 hours after exercise for 10 days reduces muscle soreness, strength loss, and markers of muscle damage after performing eccentric resistance exercise that involves 10 sets of 10 repetitions of barbell back squats at 70% of 1MR (Levers *et al.,* 2016). In addition, a few studies examined the effect of tart cherry juice after endurance exercise. Results showed that daily consumption of this juice appeared to reduce pain perception (Kuehl *et al.,* 2010; Levers *et al.,* 2016), decrease strength loss (Bell *et al.,* 2016; Brown *et al.,* 2019) and reduced markers of muscle damage (Bell *et al.,* 2014; Dimitriou *et al.,* 2015).

2.2.5 DOMS and Pineapple:

Pineapple is a fruit rich in flavonoids and phenolic acid which are two powerful antioxidant that help with inflammation and recovery. Bromelain, a proteolytic enzyme found in pineapple juice and pulps, has also shown to improve recovery. According to Miller *et al.,* (2004) who gave 20 healthy males proteolytic enzyme capsules before a downhill run at 80% of their maximal heart rate for 4 days, a decrease in muscle soreness, increase in muscle function, and a higher pain threshold pressure were detected. Another study by Udani *et al.,* (2009) also reported a decrease in muscle pain and tenderness after supplementing 10 healthy males with protease supplements for 30 days before performing a maximum repetition squat test. In addition, Buford *et al.,* (2009) reported a decrease in muscle strength loss as well as lower levels of IL-6 and IL-12, after supplementing healthy active subjects with 5.8g per day proteolytic enzymes for 21 days.

2.2.6 DOMS and Pomegranate

Pomegranate fruit and juice are both rich in antioxidants and polyphenols such as ellagitannins. Ellagitannins have been reported to have protective anti-inflammatory properties (Trombolt *et al.,* 2010).

Consuming 800ml of pomegranate juice per day for 9 consecutive days helps maintain muscle function and attenuates DOMS after an intense eccentric exercise. In another investigation by Ammar *et al.,* (2016) where 9 weightlifters consumed 750ml per day of pomegranate juice, results showed that when compared to the placebo group, weightlifting training had lower subjective soreness at the 48-hour mark and lower post-exercise levels of CK.

2.2.7 DOMS and Beetroot

Beetroot is a root vegetable that contain a high level of antioxidants, phytochemicals, flavonoids and nitrate. Furthermore, Betalain, an antioxidant with anti-inflammatory properties that is found in beetroot, is shown to have analgesic effects (Pietrzkowski *et al.,* 2014). In a study by Clifford *et al.,* (2016a) where 30 active males were supplemented 3 times day with a high (250ml) and low dose (125ml) of beetroot juice as well as a placebo juice after 100-drop jumps, results showed a decrease in muscle soreness as well as a faster recovery and a greater PPT 48 hours post-exercise. In another study by the same research group, the consumption of a high dose of beetroot juice resulted in a faster recovery, lower pain and better performance 72-hours after repeated sprints (Clifford *et al.,* 2016b). Also, according to Montenegro *et al.,* (2017), consumption of 100mg per day of beetroot juice for 7 consecutive days followed by cycling and running, decreased CK in the blood.

2.2.8 DOMS and tea

Theaflavin and catechins are polyphenolic compounds found in black and green tea and exert antioxidant properties by stimulating and inhibiting antioxidant and pro-oxidant enzymes respectively and by scavenging free radicals (Hamden *et al.,* 2008; Herrlinger *et al.,* 2015). In a study where the effect of both black and green tea in a phenolic blend containing catechin and theaflavins was studied, results showed a decrease in whole body muscle soreness, a maintenance of muscle strength and a decrease in CK levels after eccentric exercise (40 minutes of downhill running) in experimental vs placebo group after supplementing with a phenolic blend of 1000-2000mg/d for 13 weeks. Similarly, Jowko *et al.,* (2011) and Panza *et al.,* (2008) both reported reduced CK responses after sets of bench press at 75-90% of 1RM and 60% of 1RM respectively. Panza *et al.,* (2008) supplemented 14 subjects with 2g of green tea infusion dissolved in water 3 times per day for a duration of 7 days and Jowko *et al.,* (2011) gave 17 subject 640mg per day of green tea extract for 4 weeks. Kerksick *et al.,* (2010) also reported a decrease in muscle soreness in the experimental vs placebo group after supplementing 15 healthy males with 1800mg of polyphenols that are found in green tea for 14 days prior to eccentric knee extensors.

CHAPITRE 3

EFFECT OF A VEGAN DIET ON DOMS AND RECOVERY

3.1 Veganism and recovery

Throughout the years, evidence demonstrating the benefits of vegan and vegetarian diets are increasing. A vegan or a plant-based diet is characterized by a high consumption of grains, oils and nuts, fruits, vegetables beans and soy products. No source of meat or animal products is included in this type of diet.

Numerous athletes are adopting a plant-based lifestyle due to the new findings that suggest that the intake of antioxidants and polyphenol, that have anti-inflammatory properties, leads to a better performance and recovery. In a review where they analyzed the effect of a vegan/vegetarian diet compared to an omnivore diet on inflammatory markers, results showed that plant-based habits were associated with lower CRP levels (Benatar *et al.,* 2018). Thus, one can argue that a vegan diet may lead to a lower inflammation response following resistance exercise and in turn to lower levels of DOMS. To our knowledge, there are no studies that have compared vegans with omnivores on DOMS levels after exercise. However, one recent study has investigated the effect of a vegan protein-based multi-ingredient on exercise recovery (Naclerio *et al.,* 2021). In this double-blind randomized trial, participants (who were not vegans) performed 3 training sessions on a daily basis and were evaluated 1, 24 and 48-hours post training. The well-trained men were randomly allocated to consume a vegan protein-based multi-ingredient post-workout or a maltodextrin which is a carbohydrate-only supplement 10 minutes after each workout for two weeks. Results showed that consuming a vegan diet post workout enhanced the recovery of the subjects 24 to 48-hours post workout compared to the carbohydrate supplement only.

Objective and hypothesis:

The purpose of the present study was to examine the levels of DOMS markers between vegans and omnivores after acute resistance exercise. We hypothesized that vegans would exhibit lower levels of DOMS compared to omnivores.

