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Impact of Ammonia Inhalant on High Power Performance under Fatigue Conditions

アンモニア吸引が疲労によるパワー出力低下を
軽減できるかについての検証

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ABSTRACT

The aim of this study was to investigate the impact of ammonia inhalant on high power performance of trained athletes under fatigue conditions. Nine subjects performed 6-second × 12 sets of maximal pedaling (40-second inter-set recovery) on a cycle ergometer with or without ammonia inhalant immediately before the 7th and 10th pedaling sets. The decrements in peak and mean pedaling cadences over 12 sets were compared between ammonia and control (no ammonia) conditions. This testing was repeated under two ambient environments: a normal temperature (22°C, 50% humidity) and a hot temperature (30°C, 80% humidity). Blood lactate concentration, ear canal temperature, and visual analogue scale (VAS) were measured immediately before exercise, and then after the 6^{th}, 9^{th} and 12^{th} pedaling sets to evaluate the progresses of fatigue, heat stresses, and discomfort levels. The exercise generated blood lactate accumulation that was greater than $\bar{\chi}$ = 11 mmol/L for all conditions. The decrements in both peak and mean pedaling cadences were reversed with ammonia inhalant in the normal temperature. These ergogenic effects of ammonia inhalant were, however, not evident in the heat environment; despite greater discomfort levels and ear canal temperature during the exercise compared to the normal temperature environment. It was concluded that ammonia inhalant was effective in attenuating performance decrement during repeated sets of short sprints in the normal temperature environment. The hot temperature may not be a requisite to elicit ergogenic effects of ammonia inhalant.

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DECLARATION

I declare that this research thesis entitled "Impact of Ammonia Inhalant on High Power Performance under Fatigue Conditions" was completed by David Po Kuan Wu under the supervision from Professor Yoshio Suzuki and Dr. Akihiro Sakamoto. The contents of this thesis are original and have not been published previously except as indicated in the text.

David Po Kuan Wu

CHAPTER I. INTRODUCTION

Enhancement of performance in exercise or sports is pursued and demanded by many individuals at various levels of athleticism. In order for individuals to excel beyond the normal boundaries of their standard capabilities, the natural state of energy supplies and resources in the body may not be sufficient or efficient enough, particularly during high intensity exercises or in adverse environments. Advantageous products, therefore, have been widely used to overcome those boundaries. However, legality issues and negative side effects are two important components to consider when using aids. These components, however, may be disregarded by individuals at high competitive levels or by those who strive for success over others. Common users such as athletes will often apply and consume excess amount of certain products compared to other normal users to gain greater and faster benefits expected from these products (Maughan 1999). Despite underlying principles, fundamentals and hypotheses, there are still many grey areas in the usage of certain aids that need to be researched and observed. To ensure that the improvements of the psychological and physiological responses truly originate from the substances, further research is warranted. Particularly, it should be clarified that the effects are safe and favorable not just temporarily, but also in the long run.

As an example, a stimulant known as ammonia inhalant has caught researchers' attention. Ammonia inhalant has been used by many training individuals to maximize performance. Most of the previous studies of ammonia inhalant investigated its ergogenic effects with the absence of fatigue (Bartolomei et al. 2017; Perry et al. 2015; Richmond et al. 2014; Vigil et al. 2017). In general, ammonia inhalant failed to demonstrate significant ergogenic effects on maximum strength, although a few studies reported significantly increased cardiovascular responses and improved rate of force development (Bartolomei et al. 2017; Perry et al. 2015). There is one unpublished study (Secrest et al. 2015) in which fatigue was induced before testing the effect of ammonia

inhalant. In the study, ammonia inhalant was successful in improving pedaling power. The experimental procedures, however, were not provided in full details.

Accordingly, the aim of this study was to investigate the ergogenic effect of ammonia inhalant under metabolically or centrally fatigued state, induced by maximal repeated pedaling sprints. Trained athletes underwent the exercise test with and without ammonia inhalant on separate occasions. This testing was repeated in normal and hot temperature environments. The expected effects of ammonia inhalant were increased arousal state and stimulated cardiovascular or cardiorespiratory responses, which may counter performance decrement associated with fatigue. It was hypothesized that the ergogenic effects of ammonia inhalant would be better elicited when tested under physiological and psychological strains resulting from exhaustive metabolic challenges, compared to the previous research settings with no fatigue induction. Particularly, the ergogenic effect of ammonia inhalant was expected to be greater under the heat, where the development of central fatigue may be greater. The present study was the first to investigate the effect of ammonia inhalant under fatigue condition in a controlled crossover design.

CHAPTER II. LITERATURE REVIEW

Background

In sports, numerous advantageous products are often used by individuals, particularly athletes, to enhance performance. Such aids, which come in various forms, are aimed at increasing recovery rates, reducing chances of injuries, and improving mental and muscular strengths (Antonio et al. 2000; Kreider et al. 2004; Shimomura 2010). Although these products are widely available, many are banned in training and competition, as shown in the prohibited list of the World Anti-Doping Agency (WADA), due to the risks and overpowering benefits resulting from the substances. Various studies have investigated on the characteristics of many supplements, ergogenic aids and other products to scientifically prove the physiological and psychological benefits or detriments within the body.

Strength Training in Adverse Environments

There are many components and approaches for improving muscular strength and endurance in combination with supporting products. Given that sporting competitions may be held in various environments such as high altitude, water, heat and cold conditions, training in an adverse environmental condition may be required to achieve better performance outcomes (Acevedo & Ekkekakis 2001; No & Kwak 2016; Quindry et al. 2015; White et al. 2015). Training in a unique and challenging environment allows the human body to adapt to the psychological and physiological demands imposed by the unfamiliarity of the environment. However, along with the benefits derived from undergoing various types of training, negative impacts may develop within the body such as excessive physical and psychological stresses.

In the heat, there would be an increase in skin blood flow, heart rate, hydration or sweat rate which prevents excessive rise in the body core temperature. Under heat

that exceeds one's thermoregulatory capacity due to impaired processes of convection, conduction, evaporation and radiation, hyperthermia may occur with psychological and physiological functions disturbed (Maughan 2003). Exercising under such circumstances, motivation for effort or further exercise bouts may be reduced since the central nervous system may be negatively affected (Febbraio 2000). In this state, described as central fatigue, reductions in muscular strength and speed may also result along with slow and shallow breathing (Acevedo & Ekkekakis 2001; Nybo & Nielsen 2001). In other instances, with increased body core temperature, the cardiovascular system is highly affected due to the disruption of blood flow circulation, which reduces the availability of oxygenated blood flow to active muscles (Gonzalez-Alonso 2008). With these natural occurring complexions, the overall performance is impaired under heat (Nybo 2008). Furthermore, when the environment is both hot and humid, heat stress may be emphasized due to the inefficiency of evaporative heat loss through sweating. Therefore, symptoms such as weakness, exhaustion, headache, dizziness may be imminent (Burton et al. 2004).

Endogenous Ammonia Production under Intense Exercise

Fatigue is generally caused by a complex interaction among several mechanisms including the depletion of energy substrates, the accumulation of metabolic by-products, and the influence of the central nervous system that leads to impairments of both cerebral and muscular functions (Roelands et al. 2010). The contribution of each of these fatigue mechanisms may be dependent on the frequency, intensity and duration of exercise.

The production of ammonia (NH_3), usually in the form of ammonium ion (NH_4^+), during exercise has been observed as a result of the reactions of the purine nucleotide cycle (PNC). In the initial stage of PNC, the deamination of adenosine monophosphate

(AMP), converting it to inosine monophosphate (IMP), results in NH_3 productions (MacLean et al. 1991, MacLean et al. 1994, MacLean et al. 1996; MacLean & Graham 1993; Graham et al. 1990). This reaction is common when undergoing prolonged submaximal exercise with low muscle glycogen, or undergoing maximum or near-maximum intense exercise to exhaustion (Broberg & Sahlin 1989; Houston 1995). The product NH_3 is a base, hence is a proton acceptor. This protonation (the formation of NH_4^+) initially prevents muscles from becoming too acidic. However, the resulting slowness of the rate of pH fall sustains the activity of a glycolytic enzyme, phosphofructokinase (PFK), or NH_4^+ may directly stimulates PFK activity (Houston 1995). Consequently, the rate of glycolytic energy supply may be sustained or increased, resulting in greater production of lactic acid. Eventually, muscle is forced to stop working due to much lower pH, accompanied by greater lactate production (Vanuxem 1986; Houston 1995).

When ammonia metabolism occurs, the product ammonium may be leaked and distributed into other organs (Huizenga et al. 1996; Lockwood et al. 1979). It was observed that the direction of ammonium dispersion in the body may depend on pH gradients in tissues. Commonly, ammonium may come in contact with the blood-brain barrier (BBB). Since the BBB is a semipermeable membrane barrier, there may be opportunities for ammonium to infiltrate past the barrier (Stabenau et al. 1959; Warren & Nathan 1958). It has been reported that the infiltration of ammonium into the central nervous system regions, which can potentially disrupt performance, may be more apparent as the intensity of exercise increases (Banister et al. 1990). Other studies demonstrated that the duration of exercise was another factor that determined the amount of cerebral ammonium uptakes (Dalsgaard et al. 2004; Wilkinson & Smeeton 2010). With a high level of cerebral ammonium, exercise performance was significantly affected, confirming that ammonium affects muscle metabolism and the level of central

fatigue (Nybo et al. 2005). When ammonium is present in the brain at large doses or at a rapid rate due to intense or prolonged exercise, detoxification mechanisms are unable to effectively reverse the excessive accumulation of ammonium. Consequently, the central nervous system or the neurotransmitter activities may be disrupted, resulting in impaired motor control, consciousness, and cognition (Banister et al. 1990; Vanuxem 1986).

