The Effects of Smelling Salts on Hockey Players' Reaction Time, Anaerobic Performance and Sympathetic Nervous System

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Abstract

Background/Objectives: Smelling salts are a commonly used ergogenic aid in various sports, particularly in elite hockey. However, the extent of performance enhancing effects of smelling salts on reaction time and performance remains unclear. Therefore, the purpose of this study was to compare the effects of smelling salts vs. no salts on: 1) simple and choice reaction time tasks; 2) anaerobic power through measurement of peak power, mean power, and power drop of a Wingate test and; 3) the sympathetic cardiorespiratory response as measured by heart rate and breathing rate. It was hypothesized that smelling salts would stimulate the sympathetic nervous system, which may in turn improve reaction time and anaerobic performance that may improve hockey player performance.

Methods: Sixteen male hockey players (mean age = 21 ± 2 years; height = 180 ± 6 cm; weight 82.8 ± 6.5 kg; BMI 25.58 ± 2.93 kg/m^2) participated in the study. Participants took part in a randomized crossover design, with treatment (salts vs. no salts) and sequence (week one vs. week two) as independent variables. In both trials baseline supine resting heart rate (beats per minute) and breathing rate (breaths per minute) were recorded, followed by a standardized five-minute warm-up on the cycle ergometer. Participants were then seated in front of a computer monitor during the reaction time testing. In the smelling salts trial, the participant inhaled a smelling salt that was cracked capsule 30 cm away from nostrils and brought closer to nostrils until withdrawal reflex, while their heart rate (beats per minute) and breathing rate (breaths per minute) were continuously recorded (Zephyr Bioharness™). After 60 seconds of monitoring, a series of simple and choice reaction time tasks (ms) (total of 60 trials) that involved keyboard responses to visual stimuli on the monitor commenced. Reaction time testing lasted six minutes and was immediately followed by a maximal effort 30 sec Wingate cycle ergometer test. Peak power (W/kg), mean power (W/kg), and power drop (W/sec/kg) were recorded. During the 'no salts' trial participants performed the same tasks previously described followed by a deep inhalation through the nostrils without the smelling salts.

Results: Seven 2 (treatment: salt vs. no salt) x 2 (sequence: week one vs. week two) mixed factor ANOVAs with repeated measures on the first factor, were used to compare the effects of smelling salts on all the dependent variables including simple and choice task reaction times, peak power, mean power, and power drop as well as the cardiorespiratory measures of change in heart rate and change in breathing rate. Analyses identified no interaction effect between treatment and sequence, nor were there any main effects of treatment or sequence for the performance variables. The smelling salts significantly increased the cardiorespiratory variables between treatments (salts vs. no salts) with no main effect of sequence.

Conclusion: Although heart rate and breathing rate were significantly elevated following the smelling salt inhalation, within six minutes of inhalation smelling salts do not serve as an ergogenic aid for reaction time or anaerobic power of hockey players.

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Chapter 1

Introduction

Ammonium carbonate inhalants, frequently referred to as smelling salts, are most collectively known for their ability to stimulate faint or unconscious people (Dynarex Corporation, 2015). Despite ammonia products being well known for their hazardous properties, with well-documented dangers of exposure to the substance, including addiction, burns, toxicity, and death, many athletes use smelling salts as an ergogenic aid to enhance performance (Herrick & Herrick, 1986; Leduc, et al., 1992; Perkins et al., 2017). Hockey players often use smelling salts in hopes to increase arousal and anaerobic power output (McCrory, 2006; Prewitt, 2016; Velasquez, 2011). Research on the benefits of smelling salts is limited and inconsistent, leaving the mechanism behind potential performance enhancement as highly speculative. The effects of smelling salts on anaerobic power vary; this seems dependent on the duration of the event they are used for. Research regarding the effects of smelling salts on ultra short-term anaerobic power (i.e. powerlifting) demonstrates no effect (Perry, Pritchard, & Barnes, 2016; Richmond, Potts, & Sherman, 2014; Vigil, Sabatini, Hill, Swain, & Branch, 2017). However, research identifying the impact of smelling salts on anaerobic power events of 30 seconds have shown significant improvements in peak and mean power (Secrest, 2014).

Previous research has primarily focused on understanding the anaerobic benefits of smelling salts on power-lifters. According to Pritchard and colleagues (2014) roughly 50 percent of power-lifters use smelling salts in competition and/or training bouts. Preliminary evidence on effects of smelling salts on ultra-short anaerobic performance suggests it is ineffective for powerlifting one repetition maximum (1RM), nonetheless they have shown to be prevalent in the sport (Perry et al., 2016; Pritchard et al., 2014; Richmond et al., 2014; Vigil et al., 2017).

Anecdotal evidence regarding the prevalence of use of smelling salts by hockey players suggests a large population of hockey players use smelling salts regularly. For example, one professional hockey player stated, "it's almost like a cerebral way of saying, 'Hey, it's game time now. It's time to get going'" (Prewitt, 2016). Many hockey players have claimed a similar cognitive and performance benefit through this raised arousal, however the research as to how and/or if such substances benefit performance has yet to be identified. Hockey is considered a metabolically unique sport, so the current research around smelling salts effects on power-lifters should not be extrapolated to the athletic performance involved in hockey (Cox, Miles, Verde, & Rhodes, 1995). The most notable difference between hockey players and power lifters is in energy pathways accessed by athletes performing these two sports; hockey demands predominantly an intense glycolytic activity and aerobic fitness, power-lifters would rely more heavily on the ATP-PC energy pathway (Cox et al., 1995; Rivera-Brown & Frontera, 2012).

The prevailing concept of the underlying physiological mechanics are that smelling salts act as an irritant to the respiratory passages and this irritation stimulates the body's autonomic nervous system; specifically, the sympathetic nervous system (Velasquez, 2011). Stimulation of the autonomic level is likely related to activation of the trigeminal and olfactory nerves (Bensafi et al., 2002). The sympathetic nervous system division in turn primes the body for action by releasing norepinephrine, activating the adrenergic receptors on the peripheral tissue, as well as increasing cardiac output (Marshall, 1982).

As previously mentioned, the research surrounding smelling salts on powerlifting identified no significant effects on performance (Perry et al., 2016; Richmond et al., 2014; Vigil et al., 2017). Some improving results, however, have been reported in studies using Wingate anaerobic testing (i.e. a 30 second all out sprint cycle against a set resistance) (Secrest, 2014).

The Wingate test has been recognized by many as the standard method for studying anaerobic power outputs due to its high reliability and is considered the standard to infer anaerobic power for hockey performance (Bar-Or, 1987; Bringhurst, Wagner, & Schwartz, 2017; Malone, Blake, & Caulfield, 2014). This anaerobic cycling test measures peak and mean power over a 30 second period that test the ATP-PC (peak power) and glycolytic pathways (mean power) (Bar-Or, 1987). Studies to date have not examined the claim of raised psychological arousal after exposure to smelling salts in connection to athletic performance, however previous research has demonstrated that psychological arousal can have a significant positive effect on anaerobic performance as well as reaction time performance (Parfitt, Hardy, & Pates, 1995; Santos et al., 2014).

Psychological arousal effect associated with smelling salts has been compared to the responses resulting from the ingestion of caffeine (McCrory, 2006; Prewitt, 2016; Velasquez, 2011). The effects of caffeine as a psychological stimulant have been examined more thoroughly than smelling salts, with findings that demonstrate an improvement in reaction time (Santos et al., 2014; Souissi et al., 2013). These improvements stem from an increased information-processing speed of relevant information along neuronal pathways (Dixit, Goyal, Thawani, & Vaney, 2012). Despite the frequent comparison of smelling salts to caffeine, the impact of smelling salts on reaction time is not understood. Due to their similar psychological arousal effects, smelling salts may have a comparable result on reaction time.

The proposed research aimed to examine the effectiveness of smelling salts as an ergogenic aid for elite hockey players. The impact of smelling salt usage on simple reaction time tasks allows for inference on the stimulus identification of the speed of information processing, and choice reaction time tasks allows for implications on decision making. Simple and choice

reaction time tests are simplified versions of performances that hockey players complete during gameplay; for example a faceoff draw, or quick decisions to advance the puck. The impact of smelling salts on the Wingate anaerobic tests performance will demonstrate the affect on anaerobic power. The Wingate test measures peak power, mean power, and power drop (difference from peak to lowest power) over a 30 second time frame, which are key performance characteristics associated with a hockey shift (Bringhurst et al., 2017).

Purpose

The purpose of this study was to compare the effects of smelling salts vs. no salts on: 1) simple and choice reaction time tasks; 2) anaerobic power through measurement of peak power, mean power, and power drop of a Wingate test and; 3) the sympathetic cardiorespiratory response as measured by heart rate and breathing rate.

Hypothesis

It was hypothesized that smelling salts would:

1) Improve reaction time on both simple and choice task reaction time (ms) suggestive of an improvement in the speed of relevant information processing, with no difference seen across the sequence of the study,

2) Improve peak and mean power (W/kg) potentially due to an arousing effect from the smelling salts, which may increase sympathetic nervous system activity, leading to greater power values. This would lead to an increase in power drop (W/sec/kg) due to raised peak power accelerating ATP-PC depletion rate. A difference due to sequence may be observed in peak power and mean power, as Wingate anaerobic results may be subject to a learning curve, and

3) Increase heart rate (beats per minute) and breathing rate (breaths per minute) within the 30 seconds after smelling salt inhalation by the irritation of the airway, which is indicative of an increase in sympathetic nervous system activity. It was hypothesized there would be no difference seen between the sequences of the study, as the order should not affect the individuals' stimulation.

Significance

This research provided insight into the possible effects of smelling salts on performance or physiological response in male hockey players. Results from this study expand upon the

limited knowledge on smelling salts effects as an ergogenic aid, with details on the cognitive arousal and reaction time, anaerobic performance in a longer range of time, as well as the sympathetic nervous system response through cardiorespiratory measures. There is a widespread use of smelling salts in the sport of hockey, with no literature that support the validity of the ergogenic properties. Because there is very little information regarding the acute effects of smelling salts, and no research regarding the long term effects, information from this study will be valuable for players and trainers to make informed decisions regarding the use of smelling salts as a performance enhancer. They can then take into consideration the known hazardous properties that can occur in large doses of ammonia including addiction, burns, toxicity, and death, with the performance benefits that may or may not be present (Leduc et al., 1992 Perkins et al., 2017; Perry et al., 2016).

Chapter 2

Literature Review

As noted before, the relationship of smelling salts and key performance variables associated with hockey has yet to be explored. This literature review will examine the properties of smelling salt capsules and detail the research surrounding their use as an ergogenic aid; including the mechanism involved, the dangers associated with use, and impacts smelling salts have on the body. Particular performance variables (reaction time and anaerobic performance) associated with hockey performance will be outlined, with information on the influence that stimulants may have on them. Lastly sympathetic nervous system activity and its relation to performance will be outlined. This review illuminates the gaps in the literature on smelling salts as a stimulant for hockey players.

Smelling Salts

Ammonium carbonate inhalants [$(NH_4)_2CO_3H_2O$] are comprised of 15% ammonia and 35% alcohol, with the remainder of the capsule being composed of inactive ingredients red dye, lavender oil, lemon oil, nutmeg oil, and purified water (Dynarex Corporation, 2015). There are different forms of the substance, however this capsule composition is the most commonly observed form used in most anaerobic sports, with the exception of powerlifting that has a mix of capsule and liquid vial users. Smelling salts are used by a large number of athletes involved in anaerobic events for their purported stimulating effect in an attempt to gain an advantage over their competitors (Pritchard et al., 2014; Velasquez, 2011). Athletes claim that smelling salts provide them with an alert state of mind, which helps them perform a challenging task with less effort or at a higher performance level (McCrory, 2006; Pritchard et al., 2014; Velasquez, 2011). However, current literature contains little empirical evidence to substantiate these claims (Perry

et al., 2016). Consequently, little is known about the extent to which performance can be affected by smelling salt inhalation nor has there been consensus on the underlying mechanism(s) involved; without information regarding the underlying mechanisms and the response associated, it is not possible to make informed decisions on smelling salt usage (Ott & Vilstrup. 2014; Perry et al., 2016; Velasquez, 2011).

Mechanism of Absorption. It is unclear how the nervous and cardiovascular system responds to acute use of the ammonia. The mechanism behind the effects of smelling salts is not clear, as different hypotheses have been noted in the literature. The effects of smelling salts may be attributed to central nervous system stimulation of the sympathetic nervous system, leading to an increased cardiovascular response, cognitive arousal, and anaerobic power output (McCrory, 2006; Perry et al., 2016; Richmond, et al., 2014). Perry and colleagues (2016) suggested that smelling salts act similar to the immediate effects of caffeine. If the mechanism associated with the intake of the salts mimics the mechanism associated with caffeine ingestion, then smelling salts would release noradrenaline and methylxanthine in the brain, which increases arousal, vigilance, and reduces fatigue (Nehlig, Daval, Debry, 1992). Though, there have also been noted adverse effects associated with the use of caffeine, including anxiety, jitters, inability to focus, gastrointestinal discomfort, insomnia, irritability, cardiac arrhythmia, hallucinations, and even death when used in conjunction with ephedrine (Silver, 2001). However, it remains unclear if the positive and negative effects associated with the absorption of caffeine are consistent with those when inhaling smelling salts.

It is also hypothesized that the increase in respiratory rate is due to the irritation of the upper respiratory tract from ammonia (Church et al., 2016; McCrory, 2006; Velasquez, 2011). Ammonia is highly soluble in water, and thus can be absorbed through the mucosa in the

respiratory tract. This irritant then causes the lungs to react by coughing, followed by an increase in respiratory rate (Widdicombe & Lee, 2001). The period of time when ammonia increases breathing rate is hypothesized to be the time when performance-enhancing effects are to be observed. However, the exact physiological events and time span of effects resulting from acute ammonia exposure remains unclear (Ott & Vilstrup. 2014; Perry et al., 2016; Velasquez, 2011).

Dangers of Ammonia. Ammonia is a common ingredient in fertilizers, pesticides, and household cleaners (Leduc et al., 1992). There are well-documented dangers of exposure to ammonia gas through case studies and animal studies alike, including addiction, burns, toxicity, and death (Herrick & Herrick, 1986; Leduc et al., 1992; Perkins et al., 2017). Ammonia is a water-soluble gas; consequently it is readily absorbed by the mucosal membranes and irritates the skin when it reacts with moisture. Damage to the lungs after an exposure to ammonia gas is dependent on the duration of exposure, the concentration of gas, and the volume inhaled (Leduc et al., 1992). It has been observed that an exposure to a single dose of 20,000 ppm of ammonia resulted in a significant drop in body weight and damage to the lungs (Perkins et al., 2017). This quantity is significantly higher than the amount of ammonia gas inhaled from a smelling salt capsule. It is estimated that smelling salts release about 50-100 ppm of ammonia gas, whereas death due to exposure has been reported at as low as 10,000 ppm for an undetermined amount of time ("Ammonia", 2017). An additional danger of using ergogenic aids includes addiction, but inhalant disorders are one of the least prevalent substance use disorders with an estimated 0.6% of the population between the ages of 15-24 (Anthony, Warner, & Kessler, 1994). Consequently, it does not appear that addiction to smelling salts is the cause of the high prevalence of use.

In one case study (Herrick & Herrick, 1996), the individual described was a consistent smelling salt user during powerlifting competitions. She inhaled the aromatic ammonia prior to a

record attempting lift. Post-lift she started experiencing rhinitis, rhinorrhea, conjunctivitis, dizziness, and headaches. The reaction then turned into wheezing, shortness of breath, and loss of vision after an hour. The symptoms were treated as an allergic reaction (to a filler product involved in the capsule) and were resolved immediately. This example suggests caution should be used when experimenting with inhaled ergogenic aids. The ingredients in the capsule should be crossed-referenced with known allergies for anyone who may come into contact with it.

Another prevalent danger of smelling salts use in sports is related to their original use. Smelling salts are traditionally used to restore alertness to faint/unconscious individuals, however when athletes use this after concussions it can be extremely dangerous (McCrory, 2006; Velasquez, 2011). If athletes become unconscious or dizzy after head contact, and then take a smelling salt to restore their alertness or mask their symptoms, the diagnosis of a concussion may be harder to make. This can result in a false negative decision, which may lead to a resumption of play when it is not safe to do so (Velasquez, 2011). Smelling salts are characterized by a withdrawal reflex that is experienced after use. This quick and sudden motion can do further unwanted damage to the brain of an athlete after a concussion (McCrory, 2006).

