ALTERATIONS IN LIPID METABOLISM AND EXERCISE PERFORMANCE DURING PASSIVE HEAT EXPOSURE AND SUBSEQUENT EXERCISE IN THE HEAT

par / by

Katharine O'Hearn

Thèse soumise à
La Faculté des études supérieures et postdoctorales
Université d'Ottawa
en vue de l'obtention de la maîtrise à
L'École des sciences de l'activité physique

Thesis submitted to the
Faculty of Graduate and Postdoctoral Studies
University of Ottawa
In partial fulfillment of the requirements for the master's degree in the
School of Human Kinetics

January 2013

Master's degree (2013)
University of Ottawa
(Human Kinetics)

Title: Alterations in lipid metabolism and exercise performance during passive heat exposure and subsequent exercise in the heat

Author: Katharine O'Hearn, B.Sc. (Human Kinetics)

Thesis advisor: François Haman, Ph.D., Department of Human Kinetics, Faculty of Health Sciences, University of Ottawa

Research funded in part by:
National Science and Engineering Research Council (NSERC) - Discovery Grant
Canadian Institutes of Health Research (CIHR) - Master's Award
Ontario Graduate Scholarship (OGS)

SUMMARY

Heat exposure results in several physiological and metabolic alterations during both passive heat stress and exercise in the heat. Changes in carbohydrate metabolism during exercise in the heat are fairly well understood, namely, an increased reliance on carbohydrate oxidation, increased glycogen utilization, increased hepatic glucose output, and an accelerated rate of lactate accumulation. Alterations in lipid metabolism, on the other hand, are not as clear, although the available information suggests that non-esterified fatty acid (NEFA) concentrations are increased as a result of heat exposure. CHAPTER 1 reviews the known metabolic alterations induced by passive heat exposure and exercise in the heat, with a specific focus on changes in whole-body lipid utilization and plasma lipids. A second purpose of this chapter is to outline physiological changes caused by heat stress at rest and during exercise, and to determine how these changes serve to reduce exercise performance in the heat. The study presented in CHAPTER 2 has shown that, compared to thermoneutral conditions, NEFA concentrations were 37% higher following passive heating and 34% higher following exercise in the heat, without significant changes in whole-body lipid utilization. In addition, the level of hyperthermia attained during two hours of passive heat exposure combined with heat stress during exercise resulted in a 13% decrease in total work capacity and a significantly higher rate of perceived exertion. Lastly, as a general conclusion, CHAPTER 3 will summarize the study results as to the effects of passive heat exposure and subsequent exercise in the heat on lipid metabolism and work capacity. The limits and applications of the study will also be presented in this final chapter.

RÉSUMÉ

Lorsque le corps humain s'expose à la chaleur passive, plusieurs changements physiologique et métabolique surviennent. Les modifications du métabolisme glucidiques lors de l'exercice à la chaleur sont bien clairs, c'est-à-dire, une dépendance accrue sur les métabolismes glucidiques, une augmentation de l'utilisation du glycogène, une augmentation de la production hépatique du glucose, et un taux accéléré de l'accumulation de lactate. Les changements de métabolisme lipidique, par contre, ne sont pas aussi clairs. Les renseignements disponibles semblent suggérer que la concentration d'acides gras non estérifiés augmente avec la chaleur. Le but premier du CHAPITRE 1 est d'examiner les modifications métaboliques provoquées par la chaleur passive pendant l'exercice, avec un accent particulier sur les changements dans l'utilisation des lipides et des lipides plasmatiques. Le deuxième but est d'étudier les changements physiologiques causés par l'exposition à la chaleur au repos et à l'exercice, et de déterminer comment ces changements réduisent la performance d'exercice. L'étude présentée dans le CHAPITRE 2 démontre que, en comparaison des conditions neutres, les concentrations d'acides gras non estérifiés sont 37% plus élevées suivant le chauffage passif, et 34% plus élevées suivant l'exercice à la chaleur, sans modifications significatives dans l'utilisation des lipides. De plus, le degré d'hyperthermie atteint pendant deux heures de chauffage passif combiné avec le stress thermique pendant l'exercice a entraîné une diminution de la capacité de travail par 13% et un taux perception à l'effort plus élevé pour le même niveau d'exercice. Finalement, en guise de conclusion, le CHAPITRE 3 comprend un résumé des effets du chauffage passif et de l'exercice sur le métabolisme lipidique et de la capacité de travail. Les limites et les applications de cette étude seront également présentées dans ce chapitre.