CHAPITRE 4
METHODOLOGY

4.1 Participants:

Fifty-four young healthy women between 18 and 35 years old were recruited via social media and classroom presentations. Twenty-seven of them were vegans who followed a vegan diet for at least two years, and twenty-seven were omnivores who ate meat at least 3 times a week. Women were chosen because the prevalence of vegans are higher in women than in men (Boutros *et al.,* 2020).
A recruitment form was filled during a phone interview to confirm that the participants fit the study criteria which are: (1) female, (2) between the age of 18 and 35 years, (3) healthy BMI between 18.5 and 24.9 kg/m^2, (4) non-smokers, (5) less than 2 alcoholic drinks per day and (6) less than 150 minutes per week of endurance exercise. Exclusion criteria are: (1) performing resistance training, (2) being pregnant and (3) having a history of medical or orthopedic diseases. Participants were identified as vegan or omnivores via the recruitment and was later confirmed by the 3-days dietary journal provided by them. Participants were invited to come to the Department of Exercise Science at the Université du Quebec a Montreal if they meet all the criteria.

4.2 Study procedure:

The experiment consisted of 2 visits, in which measurements were taken before and 48 hours after one eccentric resistance exercise session. Studies have shown that DOMS peaks between 24 to 48 hours post-exercise in young active subjects which will be our ideal period to measure the markers of recovery (Talag e*t al.,* 2015). Also, women were tested in the follicular phase of the menstrual cycle. Visit 1 took around 2 hours whereas visit 2 took an hour of repeated measurements.
After reading, understanding, and signing the consent form that was approved previously by the ethics committee, participants started with the testing in the laboratories of Université du Québec à Montréal. The procedure consisted of the following:

4.3 Measurements

Wellness and anxiety questionnaires

Validated questionnaires were filled by the participants at the beginning of the session with the help of the team. There are English and French versions of the questionnaires in case needed. The anxiety, arousal and feeling state well-being questionnaires was used before and after the training session to quantify the self-reported well-being of each participant. There were 4 questionnaires to fill that would describe how they were feeling physically and mentally before and after the intervention.

Muscle circumferences

We measured the circumferences of the bicep, thigh, and calves before and after the training session using a Guilk measuring tape. This measurement indicates the swelling of the targeted muscles. In these measurements, the subject was standing straight with their arms relaxed on both sides in the zero anatomical position. To measure the bicep circumference, the measurement tape was placed on the largest circumference which represent approximately the mid-belly of the bicep which was 1/3 of the distance from the lateral epicondyle on each side. Each measurement was taken twice on each side and the mean was calculated. To measure the thigh circumference, we took the midpoint of the rectus femoris which was also the midpoint distance between the patella and the anterior superior iliac spine. As for the calves, the midpoint of the muscle was ¼ from the popliteus cavity to the calcaneal tendon. We placed reference marks using a semipermanent ink pen on each site, which was kept during the whole experiment for more precision.

Pressure pain threshold

PPT was measured using an algometer (Shimpo; FGV-50XY, Japan) before and after the exercise session to quantify the pain/soreness felt by each participant. The algometer was used by applying pressure points on major muscle groups such as the quadriceps, calves, pectorals and biceps. Each measurement was taken twice on each side and a mark with a semi-permanent skin marker was placed on each chosen muscle in order to ensure precision on their next visit. A button was given to the subject, and was asked to press the button whenever they feel pain/discomfort.

Maximum hand grip strength

Grip strength was measured using a dynamometer (Shimpo; FGV-200 HX, Japan). The participant was standing in a zero anatomical position holding the dynamometer in one hand with their arm relaxed on the side and was encouraged to perform a maximum hand grip on both right and left sides. Participants was asked to press as much as possible in order to get their maximum hand grip strength. This measurement was repeated twice on each side.

Muscle endurance

The muscular endurance test was performed following the maximum grip strength test. Using the same dynamometer participants were asked to maintain the position at 30% of the maximum force measured during the previous test with their dominant hand. The hold time was then be measured until exhaustion.

One maximal repetition

Muscle strength was measured using the maximum repetition technique with two training machines including a leg press for the lower body and a seated chest press for the upper body. For all exercises, the first trial was practiced as a warm-up of 10 repetitions with a light load determined by the research professional. Subsequently, the load was increased until the maximum effort is reached. The maximum repetition was determined within five trials with a four-minute break between each trial. A failure was defined as an incomplete extension of the load 80% for lower body and 50% for upper of their 1RM body was calculated in order to determine the choice of weights during the exercise intervention.

Body composition

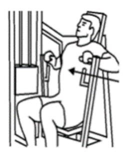
Total body weight, body fat percentage and lean body mass was measured using dual energy X-ray absorptiometry (DXA) (General Electric Lunar Prodigy; standard mode; software version 12.30.008, Madison, WI, USA). Calibration was executed with a standard phantom prior to each test.

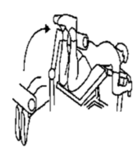
3-day dietary journal

Food intake was assessed using a 3-day dietary journal. Participants were instructed to keep a record of food intake, including condiments and beverages during 3 days (2 weekdays and 1 weekend). Participants were asked to write as much information as possible about the foods they ate (i.e., brand names, percentage of carbohydrates, fats and proteins, how the food was cooked, use of supplements, etc.). No portion-size estimation measurement aid was given to the participants, however, they were asked to use the usual tools to estimate their portion sizes (i.e., teaspoon/ tablespoon/cup in ml or ounces) and, if possible, weigh their portions. On their return, each food record was reviewed by a dietitian to verify the precision of the information written and to complete missing information. Furthermore, based on their dietary journal, the dietitian confirmed if the participants were either vegan or omnivore. No participant misidentified herself as either a vegan or an omnivore. Dietary analyses were completed using Keenoa food processor nutrition analysis software (Montreal, Quebec, Canada) to determine the 3-day average of total energy intake as well as macronutrients and micronutrients.