Ammonia Inhalant

As mentioned above, endogenous ammonia production may occasionally occur in exercising individuals. However, in the present study, ammonia will be used as an exogenous agent to examine its potential benefits for exercise performance. There is a common type of agent known as ammonia inhalant or "smelling salts", which is a type of respiratory stimulant that comprises of ammonium carbonate along with aromatic scents. When ammonia inhalant is applied, the released ammonia gas affects the nasal passage and the lungs, initiating a respiratory reflex. With even at a low concentration of ammonia, one may suffer from eye, nasal, and throat irritations along with coughing (Gorguner & Akgun 2010). However, previous cases, in which serious injuries occurred to individuals, were only when higher concentration or consistent exposure to ammonia gas was dealt with (Levy et al. 1964; Leduc et al. 1992). Nevertheless, this stimulant is not recommended for use by individuals with respiratory problems or optic issues.

Traditionally, ammonia inhalant has been applied in scenarios where fainting, light-headedness, or dizziness is present in an individual (McCrory 2006). However, in recent times, the use of ammonia inhalants has been apparent in the sports field to improve performance. This ergogenic aid is known as a "stimulant" during times of diminishing performance. The users expect both psychological and physiological benefits. Psychologically, ammonia inhalant was observed to arouse consciousness,

hence increasing focus. Physiologically, the inhalation reflex causes respiration to accelerate or to restore normal breathing patterns (Velasquez 2011). However, along with these expected benefits, there are risks associated with the use of ammonia inhalant. Due to the natural head withdrawal reaction from inhaling the ammonia, there may be a potential risk of spinal injury in the neck area or other forms of head injuries. Moreover, if large concentration of ammonia is inhaled, there may be severe risks towards the body (McCory 2006; Velasquez 2011).

In sports, the most common time frames of ammonia inhalant usage by athletes have been immediately before or during competition. After inhalation, greater performance was expected during the subsequent powerful movements. Commonly, ammonia inhalant has been used before one-repetition maximum trials (Velasquez 2011). Therefore, the use of ammonia inhalant is prevalent especially in powerlifting due to the nature of the sport's embodiment of high intensity, speed and power efforts within a short period of time. An international survey among 256 powerlifters revealed that more than half of these athletes confirmed on the usage of ammonia inhalant during competitions (Pritchard et al. 2014).

To date, ammonia inhalants are easily accessible and are not shown on the prohibited list of the World Anti-Doping Agency (WADA), hence considered to be legal. The users, however, need to be aware of the risks associated with ammonia inhalant described above. Moreover, the benefits of ammonia inhalant are not conclusive and lacking in scientific evidence. The details are discussed in the following section.

Previous Research on the Effects of the use of Ammonia Inhalant in Exercise

Although many athletes have used ammonia in their training and competitions, only few scientific studies have proven the effectiveness of ammonia inhalant. One study investigated the number of repetitions performed during bench press and back squat at

85% 1RM after inhaling either ammonia or placebo (Vick's vaporub) (Richmond et al. 2014). However, no significant differences in repetitions were observed for both exercises between the ammonia and the placebo conditions. The authors suggested that utilizing a weight closer to 100% 1RM load, rather than 85% 1RM, would have been more ideal to see potential ergogenic effects of ammonia inhalant (Richmond et al. 2014).

Another study examined the effect of ammonia inhalant on 1RM strength during deadlift (Vigil et al. 2017). This study was designed to emulate training and competition, where the maximum load would be attempted with ammonia inhalant, which was commonly used for the extra edge in strength. However, no significant differences were found in maximum strength between ammonia inhalation and control (water) conditions (Vigil et al. 2017).

A study by Perry et al. (2015) showed that the cardiovascular responses were indeed stimulated by inhaling ammonia with increased blood pressure, heart rate and cardiac output. Then, they investigated the peak strength and the rate of force development during isometric mid-thigh pull with or without ammonia inhalant. Ammonia inhalant was applied at three different timings, 15, 30 or 60 seconds before the mid-thigh pull. Despite the stimulating effects on cardiovascular parameters, peak strength was not affected by ammonia inhalant regardless of administration timing. Whereas, the rate of force development was greater with ammonia than control, however only when administered 30 seconds before the exercise trial (Perry et al. 2015). Similar to the study by Perry et al. (2015), Bartolomei et al. (2017) investigated the effects of ammonia inhalant on isometric mid-thigh pull, as well as countermovement jump height. Again, ammonia inhalant produced no effects on peak force during mid-thigh pull and counter movement jump height, but the rate of force development during the mid-thigh pull was improved with ammonia inhalant. These two studies may imply that ammonia inhalant has greater impact on the rate of force development with faster

recruitment of motor units, rather than adding motor units that are inadvertently not recruited.

Lastly, a study was done to evaluate the benefits of ammonia inhalant on maximal anaerobic performance, following fatigue induction in a hot temperature chamber (35.5°C and mean relative humidity of 30%) using simulated American football game on a Monark ergometer (Secrest et al. 2015). The fatigue challenge consisted of 5 seconds × 12 sprints, 5 seconds × 9 sprints, and 5 seconds × 6 sprints, which were randomly assigned six times (6 sets), with a 40-second rest between sprints. The sets were separated by a 6-minute recovery, except between the 3rd and the 4th sets with a 10-minute half-time break. Following the fatigue challenge, subjects performed 30-second Wingate tests three times in a normal temperate environment (21.3°C and relative humidity of 27.5%). Ammonia inhalant was applied 5 seconds before the 3rd Wingate test trial. The results showed that both peak and mean pedaling power during the Wingate test increased significantly after the application of ammonia inhalant compared to the earlier Wingate trials (Secrest et al. 2015). In comparison to other previous studies, this study was the first to evaluate the potential of ammonia inhalant under a fatigue condition, with ergogenic benefits evident. However, this research work is available as part of the proceedings, and not yet available in published form. The methodology is not provided in full detail regarding the fatigue challenge sets assigned, and the timings of the subsequent Wingate tests.

Summary

Ammonia inhalant which is commonly used as an ergogenic aid, is still considered legal under the WADA policy. Therefore, the present study aimed to prove if there are any real scientific benefits behind this particular substance. The general physiological effects of ammonia inhalant include cardiovascular or respiratory

stimulation, and increased arousal and consciousness levels. The previous studies reporting ineffectiveness of ammonia inhalant on repetitions or a single bout of high strength performance were conducted in the absence of fatigue before the movements. Secrest et al. (2015) were the first to document improved performance with ammonia inhalant following fatigue challenges. The methodology of their study was however not fully provided. Moreover, a few studies did report improved rate of force production during maximum isometric contraction with ammonia inhalant. To better clarify the effectiveness of ammonia inhalant or the conditions in which the effect of ammonia inhalant is maximized, further research is warranted.

CHAPTER III. AIMS

Primary Aim

• Investigate the ergogenic effects of ammonia inhalant on power decrement during repeated short sprint exercise.

Secondary Aim

• Examine the effectiveness of ammonia inhalant along with the levels of physiological strains between two ambient environments (normal vs. hot-humid).

CHAPTER IV. METHODS

Subjects

Nine power trained university athletes (7 men and 2 women) were recruited for this study. Their height, mass and age were respectively 172.7 ± 5.3 cm, 78.0 ± 12.4 kg and 19.6 ± 1.0 years at the time of the experiment. Their training experience ranged from 4.5 years to 16.5 years with five to six training sessions per week. Full details of the subjects' characteristics are provided in Appendix III. No existing injuries or respiratory disorders were present in all of the subjects before and during the experiment.

All subjects came to the chamber and underwent one trial test session (described below) to familiarize with the design of the experiment and the use of ammonia inhalant before the commencement of the actual experiments. During the experimental period, subjects were allowed to participate in their daily training sessions and competitions. The experiments were, however, scheduled at the same or similar time of day. No strict diets were instructed but the subjects avoided fasting or consuming caffeinated beverages before each experiment. Prior to all the testing, all participants received a session of verbal orientation of the study, read descriptions of the experiment and risks involved, and signed an informed consent form. This study was approved by the human ethics committee of Juntendo University, Graduate School of Health and Sports Science (No. 29-24)

Experimental Design

This study was designed to investigate the impact of ammonia inhalant under fatigue induced by 6 seconds × 12 sets of maximal pedaling sprints (40 seconds inter-set recovery) in both normal and heat temperatures. Each subject had to participate in a six-day period of experimental procedures, not in consecutive days. The 1st day included

the introduction and orientation of the experiment. The 2nd day included a trial test run of the experiment procedure, to examine if each subject was able to complete the full test. On days 3, 4, 5 and 6, subjects, who were able to complete the trial test run, participated in the actual experimental sessions in a cross-over counter balanced fashion. They performed the aforesaid exercise, consisting of repeated sets of maximal pedaling, on a cycle ergometer (Powermax-V_{III}; Combi Wellness, Tokyo, Japan) with ammonia inhalant or control (no ammonia) in a normal or hot temperature chamber. The two conditions (ammonia vs. control) were separated by 2-3 days to minimize the effect of changes in performance. A relatively longer period (3-7 days) was allowed between the two temperature environments (normal vs. heat). The orders of assigned condition and temperature were counterbalanced among the subjects. Subjects were asked to come at or around the same time for the four trials. The ammonia inhalant used in this study was Pac-Kit First Aid (South Norwalk, CT) ammonia capsule, containing 15% ammonia and other inactive ingredients. The distance for ammonia inhalant application was 6 cm away from the nose. Performance was evaluated with decrements in the peak and mean pedaling cadences over 12 sprint sets. Blood lactate, ear canal temperature, and discomfort levels were also measured to report physiological and psychological strains incurred by the exercise.