Impacts on the Cardiovascular System. Perry and colleagues (2016) investigated the physiological effects on the cardiovascular and cerebrovascular systems in conjunction to anaerobic outputs using fifteen active individuals. The study measured impact of smelling salts on middle cerebral artery velocity (MCAv), heart rate (HR), pressure of end-tidal CO_2 ($P_{ET}CO_2$), and mean arterial pressure (MAP). This was the first study to investigate the physiological changes and performance changes as a result of inhalation of smelling salts. The results of the study revealed that after ammonia exposure, there was a significant increase in MCAv (6 cm□s^{-1}), and in HR (6 bpm), however the MAP scores remained unchanged. The $P_{ET}CO_2$ also showed

an increase of 2 mmHg. The results of this study suggested that the acute cerebrovascular response to ammonia inhalation coincides with an elevated MCAv mediated by an ammonia dependent vasodilation, however the method by which ammonia elevates cerebral blood flow has not yet fully been defined (Ott & Vilstrup. 2014; Perry et al., 2016). It has been suggested that a decrease in MCAv as humans age could be associated with poor cognitive function, so consequently the relative increase in MCAv may suggest an increase in cognitive function (Bertsch et al., 2009). All of these changes were observed 15 seconds post-inhalation. The documented physiological changes were thought to be facilitating performance-enhancing effects. Despite the promising physiological effects of ammonium inhalant, they did not result in a significant increase in anaerobic strength in the form of an increase in one rep maximum (1RM) mid-thigh pull dead lift (Perry et al., 2016). These physiological changes are the only measured responses to smelling salts to date, which again outlines how little is known about the effects of smelling salts.

Impacts on Strength. The usage of smelling salts has been widely observed in some predominantly anaerobic sports; for example Pritchard and associates (2014) found that roughly 50% of power-lifters use smelling salts in competition. Also, anecdotal reports suggest that it has been frequently used in professional sports such as hockey and football (Prewitt, 2016; Rivera-Brown & Frontera, 2012). Such sports are under researched in their relation to the use of smelling salts, as most research focused on the ergogenic effects on powerlifting or very short-term maximal anaerobic power activities, such as dead lifts, bench press, or squats (Perry et al., 2016; Richmond et al., 2014; Vigil et al., 2017). These types of maximal anaerobic power activities heavily rely on the ATP-PC energy pathway (Rivera-Brown & Frontera, 2012). Whereas hockey players' performance would more heavily rely on the glycolytic energy

pathway for a large portion of the sport (Cox et al., 1995). There have been three studies conducted on the effects of smelling salts on powerlifting, and only one on the predominantly glycolytic output.

Perry and colleagues (2016) examined the degree to which smelling salts effect muscle strength and rate of force development by using electromyography (EMG) during a one repetition maximum (1RM) mid-thigh pull. The protocol involved measuring muscle strength using a custom-made dynamometer adjusted to 120-degree hip angle. The participants performed four maximal exertion mid-thigh pulls (immediate, 15, 30, and 60 seconds following inhalation), and then given five-minutes rest until they then performed another four maximal exertion mid-thigh pulls. The results identified no significant improvements for any of the strength related measures. Based on these results, it could be speculated that there are no significant improvements in a 1RM from smelling salt inhalation. Similarly, Vigil and colleagues (2017) examined the effects of smelling salts on ATP-PC anaerobic power. This study examined the 1RM during a deadlift between control, water (placebo) and smelling salt supplement trials. The outcome was similar to the previously described study as no significant changes in muscle strength were observed. Collectively, the review of the research clearly showed that smelling salts do not have a significant effect on 1RM powerlifting e performances that rely on the ATP-PC energy pathway.

Richmond and associates (2014) examined the number of repetitions completed of back squat and bench press at 85% of 1RM. The number of repetitions that can be completed at 85% of 1RM ranges between two and five. The design is most similar to submaximal training performances, rather than a competition performance because of its intensity effort. The participants were also exposed to the smelling salts three seconds prior to the maximal effort

testing. Participants were tested to see if smelling salts produced an increase in their anaerobic muscular endurance, however no substantial effect was found. Although the timing of smelling salts effects on performance has not yet been examined, three seconds may be too short for a substance to spread through the body and take effect. As shown in other research (Perry et al., 2016) the highest average force for mid-thigh pull was noted after 15 seconds of exposure. As a result, it appears the timing between inhalation and performance may not have been ideal for performance benefits.

Secrest (2014) contrasted all other evidence regarding the impact of smelling salts on performance and it was the only study conducted that involved a longer anaerobic power performance. Designed as a crossover study, the impact of smelling salts as an aid to improve anaerobic power and prevent fatigue amongst athletes was investigated. The affect of smelling salts on anaerobic power was assessed using Wingate anaerobic test (a 30 second short-term maximal cycle ergometer power test). This test has been shown to have reproducible results with males (Jacobs, 1980). The participants were tested using a Wingate test before and after a simulated football game. Significant differences between the control and the intervention trials were noted in peak anaerobic power ($p \leq 0.05$) with the smelling salt exposure achieving higher peak power, when compared to their control trial. The study also found significant differences between control and intervention in mean power ($p \leq 0.01$). This means the overall anaerobic power production for the Wingate test was significantly higher during the intervention than the control trial.

Although research by Secrest (2014) showed advantageous findings for glycolytic type anaerobic power through the use of smelling salts, the other previous studies indicate they are not an effective ergogenic aid for power lifting competitions or weight training (Perry et al., 2016;

Richmond et al., 2014; Vigil et al., 2017). Power lifting activities typically last less than five seconds and primarily use the ATP-PC energy system. This may mean that smelling salts are not an effective ergogenic aid for these particular types of activities. Secrest (2014) found a significant ergogenic effect for the Wingate testing peak power, and mean power outcomes. The Wingate test is 30 seconds in length and as such uses a mix of ATP-PC and glycolysis with an emphasis on the latter. Maximal outputs lasting 10-180 seconds are primarily anaerobic and predominantly rely on the glycolytic energy pathway (Rivera-Brown & Frontera, 2012). The significant differences from Secrest's study suggest that the smelling salts may be a more beneficial ergogenic aid in activities relying on the glycolytic energy pathway, such as a hockey shift. However, the design of Secrest's study does not mimic the timing of the hockey players smelling salt inhalation in relation to the pre-game inhalation. Prewitt (2016) suggests that most players that use smelling salts use it as a pre-game ritual, rather than immediately before performance. Therefore, a more externally valid approach to determine whether there is a true mechanistic impact of smelling salts on hockey players would include a longer waiting period (approximately one to six minutes) between inhalation and the anaerobic bout of exercise.

Reaction Time

In elite level sports, fractions of seconds can make the difference between winning and losing. This competitive nature can be validation enough for athletes to seek ergogenic aids that provide performance advantages to react faster than their opponents. It has been found that athletes have better visual skills than non-athletes, suggesting the importance of visual skills and response time to the success of elite athletes (Christenson & Winkelstein, 1988). In a hockey setting, the players are required to react to visual stimuli during every shift; for example, to receive a passed puck, during face-offs and/or when shooting on net.

Reaction time is the time elapsed between when a stimulus is presented and the individual recognizes and responds to the stimulus (Magill, 2007). It is commonly misunderstood as a skill, but it is instead a fundamental measure of the central nervous system capacity. It is representative of the time it takes to absorb the stimulus, process and integrate it with other sensory inputs, select a response, and execute the response (Kosinski, 2008). Reaction time can be measured using a variety of tests including: simple reaction time, choice reaction time, and discriminant reaction time. This study will focus on the first two types of reaction time tasks mentioned. These tests vary through the methodology, number of stimuli, the number of responses, intensity of the stimulus, and response selection; the less stimuli/response selections, the less complex the reaction time experiment (Ilamkar, 2014). Performance on reaction time tests has a measure of cognitive function and an indication of central nervous system health (Aranha & Samuel, 2015; Jakobsen, Sorensen, Rask, Jensen, & Kondrup, 2011; Madden, 2001).

An example of choice reaction time being used as a measure of cognitive function can be seen when examining its relationship to age. For example, there is a known relationship between cognitive performance and age as there is a 5-10% decline in cognitive performance and choice reaction with every decade of life (Salthouse & Somberg, 1982). These declines appear to be age-related and have been attributed to the progressive delay in the information-processing continuum that commences around the mid 20's (Der & Deary, 2006; Salthouse & Somberg, 1982). This example of the relationship between cognitive function (information processing) and reaction time can be translated to examine the effects of stimulants on cognitive function through reaction time tests. Stimulants such as caffeine and amphetamines are commonly used for their ergogenic properties that can raise arousal levels, and ultimately improve reaction time to a

stimulus (Avois et al., 2006; Durlach et al., 2002). Smelling salt users have made claims that the substance instantly alerts them, preparing them for action (Prewitt, 2016; MacGregor, 2018).

Simple and Choice Reaction Time. There are various reasons for utilizing the different types of reaction time tests available. The use of simple reaction time paradigm involves: the warning signal, the foreperiod, the reaction stimulus, the response, and the inter-trial interval (Donders, 1869; Naatanen, 1981). Simple reaction time tests do not involve a response selection stage, as there is only one response to the stimulus. The warning signal precedes the reaction stimulus, and is followed by the foreperiod, which is the time elapsed between the warning signal and the stimulus. A simple reaction time test also has a reduced speed-accuracy trade off established by Woodworth (1899), as the accuracy of the response is not affected by the presence of different choices in response. This means the participant does not need to go through the response selection stage to determine the appropriate response.

Choice reaction time incorporates the same aspects, as a simple reaction time test, but involves additional response time as the test involves multiple stimuli and responses. Therefore, the information-processing continuum requires time to process the additional stimulus and select the correct response. This information-processing continuum requires evolution through the following stages: stimulus identification, response selection stage, and response programming (Lutz & Huitt, 2003). Hick's law (1952) states that reaction time is linearly related to $\log^2$ of the number of stimulus-response alternatives in a choice reaction test; consequently, the more stimuli and responses that are involved in a choice reaction test, the longer processing time needed for the person to select the appropriate response.

Factors Affecting Reaction Time. There are many factors that affect reaction time, such as stimulus intensity, stimulus duration, age, gender, and compatibility of the stimulus and

response (Der & Deary, 2006; Froeberg, 1907; Pieron, 1913; Wells, 1913). Stimulus intensity can be altered in a variety of ways; for example, a visual stimulus may increase in intensity by increasing the size or the luminescence, whereas an auditory stimulus may increase in intensity by increasing the volume (dB) produced. Pieron's Law (1913) dictates that simple reaction time decreases as stimulus intensity increases. This law has been further tested in the research, determining that it holds true for choice reaction time tests as well (Pins & Bonnet, 1996).

As stimulus intensity increases, so does the rate of neuronal impulses. Stimulus duration has been shown to affect reaction time as well. A longer duration of a visual or auditory stimulus has been showing to reduce reaction time (Froeberg, 1907; Wells, 1913). Ulrich and colleagues (1998) examined the effects of varying levels of stimulus intensity and duration. The researchers concluded that a longer duration of the stimulus for simple reaction time reduced the reaction time (i.e., improved performance). Peak duration of roughly 40-60ms was found to be the plateau where a longer stimulus no longer improved reaction time. In addition, the longer the duration of the stimulus, the longer the duration of the reaction force output.

A recent longitudinal study conducted by Der and Deary (2006) examined simple reaction time and choice reaction time across different ages, ranging from 16 to 63. This study also provided data regarding the differences of gender on reaction time throughout the lifespan, which will be discussed later. Der and Deary tested over 500 participants twice for simple reaction time and choice reaction time over an eight-year difference. The study illustrates the change of reaction time over the aging process and found that there is improvement in simple and choice reaction time up until the mid 20's and then a gradual decline in reaction time performance. This was supported by Fozard and colleagues (1994) who found a gradual slowing

of simple reaction time of 0.5ms/year within individuals, and an accelerated increase in reaction time after the age of 60.

Many of the studies that looked at the cross-sectional or longitudinal differences between reaction time amongst ages also examined the differences between reaction times of males versus females. Der and Deary, (2006) examined simple and choice reaction time amongst males and females and found no significant impact of gender. However, it was found that males had a quicker choice reaction time than females and less variability amongst the trials. Huppert and Whittington (1993) also found that men had an advantage in both simple and choice reaction time while Fozard and colleagues (1994) found that men had a non-significantly faster simple reaction time across all ages examined, and a slower decrease in reaction time as the males aged when compared to the females.

Another factor that has been researched in relation to its influence on reaction time is arousal, which is describing the internal or mental state of attention (Kosinski, 2008). The effect of arousal on performance is often debated amongst psychologists. The debate is whether the effect of arousal on performance has an inverted "U-shaped" effect (meaning that performance is peaked at a moderate arousal level, with performance worsening the further away from medium arousal), or if it is a positive linear relationship (meaning as arousal increases, so does performance) (Bagherli, Vaez Mousavi, & Mokhtari, 2011; Sabzi, Hasanvand, & Roozbahani, 2014). The evidence of increased arousal levels improving reaction time has led some researchers to investigate the effects of arousing ergogenic aids (stimulants) on simple reaction time performance. Specifically, caffeine has been a topic of interest with regards to its impact on arousal levels and thus reaction time. Durlach and colleagues (2002) investigated the effects of caffeine on arousal levels, finding an increase in arousal after exposure to caffeine and later

examining if the increased arousal level affected reaction time performance. This study did not use a pre-post design so there was not a comparison of caffeine effects, however the researchers did not find a large difference from immediate post-consumption of caffeine to 45 minutes post-consumption. Schneider and associates (2006) compared the reaction time differences between caffeine, control, and a placebo and found that caffeine group had the fastest simple reaction time, with control and placebo being slower and similar to each other. Souissi and colleagues (2012) examined the effects of caffeine on Wingate performance along with reaction time performance and found that anaerobic peak power and mean power were improved post consumption of caffeine. This evidence demonstrates how stimulants that can increase arousal level can be beneficial to reaction time as well as anaerobic performances.

Durlach and colleagues (2002) demonstrated the effects of caffeine consumption on a two choice reaction time test, finding significantly faster reaction times post-consumption of caffeine. Even elite athletes tested using caffeine consumption for simple reaction time tests, found a significant improvement in performance, proposing that caffeine can improve the response to a visual stimulus (Santos et al., 2014; Souissi et al., 2013). Studies have also suggested that caffeine promotes faster processing of relevant information along neuronal pathways, which is relevant to the speed of a choice reaction time test (Dixit, Goyal, Thawani, & Vaney, 2012; Ruijter, De Ruiter, & Snel, 2000; Ruijter, de Ruiter, Snel, & Lorist, 2000).

Athletes with experience using ergogenic aids have compared the effects of smelling salts to the effects of caffeine (McCrory, 2006; Prewitt, 2016; Velasquez, 2011). Smelling salts have been known to affect individuals instantly and last a short period of time, whereas caffeine effects are typically measured 40-60 minutes post-consumption (Beck, Housh, Schmidt, & Johnson, 2006; McCrory, 2006; Perry et al., 2016). It has been noted as well that the effects of

caffeine are ergogenic in speed endurance exercises that range between 60-180 seconds (Davis & Green, 2009). With the average shift of a hockey player being roughly 45 seconds, this may be a reason the players have chosen the alternative of smelling salts to enhance performance. If the effects of smelling salts do act similarly to immediate dosing with caffeine, then it is hypothesized that the results of this study should mirror the results of caffeine studies (Prewitt, 2016).

Athletes' use of stimulants is not limited to smelling salts and caffeine; some consume other substances such as ephedrine, amphetamines, or cocaine (Avois et al., 2006). These are examples of central nervous system stimulants that athletes use to reduce tiredness, and increase alertness, competitiveness, and aggression (Avois et al., 2006; Seiden, Sabol, & Ricaurte, 1993). The stimulants are known for their performance enhancing properties as well as their potentially lethal side effects, and are suitably banned from use in sport from the World Anti-Doping Agency and the International Olympic Committee alike. The use of banned central nervous system stimulants during competition can carry harsh bans or even fines, if caught (World Anti-Doping Agency, 2018). Smelling salts however, do not have any restrictions placed on their consumption in hockey games. Which again may serve as a reason why players seem attracted to using it as an ergogenic aid.

Cardiorespiratory Measures/Sympathetic Nervous System Activity

The effects of smelling salts on the cardiorespiratory system and nervous system remain unclear. Aside from the study done by Perry and associates (2016), there is little research positioned to identify the physiological responses to a smelling salt exposure. Common methods to measure physiological responses to ergogenic aids involve measuring heart rate, breathing rate, and heart rate variability. These variables are largely under the control of the autonomic nervous

system (Malik, 1996). The autonomic system can be divided into two systems, the sympathetic and parasympathetic nervous system. The sympathetic nervous system is characterized by the excitatory responses of the body, whereas the parasympathetic nervous system is characterized by inhibition (Barchas, Akil, Elliott, Holman, & Watson, 1978; Barde, Edgar, & Thoenen, 1983). An increase in heart rate and breathing rate is due to a stimulatory response in sympathetic nervous system activity, more specifically, the release of epinephrine and norepinephrine (Brown, DiFrancesco, & Noble, 1979). An increase in breathing rate can lead to an oxygen surplus in the body, which in turn could increase performance (McCrory, 2006; Perry et al., 2016; Richmond, et al., 2014). These metrics are often measured through heart rate monitors or spirometers. A spirometer for breathing rate involves a mask that covers the participants face; however wearing the mask itself may adjust breathing patterns, so researchers may choose to use a non-invasive chest strap to obtain all three of these variables (Hailstone, & Kilding, 2011).