4.4 Exercise intervention

An eccentric resistance training session that targets all major muscles was performed after pre-measurement. The exercise session consisted of 4 exercises targeting the upper and the lower body. The first exercise was the leg press. The second exercise was the chest press. The third exercise was the leg curl targeting the hamstring muscles and the last exercise was the biceps curl using the cables. Every exercise was performed 4 times with 10 repetitions with a 2-0-2 tempo. There was a rest period of 2 minutes between each set. We also used the Borg Scale to measure the perceived effort of all the participants for each resistance exercise. In addition, a Q-AAP was completed before the start of physical activity sessions to ensure that participants are fit to exercise or are in need of medical clearance.



All measurements were repeated 48 hours after the exercise session during the second visit in the same order, however, the DXA scan was only performed in the pre-testing measurements.

4.5 Statistical analysis:

For the primary analysis, we used linear mixed-effects modelling for repeated measures (pre, post) over time using DOMS markers as the dependent variable and time, group as well as time by group interaction as independent variables. Within the mixed model, we calculated 95% confidence intervals (CI) and p values for 2 prespecified intergroup contrasts and for changes in DOMS makers within each group over time. For all linear mixed model analyses, we examined distributions of residuals and use transformations to achieve normality when necessary.

Sample size:

We estimated that to detect a medium to large effect size with 80 % power at an alpha error of 0.05, a sample of 27 participants in each group would be sufficient.

CHAPITRE 5

RESULTS

Table 5.1 Body composition characteristics of the participants

Variables	Omnivores (n = 27)	Vegans (n = 27)
Age (years)	24.7 ± 3.3	28.9 ± 3.8†
Height (m)	1.6 ± 0.07	1.6 ± 0.05
Total body weight (kg)	61.4 ± 6.9	58.9 ± 7.5
Body mass index (kg/m^2)	23.3 ± 2.8	21.7 ± 2.4†
Total body fat (%)	30.4 ± 5.3	28.9 ± 5.4
Total lean body mass (kg)	40.1 ± 3.8	39.9 ± 4.5

Values are mean ± SD

† Significantly different between groups ($p < 0.05$)

Baseline data:

Height, total body weight, and total body fat percentage were comparable between groups (Table 5.1). However, we observe significant differences for age and BMI ($p < 0.05$).

Table 5.2 Perception of fatigue and muscle soreness as well as quality of sleep and state anxiety of the participants before and after the exercise session

Variables	Omnivores (n = 27)		Vegans (n = 27)		Time Effect	Time * Group Interaction
	Pre	Post	Pre	Post	p	p
Perception of fatigue	3.2 ± 1.3	3.3 ± 1.4	3.2 ±1.5	3.4 ± 1.2	0.4	0.8
Quality of sleep	4.9 ± 1.4	5.0 ± 1.2	4.7 ± 1.0	5.0 ± 0.9	0.4	0.6
Sleep time (min)	452.1 ± 59.1	437.9 ± 81.8	447.8 ± 54.0	449.3 ± 55.1	0.6	0.5
State-anxiety level	10.0 ± 2.9	9.0 ± 3.0	9.1 ± 2.5	8.8 ± 2.0	0.05	0.3
Perception of soreness	0.6 ± 1.3	4.4 ± 1.5*	1.0 ± 1.4	4.5 ± 1.3*	0.001	0.6

Values are mean ± SD;

* Significantly different from baseline values ($p < 0.05$)

Psychological state:

No changes in perception of fatigue, quality of sleep, sleep time and state-anxiety were observed after the exercise session (Table 5.2). However, we observed a significant time effect for perception of soreness but no time*group interaction, suggesting that both groups significantly increased their perception of soreness similarly after the exercise session ($p < 0.05$).

Table 5.3 Swelling characteristics of the participants before and after the exercise session

Variables	Omnivores (n = 27)		Vegans (n = 27)		Time Effect	Time * Group Interaction
	Pre	Post	Pre	Post	p	p
Right thigh circumference (cm)	49.6 ± 4.0	50.3 ± 4.0*	47.0 ± 4.1	47.5 ± 3.8*	<0.001	0.4
Left thigh circumference (cm)	49.5 ± 4.2	50.2 ± 4.1*	47.4 ± 4.0	47.5 ± 4.0*	0.02	0.1
Right calf circumference (cm)	35.5 ± 2.4	35.6 ± 2.3	33.9 ± 2.2	33.9 ± 2.1	0.5	0.1
Left calf circumference (cm)	35.7 ± 2.4	35.7 ± 2.4	34.1 ± 2.0	34.0 ± 2.0	0.8	0.3
Right arm circumference (cm)	25.4 ± 2.3	25.7 ± 2.3*	24.0 ± 1.8	24.2 ± 1.6*	0.005	0.6
Left arm circumference (cm)	25.5 ± 2.3	25.6 ± 2.3	23.9 ± 1.9	24.1 ± 1.8	0.2	0.5

Values are mean ± SD;

* Significantly different from baseline values ($p < 0.05$)

Swelling:

There were no significant changes in the circumference of the right calf, left calf and left arm after the exercise session (Table 5.3). However, we observed a significant time effect for the circumference of the right thigh, left thigh and right arm but no time*group interaction, which suggests a comparable increase in both groups after the exercise session ($p < 0.05$).

Table 5.4 Pressure pain thresholds characteristics of the participants before and after the exercise session