Warm-up

The temperature and humidity set for the normal and hot environments were respectively at 22°C and 50%, and at 30°C and 80%. When testing in the hot environment, subjects stayed in the heated chamber for one hour prior to the experiment. Before each testing, subjects warmed up for 10 minutes on the cycle ergometer by pedaling at preferred cadences at 1.0-1.5 kilopond (kp) for the first 6 minute 40 second. Then after the 7th minute of warm up, a 4-5 seconds sprint at 2.0 kp

was performed every minute (×4 sets). After warm up, a 10-minute setup time was placed before starting the exercise test.

Exercise Testing

The exercise consisted of 12 sets of 6-second maximal pedaling with 40 second rest between sets (Figure 1). The pedaling load (kp) was set at 7.5% body mass in kg. For the ammonia inhalant condition, an ammonia capsule was applied 5 seconds before the 7^{th} and 10^{th} set. Each subject was asked to take one sniff near the ammonia capsule, which was held 6-cm away from the subject's nostrils, then turn his or her head away to show the completion of the ammonia inhalation. If subjects wore contact lenses, they were asked to close their eyes when sniffing the capsule to avoid any eye irritations or discomfort. For the control condition, the subjects completed the same exercise protocol in the absence of ammonia inhalant.

Measurements

The peak and mean cadences achieved in each 6-second pedaling were recorded over 12 sets by the ergometer. Blood lactate, ear canal temperature and discomfort levels were taken immediately before the 1^{st} set, and then after 6^{th}, 9^{th} and 12^{th} sets (Figure 1). Blood was collected from the right earlobe (20 μl) to measure the concentration of lactate ($[La^-]$). The samples were analyzed using a lactate analyzer (Biosen S-Line; EFK Diagnostics, Barleben, Germany). Blood $[La^-]$ was used to estimate the level of anaerobic metabolic challenges incurred in the trial. The ear canal temperature was measured with an ear thermometer (MC-510; Omron) to investigate the level of heat stress. Subjective discomfort levels were quantified using a customized 10.0-cm visual analogue scale (VAS). The figures for the overall procedure and VAS are shown below.

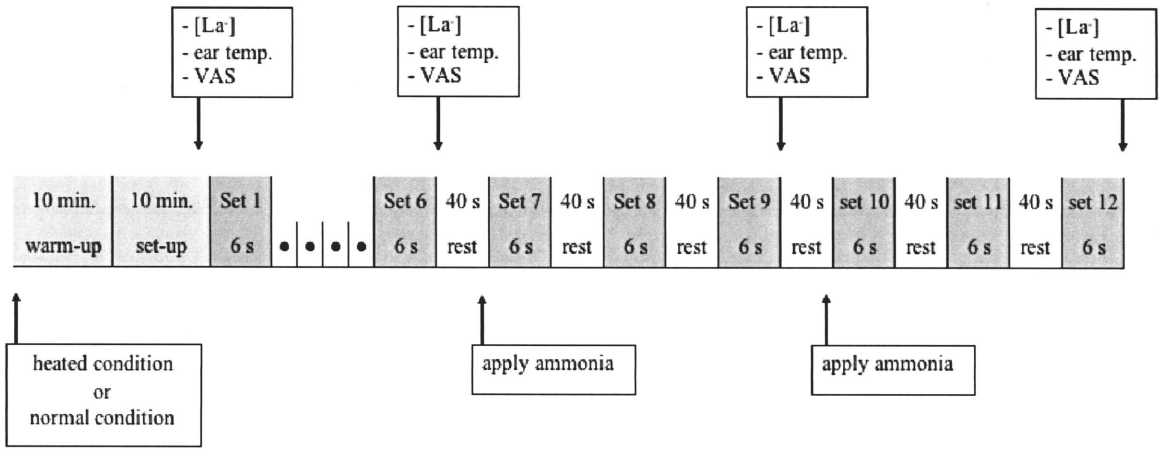

Figure 1. Experiment procedure.

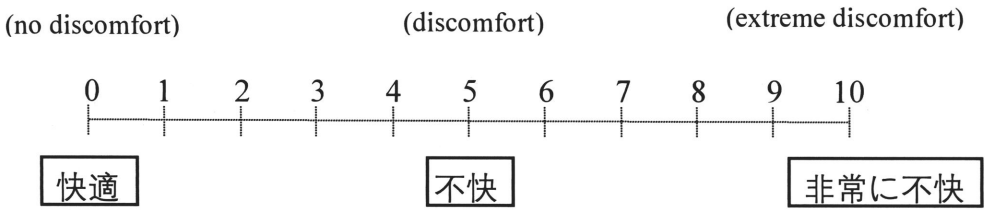

Figure 2. Customized 10-cm visual analogue scale (VAS).

Statistical Analysis

Two-way repeated measures Analyses of Variances (ANOVAs) were performed to identify the main effects of condition (with or without ammonia inhalant) and sprint set, and their interaction (condition × set) for the peak and mean cadences, blood [La^-], ear canal temperature and discomfort levels within each temperature environment.

Three-way repeated measures ANOVAs (temperature × condition × set) were performed to study the main effect of temperature (normal or heat) for all the tested variables.

When assumption of equal variances was infringed, significance was adjusted using the Huynh-Feldt method. When significant main effect or interaction was

detected, post-hoc pair-wise comparisons were performed where appropriate using the Bonferroni adjustment.

Statistical tests were conducted using SPSS version 17.0 software (SPSS Inc., Chicago, IL, USA). All data are presented as mean ± SD. P values of equal to or less than 0.05 were considered statistically significant.

CHAPTER V. RESULTS

Pedaling Performance

The peak and mean pedaling cadences are presented in Figure 3 and 4. The main effect of set was significant for the peak and mean cadences in both normal and heat temperatures (P = 0.000~0.004), indicating a gradual performance decrement. Temperature had no effect on the peak and mean cadences.

A significant condition × set interaction was observed for the peak (P = 0.012) and mean (P = 0.019) cadences only in the normal temperature environment, indicating that the performance decrement was slightly reversed with ammonia inhalant, especially after the 7th set (Figure 3 and 4 left). Post-hoc analyses revealed that both peak (P = 0.005) and mean (P = 0.015) cadences at the 7th set were significantly greater for the ammonia condition than the control. However, the pedaling performance did not significantly differ between the two conditions at the 10th sprint set. Additionally, the main effect of condition was significant for the mean cadence (P = 0.033), showing that the overall mean cadence over 12 sets was greater for the ammonia condition (Figure 4 left). Ammonia inhalant, on the other hand, showed no benefits under the heat environment (Figure 3 and 4, right).

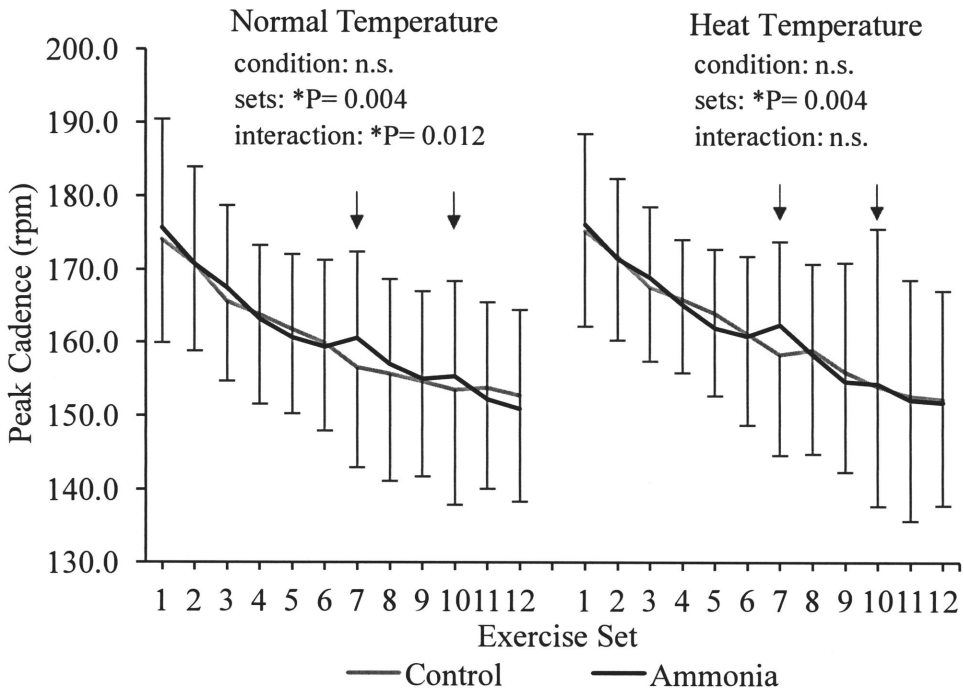

Figure 3. Peak cadences over 12 sets of maximal pedaling for both temperatures (normal vs. heat). Arrows indicate ammonia application that took place 5 seconds before 7th and 10th set. *significant main effect or interaction. n.s., non-significant where $p > 0.05$.