Sympathetic nervous system activity has been shown to increase as exercise percent of VO_2max intensity increases (Saito, Tsukanaka, Yanagihara, & Mano, 1993). Jost and associates (1989) compared the sympatho-adrenergic circulatory component of the sympathetic nervous system, finding that power-lifters had a poor response when compared to other athletes such as runners or swimmers. These findings suggest that power-lifters are desensitized to the sympathetic response thus making them an unfavourable population to study in relation to the effects smelling salts. However, hockey is a metabolically unique sport where the players must utilize intense glycolytic activity related to quick bursts involved in a shift, but also excellent aerobic power and endurance (Cox et al., 1995). In addition, it has been noted that aerobically trained athletes have higher epinephrine response to work loads (Jost, Weiss, Weicker, 1989; Kjaer & Galbo, 1988). This would infer that hockey players are a more ideal population to

measure for effects of smelling salts on the sympathetic nervous.

Research Problem

The preceding review of literature identified the gaps in the research surrounding smelling salts and their ergogenic properties. The use of smelling salts is high in anaerobic sports such as powerlifting, where roughly 50% of the athletes use smelling salts during competition (Pritchard et al., 2014). Most of the research is limited to the effects of smelling salts on very short-term anaerobic performance such as powerlifting (Perry et al., 2016; Pritchard et al., 2014; Richmond et al., 2014). With high rate of smelling salt usage among athletes and potential risks associated with its use, it is important to clarify the mechanisms how smelling salts affect athletes. Furthermore, it is still not known if there is a beneficial impact on hockey performance, as the sports of hockey and powerlifting use different primary metabolic pathways during the activity. Anecdotally, smelling salts are frequently used prior as a pre-game ritual during competition in collegiate or professional sports by athletes (e.g. hockey). However the research currently examines power-lifters immediately after smelling salt inhalation, instead of hockey players in a more realistic timeline. While ergogenic aids are used for their performance enhancing effects, there are also a broad range of adverse effects that may accompany them, including behaviour changes, organ damage, nausea, anxiety, and more (Silver, 2001). There has been evidence of ammonia causing bodily harm in large doses, and though the small concentration does not appear to have adverse effects, more detail on the acute and long-term effects of smelling salts will provide more insight. Despite the claims of increased arousal provided by smelling salts, there has been no research to date investigating the cognitive effects of smelling salts. Tests such as simple or choice reaction time, can be indicative of hockey players' abilities in common game-play situations such as face-offs. The proposed study also

used Wingate anaerobic cycling test to determine anaerobic power outputs because it is considered the standard measure for anaerobic power associated with hockey (Bringhurst et al., 2017). The foundational questions for the presented research are: "do smelling salts benefit the hockey players' reaction time (simple or choice) or anaerobic performance (peak or mean power), and does smelling salts inhalation alter heart rate and breathing rate"

The purpose of this study was to compare the effects of smelling salts vs. no salts on: 1) simple and choice reaction time tasks; 2) anaerobic power through measurement of peak power, mean power, and power drop of a Wingate test and; 3) the sympathetic cardiorespiratory response as measured by heart rate and breathing rate.

Chapter 3

Method

Participant Inclusion/Exclusion Criteria

Participants were included in this study if they were: 1) a healthy male; 2) aged 16-24 years (age range of Junior hockey players); and 3) a hockey player with experience of at least the Junior B hockey level. Participants were excluded from the study if they: 1) had suffered from a diagnosed respiratory disease/obstruction (e.g., asthma, cold, and congestion) within the two weeks prior to the study; 2) were allergic to ammonia, red dye, lavender oil, lemon oil, or nutmeg oil; or 3) had suffered from a concussion in the recent month and/or were still suffering headaches from a previous concussion indicative of post-concussion syndrome.

Sixteen participants were recruited for this study. Anecdotal evidence suggests that primarily male hockey players use ergogenic aides to support their performance. As well, males are significantly more likely to use performance-enhancing drugs than females (Alaranta et al., 2006; Lucidi, et al., 2008). In the local area of Thunder Bay, there is no Junior or varsity level women's hockey. Thus, the sample was the most convenient and highest calibre available to reproduce the population that is commonly seen using the smelling salts during televised professional hockey games.

Research Recruitment Procedures

Convenience sampling was utilized, as only local hockey players were approached. Participants were invited to take part in the study by verbal or personal invitation, or through posters handed out to the team coaches/managers (Appendix B). Specifically, the Thunder Bay North Starts Junior A team was invited to participate in the study, whereas other Junior hockey players were invited through email or oral invitations.

After the participant had expressed an interest in enrolling in the study, he was presented with a copy of the information letter (Appendix C). This information letter summarized the details of the intervention, the task details that the participant was required to perform, the inclusion/exclusion criteria, and the potential harms and benefits of participation. If the participant was deemed suitable to participate in the study, he voluntarily signed up for a testing session at his convenience.

Instruments

Reaction time software called OpenSesame™ was used to record simple and choice reaction time across all trials, as well as calculate the mean reaction time. A Zephyr Bioharness™ physiological monitoring device was used and synced to OmniSense™ 4.0 Live & Analysis software to record heart rate and breathing rate. A Wingate test was used to determine peak power, mean power, and power drop. The model of bike ergometer used was a Monark Ergomedic 894 E.

Psychometric Properties of Instrumentation

Zephyr. The Zephyr Bioharness™ physiological monitoring device is wearable technology capable of measuring multiple physiological metrics including heart rate, heart rate variability, and breathing rate. A study compared the breathing rate values produced by the Zephyr Bioharness™ monitor and the values recorded by a Metamax 3b online gas-analysis system found no significant differences in values; with the exception of at 70% peak treadmill speed ($p < .05$) where the reliability begins to decline; this suggests the Zephyr Bioharness™ provides a valid method to measure breathing rate (Hailstone & Kilding, 2011). The Zephyr demonstrated low random measurement typical error (4.3-7.3%) when measuring breathing rate during physical activity (Hailstone & Kilding, 2011). Johnstone and colleagues (2012b)

investigated the reliability of the Zephyr Bioharness™ to monitor heart rate and breathing rate, finding strong reliability for both (r >0.8). Overall the study concluded that the Zephyr Bioharness™ monitor is a reliable multivariable physiological monitoring device. Kim and colleagues (2013) found high validity for the device as well, heart rate measurements to have high correlation coefficients (r = 0.87–0.96) and breathing rate as well (r = 0.90–0.99).

Wingate. The Wingate test is an objective, reliable, and valid test for evaluating anaerobic cycling performance (Bar-Or, 1987). The Wingate anaerobic test is a 30 second test, in which an individual cycles against 7-12% resistance of their body weight. The test can provide a variety of anaerobic data; this study focused on peak power, mean power, and power drop. Peak power is the highest anaerobic power output within a three to five second interval linked to the ATP-PC pathway output. Mean power details the average power maintained throughout the test, which reflects the output of the combined ATP-PC and glycolytic energy pathway. Finally, power drop describes the drop in W/kg per second of the test, which can reflect the anaerobic endurance of the athletes (Beneke, Pollmann, Bleif, Leithauser, Hütler, 2002). Jaafar and colleagues (2014) found that higher percentage of brake force (resistance) is more optimal because of a higher reliability and validity when determining anaerobic outputs of trained individuals (11% body weight resistance, r = .98), when compared to a lower resistance (8.7% body weight resistance, r = .88). For the current study, participants were anaerobically trained individuals, so they completed the Wingate test at 11% body weight resistance.

Procedures

When participants expressed a willingness to participate in the study, and were deemed eligible, they were given an information letter (Appendix C) that outlined the pertinent details of the study. The participant was also asked to read and sign the necessary consent form prior to

enrolling in the study (Appendix E). The participant then signed up for a specific testing session that was convenient for both parties. Each testing session lasted approximately 30 minutes. The study was a counter-balanced crossover design, so the participant was required to be available at the same time for two consecutive weeks. This helped ensure the participants came during a similar time in their micro-cycle of training. As well, student athletes tend to have a similar weekly routine of meals, classes, and training that will help provide some measure of consistency. To provide a randomized order for the cross-over design, the participants were assigned a number. These numbers were put into a randomized sorter before research commenced. If the participant was grouped into group 1, he completed the salts trial first followed by the no salts trial. If he was grouped into the group 2, he completed the no salts trial first followed by the salts trial.

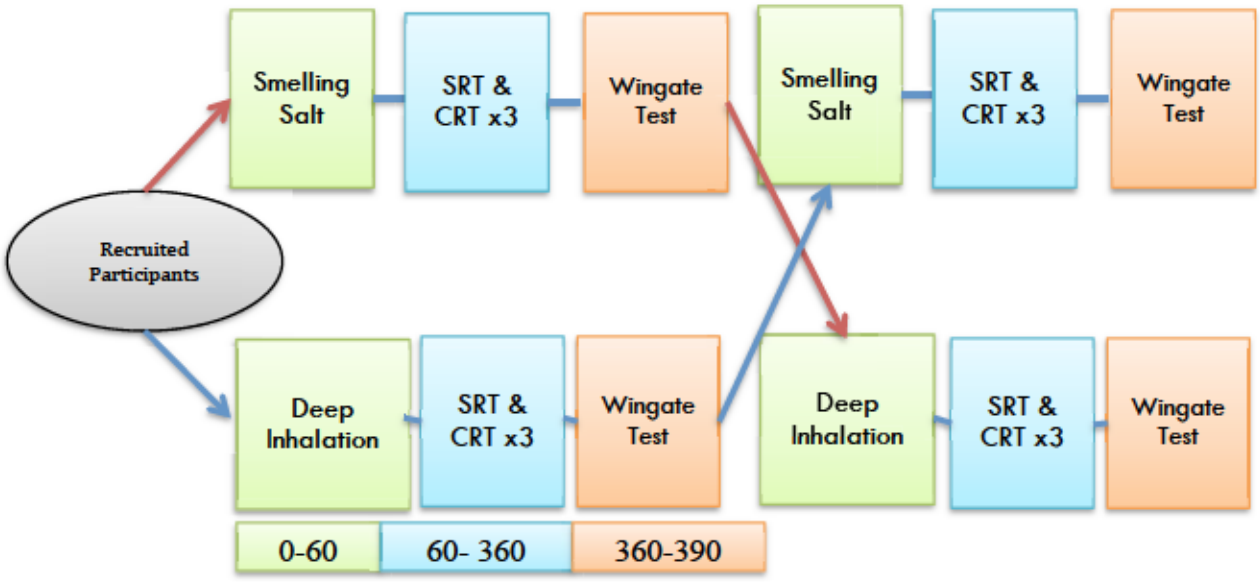

Figure 1. Flowchart of the trials. Figure illustrates the timeline that each participant followed during the trials and the average duration (seconds) for each stage of the trial. Note: Stimulus* was replaced with a deep breath for control trial of the cross-over design. Simple reaction time (SRT), and choice reaction time (CRT).

Before participating in the study, the participant was asked to attempt to keep stress and exercise levels similar between testing days; this was confirmed by monitoring resting heart rate at the beginning of both sessions. The participant was asked via email to avoid caffeine, alcohol, and strenuous exercise within 12 hours prior to the days of testing. For each assigned testing session, participants were asked to arrive at the Sanders Building in room SB-1025 on time. The participant was greeted by the student researcher and directed to seat himself at a table where he read the cover letter. The researcher fully explained the information contained in the letter, what was involved in the study, and answered any questions or concerns the participant may have had. After full consent was obtained from the participant, he was required to complete a Physical Activity Readiness Questionnaire (PAR-Q) form (Appendix F).

Upon completion of the required documents, anthropomorphic measurements of height, weight, and age of the participant was measured and recorded on the data collection sheet (Appendix G) and the OmniSense™ program by the researcher. The participant was fitted with the Zephyr Bioharness™ monitor device as recommended by the manufacturer (Appendix H). The monitor was attached to the front of the chest strap, and acted as a data logger and transmitter. The Zephyr Bioharness™ monitor was synced with the OmniSense™ 4.0 Live & Analysis software, which recorded the data from the heart rate monitor and later exported the data to analyze. The Bioharness recorded measurements for heart rate and breathing rate every two and a half seconds. For statistical purposes, baseline heart rate and breathing rate were defined as the values recorded immediately (2.5 seconds) prior to smelling salts exposure, while the average value over the 10 seconds post smelling salt inhalation was used to reflect the post measurement value.

After being fitted with the heart rate monitor, the participant was asked to lie supine on a cushioned mat on the floor for one minute. This was done to ensure a valid resting heart rate and blood pressure measurements. The participant was then fitted with a Prestige Medical 79 sphygmomanometer (blood pressure cuff) on their right arm, above the elbow with the guiding arrow on the cuff in line with the brachial artery. The same researcher conducted the blood pressure reading on the participant by inflating the cuff to 170 mmHg and deflating it slowly, recording both the diastolic and systolic readings using a MDF Classic stethoscope. The researcher was experienced in taking blood pressure measurements. After both baseline measurements of heart rate and blood pressure were established, the participant was guided through the procedures of the simple and choice reaction time tests by completing four practice trials of each. If the participant had any questions regarding the any of the tests, they were answered then.

At this time, the researcher set the height for the seat of the Wingate test stationary bike to an appropriate height. This allowed the participant to sit comfortably on the seat with his knee just slightly flexed (10 degrees of flexion) at the bottom of the cycle. The researcher set the body weight resistance to the 11% body weight resistance for the participant. The researcher explained the Wingate procedures were, to minimize time between exposure to the smelling salt and performing the Wingate test. The hockey players were already familiar with the Wingate testing procedure due to previous experience.

Then the participant was guided through a brief warm-up for the Wingate test. The warm up consisted of the participant cycling on a stationary bicycle for five minutes with ten-second sprints conducted at minute two, three, and four. The resistance of the bike was set to 2 kPa, but the participant self-selected the intensity (rotations per minute) of the warm up.

The participant was then asked to sit in the chair facing the reaction time screen (Appendix I). Once the participant was seated comfortably in front of the reaction time testing station (comprised of a chair, desk, and laptop), and the researcher had restarted the heart rate monitor, the participant was asked to sit still for a minute for another resting heart rate reading. Then the researcher released a smelling salt capsule at a distance of 30 cm away from the nostrils of the participant. The participant was then instructed to inhale through his nostrils, as the researcher brought the smelling salt capsule closer to the participant's nostrils. While approaching the nostrils, the capsule was shaken by the researcher to facilitate the release of the gas from the capsule. The participant continued to inhale until the withdrawal reflex was observed, at which point the smelling salt was disposed. The withdrawal reflex was normally seen when the ammonia reached a distance of about 10 cm away from the nostril, with the closest being 5 cm away. The participant was exposed to the released smelling salt capsule for no more than three seconds.

The reaction time tests commenced 60 seconds after the smelling salt exposure had been conducted. Allowing for heart rate and breathing rate readings to be undisturbed from extra stress. The participant was then asked to commence the reaction time tests. The participant began with a block of 10 trials of simple reaction time tests. The simple reaction time test consisted of a single stimulus (a large blue circle) appearing on the screen, and a single proper response needed by the participant. Once the stimulus appeared on the screen, the participant pushed the "B" key as quickly as he could. The program was set to randomize the timing of the stimulus so the participant could not sense a pattern of timing. The ranges for the stimulus appearing was anywhere between one to three seconds from the previous response. The range of timing was consistent through the choice reaction time test as well.

After the first block of simple reaction time tests were completed, the participant began a block of 10 trials of choice reaction time tests. The choice reaction time test consisted of two different stimuli, with each having a single proper response. Once the stimuli appeared on the screen, the participant cognitively determined which response was correct, and pushed the appropriate button. If the green triangle stimulus appeared in the middle of the screen, then he pushed the "F" key as quickly as possible; if the red circle stimulus appeared in the middle of the screen, then the participant pushed the "J" key as quickly as possible. If a participant responded incorrectly to a stimulus, or too quickly (i.e. before the stimulus appears) then the specific trial was not counted and the participant performed an additional trial (i.e. 11 trials of choice reaction time).

The participant continued to alternate between blocks of 10 trials of simple reaction time and choice reaction time. The researcher wrote down the time the participant started and finished each block of reaction time tests on the data collection sheet (Appendix G), and later cross-referenced the heart rate data against the activity the participant was engaged in. After the participant had finished the three blocks of 10 trials of each reaction time test, the participant was asked to begin the Wingate test. The average time from smelling salt exposure until the start of the Wingate testing was six minutes. Although this may seem like a large period of time, players commonly use smelling salts as a part of their pre-game ritual, so there is also a waiting period before the players would begin their shift. The researcher pressed start - beginning the recording of the anaerobic power output (W), and the resistance as well as the data collection began when the participant reached a threshold of 120 rotations per minute. After this threshold was achieved, the resistance weight (11% body weight) dropped and the watts output was collected. The participant continued to pedal at maximal effort for 30 seconds on the bike ergometer. The

researcher recorded the time the participant began and finished the Wingate test on the data collection sheet. After the 30 seconds had been completed, the participant was asked to gently cycle on a stationary bike for another 5 minutes. Once the participant felt sufficiently cooled-down and had biked for at least 5 minutes, he was free to stop and rest.