Variables	Omnivores (n = 27)		Vegans (n = 27)		Time Effect	Time * Group Interaction
	Pre	Post	Pre	Post	p	p
Right pectoralis (N)	23.1 ± 10.4	19.7 ± 11.7	23.3 ± 8.8	27.5 ± 15.8 †*	0.8	0.01
Left pectoralis (N)	23.1 ± 11.0	21.8 ± 13.0	26.2 ± 10.8	27.2 ± 15.2	0.9	0.3
Right biceps (N)	25.6 ± 12.3	19.8 ± 9.5*	25.1 ± 11.5	29.2 ± 16.2†	0.6	0.002
Left biceps (N)	23.4 ± 12.6	21.2 ± 10.4	25.1 ± 11.1	26.7 ± 14.7	0.7	0.09
Right vastus intermedius (N)	46.3 ± 19.6	42.9 ± 20.2	42.9 ± 15.1	48.3 ± 20.1*	0.5	0.008
Left vastus intermedius (N)	45.3 ± 19.6	42.7 ± 19.5	42.6 ± 13.9	46.1 ± 16.7	0.8	0.8
Right vastus medialis (N)	35.9 ± 16.8	33.2 ± 19.2	36.9 ± 14.2	37.4 ± 16.8	0.5	0.3
Left vastus medialis (N)	35.2 ± 15.4	31.7 ± 17.7*	38.1 ± 12.9	39.3 ± 16.8	0.3	0.03
Right vastus lateralis (N)	37.1 ± 16.9	29.5 ± 11.4*	36.0 ± 15.7	38.5 ± 20.3†	0.1	0.002
Left vastus lateralis (N)	33.5 ± 19.3	28.5 ± 12.2	35.7 ± 14.2	37.7 ± 18.8	0.5	0.07
Right calf (N)	37.6 ±15.8	34.6 ± 15.3	34.6 ± 12.9	39.6 ± 18.0*	0.5	0.008
Left calf (N)	36.8 ± 14.1	34.4 ± 17.9	36.0 ± 13.4	39.2 ± 20.2	0.8	0.1

Values are mean ± SD;

* Significantly different from baseline values ($p < 0.05$);

† Significantly different between groups ($p < 0.05$)

Pain soreness:

No changes in the PPT of the left pectoralis, left biceps, left vastus intermedius, right vastus medialis, left vastus lateralis and left calf were observed after the exercise session. However, we observed a significant time*group interaction for the PPT of the right pectoralis, right vastus intermedius and right calf but with no significant time effect. Indeed, a significant increase was only observed in the vegan group for these

PPT ($p < 0.05$). In addition, vegans had significantly higher-pressure pain thresholds of the right pectoralis at post values when compared to omnivores. We also showed a significant time*group interaction for the PPT of the right biceps, left vastus medialis and right vastus lateralis but no significant time effect was observed. Indeed, we observed a significant decrease in the omnivore group only for these PPT ($p<0.05$). Moreover, PPT of the right biceps and right vastus lateralis were significantly higher in vegans at post values when compared to omnivores.

Table 5.5 Muscle strength and endurance characteristics of the participants before and after the exercise session

Variables	Omnivores (n = 27)		Vegans (n = 27)		Time Effect	Time * Group Interaction
	Pre	Post	Pre	Post	p	p
Right grip strength (N)	228.4 ± 59.9	213.7 ± 57.7*	231.2 ± 60.2	233.6 ± 54.6	0.1	0.04
Left grip strength (N)	207.4 ± 52.2	208.0 ± 56.5	215.5 ± 58.6	219.3 ± 58.7	0.6	0.7
Grip endurance (sec)	162.2 ± 68.2	126.2 ± 70.3*	230.9 ± 122.8†	221.6 ± 102.4*†	0.02	0.2
Chest press (kg)	49.0 ± 11.4	46.5 ± 11.7*	45.4 ± 12.6	44.5 ± 13.3*	0.03	0.3
Leg press (kg)	101.2 ± 20.6	98.7± 29.0	100.2 ± 42.2	108.5 ± 56.4	0.4	0.1

Values are mean ± SD;

* Significantly different from baseline values (p < 0.05);

† Significantly different between groups (p < 0.05)

Muscle strength:

No changes in left grip strength and leg press were observed after the exercise session (Table 5.5). However, we showed a significant time*group interaction for right grip strength but with no significant time effect. Indeed, we observed a significant decrease in the omnivore group only after the exercise session (p < 0.05). We also observed a significant time effect for grip endurance and chest press but no time*group interaction, suggesting that both groups decreased similarly after the exercise session. Furthermore, vegans had significantly higher grip endurance at pre and post values compared to omnivores.

Table 5.6 Dietary characteristics of the participants

Variables	Omnivores (n =27)	Vegans (n = 27)
Total energy intake (kcal)	1781.5 ± 483.1	1909.1 ± 458.1
Carbohydrates (g)	203.7 ± 67.7	262.2 ± 55.5†
Dietary fiber (g)	18.4 ± 7.6	32.6 ± 11.6†
Proteins (g)	73.2 ± 15.7	62.1 ± 16.4†
Protein (g/kg body weight)	1.2 ± 0.3	1.1 ± 0.3
Isoleucine (g)	2.8 ± 0.7	1.7 ± 0.7 †
Leucine (g)	4.7 ± 1.2	2.3 ± 1.2†
Valine (g)	3.0 ± 0.7	2.0 ± 0.8†
Alanine (g)	2.9 ± 0.8	1.8 ± 0.7†
Fat (g)	76.9 ± 27.3	74.6 ± 34.0
Trans fat (g)	0.6 ± 0.3	0.2 ± 0.2†
Saturated fat (g)	23.8 ± 11.2	16.2 ± 7.1†
Monounsaturated fat (g)	29.1 ± 10.7	28.1 ± 17.2
Polyunsaturated fat (g)	16.6 ± 7.3	16.1 ± 7.6
Vitamin B12 (mcg)	3.2 ± 1.0	1.7 ± 2.6†
Vitamin C (mg)	76.5 ± 52.6	148.1 ± 110.1†
Vitamin D (IU)	98.3 ± 59.6	63.3 ± 86.3
Iron (mg)	12.1 ± 3.3	18.8 ± 5.8†
Zinc (mg)	9.0 ± 2.6	8.8 ± 4.4
Copper (mg)	1.2 ± 0.5	1.9 ± 0.7†
Magnesium (mg)	268.0 ± 97.5	382.7 ± 126.9†
Beta carotene (mcg)	4150.6 ± 2894.6	7034.5 ± 6442.0†

Sodium (mg)	2435.9 ± 906.6	2464.2 ± 932.3

Values are mean ± SD

† Significantly different between groups ($p < 0.05$)

Total energy intake, protein in g/kg of body weight, fat, monounsaturated fat, polyunsaturated fat, vitamin D, zinc and sodium were comparable between groups (Table 5.6). However, we observe significant differences for carbohydrates, dietary fibers, proteins, isoleucine, leucine, valine, alanine, trans fat, saturated fat, vitamin B12, vitamin C, iron, copper, magnesium and beta carotene ($p < 0.05$).