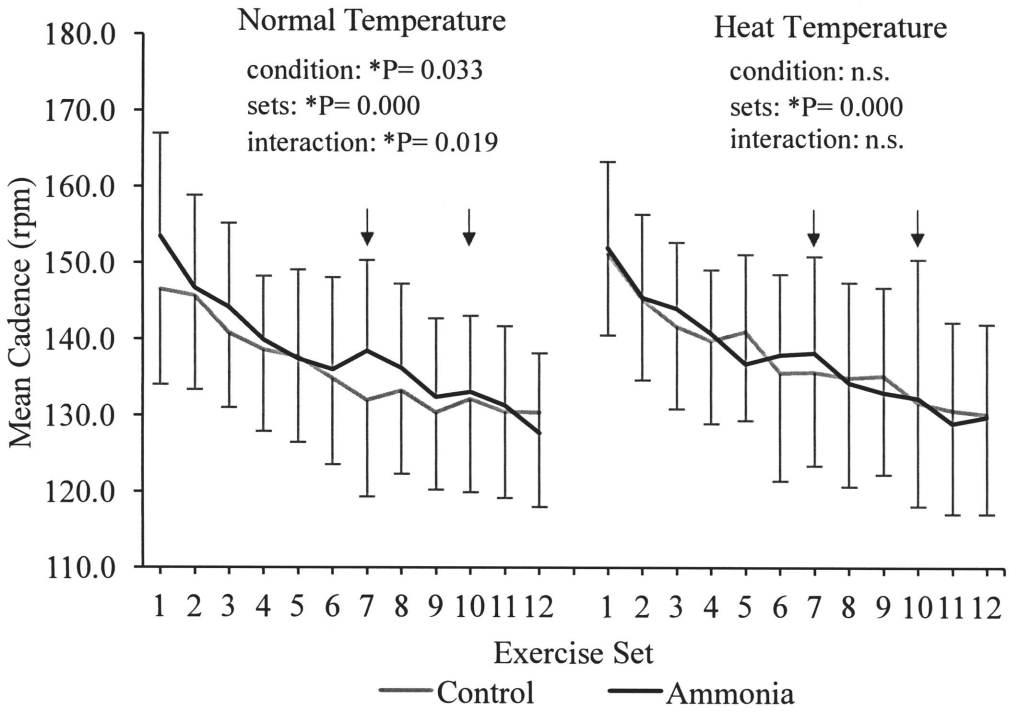

Figure 4. Mean cadences over 12 sets of maximal pedaling for both temperatures (normal vs. heat). Arrows indicate ammonia application that took place 5 seconds before 7th and 10th set. *significant main effect or interaction. n.s., non-significant where $p > 0.05$.

Ear Canal Temperature and Discomfort Levels

Overall, the ear canal temperatures and discomfort levels were greater under the heat than the normal temperature (P = 0.000, Figure 5). The progression of sprint sets resulted in a gradual increase in discomfort levels for both normal and heat environments (P = 0.000, Figure 5 left). A rise in ear canal temperature with sprint sets, however, was evident only under the heat environment (P = 0.038, Figure 5 right). Ammonia inhalant had no effect to alter ear canal temperature or discomfort levels (Figure 5).

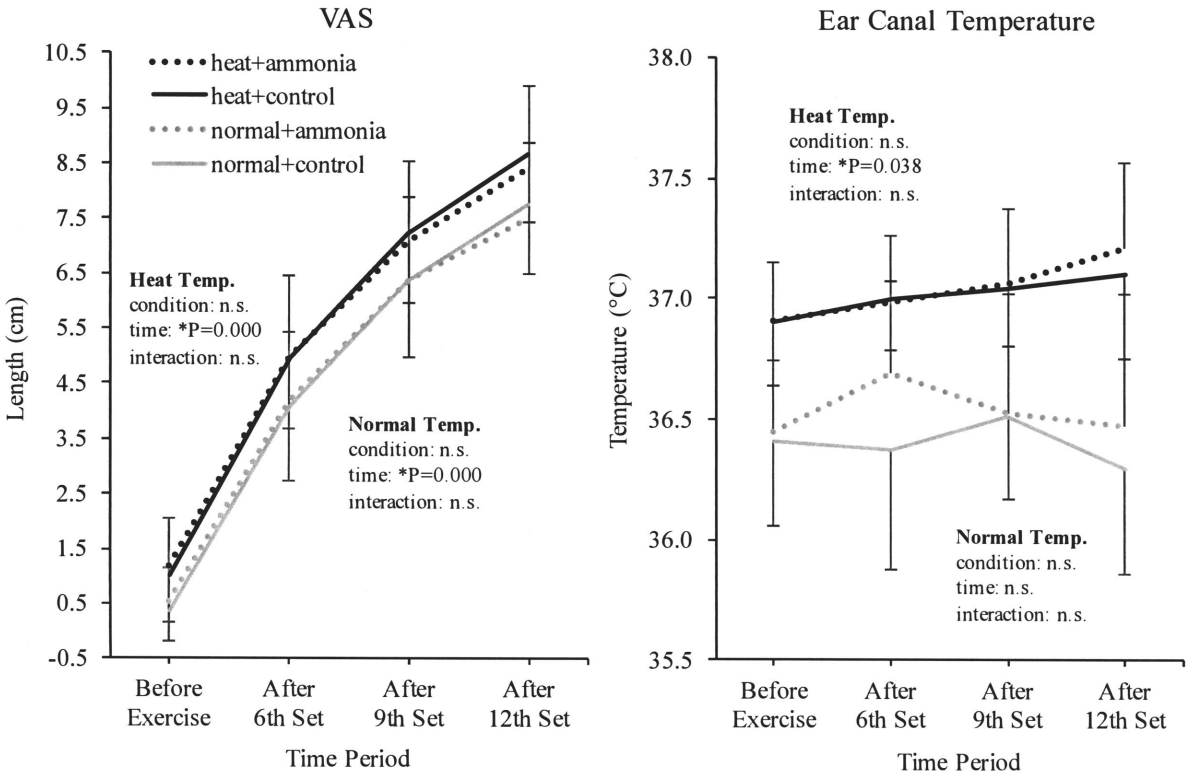

Figure 5. VAS scaling (left) and ear canal temperature (right) measured at 4 time points (before exercise, after 6th, 9th and 12th set) to evaluate discomfort levels and heat stresses. *significant main effect or interaction. n.s., non-significant where p > 0.05.

Blood Lactate

Blood [La$^-$] increased gradually with sprint sets (P = 0.000, Figure 6), with the average values exceeding 11 mmol/L after the exercise. No differences were found in [La$^-$] between normal and heat temperatures. Under the heat environment, however, ammonia inhalant resulted in slightly but significantly greater [La$^-$] than the control condition (P = 0.039, Figure 6).

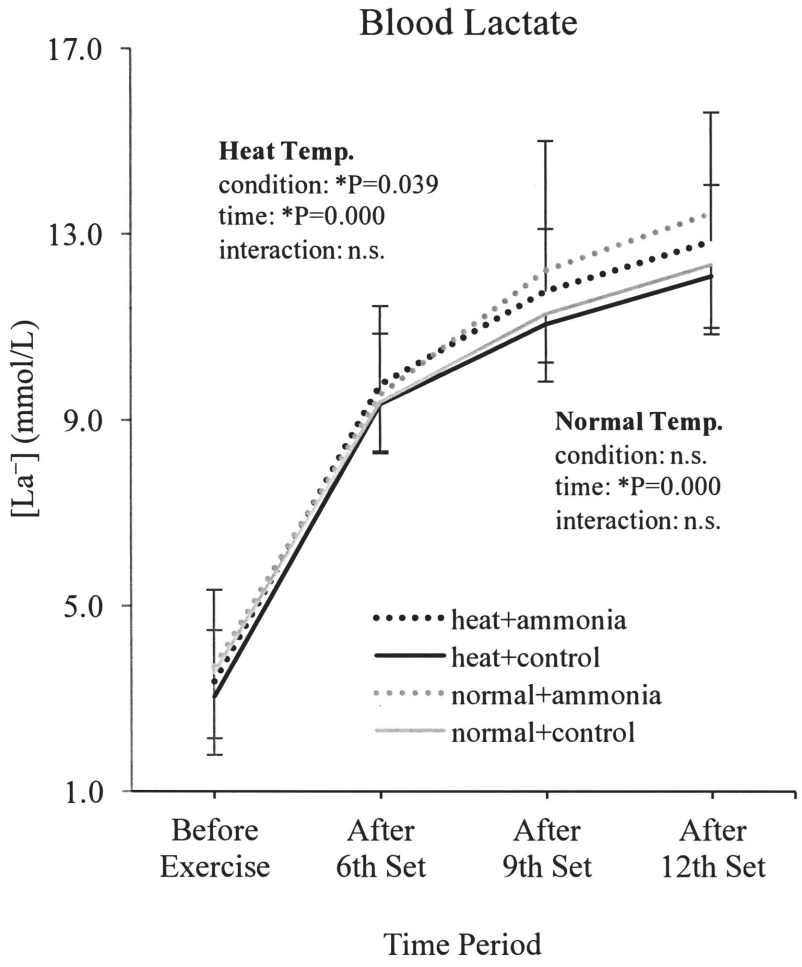

Figure 6. Blood lactate measured at 4 time points (before exercise, after 6th, 9th and 12th set). *significant main effect or interaction. n.s., non-significant where p > 0.05.