The participant was asked to recover for an additional 15 minutes. The researcher checked to ensure that the heart rate and blood pressure of the participant had normalized to a similar reading (within 20 bpm and 10 mmHg difference) as the initial readings. If the measures had not resumed to normal, the participant was asked to wait to leave until it had. At this point in time, the participant was asked to remove the Zephyr Bioharness™ monitor, or aided by the researcher to remove it.

The participant was asked to return to the testing area on the same day and time the following week from the initial session. During the second trial, the participant followed the same guidelines and procedures, beginning with the baseline heart rate and blood pressure readings. The difference in procedures from salts to the no salts trial was that instead of smelling salt exposure participants were asked to take a deep inhalation through his nostrils 60 seconds before beginning the reaction time tests. The deep breath was used in place of a placebo, to instead act as a control. It was expected that participants recruited for the study would have been exposed to a smelling salt prior to the testing, either directly through self-administration or from close proximity to another player using one, so a placebo would most likely be detected from the players, thus nulling the effect of using a placebo. An experimental control of deep breathing still allows for the inference that changes in the dependent variables are due to the smelling salts and not an associated deeper breath that comes with smelling salt inhalation.

Design/Data Analysis

The study utilized a cross over design with randomized ordering to assess the differences between salts and no salts treatments in regards to simple reaction task (ms), choice reaction task (ms), anaerobic peak power (W/kg), anaerobic mean power (W/kg), power drop (W/sec/kg), change in heart rate (beats per minute), and change in breathing rate (breaths per minute). The cross over design was used to provide a more efficient comparison of treatments, as half the participants were randomly assigned to a salt, then no salt sequence while the other half of the participants experienced the opposite sequence (i.e. no salts then salts). The design also removes threats to internal validity; by using the same participants, they act as both the control and experimental subjects, thus having a matched sample. To characterize magnitude of effect size, Cohen's D was used as an index.

Reaction time. The first research question aimed to determine the effects of the independent variable of treatment (salts vs. no salts) on both simple and choice task reaction times. The other independent variable used in this analysis was sequence (week one vs. week two). First, to determine that there were no significant differences between the blocks of the reaction time trials, a one-way ANOVA was conducted. It was determined that the timing of the blocks did not impact performance; thus the blocks were combined in order to complete a more robust analysis. In order to examine the potential differences in reaction time across the different treatments a $2_{(\text{treatment})} \times 2_{(\text{sequence})}$ mixed measures ANOVA with repeated measures on the first factor was used. This analysis was conducted for the dependent variables of simple task reaction time (ms) and choice task reaction time (ms).

Anaerobic power. The second research question aimed to determine the effects of salts on anaerobic power. The independent variables for this analysis were sequence (week 1 vs. week 2)

and treatment (salts vs. no salts). To examine the potential differences in anaerobic power a 2 $_{(treatment)}$ x 2 $_{(sequence)}$ mixed ANOVA with repeated measures on the first factor was used. This analysis was conducted separately for the dependent variables of peak power (W/kg), mean power (W/kg), and power drop (W/sec/kg).

Cardiorespiratory response. The third research question aimed to determine the effects of the salts on the cardiorespiratory system, which was inferred from the dependent variables of change in heart rate (beats per minute), and change in breathing rate (breaths per minute) from before inhalation to the ten seconds after inhalation. Before inhalation values was the measured rate over the five seconds immediately before inhalation of the smelling salt (or deep breath), and the post inhalation was the average measured rate across the ten seconds after smelling salt (or deep breath) inhalation. Similar to the other measurements, the independent variables were treatment and sequence. To examine the differences in cardiorespiratory responses 2 $_{(treatment)}$ x 2 $_{(sequence)}$ mixed ANOVA with repeated measures on the first factor was used. This analysis was conducted separately for the dependent variables of change in heart rate and change in breathing rate change.

For all the statistical tests conducted, the respective normalities of the data were tested and met, using the Shapiro-Wilk test of normality to test ensure the data was normally distributed. There was homogeneity of variances ($p > .05$) and covariances ($p > .05$), as assessed by Levene's test of homogeneity of variances and Box's M test, respectively. Mauchly's test of sphericity indicated that the assumption of sphericity was met for the two-way interaction effects.

Post hoc analysis on warm-up intensity. After noting that some individuals experienced large heart rate increases after smelling salt exposure while others had modest increases (Appendix K, figure 12), it was hypothesized that perhaps the intensity of the warm-up may have contributed to

the variability (only resistance was standardized to 2 kpa, not intensity). Those individuals who pushed themselves a bit more in the warm up would conceivably have a higher heart rate prior to the smelling salt exposure and they would thus experience less of an increase in heart rate. Therefore, an additional analysis was run to examine if the warm up intensity altered the effect of smelling salts on heart rate. In order to examine the effect of warm up intensity on heart rate response to smelling salts a $2_{\text{(high vs. low)}} \times 2_{\text{(time: before vs. after inhalation)}}$ mixed ANOVA with repeated measures on the second factor was used. This was done by dividing the pool of participants into two groups of eight, one group containing the lowest heart rates ($M = 73.87$, $SD = 11.56$) after completing the warm up and the other with the highest after the warm up ($M = 102.83$, $SD = 17.42$). The independent variables for the mixed ANOVA were the high vs. low grouping and time (before salt inhalation vs. after salt inhalation). Because there was no interaction present, no additional analysis was conducted on the interaction effect.

Chapter 4

Results

Anthropometric Analysis

Sixteen male hockey players who regularly participate in strength training were the study participants (see Table 1 for demographics). The table includes the mean amount of smelling salt capsules used per week by the participants. There were no observed significant changes in the performance variables, however heart rate and breathing rate were significantly higher during the ten seconds after exposure to smelling salts.

Table 1

Demographics Sample

Measure	Mean	Standard Deviation
Age (years)	21.19	2.16
Height (cm)	180.38	6.23
Weight (kg)	82.84	6.52
BMI (kg/m^2)	25.58	2.93
Previous use of salts (average per week)	1.10	1.32

Note. cm = centimeters; kg = kilogram; kg/m^2 = $kilogram/meter^2$

Reaction Time

Table 2 summarizes the findings of the simple and choice task results for both treatments of salts and no salts. The data demonstrates no large differences between treatments, for either of the tasks.

Table 2

Mean Reaction Time Across Treatments and Sequence

	Treatment	Week 1	Week 2
Simple Task (ms)	Salts	M = 270.78, SD = 22.44	M = 272.22, SD = 28.50
	No Salts	M = 270.43, SD = 21.39	M = 275.04, SD = 28.57
Choice Task (ms)	Salts	M = 403.00, SD = 30.29	M = 387.12, SD = 46.29
	No Salts	M = 409.30, SD = 39.40	M = 396.93, SD = 52.61

Note. ms = milliseconds

Simple task. The 2 $_{(treatment)}$ x 2 $_{(sequence)}$ mixed measures ANOVA identified no statistically significant interaction between the sequence (week one vs. week two) and the treatment (salts vs. no salts) when analyzing simple task reaction time with a small effect size, (F (1, 14) = .08, p = .79, η^2 = .01). There was no main effect for treatment on simple task reaction time when smelling salts and no salts were compared, (F (1, 14) = .05, p = .83, η^2 = .00). There was also no significant main effect for trial order when week 1 and week 2 were compared, (F (1, 14) = .07, p = .79, η^2 = .01).

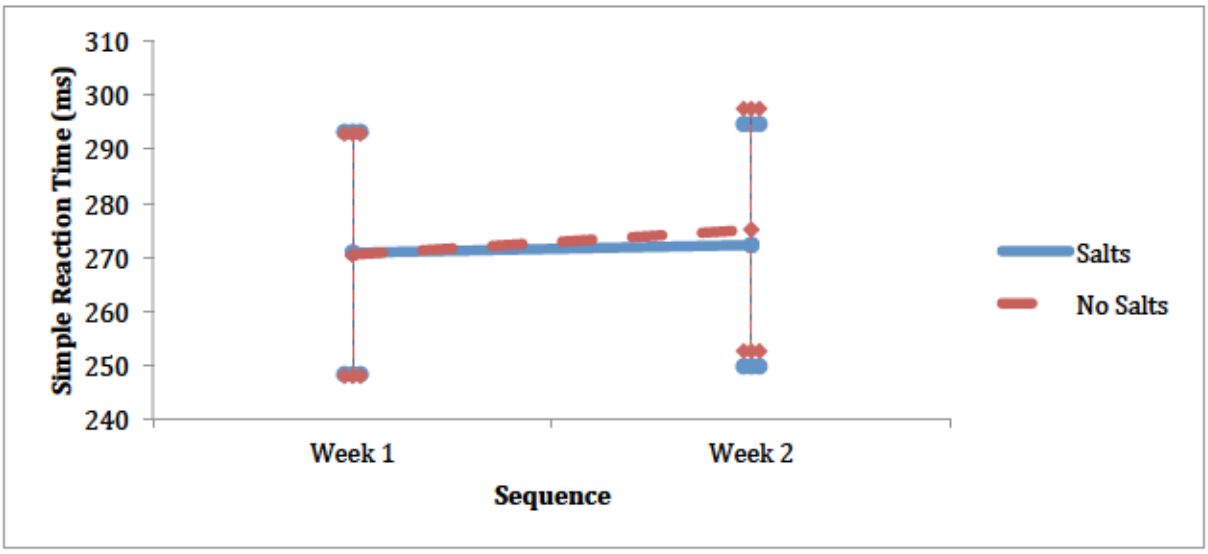

Figure 2. Simple task reaction time across sequences and treatments.

Choice task. The 2 $_{(treatment)}$ x 2 $_{(sequence)}$ mixed measures ANOVA identified no statistically significant interaction between the sequence and the treatment when analyzing choice task reaction time with a small effect size, (F (1, 14) = .05, p = .83, η^2 = .00). There was no significant main effect for treatment on choice task reaction time, (F (1, 14) = 1.00, p = .33, η^2 = .07). There was also no significant main effect for sequence, (F (1, 14) = .50, p = .49, η^2 = .35).

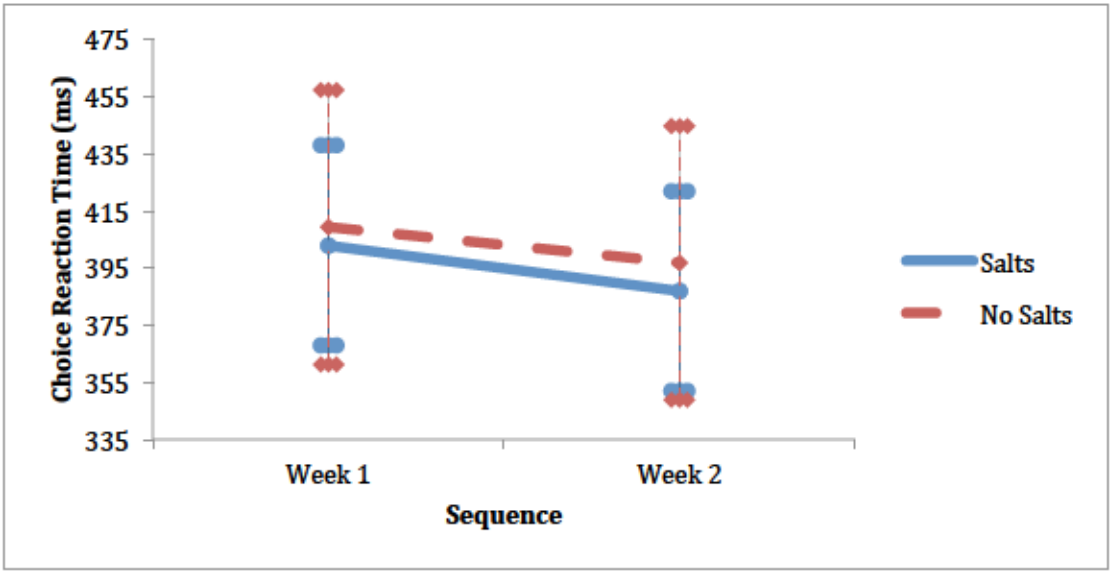

Figure 3. Choice task reaction time across sequence and treatments.

Anaerobic Power

Table 3 summarizes the average anaerobic power outputs for both sequences and treatments for all 16 participants. The results reveal no large differences between the sequences or the treatments.

Table 3

Anaerobic Power Across Treatments and Sequences

	Treatment	Week 1	Week 2
Peak Power (W/kg)	Salts	M = 12.96, SD = 1.46	M = 12.60, SD = 1.39
	No Salts	M = 12.70, SD = 1.91	M = 12.56, SD = 1.42
Mean Power (W/kg)	Salts	M = 6.58, SD = 1.28	M = 6.46, SD = 1.20
	No Salts	M = 6.22, SD = 1.77	M = 6.49, SD = 0.93
Power Drop (W/sec/kg)	Salts	M = 0.23, SD = 0.04	M = 0.21, SD = 0.04
	No Salts	M = 0.22, SD = 0.05	M = 0.20, SD = 0.05

Note. W = watts; kg = kilogram; sec = seconds

Peak power. There was no statistically significant interaction between the sequence (week one vs. week two) and treatment (salts vs. no salts) on peak power, (F (1, 14) = .19, p = .67, partial η^2 = .027). There was no main effect of treatment with a small effect size, (F (1, 15) = 0.78, p = .41, partial η^2 = .10), or sequence (F (1, 15) = .240, p = .64, partial η^2 = .03) observed in the study.

Mean power. There was no statistically significant interaction between the sequence and the treatments on mean power, (F (1, 14) = 1.267, p = .297, partial η^2 = .15). The main effect of sequence showed that there was no statistically significant difference in mean power from week 1 to week 2 with a small effect size, (F (1, 15) = .016, p = .903, partial η^2 = .00). The main effect

of treatment showed no statistically significant difference in mean power between smelling salts and no salts with a small effect size, (F (1, 15) = 0.591, p = .467, partial η^2 = .08).

Power drop. There was no statistically significant interaction between the sequence (week 1 vs. week 2) and treatment (salts vs. no salts) on power drop, (F (1, 14) = 0.29, p = .87, partial η^2 = .00). There were no significant differences from treatment, (F (1,15) = 1.31, p = .27, partial η^2 = .08) or sequence, (F (1,15) = 1.28, p = .28, partial η^2 = .08).

Cardiorespiratory Response

Table 4 summarizes the findings of the cardiorespiratory response to smelling salts and during the no salts treatments. Cardiorespiratory responses were determined by calculating the difference between the pre-inhalation values and the post-inhalation. Pre-inhalation was defined by the value within five seconds before the treatment (salts vs. no salts) exposure, whereas post-inhalation was defined by the mean value up to ten seconds after the treatment. Note that a positive number indicates heart rate increased from pre to post values, and a negative is indicative of a decline in values from pre to post.

Table 4

Change in Cardiorespiratory Variables Across Treatments and Sequences

Variable	Treatment	Week 1	Week 2
Heart Rate (post – pre)	Salts	M = 5.73, SD = 7.26	M = 10.92, SD = 6.96
	No Salts	M = -2.04, SD = 3.03	M = -1.90, SD = 4.74
Breathing Rate (post – pre)	Salts	M = 0.73, SD = 1.46	M = -0.10, SD = 1.49
	No Salts	M = -1.44, SD = 1.53	M = -0.37, SD = 2.28

Note. Changes in cardiorespiratory variables were calculated as a difference by subtracting the pre-inhalation value from the post-inhalation value.

Heart rate. There was no statistically significant interaction between the sequence (week 1 vs. week 2) and the salts treatment (salts vs. no salts) on heart rate, (F (1, 14) = 2.08, p = .17, partial η^2 = .16). The main effect of treatment illustrated a significant difference between the salts and the no salts, (F (1,14) = 34.38, p < .01, partial η^2 = .71). There were no significant differences from sequence between the week 1 and week 2, (F (1,14) = 1.37, p = .26, partial η^2 = .09).

Breathing rate. There was no statistically significant interaction between the sequence (week 1 vs. week 2) and the treatment (salts vs. no salts) on breathing rate, (F (1, 14) = 2.57, p = .13, partial η^2 = .16). The main effect of treatment illustrated a significant difference between the salts and no salts, (F (1,14) = 4.24, p = .05, partial η^2 = .23), with no main effects from sequence, (F (1,14) = .04, p = .85, partial η^2 = .00).

Figure 4 demonstrates the differences observed in the change in heart rate and breathing rate immediately post treatment in both the salts and no salts trial. This demonstrates the large increase in heart rate that follows after smelling salt inhalation, whereas a decrease in heart rate was observed during the no salts trial. Similar to the heart rate response, the no salt treatment prompted a decrease in breathing rate, where as the salt treatment elicited an overall stimulatory increase in breathing.