CHAPITRE 6
DISCUSSION

The aim of this intervention study was to compare the effect of a vegan versus an omnivore lifestyle on DOMS in young females. We hypothesized that vegans will have a better recovery of DOMS markers after a resistance training compared to omnivore due the anti-inflammatory properties a plant-based diet has. The results of the present study partially support our hypothesis. In fact, when comparing pre and post measurements for the PPT profile, we observed that vegans had a better recovery of the right biceps and right vastus lateralis at post values when compared to omnivores at 48 hours post exercise. These results are comparable with the results of Nicol *et al.,* (2015) who also showed that leg pain was reduced when performing single leg squat, gluteal stretch, vertical jump and walking down the stairs in the group that took curcumin versus the control group 48 hours after exercise. Also, Tanabe *et al.,* (2019b) showed an attenuation of muscle soreness in the group who consumed curcumin post exercise compared to the placebo group in the upper arms. Similarly, Drobnic *et al.,* (2014) reported less pain only for the anterior thighs in the experimental group who consumed a supplement of curcumin when compared to the control group. However, they did not find a statistically significant difference for the lower limbs for both groups. Furthermore, in another study by Jenkins *et al.,* (2013), the authors showed that consumption of a rich antioxidant herb anatabine, which found in the Solanaceae family of plants, had no effect on muscle pain in the forearm after eccentric isokinetic forearm flexion muscle contractions. A potential mechanism that could explain the difference in pain and better recovery in the vegan group is that their food is higher in anti-oxidant rich foods which could attenuate the inflammatory reaction and therefore reduce DOMS. As for the perception of soreness, we observed a similar significant increase in both groups after the exercise intervention. However, Herrlinger *et al.,* (2015) found a decrease in the subjective muscle soreness of the whole body and hamstrings in the experimental vs control group after supplementing them with a polyphenolic high oxidant blend after 40 min of downhill treadmill running. It should be noted that the perception of soreness is entirely subjective, which is why we used an algometer to be able quantify pain in a more objective manner. For the measurement of swelling, we observed a significant comparable increase in the thighs and right arm circumference for both the vegan and omnivore groups. Similarly, three other studies showed that curcumin supplementation had no effect on reducing swelling after an exercise intervention in the legs and glutes (Nicol *et al.,* 2015; Tanabe *et al.,* 2015, 2019a). However, in a study by O'Fallon *et al.,* (2012) results showed an attenuation in swelling of the upper arm in the group who was supplemented with quercetin.

In the present study, we also measured muscle strength using a hand dynamometer as well as a 1RM for leg press and chest press as another marker of DOMS. No differences were observed between groups for leg press and chest press. However, our results showed that grip strength of the right arm significantly decreased in the omnivore group only and was preserved in the vegan group after the exercise session, which suggests that the vegan group was able to recover better after the intervention. Likewise, in a study by Naclerio *et al.,* (2021), participants who consumed a vegan-protein multi-ingredient compared to a maltodextrin solution post workout was able to better preserve muscle strength after performing bench press and squats exercises. In contrast, Jenkins *et al.,* (2013, 2014) reported that consumption of a rich antioxidant herb had no effect on preserving muscle strength of the forearms. As for grip endurance, both groups decreased similarly after the exercise session. To our knowledge, no other study has investigated the effect of a vegan diet or plant-based food on muscle endurance after inducing DOMS. Furthermore, vegans had significantly higher grip endurance at pre and post values compared to omnivores. This finding is in line with the previous study by Boutros *et al.,* (2020), who found that vegans had significantly higher VO2max and submaximal endurance compared to omnivores. This phenomenon could be explained by the simple fact that vegans consume more carbohydrates in their diets, which in turn could result in higher muscle glycogen storage and better muscle endurance during exercise. Collectively, it should be noted that our intervention was different from the existent literature since we tried to mimic the effect of these diets on real life workouts. This is why we decided to induce DOMS by performing exercises that are found in fitness centers, whereas in previous literature a specific protocol consisting of one only exercise in order to induce DOMS was performed.

Taken together, the results of our study demonstrate great significance to clinicians and healthcare professionals such as nutritionists and kinesiologists in regard to the better understanding the role of a vegan diet on recovery. It is highly recommended that vegan diets not be discouraged, but instead be implemented alongside an exercise training program for a better recovery. This being said, these findings, although preliminary, pave the way to additional research on the impact of a vegan diet on exercise performance in different populations.

CHAPITRE 7

LIMITS AND PERTINENCE

It is essential to bring to light new strategies that could be an added value to the quality of our lives and to the advancement of science. In this study, we evaluated the effect of two separate diets on DOMS by combining many tests in an understudied subject. Which is why this project will give us a better understanding of the recovery process of vegans after a resistance training session. This study will clarify the misconceptions regarding a vegan diet, which is generally seen as a limitation to performance and recovery. It will also provide useful information to health professionals such as kinesiologists and nutritionists, as well as athletes and coaches. Our data will also contribute significantly to the progression of future research. Our findings were, however, limited to a population of young, healthy, lean, and physically active women. Another noteworthy limitation was that this is an observational study, therefore, future trials might want to examine the effect of vegan diet during a long-term intervention, in which participants adopt a vegan or an omnivore diet for several months and observe how these opposite lifestyles effect muscle recovery.

CONCLUSION

The aim of this interventional study was to evaluate the effect of two types of diets which were plant based and animal based on recovery 48 hours after an exercise training.

Our results do show that a vegan diet might attenuate DOMS when compared to an omnivore diet in some measurements. More specifically, when measuring PPT with an algometer, the vegan group had a better tolerance for pain compared to the omnivore group after an eccentric exercise session, suggesting that the vegan group recovered better in this measurement. This shows that adopting a vegan lifestyle does not seem to limit recovery and may be effective in speeding it. Therefore, our findings might be interesting to conduct future research and will help with providing additional information.