CHAPTER VI. DISCUSSION

Application of ammonia inhalant has been used by many athletes to gain physiological and psychological benefits in sports performance (McCory 2006). Ammonia inhalants were originally described and observed as stimulants that acquire the mechanisms to increase level of consciousness (Velasquez 2011). Accordingly, when individuals experience a higher level of fatigue or when they need a quick burst of increase in arousal state, ammonia inhalant may play a role in supporting those factors.

In our study, we have taken account of the fatigue factor with the application of ammonia inhalant in two environments (normal vs. heat) under high intensity exercise. Our main findings were as follows: 1) under normal temperature environment, there was a significant increase in peak and mean pedaling cadences with ammonia inhalant compared to control, 2) ear canal temperature and discomfort levels were found to be greater under heat temperature environment, and 3) the application of ammonia inhalant resulted in a higher level of blood lactate concentrations than the control under heat environment.

Elaborating further on the main findings above in relation to our hypothesis, it was believed that the ergogenic effects of ammonia inhalant may be more apparent under physiological and psychological strains, particularly in the heat temperature. However, the results of this study contradicted our hypothesis. In this present study, peak and mean cadences were improved with ammonia inhalant in the normal temperature environment only (Figure 3 and 4). As for the peak pedaling cadence, our finding agreed with Secrest's study (2015), in which increased peak power was observed with the usage of ammonia inhalant. However, the Secrest's study may raise inconsistencies with the ergogenic effect due to unclear methodology in the experiment. In the present study, we demonstrated a clear and organized procedure in consideration of the usage of ammonia inhalant. Hence, the finding of the Secrest's study has been

consolidated by our results. In addition to the improvement in peak cadences, mean pedaling cadences were also improved in the present study. Accordingly, this finding shared a similar significance with previous studies that tested on an isometric mid-thigh pull and Wingate trials, in which rate of force development and mean pedaling power were increased by ammonia inhalant (Bartolomei et al. 2017; Perry et al. 2015; Secrest et al. 2015). A plausible mechanism of acquired benefits in enhancing the rate of force or power development may be a faster recruitment of motor units, but stronger scientific reasoning is still required.

In our study, however, the finding of increased mean cadence with ammonia inhalant may be partly contributed by day-day performance variation since a greater mean cadence was apparent for the 1st set ($P = 0.015$) before the administration of ammonia (Figure 4 left). Nonetheless, there were upwards shifts in the time-course of performance decrement, which coincided with the timings of ammonia inhalant, particularly at the 7th set ($P = 0.015$), (Figure 4 left). Therefore, the observed significant condition effect ($P = 0.033$) as well as significant condition × set interaction ($P = 0.019$) may indeed indicate the ergogenic effects of ammonia inhalant.

Post-hoc analyses, however, revealed that the greater peak and mean cadences resulting from ammonia inhalant were evident only at the 7th set. One interpretation may partially be the close timing of the ammonia inhalant between the 7th and 10th set. The first application of ammonia inhalant was applied after 6 sets of maximal pedaling sprints, which the subjects may have been more prone to a stimulant effect due to the fatigue factor. On the other hand, the second application of ammonia inhalant was applied within 3 sets of maximal pedaling sprints. Therefore, there may have been a refractory period before the second application of ammonia inhalant, in which the ergogenic effect may not have taken effect yet. Alternatively, there may have been a potential ergogenic effect of ammonia inhalant at the 10th pedaling set, through which

the subjects were able to maintain the peak and mean cadences similar to the control condition despite the greater cadence outputs achieved during earlier sets, possibly countering the aftermath. Further research is needed to identify the ideal frequency and timing of ammonia inhalant application.

Unexpectedly, the present study showed no ergogenic effects of ammonia inhalant in the heat environment despite greater discomfort levels and ear canal temperature than the normal environment (Figure 5). Due to higher discomfort and heat stress, fatigue may potentially be exacerbated in a higher temperature environment. However, both the peak and mean cadences were similar between the two temperatures. Therefore, subjects, under the heat environment, may not have experienced a state of central fatigue, which was high enough to accelerate the performance decrement. With a higher discomfort level, inhalation of ammonia may add to, rather than reduce discomfort sensation due to its strong unpleasant smell. This could partly explain the lack of performance enhancement with ammonia inhalant under the heat condition. However, our VAS measurements showed that discomfort levels were nearly the same between ammonia inhalant and control in the heat temperature. The exact mechanisms, therefore, remain unclear. Notably, the Wingate tests of Secrest's study (2015), which demonstrated ergogenic effects of ammonia inhalant, were performed under normal temperature (21.3°C and 27.5% humidity), although the preceding fatigue challenges were attempted under heat environment (35.5°C and 30% humidity). Therefore, it can be suggested that heat environment may not be imperative in identifying the benefits of ammonia inhalant.

Lastly, in the present study, there was greater blood lactate accumulation with ammonia inhalant under the heat environment (Figure 6). Studies have shown that endogenous ammonia production stimulates the rate of glycolysis, hence resulting in greater lactic production (Vanuxem 1986; Houston 1995). However, in the present study,

one sniff of ammonia inhalant was applied exogenously on two occasions only (before the 7^{th} and 10^{th} sprint sets). Therefore, it was unlikely that the concentration of systemic ammonia levels increased with the current administration method. If ammonia inhalation increased the level of body ammonia concentration, we would have observed greater lactate production with ammonia inhalant under the normal temperature as well. This was, however, not observed in the present study (Figure 6). Lactate production also depends on work done. In the normal temperature, the lactate concentrations, however, were similar between ammonia inhalant and control conditions, despite greater performance achieved in the ammonia condition. In contrast, under the heat condition, the ammonia inhalant, which resulted in greater lactate concentration, produced similar performance to that of control condition. Therefore, no clear association was established among ammonia inhalant, performance and blood lactate.

Conclusion

Ammonia inhalant was effective in reversing performance decrement during repeated sets of maximal pedaling sprints. The ergogenic effect was, however, present in the normal temperature only. Therefore, the heat may not be a requisite to elicit the ergogenic effects of ammonia inhalant.

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APPENDIX I

被験者用説明書

順天堂大学大学院
スポーツ健康科学研究科

研究課題名:
"アンモニア吸引が最大運動時の疲労およびヒートストレスによる出力低下を軽減できるかについての検証"

[学術的背景]

アンモニア吸引は、"混濁した意識を回復し奮起レベルを向上させる"ことで最大筋力とパワー能力を高め、運動競技のパフォーマンスを強化できることが期待されている(Velasquez 2011)。しかし、多くのパワースポーツ選手により使用されたという事実にも関わらず、スポーツパフォーマンスがアンモニア吸引により向上したことは、科学的に証拠が示されていない(McCrory 2006)。これらの先行研究では、アンモニア吸引を疲労が発生していない状況で検証しており、本来期待される"意識回復の効果"が適切に検証された実験デザインとは言い難い。そこで、本研究は、最大繰り返し運動を対象とし、アンモニア吸引が疲労による筋出力低下を回復できるかについて検証する。また、上記検証を常温環境と暑熱環境で行い、中枢疲労をより大きく発生させるとされる暑熱環境にて、アンモニア吸引の効果が増大するかについても検証する。

[測定の流れ]

被験者は日常的にパワートレーニングやインターバルトレーニングを行う学生アスリート(約 14 名)とし、口頭説明(30 分)× 1 日、実験練習(1 時間)× 1 日、実験本番(2 時間)× 4 日の計 6 日間の参加が要求される。

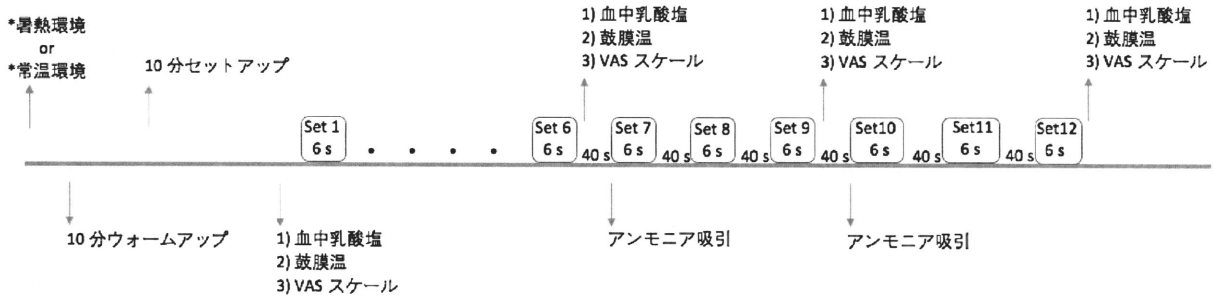
- 1 日目: 口頭説明、同意書
- 2 日目: 実験練習
- 3,4,5,6 日目: 実験本番 (4 試技、 順不同)
  - *最大ペダリング運動: 常温環境
  - *最大ペダリング運動: 常温環境 + アンモニア吸引
  - *最大ペダリング運動: 暑熱環境
  - *最大ペダリング運動: 暑熱環境 + アンモニア吸引