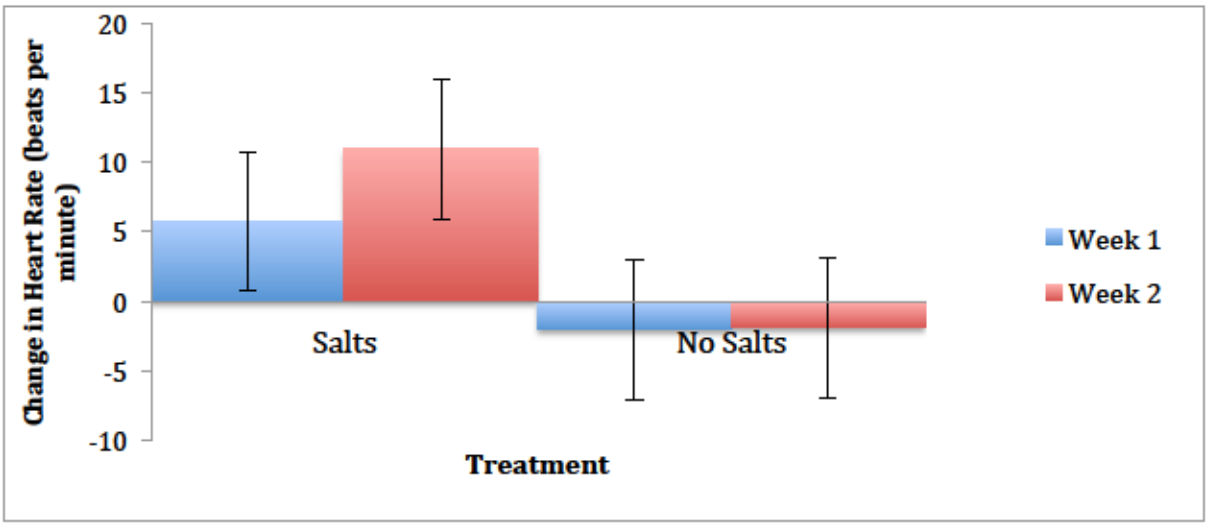

Figure 4. Change in heart rate after inhalation of smelling salt. Smelling salts produced an immediate increase in heart rate.

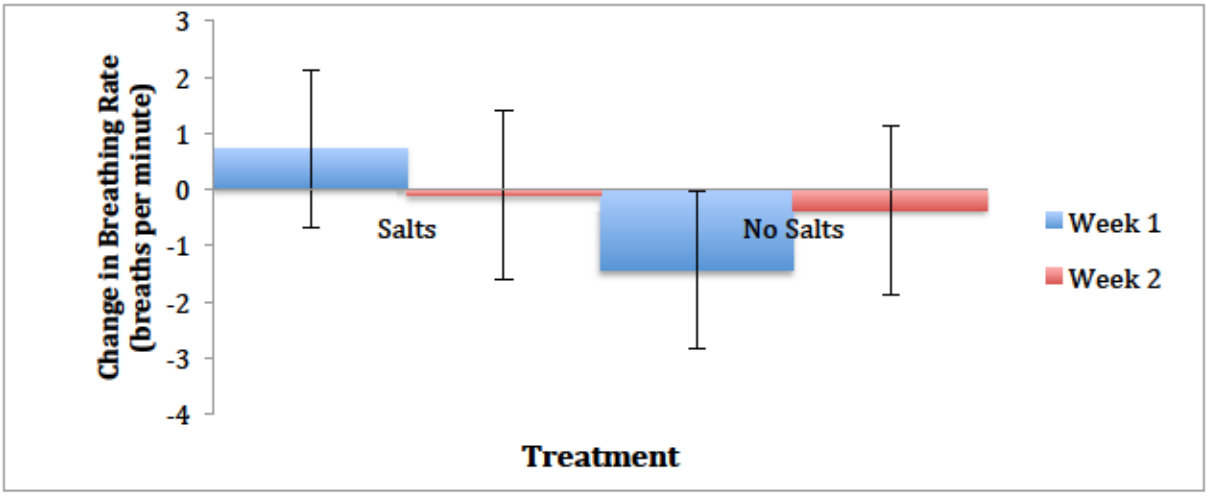

Figure 5. Change in breathing rate after inhalation of smelling salt. The breathing rate response is significantly different than no salts condition, where a decrease in breathing rate was observed.

Post hoc analysis on warm-up intensity. To determine if the self-selected warm up intensity had an effect on heart rate after smelling salts, a 2 $_{(\text{high vs. low})}$ x 2 $_{(\text{time})}$ mixed ANOVA with repeated measures on the second factor was conducted. There was no significant interaction between the high or low initial heart rate groups and time (before vs. after smelling salt

exposure), (F (1, 14) = 2.284, p = .153, partial η^2 = .140). Thus it does not appear that the variability in heart rate response to smelling salts was due to warm up intensity.

Chapter 5

Discussion

The results of the study illustrate no significant changes amongst the treatment groups for our two main performance variables: reaction time and anaerobic performance. These results are also paired with no significant effect of sequence, which indicates that the order that the treatments were executed did not affect the results. However, the players did demonstrate a significant increase in heart rate and breathing rate in the 10 seconds immediately after smelling salt exposure. Indicating that the participants did have an elevated sympathetic response to the smelling salts, but the response did continue on to any improvement in the variables indicative of sport performance.

Reaction Time

During game-play, hockey players are constantly being presented with different visual stimuli, and must quickly and efficiently react to gain a competitive advantage. The simple reaction time could be representative of a face-off situation where a player can anticipate the stimulus and have a pre-programmed response to the drop. The choice reaction time testing would then allow inferences on other situations that the player may be presented with different stimuli, with potential different responses associated with the stimuli. These reaction time tests are indicative of different situations that players may commonly come across in gameplay situations. Contrary to our hypothesis, smelling salts did not significantly improve mean reaction time for simple or choice task; simple reaction time being a reaction to a single stimulus, and choice involving information processing to be chosen between responses. Smelling salts did not impact the performance of simple reaction time; suggestive of no affect on the stimulus identification or the response programming stage involved in simple reaction time. Likewise, the

response-selection stage that is closely associated with choice reaction time was not affected. The order that the trials were completed did not have a significant effect on testing.

Ergogenic aids promoting arousal are popular amongst athletes, possibly explained by arousal being one of the few directly controllable factors during the day of the competition, while other factors need to be prepared in the days prior to the competition (Tod, Iredale, & Gill, 2003). Caffeine and smelling salts are popular arousal aids amongst athletes, and the two are reportedly considered comparable by those that utilize them in sport (Pritchard et al., 2014; Valasquez, 2011, McCrory, 2006). Caffeine is a stimulant that raises arousal levels and thus influences reaction time by promoting faster processing of relevant information along neuronal pathways (Dixit et al., 2012; Ruijter, De Ruiter, & Snel, 2000; Ruijter, de Ruiter, Snel, & Lorist, 2000). While caffeine has documented improvements in the literature for reaction time and anaerobic tests, it appears that the acute effects of smelling salts do not have the same affects. Effects of caffeine however, have not been directly compared to the effects of smelling salts in previous research, so it is difficult to definitively conclude.

After looking at the cardiorespiratory response in conjunction with the reaction time, it may be noted that the stimulatory response timing was shorter than the time until the reaction time tests. The stimulatory response lasted less than 30 seconds after smelling salt inhalation, as also seen in Perry et al., (2016), however the reaction time tests began at 60 seconds after inhalation. This may have been after any sympathetic stimulation/arousal had already dissipated. The timing of the reaction time tests was justified by examining how the smelling salts are used in the sport of hockey, as Prewit (2016) notes that smelling salts are most commonly seen in the pre-game ritual of players. Therefore an even larger gap between inhalation and the beginning of the hockey shift may be present if the smelling salts are inhaled on the bench before the first

puck drop. Therefore it could be concluded that smelling salts do not have a significant impact on the reaction time of hockey players. This conclusion can be taken in light of some external factors that may influence the timing or magnitude of the sympathetic response. For example, the player may wait until moments before the start his shift, thus delaying the stimulation closer to the activity. Furthermore, the player may also have a higher sympathetic response because of the arousal of participating in the game or hearing the crowd. These factors may still have an affect on the arousal and overall performance of the player that has yet to be investigated.

Anaerobic Performance

Similar to the lack of effect observed on reaction time, smelling salts did not have an effect on the anaerobic performance measurements (peak power, mean power, or power drop). The results of the study illustrate a non-significant difference in peak power between the salts and no salts treatments. This contradicts the only other study conducted on smelling salts effects on peak and mean power as measured by Wingate testing (Secrest, 2014). The time between administration of the smelling salts and the Wingate test was quite different between these studies, and could account for the difference in findings between the presented study and Secrest (2014). The average time between the smelling salt inhalation and Wingate performance was six minutes and five seconds. Secrest (2014), did not have a waiting period, and began the Wingate testing immediately post-inhalation that observed significant differences in peak power as well as mean power between treatment trials. Similarly, Perry et al., (2016) found a significant increase in rate of force development 30 seconds after smelling salt inhalation; these results may indicate the optimal timing between the time of inhalation and the peak of arousal/strength is very short. In combination with our results, this implies that if there is an effect of smelling salts on power,

it is not long lasting. However, the exact timing of the smelling salts may be better revealed using a time course study.

The time period between the inhalation of smelling salts and the Wingate anaerobic test in the current study serves to mimic a hockey game situation. Even a first line player would have to take the smelling salt in the change room, during the warm up, or on the bench before skating out to center ice for the first draw, and the delay until athletic performance began could be estimated between 60 seconds to ten minutes, longer still for second through fourth line players. Although smelling salt use prior to hockey performances is common, the results of this study indicate that there is no significant effect from smelling salts to increase anaerobic performance. Results from previous literature on smelling salts as an ergogenic aid for powerlifting demonstrated similar results, with no significant change in power (Richmond et al., 2014; Perry et al., 2016; Vigil et al., 2017).

There were a few participants that performed consistently better after using smelling salts for both reaction time and anaerobic power. This may be foundation for a more in depth analysis into a possible placebo effect. There have been studies that utilized placebos in conjunction with smelling salts (Richmond et al., 2014; Vigil et al., 2017) and did not find significant differences between the two, whereas Secrest (2014) found a significant difference in anaerobic power without the use of a placebo. This furthers the conclusion that smelling salts are not an effective ergogenic aid, as the two studies utilizing placebos did not find any significant difference. However, the participants in the studies mentioned may have had previous experience with using ammonia inhalants that may have informed them which was the real treatment and which was placebo; nullifying the placebo treatment trial.

Another possible reason for the differences in results between the placebo studies and Secrest (2014) may be attributed to the design of the anaerobic performance portion of the study. Secrest (2014) used the smelling salts after the participants had already completed preliminary game simulation, which would then have made the smelling salts act more as a mitigating factor for fatigue rather than boosting peak power. The present study used only one Wingate per trial (separated by a span of a week), which would not have induced fatigue. This again serves to mimic the accounts of how smelling salts are used in hockey, which is most commonly seen in pre-game rituals by the players; before the players have begun the physically demanding game play (MacGregor, 2018; Prewitt, 2016). However there are players that use the smelling salts between the periods or during the games as an aid to combat fatigue, which currently remains unexplored.

Cardiorespiratory Response

The smelling salts had a significant impact on the change in heart rate and breathing rate of participants during the ten seconds immediately after inhalation. This adds to the findings of Perry et al. (2016) that found a significant increase in heart rate 15 seconds after smelling salt inhalation. Perry et al. (2016) found a difference in values from pre-inhalation to post-inhalation (83 to 88 bpm ± 16) and the present study found a difference in pre-post values of 86 to 96 bpm ± 17. The results of this study observed the highest heart rate values at seven and a half seconds and ten seconds after exposure. When comparing heart rate along with the results of Perry et al. (2016), the results indicate that after ten seconds, the heart rate is beginning to return to homeostasis. As observed by Perry et al. (2016) there was a smaller difference in heart rate at 15 seconds, and participants heart rate had returned to baseline by 30 seconds post inhalation. This indicates that smelling salts effects are very short term, and not helpful in the way that hockey

athletes currently utilize them: unless the arousal from increased sympathetic nervous system stimulation lasts longer than the increased response.

The change in breathing rate of participants after smelling salts inhalation was significantly different than the no salt trial. This difference was not due to a large increase in breathing rate, but rather the breathing rate elevated for a short time after inhalation compared to the no salt trial where a drop in breathing rate was observed. A drop in breathing rate is indicative of a decrease in sympathetic nervous system activity, so the no salts trial would have a less active sympathetic nervous system for the time measured after inhalation. This finding was hypothesized that both heart rate and breathing rate would similarly increase due to arousal of the sympathetic nervous system, however with the slight difference of the breathing elevating slightly after the warm-up rather than decreasing.

The significantly elevated heart rate and significant difference in breathing rate is indicative of a stimulatory effect caused by the smelling salts. The presence of the withdrawal reflex by the participants, along with the elevated heart rates is consistent with an adequate intake of the ammonia upon inhalation. This suggests that the volume during the experiment was the correct amount to mimic the use in sport. Despite these evident stimulatory responses, neither the participants' reaction time or anaerobic power was altered after exposure. This finding is consistent with previous literature that also considered the impact of smelling salts on cardiorespiratory response and anaerobic power (Perry et al., 2016; Richmond et al., 2014; Vigil et al., 2017).

Post Hoc Analysis on Warm-up Intensity

Individual results from the reaction time tasks, anaerobic performance, and cardiorespiratory measurements can be seen in appendix K, which demonstrate the highly

variable response to smelling salts amongst all of the participants. Due to the variability in the results, particularly in the heart rate before salt inhalation, a post-hoc analysis was conducted to determine if the warm-up intensity altered the results. Despite the warm-up that elevated the heart rate/breathing rate of the participants, there was still a significant increase in mean heart rate just after exposure. This demonstrates that the smelling salts acted as a stimulant to the participant that further stimulates the cardiorespiratory factors past the original post-warm-up heart rate. Our results indicate that there were no interaction effects between the intensity of the warm up and heart rate before and after smelling salts, suggesting that regardless of how elevated the sympathetic nervous system is, the smelling salts do not have a different effect but rather remains a stimulant that elevates cardiorespiratory responses.

Practical Implications

The results of this study show that smelling salts may act as a very short-term stimulatory ergogenic aid, but the results are small and appear to be negligible after just a few minutes. The smelling salts did temporarily significantly raise heart rate and breathing rate that may temporarily raise alertness, but these elevations are unlikely to impact or improve performance. The cardiovascular elevations observed in the present study did not to transfer to the other performances aspects during the reaction time tasks or anaerobic performance tests. Despite the previous and present findings, the observed prevalence of smelling salts in elite hockey is high. Many players may consider smelling salts a ritualistic aspect of their pre-game preparations, which might be all the benefit they receive from them.

Limitations

The study was designed to measure constructs important to hockey performance, however they were done in a laboratory, so the environment was different. The anaerobic

performance and response test would usually be performed at the same time for a player in competition, however in this study they were conducted separately. We had a limited sample size of 16, which was smaller than the desired sample before testing took place. The participants were selected to mimic an elite hockey population that would use the smelling salts every game, however the average use of smelling salts was around once per week. The participants were instructed to not participate in exercise 12-hours prior to participating in the study, however exercise prior to the 12-hour mark may have lingering effects on the participants. Likewise, the participants were instructed to warm-up at a difficulty of 2 kpa resistance, but were not instructed on a specific intensity. The study was also limited to a control trial instead of a placebo: this was because the participants involved would be able to notice the irritation of the nostrils of a real smelling salt, and would likely notice the difference in smell from another item used. This lack of placebo control trial may have allowed for a possible psychological influence during experimental compared to the control trial.

Delimitations

The study design was meant to mimic a shift in hockey game, with reaction tests and an anaerobic performance. There was a time delay between the use of the smelling salt and the anaerobic performance (because of the reaction tests), which increased external validity to more closely mimic a player that would use the smelling salt on the bench and wait until their shift begins. The specific dosage of the smelling salt capsule is also the same capsule that is observed commonly in professional hockey games. The population generalized in this sample was at Junior A/B level players, which was the highest level of players available in Northwestern Ontario.

Chapter 6

Conclusion

In conclusion, this study evaluated the effects of smelling salts on reaction time, anaerobic performance, and the cardiorespiratory system. There is still limited evidence of the effects of smelling salts on anaerobic power and the cardiorespiratory system. The results of this study show no evidence of smelling salts affecting reaction time, through the measure of the information processing continuum or response to stimuli. This indicates that the smelling salts are not a useful ergogenic aid in reaction time performances, or sports/situations that may benefit from a quicker response time.

The cardiovascular response of heart rate and breathing rate was significantly altered from smelling salts, indicating a stimulating effect immediately after inhalation. Despite the noted stimulation, our findings regarding Wingate performance do not show any improvement to anaerobic peak power, mean power, or power drop, at seven minutes after inhalation. Again, this indicates that smelling salts are not useful as an ergogenic aid in a hockey shift after a waiting period of roughly seven minutes. If participants feel like the smelling salts are helping their performance, there is no known contraindication to smelling salts in a healthy individual, but caution should be used with players that are suspected to have a head injury.

Future Research

It appears there may be a short period of time in which the smelling salts may improve anaerobic performance; so more research regarding different timing could provide more precise information regarding this time period. Anecdotally, smelling salts have often been compared to caffeine and perhaps a study with these two substances may provide an accurate comparison. It may be of benefit to measure for skin conductance level as a way to quantify arousal after

inhalation. A study detailing the acute effects of smelling salts on the cardiorespiratory system with a larger sample size could provide further insight into the ergogenic aid. It would also be valuable to qualitatively examine the history of the use of smelling salts, with focus on the reasons behind the use, the claims of the benefits, and experience of using the smelling salts.