ANNEXE A

EPTC2 CERTIFICATION

Groupe en éthique de la recherche

Piloter l'ethique de la recherche humaine

EPTC 2: FER 2022

Certificat de réussite

Ce document certifie que

Pressila Njeim

a complété avec succès la Formation en éthique de la recherche basée sur l'Énoncé de politiques des trois Conseils : Éthique de la recherche avec des êtres humains (EPTC 2: FER 2022)

Numero de certificat 0000787932

2 fevrier, 2022

ANNEXE B

ETHICS APPROVAL

UQÀM | CIEREH

CERTIFICAT D'APPROBATION ÉTHIQUE
RENOUVELLEMENT

No. de certificat : 2022-4217
Date : 23 février 2023

Le Comité d'éthique de la recherche avec des êtres humains (CIEREH) a examiné le rapport annuel pour le projet mentionné ci-dessous et le juge conforme aux pratiques habituelles ainsi qu'aux normes établies par la *Politique No 54 sur l'éthique de la recherche avec des êtres humains* (janvier 2020) de l'UQAM.

Protocole de recherche

Chercheur principal : Antony Karelis
Unité de rattachement : Département des sciences de l'éducation physique
Titre du protocole de recherche : Comparaison entre les omnivores et végétaliennes sur la récupération retardée des douleurs musculaires chez les jeunes femmes
Source de financement (le cas échéant) : s.o.
Date d'approbation itiniale du projet : 21 avril 2022

Équipe de recherche
Doctorant: Guy El Hajj Boutros (McGill University)
Étudiants réalisant un projet de mémoire : Njeim Pressila (UQAM)

Modalités d'application

Le présent certificat est valide pour le projet tel qu'approuvé par le CIEREH. Les modifications importantes pouvant être apportées au protocole de recherche en cours de réalisation doivent être communiqués rapidement au comité.

Tout évènement ou renseignement pouvant affecter l'intégrité ou l'éthicité de la recherche doit être communiquée au comité. Toute suspension ou cessation du protocole (temporaire ou définitive) doit être communiquée au comité dans les meilleurs délais.

Le présent certificat est valide jusqu'au **21 avril 2024**. Selon les normes de l'Université en vigueur, un suivi annuel est minimalement exigé pour maintenir la validité de la présente approbation éthique. Le rapport d'avancement de projet (renouvellement annuel ou fin de projet) est requis dans les trois mois qui précèdent la date d'échéance du certificat.

Gabrielle Lebeau
Coordonnatrice du CIEREH

Pour Yanick Farmer, Ph.D.
Professeur
Président

Signé le 2023-02-23 à 11:38

NAGANO Approbation du renouvellement par le comité d'éthique 1 / 1

ANNEXE C

CONSENT FORM

UQÀM
Université du Québec à Montréal

FORMULAIRE D'INFORMATION ET DE CONSENTEMENT

Titre du projet de recherche :	Comparaison entre les omnivores et végétaliennes sur la récupération retardée des douleurs musculaires chez les jeunes femmes.
Chercheur responsable :	Antony Karelis, PhD., Université du Québec à Montréal
Membres de l'équipe :	Guy Hajj-Boutros, PhD., Centre Universitaire Santé McGill Pressila Njeim, candidate à la maîtrise, Université du Québec à Montréal.
Coordonnateur :	Aucun
Organisme de financement :	Aucun

Préambule

Nous vous invitons à participer à un projet de recherche.

Avant d'accepter de participer à ce projet et de signer ce formulaire, il est important de prendre le temps de lire et de bien comprendre les renseignements ci-dessous. S'il y a des mots ou des sections que vous ne comprenez pas ou qui ne semblent pas clairs, n'hésitez pas à nous à poser des questions ou à communiquer avec le responsable du projet ou le coordonnateur de recherche.

Objectifs du projet

Le but de la présente étude sera d'examiner le niveau de récupération des douleurs musculaires retardée entre les végétaliennes et les omnivores chez les jeunes femmes. Nous émettons l'hypothèse que les végétaliennes auront une meilleure récupération des douleurs musculaires retardée après une séance d'entrainement en résistance comparé aux omnivores.

Nature de la participation

Vous êtes invité à vous rendre deux fois à l'Université du Québec à Montréal au Département des sciences de l'activité physique. Lors de la rencontre, le projet de recherche vous sera expliqué en détail, puis le formulaire de consentement sera signé. Des explications seront données pour pouvoir compléter le journal alimentaire et les questionnaires. Ensuite, nous procéderons aux mesures anthropométriques en mesurant la circonférence de la cuisse et des bras à l'aide d'un ruban à mesurer. Par la suite, l'angle de mouvement de flexion des bras, du genou et de la hanche sera effectué à partir d'un goniomètre pour mesurer les angles articulaires. Par la suite, nous utiliserons un algomètre pour mesurer le seuil des points de pression au niveau des muscles quadriceps, ischio-jambier, fessiers, gastrocnémiens, pectoraux, biceps et triceps. La force de préhension maximale et un test d'endurance sous maximale seront mesurés à l'aide d'un dynamomètre ainsi qu'une mesure de force maximale des membres inférieurs et des membres supérieurs sera évaluée. Par après, une mesure de votre composition corporelle à l'aide de la méthode l'absorptiomètre bi photonique à rayon X (DEXA) sera déterminée. À la fin, une session d'entrainement en musculation composée de 3 excises (squat, développé assis et flexion des bras) sera effectuée dans la salle d'entrainement. Toutes les mesures précédentes seront reprises 2 jours après la session d'entrainement.

Approbation du CIEREH : (Avril, 2022)

Votre visite à l'UQAM consistera :

JOUR 1 :

Procédure de la visite	Temps alloué
- Explication du projet - Signature du formulaire de consentement	10 minutes
- Questionnaire du bien-être, du réveil, de l'anxiété et du ressenti	5 minutes
- Circonférence du haut des jambes et des bras	5 minutes
- L'angle de mouvement de flexion des bras, de la jambe et de la hanche	10 minutes
- Seuil des points de pression au niveau des muscles du quadriceps, ischio-jambier, fessiers, mollets, pectoraux, biceps et triceps	15 minutes
- Force de préhension	5 minutes
Force maximale des membres inferieures avec la presse a cuisse inclinée (Leg Press) et membres supérieurs avec un développé couché (Chest Press)	30 minutes
- DEXA scan	15 minutes
- Séance d'entrainement en musculation	60 minutes
- Journal alimentaire	60 minutes (à domicile)