[測定項目詳細]

- **最大ペダリング運動時の各セットにおけるピーク & 平均回転数**:
  6 秒×12 セット(セット間 40 秒)
  負荷 : 体重×0.075 kp
- **血中乳酸、鼓膜温**: 運動テスト開始前、6 セット後、9 セット後、12 セット後に測定。
- **VAS スケール**: 6 セット後、9 セット後、12 セット後に測定。

APPENDIX I continued

・**アンモニア吸引**: 7 セット、10 セット開始直前に吸引。
アンモニア使用距離：鼻から 6cm
・**コントロール**: 空気
・**暑熱環境**(摂氏 30 度・湿度 80%):実験の 1 時間前に実験室に入るように求められる。
・**常温環境**(摂氏 22 度・湿度 50%)



[•]:セット 2 - 5

[実験に伴うリスク・対応・ポリシー]

実験遂行日は被験者の都合を優先して決定される。実験への参加は自主的であり強制されるものではない。実験中、被験者は最大努力による運動が要求される為、疲労・不快感に耐えられない場合、痛みを感じた場合、実験から辞退したい場合はいつでも被験者の意志で中断することができる。また、このような判断で辞退を申し出た個人に不利益が生じることは一切ない。

測定期間中に、実験対象者として不適切な健康状態、測定値に影響を及ぼすような行動や怪我を所持、発生させた場合、研究代表者から実験の中断を申し受ける場合がある。

実験中に得られた個人情報は漏洩することなく、研究室のコンピューターに安全に保管される。この保管場所は研究代表者、測定協力者しかアクセスできない環境に設けられる。実験結果は研究論文への出版、学会での発表等で使用されるが、個々の情報やプライバシーが他人に明かされることは一切ない。

研究の途中、終了後でも人権保護に関して疑問が生じた場合、被験者は倫理委員会へ問い合わせるか、訴えることができる。

[謝金のついて]

本実験を全て終了した際に、謝礼として金 12,000 円が支給される。但し、途中で辞退した者や中止した者については、実験本番に参加した日割り計算で謝金が支払われる(実験練習は 2,000 円、実験本番は 2,500 円×参加日数)。

[この説明書は、被験者用に研究概要を簡潔にまとめたものです。質問、詳細な情報提供を求める場合は、遠慮なく研究代表者・研究協力者にご連絡ください]

APPENDIX I continued

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被験者が保有するこれらの権利が脅されたり侵されたりしたと感じた場合、いつでも「順天堂大学大学院スポーツ健康科学研究科　研究等倫理委員会」に連絡してください。お申し出しに対する秘密は厳守します。

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APPENDIX II

同意書（コンセントフォーム）

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研究課題名：

“アンモニア吸引が最大運動時の疲労およびヒートストレスによる出力低下を軽減できるかについての検証”

私は、「順天堂大学院　研究等倫理審査」で承認された上記の課題名の研究内容、研究方法及び考えられる危険性についての説明を受けました。

私は、

1. 私の人権が尊重され、私の個人情報に関しての機密が守られる。
2. 私の個人情報は、説明を受けた研究目的以外に用いられない。
3. 私の安全性に関して、十分な配慮及び対策と適切な処置が取られる。
4. 私が説明を受けた研究計画に基づいて実施される。万一、何らかの変更があった場合には、如何なる場合でも私への説明が行われ、私の合意を得る。
5. 私が説明を受けた測定項目以外の測定は、行われない。
6. 私に疑問や質問が生じた場合には、適切な説明がなされる。
7. 私に不都合が生じた場合、あるいは研究に疑義が生じた場合、私の意志で研究の中断及び研究への参加を中断できる。
8. 研究対象者として不適切と思われる健康状態、測定期間中での測定値に影響を及ぼす可能性のある行動や怪我を所持又は発生させた場合、研究参加の中断を研究責任者・実行者から申し受ける場合がある。

という条件の基に、本研究の対象者・被験者として参加する事に同意します。

平成　年　月　日

氏名：　　印

住所：

APPENDIX III

Subject	Gender	Age (yrs)	Height (cm)	Mass (kg)	Sport	Training Exp. (yrs)	Training Session /week
1	Female	19	164.0	66.1	Cycling, Track/Field	7.5	6
2	Male	20	177.3	82.6	Swimming	15.5	6
3	Male	19	181.8	73.6	Swimming	6.5	6
4	Male	19	170.8	92.3	Hammer Throw	4.5	5
5	Male	19	174.5	94.8	Shot Put	7.5	5
6	Male	22	168.6	59.9	Cycling, Track/Field	16.5	6
7	Male	20	172.8	89.7	Hammer Throw, Shot Put	7.5	5
8	Male	19	175.2	73.8	High Jump, Long Jump	4.5	5
9	Female	19	168.9	69.2	Heptathlon	5.5	5
Mean		20	172.7	78.0		8	5
SD		1	5.3	12.4		4	1

APPENDIX IV

名前: _____ __月____日
年齢: _____
身長: _____
体重: _____

Set	1	2	3	4	5	6	7	8	9	10	11	12
RPM												

	ベースライン	6セット後	9セット後	12セット後
血中乳酸塩				
鼓膜温				
VAS スケール				

Height:
Bar handle-
Seat bar-

Kp:

APPENDIX V

Trial tests. Peak cadence (normal temperature) (control)

Subject	1	2	3	4	5	6	7	8	9	10	11	12
1	151.0	153.0	153.0	152.0	153.0	153.0	154.0	153.0	153.0	153.0	152.0	151.0
2	176.0	174.0	170.0	172.0	169.0	169.0	169.0	169.0	167.0	169.0	168.0	170.0
3	179.0	172.0	168.0	168.0	166.0	164.0	161.0	162.0	160.0	161.0	161.0	160.0
4	182.0	169.0	158.0	149.0	147.0	140.0	133.0	132.0	130.0	127.0	131.0	128.0
5	175.0	172.0	164.0	163.0	159.0	155.0	146.0	137.0	144.0	134.0	136.0	134.0
6	187.0	181.0	178.0	176.0	170.0	170.0	168.0	165.0	162.0	167.0	163.0	162.0
7	165.0	167.0	163.0	159.0	160.0	160.0	157.0	159.0	158.0	156.0	157.0	155.0
8	195.0	192.0	185.0	184.0	183.0	179.0	176.0	176.0	172.0	171.0	170.0	168.0
9	157.0	156.0	152.0	151.0	149.0	149.0	145.0	148.0	146.0	144.0	146.0	147.0
Mean	174.1	170.7	165.7	163.8	161.8	159.9	156.6	155.7	154.7	153.6	153.8	152.8
SD	14.2	11.8	11.0	12.2	11.5	12.0	13.6	14.6	13.0	15.0	13.7	14.5

Trial tests. Peak cadence (normal temperature) (ammonia inhalant)

Subject	1	2	3	4	5	6	7	8	9	10	11	12
1	151.0	151.0	152.0	153.0	154.0	154.0	157.0	154.0	154.0	154.0	153.0	154.0
2	176.0	171.0	171.0	167.0	167.0	167.0	174.0	168.0	168.0	172.0	169.0	170.0
3	182.0	175.0	173.0	167.0	165.0	165.0	165.0	164.0	161.0	159.0	156.0	157.0
4	180.0	171.0	159.0	150.0	143.0	137.0	140.0	137.0	133.0	130.0	128.0	128.0
5	177.0	173.0	168.0	165.0	159.0	156.0	153.0	148.0	143.0	146.0	139.0	136.0
6	189.0	183.0	176.0	172.0	167.0	167.0	165.0	160.0	159.0	157.0	154.0	149.0
7	172.0	166.0	165.0	161.0	159.0	157.0	160.0	156.0	157.0	161.0	154.0	150.0
8	198.0	193.0	188.0	181.0	182.0	179.0	179.0	176.0	171.0	171.0	170.0	168.0
9	156.0	153.0	155.0	153.0	150.0	152.0	152.0	150.0	149.0	148.0	147.0	146.0
Mean	175.7	170.7	167.4	163.2	160.7	159.3	160.6	157.0	155.0	155.3	152.2	150.9
SD	14.8	13.2	11.2	10.1	11.3	11.9	11.0	11.6	12.0	13.0	13.3	13.6

APPENDIX V continued

Trial tests. Mean cadence (normal temperature) (control)