List of Appendices

The following documents are included as appendices:

- 1 Copy of the TCPS 2 Tutorial: Course on Research Ethics Completion Certificate
- 1 Smelling Salts Article Summary
- 1 Recruitment Poster
- 1 Information Letter
- 1 Consent Form
- 1 PAR-Q Plus Form
- 1 Data Collection Sheet
- 1 Zephyr Bioharness™ Monitor Positioning
- 1 Diagram of the Initial Position for Every Test
- Definitions
- Individual Results

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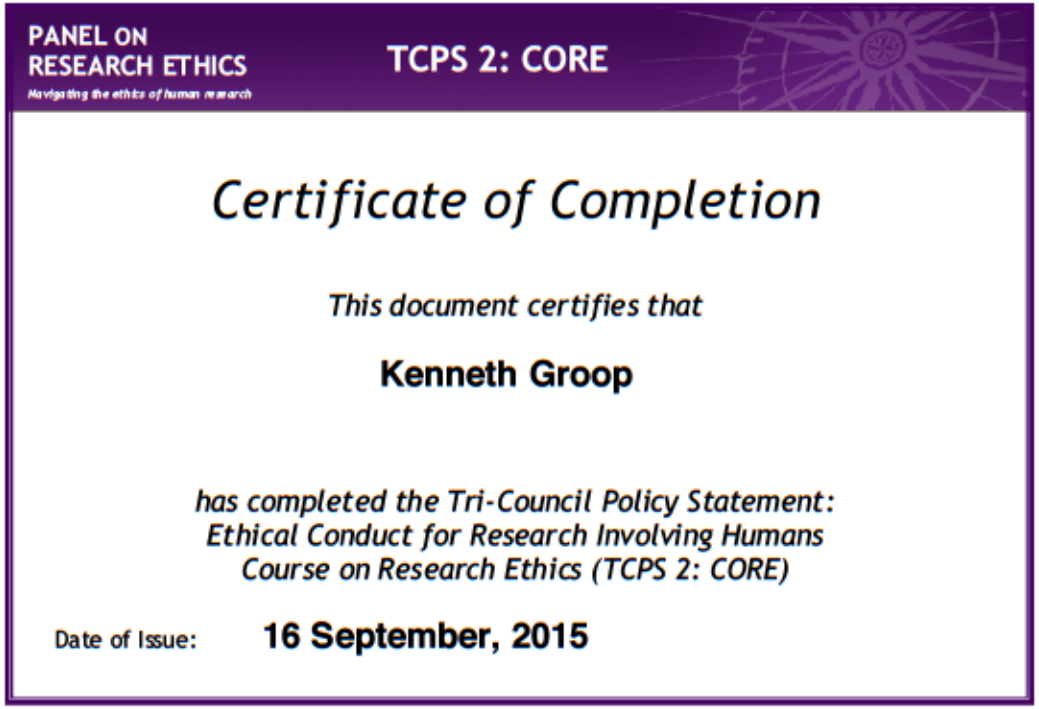
Appendix A

TCPS 2 Tutorial: Course on Research Ethics Completion Certificate



PANEL ON RESEARCH ETHICS
Navigating the ethics of human research

TCPS 2: CORE

Certificate of Completion

This document certifies that

Kenneth Groop

has completed the Tri-Council Policy Statement:
Ethical Conduct for Research Involving Humans
Course on Research Ethics (TCPS 2: CORE)

Date of Issue: **16 September, 2015**

Appendix B

Smelling Salts Article Summary

Table 5

Articles Examining Ergogenic Properties of Smelling Salts

Reference	Performance Factor/Dependent Variable	Participants/Study Design	Results
Perry et al., (2016)	• Middle cerebral artery velocity (MCAv) • Heart rate (HR) • Partial pressure of end tidal CO_2 ($P_{ET}CO_2$) • One rep maximum of mid-thigh pull (MTP) • Rate of force development (RFD) • Electrical myography (EMG)	• 15; males (crossover) • 1 trial to monitor physiological changes in anthropomorphic measures • 1 trial to measure MTP, RFD, and EMG	• Significant increase in MCAv (6cm/s; $p<0.001$) • Significant increase in HR (6 bpm ±11; $p<0.001$) • No effect on maximal force, RFD, or EMG
Richmond, Potts, & Sherman, (2014)	• Number of repetitions of back squat and bench press at 85% of 1RM	• 25; males (crossover) • Used a placebo, ammonia inhalant, and no scent	• No significant changes in repetitions of back squat • No significant changes in repetitions of bench press
Secrest (2014)	• WanT performance • Peak power change (ΔPP) and mean power change (ΔMP)	• 10 trained males tested before and after a simulated football game • Counter balanced and crossover design	• Significant differences between control and intervention groups' ΔPP ($p\leq0.05$) • Significant differences between control and intervention groups' ΔMP ($p\leq0.01$)
Vigil, Sabatini, Hill, Swain, & Branch, (2017)	• 1 rep maximum of deadlift	• 20; 10 males, and 10 females (crossover) • Used a control trial, water supplements, and ammonia inhalant	• No significant changes in weight for one rep maximum between trials

Appendix C

Recruitment Poster

Participants Wanted For Study

The Effects of Smelling Salts on Reaction time and Anaerobic Performance

Conducted by Kenneth Groop
School of Kinesiology
Lakehead University

Looking for Participants

Healthy individuals between the ages of 18-30
People that participate in strength training 3 times/week
Not diagnosed with concussion within last 6 months
Or a respiratory disease within last 5 years
Not allergic to ammonia, red dye, lavender oil, lemon oil, or nutmeg oil

No experience is necessary. All measurements are non-invasive, and all information is confidential and anonymous. You will be tested in two 45-60 minute session, where you will be asked to perform 3 sets of reaction time tests and an Anaerobic Wingate Test, all will be done with and without smelling salts.

Researcher: Kenneth Groop; kgroop@lakeheadu.ca
Supervisor: Dr. Ian Newhouse; inewhouse@lakeheadu.ca

Lakehead UNIVERSITY

Any further questions can be directed to the ethics board of Lakehead University

Appendix D

Information Letter

On Lakehead University Letterhead

Dear Potential Participant,

Thank you for expressing an interest in the study titled "The Effects of Smelling Salts on Cognitive Reaction Time, Anaerobic Performance, and Cardiovascular Responses." I am a second year Lakehead University Kinesiology graduate student, and will be undertaking this study under the supervision of Dr. Ian Newhouse, Professor in the School of Kinesiology. You have been selected to participate in this study because you are a physically active student at Lakehead University between the ages of 18 and 30. You have also not suffered from a major respiratory illness in the past six months, have not suffered from any breathing obstructions in the last week, have not been diagnosed with a concussion, or have an allergy to ammonia. These are the criteria for the population being examined in the study.

The purpose of this study is to examine the effect of smelling salts on the cognitive reaction time and anaerobic performance, as well as to measure the cardiovascular response through heart rate, breathing rate, and heart rate variability using a Zephyr Bioharness™ monitor on a healthy population.

As a participant, you will be asked to sign up for two of the designated testing sessions. Each testing session will last no longer than 30-45 minutes and will take place at the Sanders Building in room SB-1025. A total of 30 participants will be recruited for this study. Upon arrival to your testing session, you will be asked to complete a consent form indicating that you understand your rights as a participant. You will also be asked to complete a PAR Q+ to ensure that you are able to participate in the study. The researcher will explain the reaction time tests and allow a practice trial for you to become familiar with the process. Once these steps have been completed, you will be fitted with a heart rate monitor, and have some baseline measurements taken, such as height, weight, blood pressure, and heart rate. After it is ensured that the heart rate monitor is fixed in a proper position, you will be asked to complete a five-minute cycling warm up with three short ten second sprints. This will be done to warm-up your muscles for the Wingate test and prevent injury. You will then be asked to sit in the area designated for the reaction time tests.

You will then either be exposed to a smelling salt by the researcher, or move on to the reaction time tests. This procedure may cause some discomfort, presenting as a burning sensation in your nostrils. When the exposure has been completed, you will begin the reaction time tests. It will begin with a simple reaction time test, which consists of a single stimulus appearing on the screen, and a response of hitting the "B" key on the keyboard. After you complete every block of trials (i.e. 10 trials), inform the researcher. Following 10 trials of the simple reaction time, you will begin the choice reaction time test session. This will consist of two different stimuli, each with their own correct response ("F" or "J"). This session will also consist of 10 trials. This pattern of simple then choice reaction time tests will be completed until you have completed three blocks of each test. Throughout the reaction time tests, your errors, mean time, and best times will be recorded.

When you are finished each of the reaction time trials, you will be asked to mount the bike ergometer to commence the Wingate test. The test begins once you pedal over 120 RPM. It

is a 30 second, maximal test. This involves you putting maximal effort to achieve the best results. After you have completed the Wingate test, you will be asked to cool down on the bike for at least 5 minutes. After your blood pressure has returned to a normal value (10 minutes), you will be thanked for your participation and asked to leave the testing area.

As a researcher, it is my responsibility to inform you of your rights as a participant. You must understand that as a participant, your participation is completely voluntary. You may refuse to answer any questions or refuse to participate in any activity at any time throughout the study. You may also withdraw from this study at any time without penalty. Each participant has the right to remain anonymous. To ensure this, all results from this study will be presented anonymously, and your name will be replaced with a unique number. The data will only be accessible to the researchers conducting this study (i.e., Dr. Newhouse and myself). The data will be stored at Lakehead University for five years time in a locked filing cabinet in the office of the supervisor. If the data is presented to the public as a written report or publication, or in the form of a verbal presentation, all participant data remains anonymous.

There will be minimal direct physical harm to you as a participant completing this study. There is a risk that you may experience burning, itchiness, or redness from an inhaling the smelling salts. Prior to being admitted into the study, you will be asked whether you are allergic or sensitive to ammonia; if you indicate that you are, then you will not be eligible to participate in the study. This minimizes the risk that you will have any further complications from the exposure to the smelling salt. Also, as you are a healthy individual, any health-related risks will be minimized.

The results from this study may have a direct benefit to society. The results may reveal the effect that smelling salts has on the cognitive or anaerobic performance when completing various tests. When considering smelling salts as an ergogenic aid, the information from this study can potentially weigh on the decision, especially with performance in mind. This information can potentially be used by healthcare providers, athletes, and average populations. As a participant, you may benefit from an enhanced alertness after inhalation of the smelling salt for a brief period of time, as well as knowledge from your results on reaction time and anaerobic performance.

Please contact me via email (given below) if you wish to receive a copy of the results. If you wish to participate in the study or have any additional questions or concerns, then please do not hesitate to contact me directly or via email. Also, feel free to contact the Lakehead University School of Kinesiology Ethics Chair if you have any other questions (contact information listed below).

Thank you for your consideration,

Kenneth Groop kgroop@lakeheadu.ca

Dr. Ian Newhouse ian.newhouse@lakeheadu.ca

Ethics Chair, School of Kinesiology, Lakehead University, Dr. Paolo Sanzo (807) 343-8647

Appendix E

Consent Letter

On Lakehead University Letterhead

Consent to Participant in Research

I _____ have read and understand the terms and conditions of this research study as outlined in the information letter. I willingly agree to participate in this study. I understand the potential risks and benefits of the study. I also understand that I have certain rights as a participant in this study. I understand that as a volunteer, I may withdraw at any time throughout the study and may refuse to perform any activities. I am also aware that the data recorded in this study will be securely stored at Lakehead University for five years after the study is complete. I have been informed that the final results from this study will be made available to me via email once the study has been completed, if I so desire. I understand that personal information used will remain anonymous and will only be used by the researchers conducting the study. I understand that I will be protected and remain anonymous if publication or public presentation of the research findings should occur. I give my permission for my anonymous data to be published and presented publicly.

_____ (Signature of Participant) _____ (Date)

_____ (Signature of Researcher) _____ (Date)

[ ] *Check if you desire an emailed copy of the final results from this study

_____ (Email address if applicable)

Appendix F

PAR-Q Plus Form

CSEP approved Sept 12 2011 version

PAR-Q+

The Physical Activity Readiness Questionnaire for Everyone

Regular physical activity is fun and healthy, and more people should become more physically active every day of the week. Being more physically active is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor OR a qualified exercise professional before becoming more physically active.

SECTION 1 - GENERAL HEALTH

	Please read the 7 questions below carefully and answer each one honestly: check YES or NO.	YES	NO
1.	Has your doctor ever said that you have a heart condition OR high blood pressure?	☐	☐
2.	Do you feel pain in your chest at rest, during your daily activities of living, OR when you do physical activity?	☐	☐
3.	Do you lose balance because of dizziness OR have you lost consciousness in the last 12 months? Please answer NO if your dizziness was associated with over-breathing (including during vigorous exercise).	☐	☐
4.	Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)?	☐	☐
5.	Are you currently taking prescribed medications for a chronic medical condition?	☐	☐
6.	Do you have a bone or joint problem that could be made worse by becoming more physically active? Please answer NO if you had a joint problem in the past, but it does not limit your current ability to be physically active. For example, knee, ankle, shoulder or other.	☐	☐
7.	Has your doctor ever said that you should only do medically supervised physical activity?	☐	☐

If you answered NO to all of the questions above, you are cleared for physical activity.

Go to Section 3 to sign the form. You do not need to complete Section 2.

- Start becoming much more physically active – start slowly and build up gradually.
- Follow the Canadian Physical Activity Guidelines for your age (www.csep.ca/guidelines).
- You may take part in a health and fitness appraisal.
- If you have any further questions, contact a qualified exercise professional such as a CSEP Certified Exercise Physiologist® (CSEP-CEP) or CSEP Certified Personal Trainer® (CSEP-CPT).
- If you are over the age of 45 yrs. and NOT accustomed to regular vigorous physical activity, please consult a qualified exercise professional (CSEP-CEP) before engaging in maximal effort exercise.

If you answered YES to one or more of the questions above, please GO TO SECTION 2.

Delay becoming more active if:

- You are not feeling well because of a temporary illness such as a cold or fever – wait until you feel better
- You are pregnant – talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the PARmed-X for Pregnancy before becoming more physically active OR
- Your health changes – please answer the questions on Section 2 of this document and/or talk to your doctor or qualified exercise professional (CSEP-CEP or CSEP-CPT) before continuing with any physical activity programme.

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SECTION 2 - CHRONIC MEDICAL CONDITIONS

Please read the questions below carefully and answer each one honestly: check YES or NO.			YES	NO
1.	Do you have Arthritis, Osteoporosis, or Back Problems?		☐ If yes, answer questions 1a-1c	☐ If no, go to question 2
	1a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)	☐	☐
	1b.	Do you have joint problems causing pain, a recent fracture or fracture caused by osteoporosis or cancer, displaced vertebra (e.g., spondylolisthesis), and/or spondylolysis/pars defect (a crack in the bony ring on the back of the spinal column)?	☐	☐
	1c.	Have you had steroid injections or taken steroid tablets regularly for more than 3 months?	☐	☐
2.	Do you have Cancer of any kind?		☐ If yes, answer questions 2a-2b	☐ If no, go to question 3
	2a.	Does your cancer diagnosis include any of the following types: lung/bronchogenic, multiple myeloma (cancer of plasma cells), head, and neck?	☐	☐
	2b.	Are you currently receiving cancer therapy (such as chemotherapy or radiotherapy)?	☐	☐
3.	Do you have Heart Disease or Cardiovascular Disease? This includes Coronary Artery Disease, High Blood Pressure, Heart Failure, Diagnosed Abnormality of Heart Rhythm		☐ If yes, answer questions 3a-3e	☐ If no, go to question 4
	3a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)	☐	☐
	3b.	Do you have an irregular heart beat that requires medical management? (e.g. atrial fibrillation, premature ventricular contraction)	☐	☐
	3c.	Do you have chronic heart failure?	☐	☐
	3d.	Do you have a resting blood pressure equal to or greater than 160/90 mmHg with or without medication? (Answer YES if you do not know your resting blood pressure)	☐	☐
	3e.	Do you have diagnosed coronary artery (cardiovascular) disease and have not participated in regular physical activity in the last 2 months?	☐	☐
4.	Do you have any Metabolic Conditions? This includes Type 1 Diabetes, Type 2 Diabetes, Pre-Diabetes		☐ If yes, answer questions 4a-4c	☐ If no, go to question 5
	4a.	Is your blood sugar often above 13.0 mmol/L? (Answer YES if you are not sure)	☐	☐
	4b.	Do you have any signs or symptoms of diabetes complications such as heart or vascular disease and/or complications affecting your eyes, kidneys, and the sensation in your toes and feet?	☐	☐
	4c.	Do you have other metabolic conditions (such as thyroid disorders, pregnancy-related diabetes, chronic kidney disease, liver problems)?	☐	☐
5.	Do you have any Mental Health Problems or Learning Difficulties? This includes Alzheimer's, Dementia, Depression, Anxiety Disorder, Eating Disorder, Psychotic Disorder, Intellectual Disability, Down Syndrome)		☐ If yes, answer questions 5a-5b	☐ If no, go to question 6
	5a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)	☐	☐
	5b.	Do you also have back problems affecting nerves or muscles?	☐	☐

Please read the questions below carefully and answer each one honestly: check YES or NO.			YES	NO
6.	Do you have a Respiratory Disease? This includes Chronic Obstructive Pulmonary Disease, Asthma, Pulmonary High Blood Pressure		☐ If yes, answer questions 6a-6d	☐ If no, go to question 7
	6a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)	☐	☐
	6b.	Has your doctor ever said your blood oxygen level is low at rest or during exercise and/or that you require supplemental oxygen therapy?	☐	☐
	6c.	If asthmatic, do you currently have symptoms of chest tightness, wheezing, laboured breathing, consistent cough (more than 2 days/week), or have you used your rescue medication more than twice in the last week?	☐	☐
	6d.	Has your doctor ever said you have high blood pressure in the blood vessels of your lungs?	☐	☐
7.	Do you have a Spinal Cord Injury? This includes Tetraplegia and Paraplegia		☐ If yes, answer questions 7a-7c	☐ If no, go to question 8
	7a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)	☐	☐
	7b.	Do you commonly exhibit low resting blood pressure significant enough to cause dizziness, light-headedness, and/or fainting?	☐	☐
	7c.	Has your physician indicated that you exhibit sudden bouts of high blood pressure (known as Autonomic Dysreflexia)?	☐	☐
8.	Have you had a Stroke? This includes Transient Ischemic Attack (TIA) or Cerebrovascular Event		☐ If yes, answer questions 8a-c	☐ If no, go to question 9
	8a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)	☐	☐
	8b.	Do you have any impairment in walking or mobility?	☐	☐
	8c.	Have you experienced a stroke or impairment in nerves or muscles in the past 6 months?	☐	☐
9.	Do you have any other medical condition not listed above or do you live with two chronic conditions?		☐ If yes, answer questions 9a-c	☐ If no, read the advice on page 4
	9a.	Have you experienced a blackout, fainted, or lost consciousness as a result of a head injury within the last 12 months OR have you had a diagnosed concussion within the last 12 months?	☐	☐
	9b.	Do you have a medical condition that is not listed (such as epilepsy, neurological conditions, kidney problems)?	☐	☐
	9c.	Do you currently live with two chronic conditions?	☐	☐

Please proceed to Page 4 for recommendations for your current medical condition and sign this document.