Jour 2 :

Procédure de la visite	Temps alloué
- Questionnaire du bien-être, du réveil, de l'anxiété et du ressenti	5 minutes
- Circonférence des haut des jambes et des bras	5 minutes
- L'angle de mouvement de flexion des bras, de la jambe et de la hanche	10 minutes
- Seuil des points de pression au niveau des muscles quadriceps, ischio-jambier, fessiers, mollets, pectoraux, biceps et triceps	15 minutes
- Force de préhension	5 minutes
- Force maximale des membres inferieures avec la presse a cuisse inclinée (Leg Press) et membres supérieurs avec un développé couché (Chest Press)	30 minutes

Questionnaires
Les questionnaires du bien-être de l'état de l'anxiété, de l'éveil et du ressenti seront utilisés avant et après la séance d'entrainement pour quantifier le bien être auto-reporté de chaque participante. De plus, un Q-AAP sera rempli avant le début des séances d'activités physiques pour s'assurer que les participants sont aptes à faire de l'exercice ou ont besoin de l'accord du médecin.

Circonférence des jambes et des bras
La mesure des circonférences des membres supérieurs et inférieurs sera mesurée avant et après la séance d'entrainement. Cette mesure nous indiquera le gonflement des muscles ciblés pour étudier la récupération directe suite à une séance de musculation.

L'angle de mouvement de flexion des bras, de la jambe et de la hanche
L'angle de mouvement sera mesuré à l'aide d'un goniomètre avant et après la séance d'entrainement pour mesurer la capacité de mouvement des muscles au niveau du haut et du bas du corps. Les articulations ciblées sont le coude, le genou et la hanche.

Seuil des points de pression

Le seuil de points de pression sera mesuré avant et après la séance d'exercice pour mesurer la douleur/courbatures ressenti par chaque participant. L'algomètre sera utiliser en appliquant des points de pression sur les groupes de muscles majeurs tel que les quadriceps, les ischio-jambiers, les gastrocnémiens, les pectoraux, les fessiers, les biceps et les triceps.

Force de préhension maximale

Mesurée par dynamomètre : La force maximale développée par chaque main sera mesurée par un dynamomètre. Pour effectuer ce test, vous devrez, en position debout le bras à 10 degrés du corps, serrer l'appareil le plus fort possible avec la main. Le test sera effectué à trois reprises pour chaque main.

Endurance musculaire

Le test d'endurance musculaire est réalisé à la suite du test de force de préhension maximale. En utilisant le même dynamomètre vous êtes invité à maintenir la position à 20% de la force maximale mesuré lors du test précèdent. Le temps de maintien sera par la suite chronométré jusqu'à l'épuisement (le moment ou vous êtes dans l'incapacité de maintenir 75% de la force maximale).

Test de Force 1RM

La force musculaire sera évaluée à l'aide de deux appareils d'entraînement incluant un développé des jambes pour le bas du corps (*leg press*) et un appareil développé assis (*chest press*) pour le haut du corps. La force musculaire sera mesurée en utilisant la technique de la répétition maximale (1-RM). Les tests de force musculaire seront réalisés dans l'ordre suivant : d'abord, l'extension des membres inférieurs, suivi du développé assis. Pour chaque appareil, les participants seront conseillés par le professionnel de recherche en ce qui concerne la position du corps sur l'appareil et les ajustements à apporter. Pour tous les exercices, la première série sera utilisée comme un échauffement de 10 répétitions avec une charge légère déterminée par le professionnel de recherche. Par la suite, la charge sera augmentée jusqu'à ce que l'effort maximal soit atteint. Normalement, la répétition maximale sera déterminée à l'intérieur de cinq essais avec une pause de quatre minutes entre chaque essai. Un échec sera défini comme étant une extension incomplète de la charge soulevée.

Composition corporelle

La composition corporelle sera mesurée par la méthode DEXA. Cette méthode sera la même que celle utilisée pour mesurer la densité osseuse. Il s'agit d'un rayon X à double énergie qui détectera la différence de densité de chacun des tissus : os, muscles, organes et gras. Vous vous allongerez sur le dos sur une table conçue à cet effet et un lecteur de densité circulera au-dessus de votre corps, de la tête aux pieds. La mesure totale prendra environ 5 à 7 minutes. La dose de radiation émise sera très faible (0.037 mrem). À titre de comparaison, deux radiographies dentaires équivalent à 20 mrem. Ce test nous permettra d'obtenir votre masse maigre et votre masse grasse totale, ainsi que votre densité osseuse totale. Contrindications : ne pas avoir passé récemment un examen au baryum ou ne pas être enceinte.

Séance d'entrainement en musculation

La séance d'entrainement sera composée de 4 exercices (Pression des jambes, développé couché, flexion des bras, ischio-jambiers). Les exercices seront effectués avec une charge prédéterminée à 85% de ton 1RM. Chaque exercice sera réalisé avec 4 séries de 6 à 8 répétitions.

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Journal alimentaire

Vous devrez noter tous les aliments et les boissons consommés (description détaillée : quantité, nature, garniture, etc.) pendant trois jours, incluant minimalement une journée la fin de semaine (soit jeudi-vendredi-samedi **ou** dimanche-lundi-mardi). Cette tache requiert un temps de ~15min par jour. Ce qui fait un total de 45 minutes pour compléter cette tâche. Ces informations seront compilées, puis entrées dans un logiciel qui nous permettra d'obtenir votre bilan alimentaire (apport énergétique, protéines, glucides et lipides). Évidemment, cet exercice peut sembler lourd et demande une certaine discipline. Toutefois, des outils (photos, exemples) vous seront fournis pour vous faciliter la tâche.

Vous devrez amener le journal alimentaire rempli lors de votre visite au Département des sciences de l'activité physique.

Avantages

Votre participation contribuera à l'avancement des connaissances par une meilleure compréhension des effets d'une alimentation type végétalienne sur la récupération des douleurs musculaires après une séance d'entrainement en musculation. Elle vous permettra également de connaitre plusieurs mesures dont votre force maximale des membres inférieurs et supérieurs, votre composition corporelle de manière précise à l'aide du DEXA et votre vitesse de récupération suite à une séance d'entrainement.
Les tests sont faciles à réaliser, valides, sécuritaires et utilisés par d'autres équipes de recherches. Le DEXA vous expose à une dose de radiation très faible (0.037 mrem). À titre de comparaison, deux radiographies dentaires équivalent à 20 mrem. Les tests de forces, de préhension et l'entrainement en musculation peuvent engendrer un effort considérable.