Subject	1	2	3	4	5	6	7	8	9	10	11	12
1	135.9	128.4	130.6	128.2	128.4	124.9	129.4	131.2	123.7	131.8	127.1	128.2
2	149.9	140.1	144.3	140.4	140.2	136.4	138.7	139.6	137.8	145.8	139.9	138.9
3	148.1	150.1	139.3	141.6	145.8	139.9	135.8	138.0	133.0	139.1	135.8	140.8
4	159.3	140.5	133.7	120.5	125.4	117.6	113.9	114.3	113.6	114.3	114.3	105.1
5	152.6	150.7	142.7	146.2	136.0	128.3	121.9	121.9	124.1	114.9	111.4	120.8
6	154.9	154.0	151.2	150.1	144.4	144.4	151.2	141.3	132.7	140.8	136.1	142.2
7	132.4	145.3	135.7	137.6	139.1	139.3	131.5	131.9	139.4	133.1	135.2	131.6
8	160.1	169.7	159.1	152.9	157.6	154.6	147.4	151.4	146.8	146.1	145.3	142.3
9	125.1	132.7	130.3	130.2	122.3	128.0	118.2	130.2	123.0	123.4	129.6	123.8
Mean	146.5	145.7	140.8	138.6	137.7	134.8	132.0	133.3	130.4	132.2	30.5	130.4
SD	12.4	12.3	9.7	10.7	11.2	11.3	12.7	10.9	10.2	12.2	11.3	12.5

Trial tests. Mean cadence (normal temperature) (ammonia inhalant)

Subject	1	2	3	4	5	6	7	8	9	10	11	12
1	132.9	130.2	132.4	132.7	127.6	128.8	127.6	132.4	133.9	130.0	132.7	128.0
2	158.8	138.4	147.1	145.5	147.5	135.0	151.1	146.8	143.8	144.0	143.8	140.7
3	153.6	145.8	150.1	139.1	136.7	143.8	144.9	144.5	132.8	135.8	134.7	128.0
4	159.6	144.5	132.2	126.0	122.3	111.9	123.2	116.2	112.7	115.2	111.4	110.6
5	156.6	152.0	147.8	148.1	143.3	139.4	133.5	133.8	126.2	126.4	119.2	122.3
6	168.3	161.9	150.1	147.2	137.9	146.5	146.7	135.1	139.5	130.6	134.9	122.7
7	151.9	148.4	141.5	141.5	135.4	134.9	133.3	134.9	129.8	137.6	135.5	131.5
8	168.6	166.3	164.8	148.3	159.7	153.6	157.2	153.6	146.3	148.9	141.3	144.7
9	130.7	132.5	131.5	130.2	127.1	130.5	128.6	128.0	126.5	129.2	128.6	121.3
Mean	153.4	146.7	144.2	139.8	137.5	136.0	138.4	136.2	132.4	133.1	131.4	127.8
SD	13.5	12.2	11.0	8.4	11.6	12.0	11.8	11.0	10.3	10.0	10.3	10.4

APPENDIX V continued

Trial tests. Peak cadence (heat temperature) (control)

Subject	1	2	3	4	5	6	7	8	9	10	11	12
1	153.0	152.0	152.0	155.0	154.0	156.0	156.0	156.0	154.0	154.0	154.0	153.0
2	176.0	173.0	169.0	167.0	168.0	167.0	164.0	166.0	163.0	163.0	162.0	162.0
3	186.0	181.0	176.0	174.0	172.0	167.0	164.0	162.0	162.0	162.0	160.0	161.0
4	177.0	171.0	159.0	151.0	145.0	136.0	129.0	128.0	128.0	121.0	116.0	122.0
5	180.0	177.0	172.0	170.0	164.0	160.0	156.0	157.0	148.0	140.0	139.0	141.0
6	186.0	179.0	175.0	173.0	171.0	170.0	170.0	170.0	166.0	168.0	166.0	156.0
7	168.0	168.0	165.0	163.0	163.0	160.0	156.0	159.0	153.0	151.0	151.0	149.0
8	192.0	188.0	183.0	182.0	183.0	181.0	178.0	179.0	177.0	176.0	174.0	173.0
9	159.0	157.0	157.0	158.0	156.0	154.0	152.0	153.0	153.0	151.0	152.0	153.0
Mean	175.2	171.8	167.6	165.9	164.0	161.2	158.3	158.9	156.0	154.0	152.7	152.2
SD	13.0	11.5	10.1	10.0	11.3	12.5	13.7	14.1	13.7	16.3	17.0	14.4

Trial tests. Peak cadence (heat temperature) (ammonia inhalant)

Subject	1	2	3	4	5	6	7	8	9	10	11	12
1	157.0	155.0	156.0	157.0	155.0	158.0	159.0	156.0	157.0	159.0	156.0	156.0
2	181.0	175.0	173.0	172.0	170.0	169.0	174.0	169.0	167.0	169.0	168.0	167.0
3	181.0	176.0	174.0	172.0	168.0	165.0	163.0	161.0	158.0	157.0	155.0	156.0
4	179.0	168.0	161.0	153.0	141.0	140.0	142.0	134.0	118.0	104.0	116.0	123.0
5	181.0	179.0	174.0	168.0	165.0	163.0	168.0	163.0	163.0	163.0	156.0	153.0
6	187.0	179.0	177.0	171.0	168.0	170.0	171.0	167.0	163.0	167.0	160.0	154.0
7	166.0	166.0	166.0	160.0	160.0	154.0	155.0	148.0	143.0	145.0	139.0	134.0
8	193.0	188.0	183.0	178.0	177.0	176.0	177.0	175.0	172.0	176.0	170.0	173.0
9	160.0	157.0	156.0	156.0	154.0	153.0	153.0	152.0	151.0	149.0	149.0	150.0
Mean	176.1	171.4	168.9	165.2	162.0	160.9	162.4	158.3	154.7	154.3	152.1	151.8
SD	12.3	10.9	9.6	8.8	10.8	10.9	11.3	12.4	16.2	21.2	16.4	15.3

APPENDIX V continued

Trial tests. Mean cadence (heat temperature) (control)

Subject	1	2	3	4	5	6	7	8	9	10	11	12
1	136.1	131.2	131.0	128.8	130.2	121.6	134.7	125.9	130.0	126.5	133.1	130.4
2	154.4	148.0	137.6	132.2	141.5	145.0	135.9	144.2	143.4	141.5	132.7	133.8
3	159.7	147.1	146.8	145.6	148.8	146.0	134.5	141.6	142.5	135.8	134.7	139.0
4	146.4	149.5	129.0	124.8	118.5	109.7	111.5	105.7	107.8	102.2	103.4	106.6
5	158.6	149.9	156.6	148.4	147.1	131.6	139.4	130.6	129.2	126.2	118.4	113.6
6	154.6	151.0	152.2	144.0	144.9	139.2	148.5	146.7	141.5	143.3	144.9	133.1
7	142.6	140.5	137.9	137.5	142.4	141.1	134.9	131.6	132.8	130.0	130.3	128.6
8	168.6	161.8	153.6	159.7	159.0	156.6	154.9	154.7	154.5	149.0	149.4	150.6
9	139.7	127.7	130.3	137.2	136.6	129.3	127.0	133.2	135.2	130.3	129.3	136.0
Mean	151.2	145.2	141.7	139.8	141.0	135.6	135.7	134.9	135.2	131.6	130.7	130.2
SD	10.7	10.5	10.8	10.8	11.6	14.1	12.3	14.3	13.0	13.6	13.6	13.2

Trial tests. Mean cadence (heat temperature) (ammonia inhalant)

Subject	1	2	3	4	5	6	7	8	9	10	11	12
1	137.3	135.7	136.9	136.3	128.2	133.9	127.1	127.3	129.8	129.0	122.4	130.8
2	159.5	140.9	140.9	145.3	137.8	145.0	150.8	144.7	140.7	139.7	146.3	140.4
3	155.7	154.7	151.9	142.1	140.4	139.9	136.7	141.4	138.4	136.4	125.2	136.2
4	158.4	133.2	137.5	127.3	108.4	115.8	118.6	108.7	104.0	92.0	104.3	105.1
5	150.4	154.2	142.7	146.1	149.4	141.4	143.1	138.0	139.2	142.1	137.5	129.7
6	161.7	153.1	152.2	150.6	142.9	146.5	147.4	144.9	138.1	145.6	139.0	133.6
7	138.4	136.7	143.2	132.5	137.6	133.4	130.4	126.7	122.0	121.2	122.0	118.4
8	167.7	163.5	158.8	151.2	158.4	152.1	157.9	150.6	151.9	154.9	141.7	146.4
9	138.7	136.4	131.7	135.2	127.9	133.6	131.9	126.2	133.2	129.5	122.4	127.6
Mean	152.0	145.4	144.0	140.7	136.8	138.0	138.2	134.3	133.0	132.3	129.0	129.8
SD	11.3	11.0	8.7	8.3	14.3	10.5	12.6	13.1	13.6	18.1	13.2	12.2

APPENDIX VI

Measurements. Blood lactate (normal temperature) (control)

Subject	Immediately Before Exercise	After 6th Set	After 9th Set	After 12th Set
1	2.15	8.41	10.06	10.99
2	2.30	7.41	8.66	10.22
3	3.50	9.71	10.97	11.65
4	6.12	10.70	12.85	13.09
5	3.34	9.16	11.95	13.72
6	5.61	10.21	12.52	13.85
7	2.28	9.05	10.70	11.71
8	3.47	10.89	13.11	14.52
9	3.26	8.96	10.76	11.33
Mean	3.6	9.4	11.3	12.3
SD	1.4	1.1	1.5	1.5

Measurements. Blood lactate (normal temperature) (ammonia inhalant)