PAR-Q+

If you answered NO to all of the follow-up questions about your medical condition, you are ready to become more physically active:

- It is advised that you consult a qualified exercise professional (e.g., a CSEP-CEP or CSEP-CPT) to help you develop a safe and effective physical activity plan to meet your health needs.
- You are encouraged to start slowly and build up gradually – 20-60 min. of low- to moderate-intensity exercise, 3-5 days per week including aerobic and muscle strengthening exercises.
- As you progress, you should aim to accumulate 150 minutes or more of moderate-intensity physical activity per week.
- If you are over the age of 45 yrs. and NOT accustomed to regular vigorous physical activity, please consult a qualified exercise professional (CSEP-CEP) before engaging in maximal effort exercise.

If you answered YES to one or more of the follow-up questions about your medical condition:

- You should seek further information from a licensed health care professional before becoming more physically active or engaging in a fitness appraisal and/or visit a or qualified exercise professional (CSEP-CEP) for further information.

Delay becoming more active if:

- You are not feeling well because of a temporary illness such as a cold or fever – wait until you feel better
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise profesional, and/or complete the PARmed-X for Pregnancy before becoming more physically active OR
- Your health changes - please talk to your doctor or qualified exercise professional (CSEP-CEP) before continuing with any physical activity programme.

SECTION 3 - DECLARATION

- You are encouraged to photocopy the PAR-Q+. You must use the entire questionnaire and NO changes are permitted.
- The Canadian Society for Exercise Physiology, the PAR-Q+ Collaboration, and their agents assume no liability for persons who undertake physical activity. If in doubt after completing the questionnaire, consult your doctor prior to physical activity.
- If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.
- Please read and sign the declaration below:

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that a Trustee (such as my employer, community/fitness centre, health care provider, or other designate) may retain a copy of this form for their records. In these instances, the Trustee will be required to adhere to local, national, and international guidelines regarding the storage of personal health information ensuring that they maintain the privacy of the information and do not misuse or wrongfully disclose such information.

NAME _ _ _ _ DATE _

SIGNATURE _ _ WIN ESS _ _

SIGNATURE OF PARENT/GUARDIAN/CARE PROVID ER __ _ _

For more information, please contact:
Canadian Society for Exercise Physiology
www.csep.ca

KEY REFERENCES
1. Jamnik VJ, Warburton DER, Makarski J, McKenzie DC, Shephard RJ, Stone J, and Gledhill N. Enhancing the cectiveness of clearance for physical activity participation; background and overall process. APNM 36(S1):S3-S13, 2011.
2. Warburton DER, Gledhill N, Jamnik M , Bredin SSD, McKenzie DC, Stone J, Charlesworth S, and Shephard RJ. Evidence-based risk assessment and recommendations for physical activity clearance; Consensus Document. APNM 36(S1):S266-s298, 2011.

The PAR-Q+ was created using the evidence-based AGREE process (1) by the PAR-Q+Collaboration chaired by Dr. Darren E. R. Warburton with Dr. Norman Gledhill, Dr. Veronica Jamnik , and Dr. Donald C. McKenzie (2). Production of this document has been made possible through financial contributions from the Public Health Agency of Canada and the BC Ministry of Health Services. The views expressed herein do not necessarily represent the views of the Public Health Agency of Canada or BC Ministry of Health Services.

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Appendix G

Data Collection Sheet

Participant ID #: _____ **Group #:** _____ **Date/Time:**_____/____

Baseline Info	**Session 1**	**Session 2**
Height		
Weight		
Age		
Initial Resting Heart Rate		
Initial Resting Blood Pressure		
Final Heart Rate		
Final Blood Pressure		
How many times/week have you used smelling salts?		
/month?		
/year?		

Times for Testing

Starting time for SRT #1		
Starting time for CRT #1		
Starting time for SRT #2		
Starting time for CRT #2		
Starting time for SRT #3		
Starting time for CRT #3		
Starting Time for Wingate		
End of Wingate		

Appendix H

Zephyr Bioharness™ Monitor Positioning

Figure 5. Positioning for Zephyr Bioharness Monitor. Diagram demonstrating the position to apply the Bioharness to properly monitor cardiovascular responses.

Appendix I

Initial Position for Reaction Time Tests

Figure 6. Initial position for Reaction Time Tests. Diagram demonstrating the initial position for simple and choice reaction time tests.

Appendix J

Definitions

Anaerobic performance: A measure of an activity that utilizes the ATP-PC and/or glycolytic energy systems more than the aerobic system (Ratamess, 2012). During this study, anaerobic performance will be measured by the power produced during the Wingate test. In this study, anaerobic performance will be measured by three variables: peak power (highest power output over one second), mean power (average power outage throughout the 30 second test), and fatigue (expressed as a percentage of power drop from peak power to low power).

Arousal: An energetic state at any particular time, or the level of cognitive awareness during the reaction time tests (Sabzi, Hasanvand, & Roozbahani, 2014). There is debate on the effects of arousal on reaction time; some research suggests that it improves performance high levels limits performance (Bagherli, Vaez Mousavi, & Mokhtari, 2011; Sabzi et al., 2014; Watters, Martin, & Schreter, 1997). Arousal will be measured through the use of heart rate (Fowles, 1980).

Ergogenic aids: Any substance that provides a mental or physical edge while exercising or competing (Committee on Sports Medicine and Fitness, 2005). This can range from caffeine and sports drinks to illegal (often harmful) substances such as anabolic steroids (Holowchak, 2002).

Reaction time: The measured time between the onset of a stimulus and the response from the participant (Magill, 2007). In this study, it will be the time between the stimulus presented (simple or choice) and the moment the participant presses the corresponding key on the laptop.

Smelling salts: Also known as ammonia inhalants, are chemical compounds often used to arouse consciousness. In recent sport, it has been utilized as an ergogenic aid to enhance performance (McCrory, 2006; Velasquez, 2011).

Sympathetic response: The autonomic nervous system's excitatory response to a situation/stimulus. This can be observed when the body releases norepinephrine, triggering the adrenergic receptors on the peripheral tissue, and thus readying the body for action (Marshall,

1982). In this experiment, the smelling salts may stimulate a sympathetic response that would increase performance. Sympathetic responses can be inferred from increases in variables such as cardiorespiratory measures (heart rate, breathing rate, and heart rate variability) (Malik, 1996).

Appendix K

Individual Data

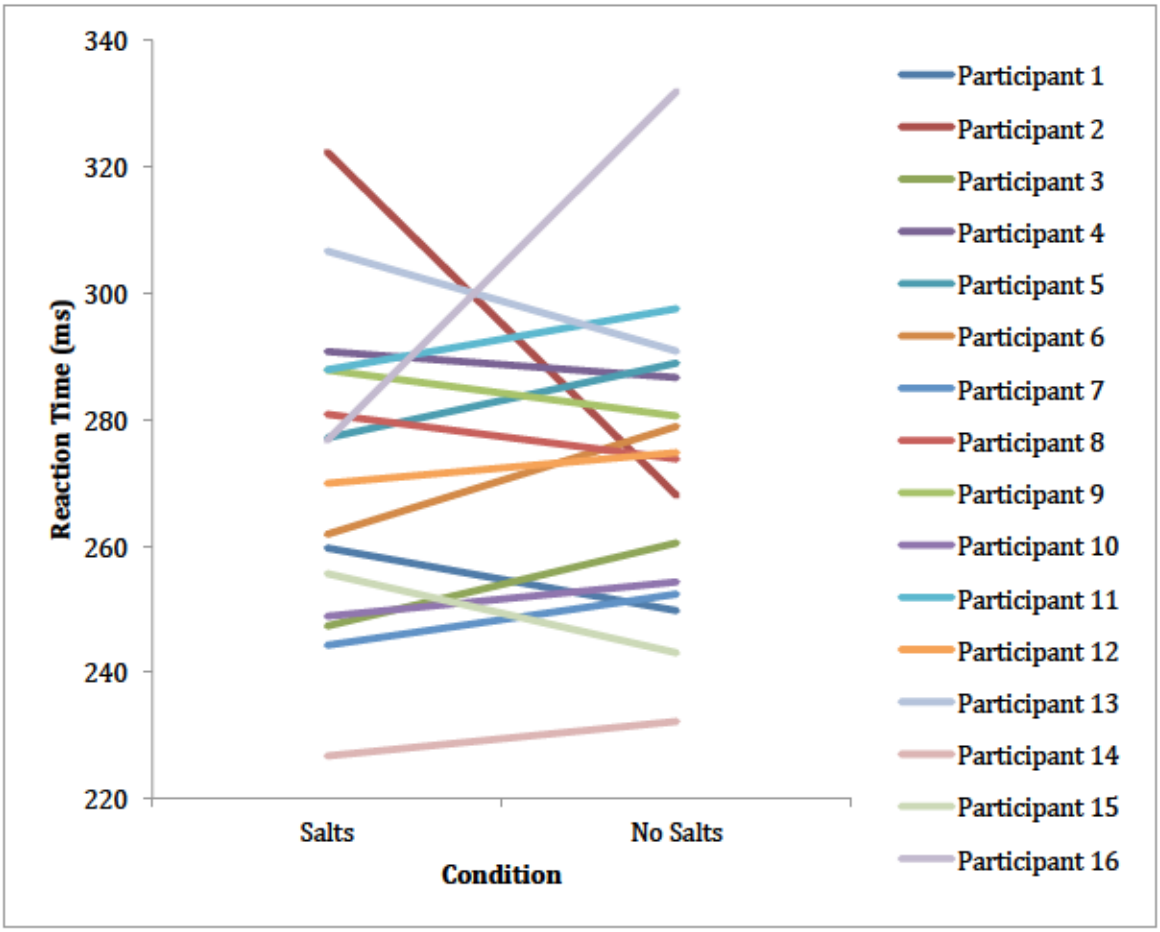

Figure 7. Mean simple task reaction time across both treatments for all participants.

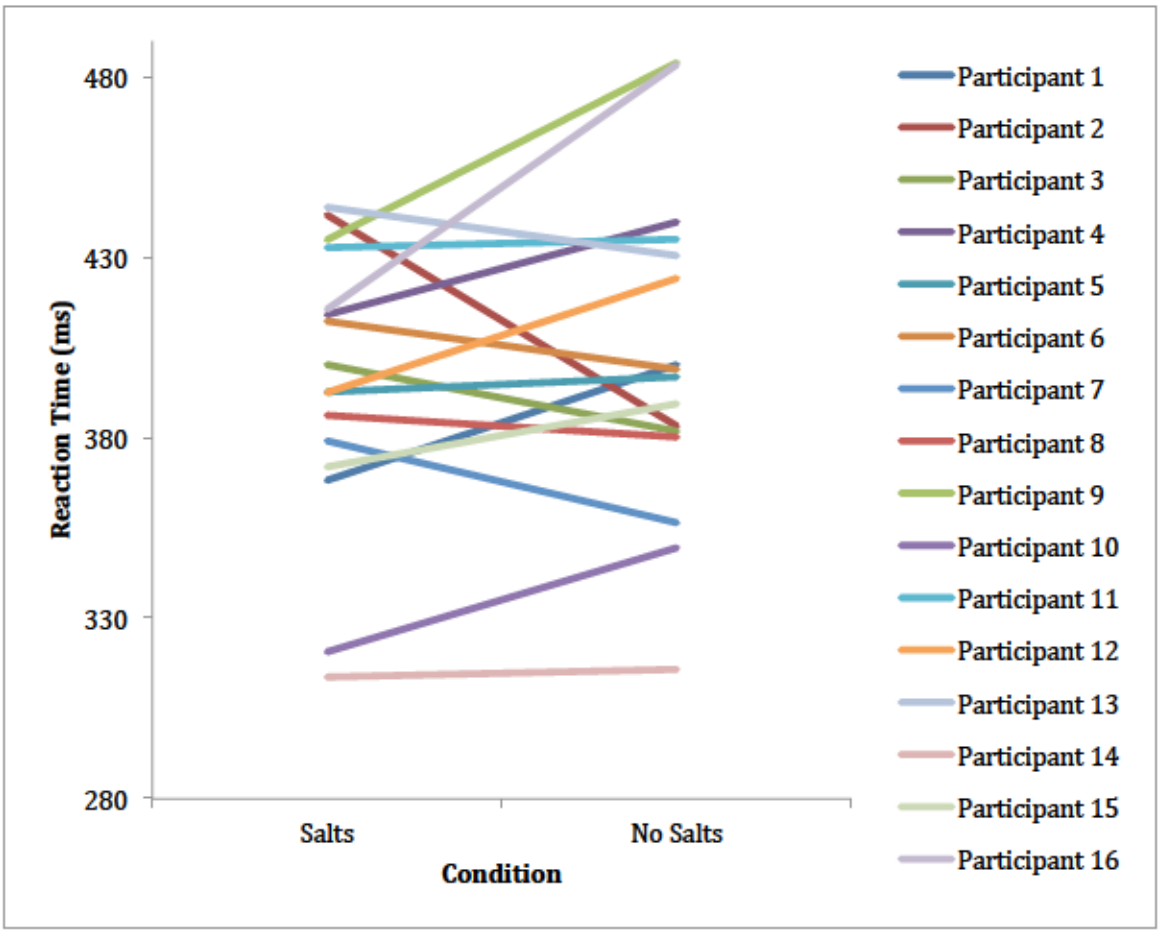

Figure 8. Mean choice task reaction time across both treatments for participants.