Risques et inconvénients

Les risques associés à ces tests sont : essoufflement, souffle court, fatigue, inconfort musculaire local. Afin qu'ils soient sécuritaires et conformes aux recommandations de l'ACSM, ils seront arrêtés si vous ressentez une difficulté respiratoire ou des douleurs au niveau de la poitrine. De plus, le personnel de recherche est certifié en réanimation cardiorespiratoire. Malgré l'intensité associée à ces tests, les risques de troubles cardiaques sont extrêmement improbables sans antécédents de maladies cardiaques. De plus, le temps requis pour compléter le journal alimentaire peut présenter un inconvénient pour les participants.

Compensation

Aucune rémunération ni compensation n'est offerte au terme de la participation à cette entrevue.

Confidentialité

Il est entendu que tous les renseignements recueillis sont confidentiels. Seuls les membres de l'équipe de recherche y auront accès. Vos données de recherche ainsi que votre formulaire de consentement seront conservées séparément au bureau du responsable du projet, le Professeur Antony Karelis, au SB-4625 pour la durée totale du projet.

Afin de protéger votre identité et la confidentialité de vos données, vous serez toujours identifié par un code alphanumérique. Ce code associé à votre nom ne sera connu que du responsable du projet et de l'assistant de recherche chargé de la codification.

Soyez conscient que malgré tous nos efforts pour protéger votre identité, il est possible que certains de vos propos permettront à un professionnel travaillant dans le même secteur que vous, de vous identifier.

Aucune publication ou communication sur la recherche (incluant les mémoires et thèses des étudiants membres de l'équipe) ne contiendra de renseignements permettant de vous identifier à moins d'un consentement explicite de votre part.

Votre dossier sera conservé sous clé pour une période de 5 ans, après quoi il sera détruit de manière sécuritaire. Si vous décidez de vous retirer du projet en cours, les renseignements vous concernant seront détruits.

Participation volontaire et droit de retrait

Clauses standard :

Votre participation à ce projet est volontaire. Cela signifie que vous acceptez de participer au projet sans aucune contrainte ou pression extérieure. Cela signifie également que vous êtes libre de mettre fin à votre participation en tout temps au cours de cette recherche, sans préjudice de quelque nature que ce soit, et sans avoir à vous justifier. Dans ce cas, et à moins d'une directive verbale ou écrite contraire de votre part, les documents, renseignements et données vous concernant seront détruits.

Le responsable du projet peut mettre fin à votre participation, sans votre consentement, s'il estime que votre bien-être ou celui des autres participants est compromis ou bien si vous ne respectez pas les consignes du projet.

Recherches ultérieures

Vos données de recherche seront rendues anonymes et conservées pendant 5 ans au terme du projet. Nous souhaitons les utiliser dans d'autres projets de recherche similaires. Vous êtes libre de refuser cette utilisation secondaire.

☐ J'accepte que mes données puissent être utilisées dans d'autres projets de recherche
☐ Je refuse que mes données puissent être utilisées dans d'autres projets de recherche

Acceptez-vous que le responsable du projet ou son délégué vous sollicite ultérieurement dans le cadre d'autres projets de recherche?

Oui ☐ **Non** ☐

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Responsabilité

En acceptant de participer à ce projet, vous ne renoncez à aucun de vos droits ni ne libérez les chercheurs, le(s) commanditaire(s) ou l'institution impliquée (ou les institutions impliquées) de leurs obligations civiles et professionnelles.

Personnes-ressources :

Vous pouvez contacter le responsable du projet au numéro (514) 987-3000 poste 5082 pour des questions additionnelles sur le projet. Vous pouvez discuter avec lui des conditions dans lesquelles se déroule votre participation.

Le Comité institutionnel d'éthique de la recherche avec des êtres humains (CIEREH) a approuvé ce projet et en assure le suivi. Pour toute information vous pouvez communiquer avec le coordonnateur du Comité au numéro (514) 987-3000 poste 7753 ou par courriel à l'adresse : ciereh@uqam.ca.

Pour toute question concernant vos droits en tant que participant à ce projet de recherche ou si vous avez des plaintes à formuler, vous pouvez communiquer avec le bureau de protectrice universitaire de l'UQAM, Courriel: protectriceuniversitaire@uqam.ca
; Téléphone: (514) 987-3151.

Remerciements : Votre collaboration est importante à la réalisation de notre projet et l'équipe de recherche tient à vous en remercier. Si vous souhaitez obtenir un résumé écrit des principaux résultats de cette recherche, veuillez ajouter vos coordonnées ci-dessous.

Consentement du participant : Par la présente, je reconnais avoir lu le présent formulaire d'information et de consentement. Je comprends les objectifs du projet et ce que ma participation implique. Je confirme avoir disposé du temps nécessaire pour réfléchir à ma décision de participer. Je reconnais avoir eu la possibilité de contacter le responsable du projet (ou son délégué) afin de poser toutes les questions concernant ma participation et que l'on m'a répondu de manière satisfaisante. Je comprends que je peux me retirer du projet en tout temps, sans pénalité d'aucune forme, ni justification à donner. Je m'engage à respecter la confidentialité des propos partagés par les autres personnes lors de l'entrevue de groupe. Je consens volontairement à participer à ce projet de recherche.

Je désire recevoir un résumé des résultats du projet : Oui ☐ Non ☐

Signature : Date :

Nom (lettres moulées) : coordonnées adresse courriel :

Déclaration du chercheur principal (ou de son délégué) :

Je, soussigné, déclare avoir expliqué les objectifs, la nature, les avantages, les risques du projet et autres dispositions du formulaire d'information et de consentement et avoir répondu au meilleur de ma connaissance aux questions posées.

Signature : Date :

Nom (lettres moulées) et coordonnées :

Approbation du CIEREH : (Avril, 2022)

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