Subject	Immediately Before Exercise	After 6th Set	After 9th Set	After 12th Set
1	2.25	7.16	9.22	10.50
2	1.86	7.07	8.92	10.38
3	3.75	9.11	12.88	14.24
4	4.48	11.88	12.18	13.85
5	4.26	9.65	12.81	14.52
6	7.20	12.24	18.14	15.89
7	3.59	9.95	11.37	13.30
8	3.94	10.89	13.93	16.52
9	1.97	7.95	10.5	11.76
Mean	3.7	9.5	12.2	13.4
SD	1.6	1.9	2.8	2.2

APPENDIX VI continued

Measurements. Blood lactate (hot temperature) (control)

Subject	Immediately Before Exercise	After 6th Set	After 9th Set	After 12th Set
1	1.98	8.15	10.24	11.00
2	2.09	8.31	9.79	11.50
3	2.74	11.05	12.09	13.21
4	3.42	8.72	10.34	10.67
5	3.02	10.04	11.90	13.74
6	5.52	10.27	11.34	12.60
7	4.28	8.88	11.06	11.17
8	1.91	9.27	11.3	12.15
9	2.40	9.41	11.48	12.78
Mean	3.0	9.3	11.1	12.1
SD	1.3	1.0	0.8	1.1

Measurements. Blood lactate (hot temperature) (ammonia inhalant)

Subject	Immediately Before Exercise	After 6th Set	After 9th Set	After 12th Set
1	2.45	8.53	10.20	11.62
2	3.13	8.54	9.89	11.22
3	4.16	11.40	13.67	14.15
4	4.54	10.49	11.95	12.08
5	2.65	9.67	12.76	13.81
6	5.42	10.88	12.68	14.44
7	3.25	8.78	10.84	12.02
8	2.74	10.56	12.95	13.84
9	1.99	9.06	11.04	12.41
Mean	3.4	9.8	11.8	12.8
SD	1.1	1.1	1.3	1.2

APPENDIX VI continued

Measurements. Ear canal temp. (normal temperature) (control)

Subject	Immediately Before Exercise	After 6th Set	After 9th Set	After 12th Set
1	36.7	36.3	36.8	36.5
2	36.5	36.7	36.7	36.7
3	36.5	37.0	36.8	36.5
4	36.2	36.0	36.3	36.3
5	36.8	36.3	36.6	36.2
6	36.6	36.3	36.5	36.4
7	36.5	37.0	36.6	36.6
8	36.3	36.4	36.6	36.3
9	35.6	35.4	35.7	35.2
Mean	36.4	36.4	36.5	36.3
SD	0.4	0.5	0.3	0.4

Measurements. Ear canal temp. (normal temperature) (ammonia inhalant)

Subject	Immediately Before Exercise	After 6th Set	After 9th Set	After 12th Set
1	36.4	37.2	37.1	36.6
2	36.6	36.6	36.8	36.9
3	36.4	37.1	36.5	36.8
4	36.4	36.7	36.5	36.7
5	36.9	37.0	37.0	36.8
6	36.4	36.4	36.3	35.5
7	36.7	36.8	36.9	37.0
8	36.4	36.4	36.0	36.3
9	35.8	36.0	35.6	35.7
Mean	36.4	36.7	36.5	36.5
SD	0.3	0.4	0.5	0.5

APPENDIX VI continued

Measurements. Ear canal temp. (hot temperature) (control)

Subject	Immediately Before Exercise	After 6th Set	After 9th Set	After 12th Set
1	36.7	37.1	36.7	37.2
2	37.0	36.7	36.9	37.1
3	37.2	37.1	37.3	36.2
4	36.8	37.2	37.1	37.2
5	36.4	37.2	37.1	37.3
6	37.1	37.0	37.0	37.4
7	37.2	37.2	37.5	37.2
8	36.9	36.7	36.9	37.2
9	36.8	36.8	36.9	37.1
Mean	36.9	37.0	37.0	37.1
SD	0.3	0.2	0.2	0.3

Measurements. Ear canal temp. (hot temperature) (ammonia inhalant)

Subject	Immediately Before Exercise	After 6th Set	After 9th Set	After 12th Set
1	37.1	37.2	37.1	37.2
2	37.0	36.9	37.1	37.4
3	36.8	37.3	37.1	37.5
4	36.8	36.8	37.2	36.8
5	36.8	37.4	37.2	37.6
6	37.1	36.9	37.3	37.4
7	37.2	37.0	37.3	37.2
8	37.0	36.9	37.0	37.3
9	36.4	36.5	36.3	36.5
Mean	36.9	37.0	37.1	37.2
SD	0.2	0.3	0.3	0.4

APPENDIX VI continued

Measurements. VAS (normal temperature) (control)

Subject	Immediately Before Exercise	After 6th Set	After 9th Set	After 12th Set
1	0.2	5.8	8.1	9.4
2	0.1	1.7	4.4	5.4
3	0.5	2.8	3.8	6.1
4	0.2	3.3	7.0	7.8
5	0.0	4.8	6.1	8.0
6	1.8	4.1	7.1	8.2
7	0.0	4.8	6.7	7.8
8	0.0	5.6	7.1	8.4
9	0.5	3.8	7.0	8.8
Mean	0.4	4.1	6.4	7.8
SD	0.6	1.3	1.4	1.3

Measurements. VAS (normal temperature) (ammonia inhalant)

Subject	Immediately Before Exercise	After 6th Set	After 9th Set	After 12th Set
1	0.2	4.5	7.5	8.9
2	0.3	2.6	3.7	5.0
3	0.6	2.8	4.3	5.9
4	0.2	2.8	5.8	6.9
5	0.1	5.2	6.4	7.2
6	2.0	4.9	7.1	8.2
7	0.2	5.3	7.3	8.0
8	1.0	5.8	7.8	9.1
9	0.2	3.8	7.6	8.3
Mean	0.5	4.2	6.4	7.5
SD	0.6	1.2	1.5	1.4

APPENDIX VI continued

Measurements. VAS (hot temperature) (control)

Subject	Immediately Before Exercise	After 6th Set	After 9th Set	After 12th Set
1	2.1	6.6	9.0	9.9
2	0.2	2.6	4.8	6.1
3	0.9	4.2	6.3	7.8
4	0.5	4.4	6.3	7.9
5	0.9	6.0	7.7	9.0
6	2.8	5.1	7.7	9.7
7	0.6	5.6	7.5	8.9
8	0.5	6.2	8.5	9.6
9	0.6	4.0	7.2	9.1
Mean	1.0	5.0	7.2	8.7
SD	0.9	1.3	1.3	1.2

Measurements. VAS (hot temperature) (ammonia inhalant)

Subject	Immediately Before Exercise	After 6th Set	After 9th Set	After 12th Set
1	0.9	5.8	8.6	10.0
2	0.6	2.5	4.5	5.6
3	1.1	3.7	5.1	7.0
4	0.1	3.9	6.9	7.9
5	1.0	5.9	6.7	8.0
6	2.9	5.9	7.6	9.6
7	1.1	6.5	8.4	9.1
8	2.2	6.7	8.0	9.6
9	0.7	3.9	8.0	9.2
Mean	1.2	5.0	7.1	8.4
SD	0.9	1.5	1.4	1.4

アンモニア吸引が疲労によるパワー出力低下を軽減できるかについての検証

【背景】

スポーツパフォーマンスを最大に発揮する為に様々な製品がアスリートに使用されている。その一つであるアンモニア吸引は、生理学的、心理学的な向上効果が期待されている。しかし、その有効性については一致した知見が得られていない。これまでのアンモニア吸引に関する研究では、運動パフォーマンスに与える効果について疲労が発生していない状態で検討している。アンモニア吸引は意識・奮起レベルの向上や循環器応答の刺激作用があることから、強い疲労状態での検証が望ましいと考えた。

【目的】

本研究は、繰り返し最大ペダリング運動により疲労を発生させ、アンモニア吸引が疲労によるパフォーマンス低下を軽減できるかについて検証した。また、この検証を常温環境と暑熱環境にて行い、アンモニア吸引の効果を比較した。

【方法】

9名のパワー系学生アスリートが6秒×12セット、セット間休息40秒の最大ペダリング運動を常温環境（摂氏22度、湿度50%）と暑熱環境（摂氏30度、湿度80%）にて行った。運動はそれぞれの環境下でアンモニア吸引有り、または無し（コントロール）の2条件にて実施された（計4回）。アンモニア条件では、アンモニアカプセルの吸引を7^{th}と10^{th}セットの直前に行った。コントロール条件では、全セットに渡り処方が何もされなかった。パフォーマンス評価には各セットで記録されたピークおよび平均回転数が用いられた。また、疲労度合いの評価として、血中乳酸値（$[La^-]$）、鼓膜温、不快感（10.0-cm visual analogue scale）が運動直前、および6th、9th、12thセット直後に記録された。

【結果および考察】

運動後の$[La^-]$は全ての条件で11 mMを超えた。暑熱環境では常温環境よりも高い不快感と鼓膜音が記録された。常温環境では、ピークおよび平均回転数の低下がアンモニア吸引により軽減された。しかし、この疲労軽減効果は7^{th}セット（吸引一回目）のみで認められ、10^{th}セット（吸引二回目）では認められなかった。一方で、暑熱環境ではアンモニア吸引による疲労軽減効果は確認できなかった。

【結論】

アンモニア吸引は繰り返し運動時の疲労を軽減できる。しかし、この効果は常温環境のみで確認され、暑熱環境では観られなかった。