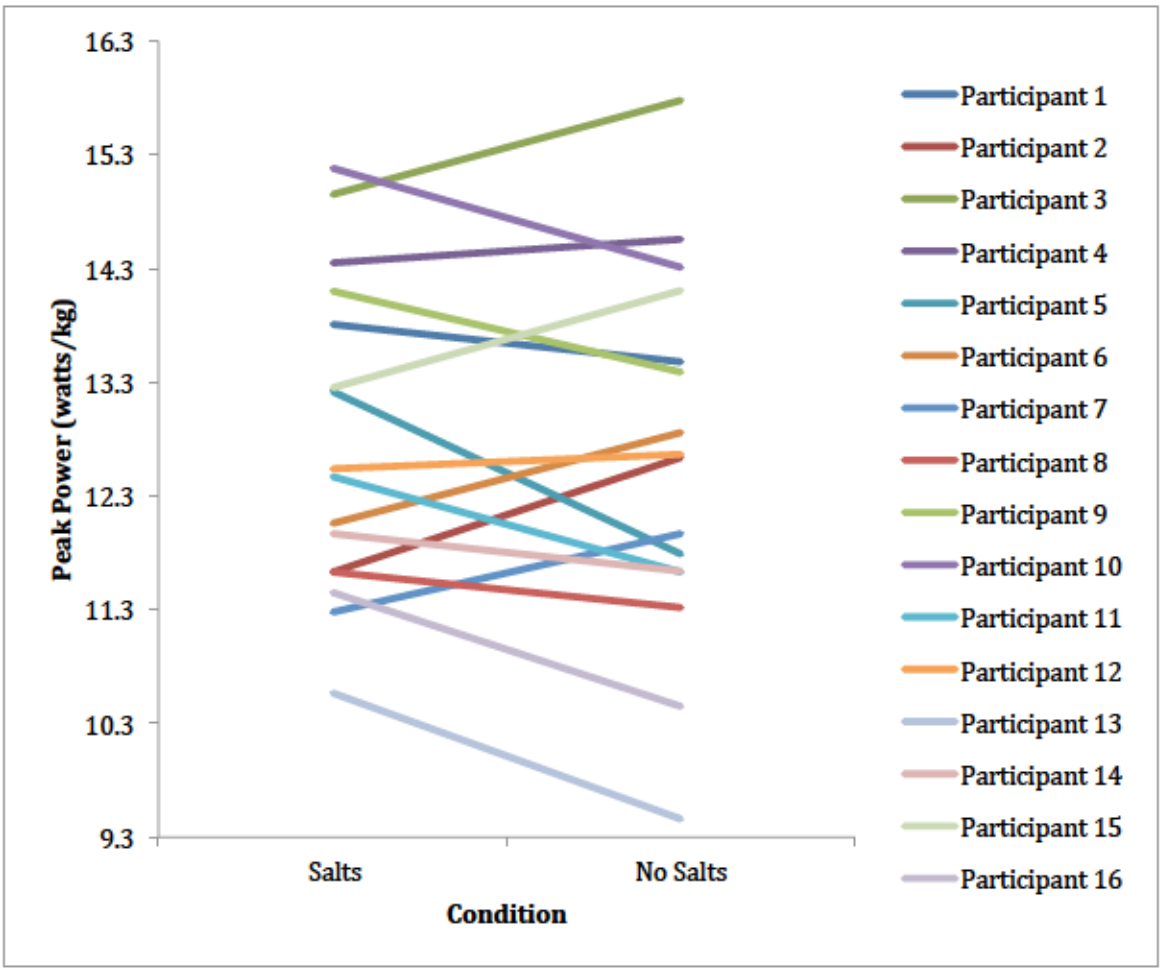

Figure 9. Peak power across treatments for individual participants.

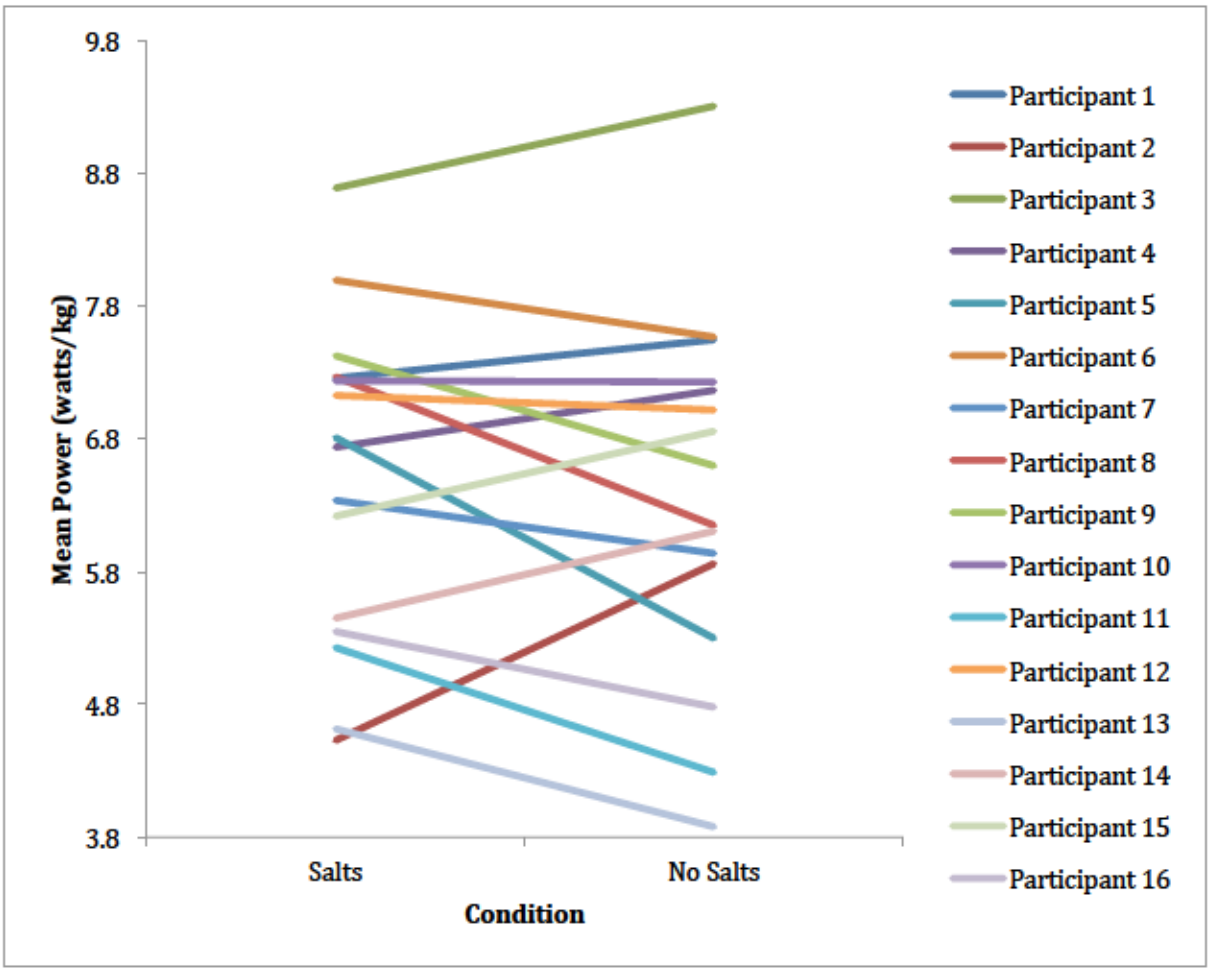

Figure 10. Mean power across treatments for all participants.

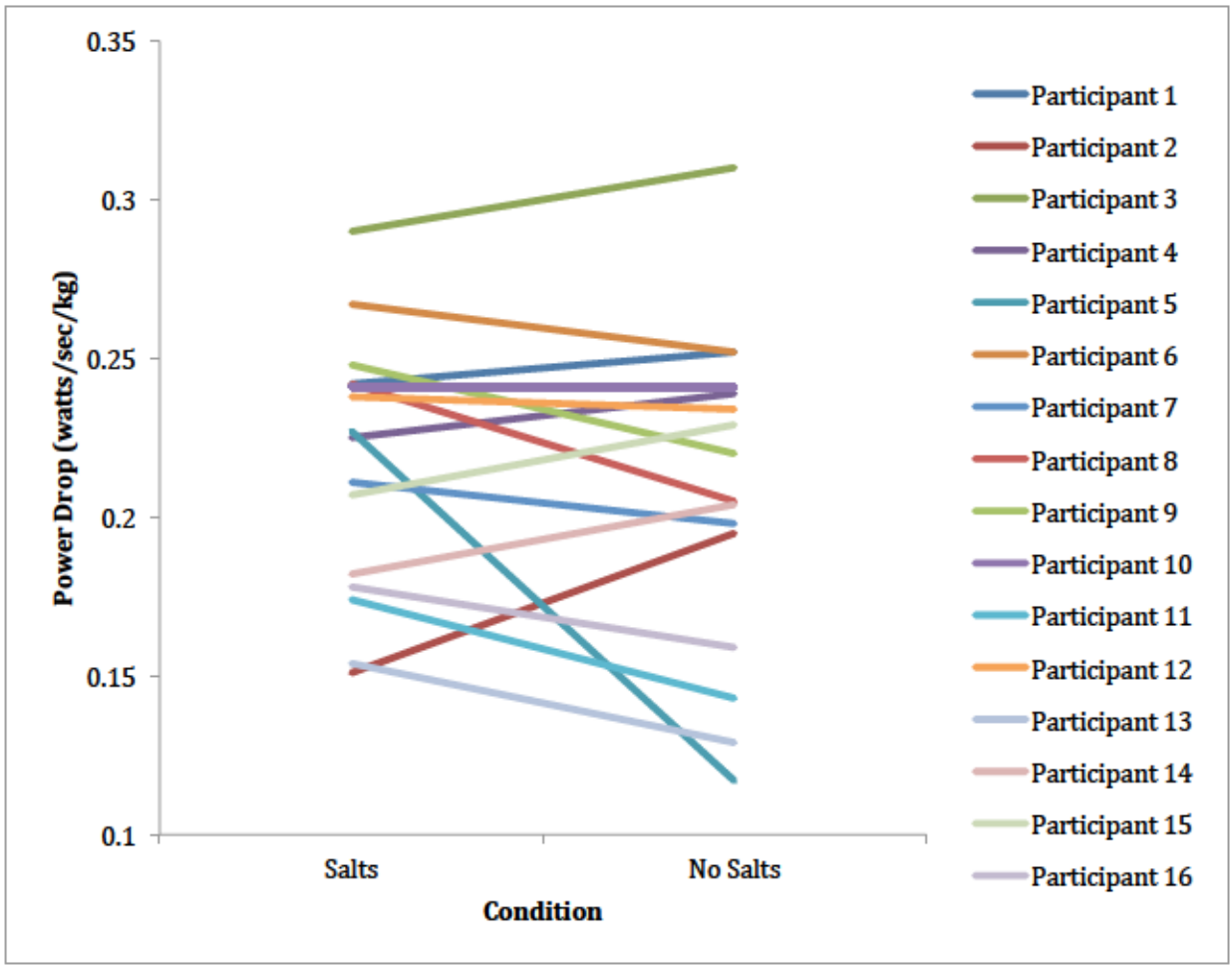

Figure 11. Power drop across treatments for individual participants.

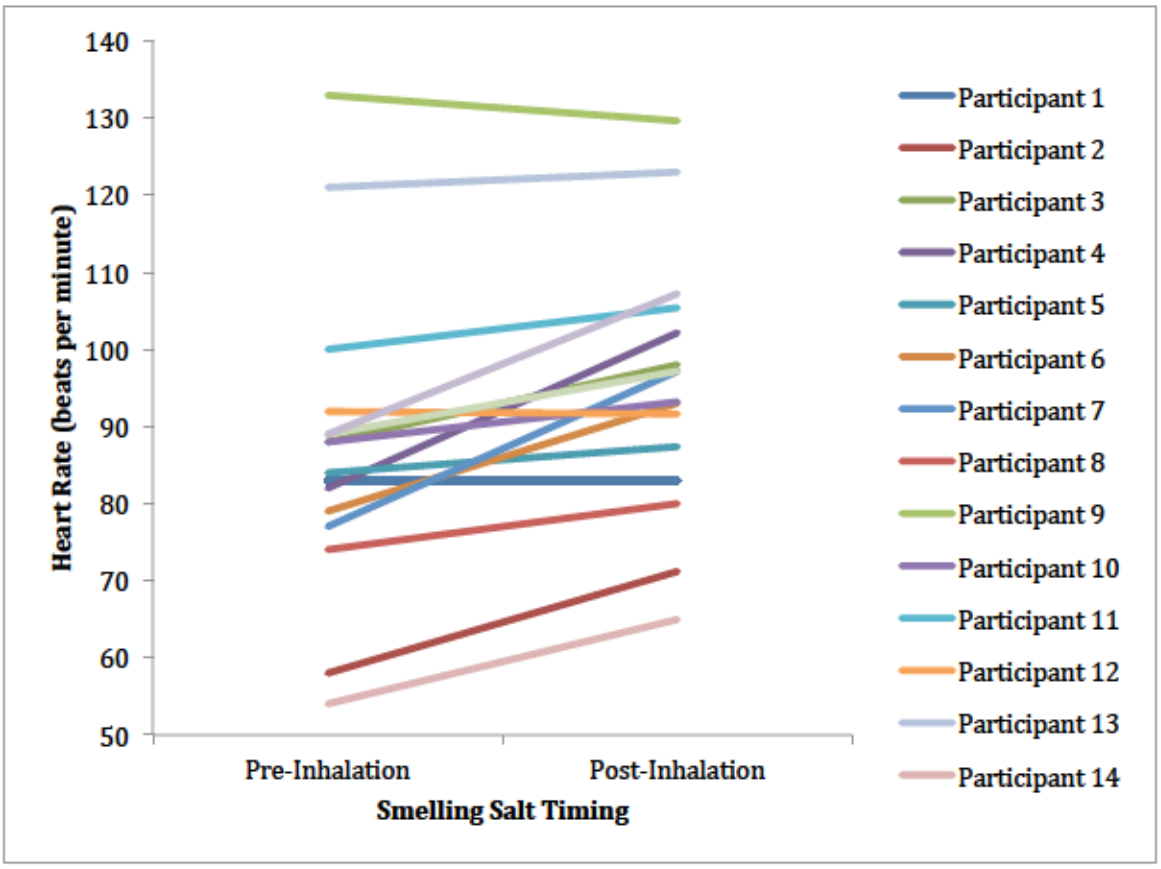

Figure 12. Heart rate responses to smelling salts for individual participants.

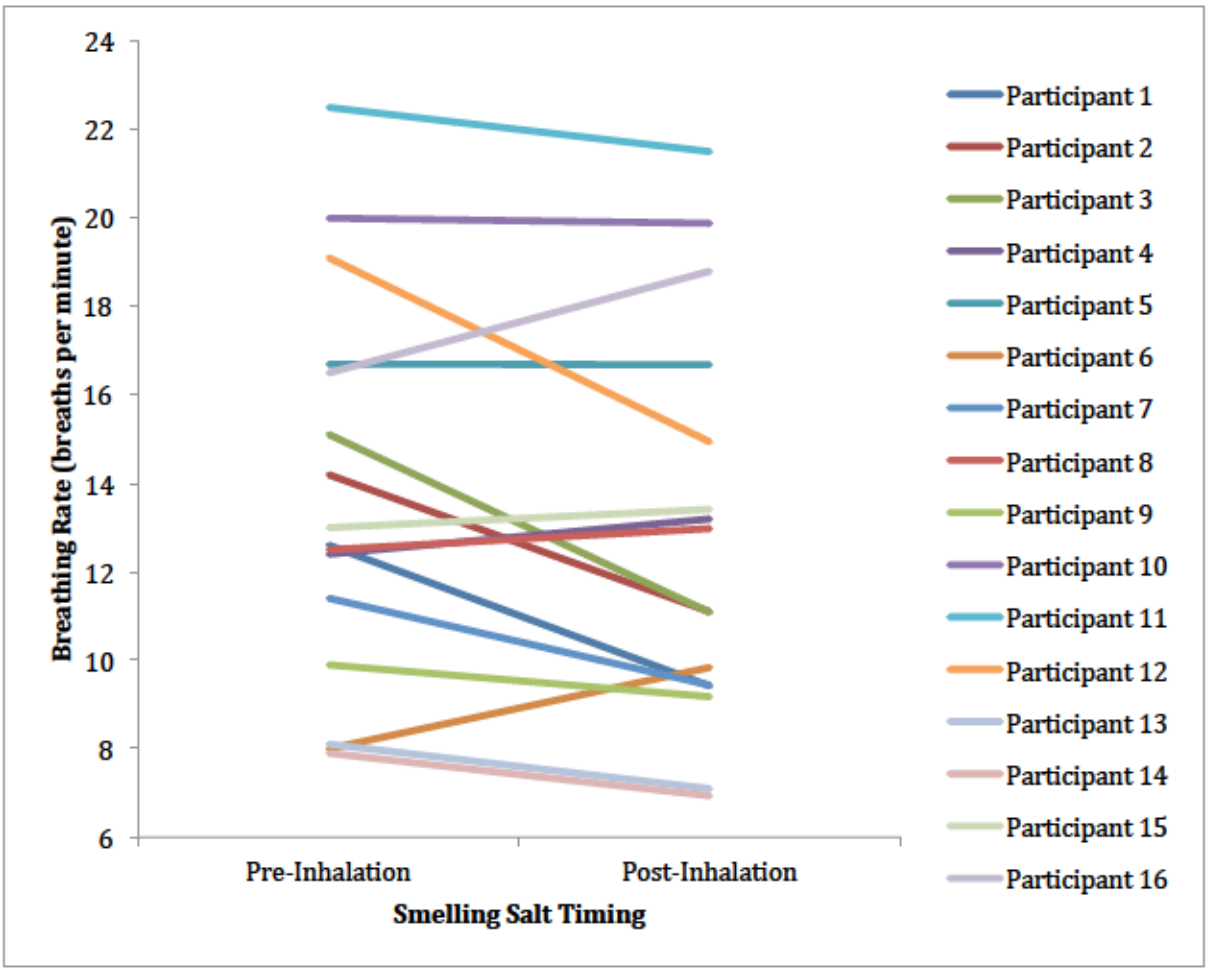

Figure 13. Breathing rate responses to smelling salts for individual participants.