ACKNOWLEDGEMENTS

I would like to first thank my thesis supervisor, Dr. François Haman who was an inspirational teacher and mentor throughout my undergraduate and graduate studies. Secondly, I am very grateful for the generosity of Dr. Glen Kenny for allowing me to use his laboratory during data collection for this project. I would also like to thank my thesis committee, Dr. Tara Reilly and Dr. Natalie Chapados, for sharing their knowledge, expertise and suggestions. Many thanks go to Bernard Pinet, Jean-François Mauger and Denis Blondin for their help with data collection and analysis, and for their priceless input and guidance. I would also like to thank Mathieu Lebreton and Elizabeth Lavoie for their help with blood sampling. And of course, thank you to all my participants for suffering through the heat and making the results of this study possible. Finally, a very special thank you goes to my parents for helping and supporting me in countless ways throughout my studies.

Table of Contents

LIST OF ABBREVIATIONS AND SYMBOLS

Abbreviations

ADP: Adenosine diphosphate

ANOVA: Analysis of variance

ATP: Adenosine triphosphate

AUC: Area under curve

CHO: Carbohydrate

CNS: Central nervous system

CO: Cardiac Output

CON: Control condition (thermoneutral)

DEH: Dehydrated

EEG: Electroencephalography

EMG: Electromyography

EPI: Epinephrine

GH: Growth hormone

HDL: High density lipoprotein

HR: Heart rate

HR_{max}: Maximum heart rate

IMTG: Intramuscular triacylglycerol

LDL: Low density lipoprotein

MVC: Maximal voluntary contraction

NE: Norepinephrine
NEFA: Non-esterified fatty acids

PL: Phospholipid

R_a: Rate of appearance
R_d: Rate of disappearance
REH: Rehydrated
RER: Respiratory exchange ratio
RPE: Rate of perceived exertion

SV: Stroke volume

T_{core}: Core temperature
T_{es}: Esophageal temperature

TG: Triacylglycerol

T_{skin}: Skin temperature

VE: Ventilation

VO_2: Oxygen consumption

VO_{2max}: Maximum oxygen consumption

Symbols

bpm: beats per minute

°C: Celsius

kg: kilograms

l: litres

min: minutes

mg: milligrams

mM: millimoles per litre

µM: micromoles per litre

%: percent

±: plus or minus

~: approximate value

LIST OF TABLES, FIGURES AND ILLUSTRATIONS

Tables

Table 2.1. Physical characteristics of subjects (n=8)

*Underwater weighing (Brosek, Grande, Andersen & Keys 1963)

† Bruce Ramp treadmill protocol

Table 2.2. Changes in body mass (kilograms) at before (Baseline), following passive heat exposure (End of Passive), and after exercise in the heat (Post Exercise) compared to control (CON).

*Significantly lower than baseline value, $p < 0.05$.

Table 2.3. Absolute oxidation rates and relative contributions of lipids, carbohydrates and proteins to total heat production before heat exposure (23°C), during passive heat exposure (42°C) and during exercise in the heat (42°C) compared to control (CON; 23°C).

Values are means ± SE; n=8 subjects (baseline and passive), n = 6 subjects (exercise). $\dot{H}_{prod}$, total heat production.

Table 2.4. Plasma NEFA, TG, PL and cholesterol concentrations before (Baseline) and during (T_{60}), and after (T_{120}) passive heat exposure and after exercise in the heat (Post Ex) compared to control (CON).

*Significantly higher than CON, $p < 0.05$

Figures

Figure1.1. Total non-esterified fatty acid (NEFA) concentration in plasma (A) before (Baseline) and after passive heat stress to increase T_{core} by 1.4°C when dehydrated and when rehydrated (Eddy *et al.* 1976); (B) after 60 min exposure to 25.2°C (Control), moderate heat (35.5°C) and high heat (39.8°C) (Yamamoto *et al.* 2003); and (C) before (Baseline) and after 180 min exposure at 42°C while wearing light protective clothing and heavy protective clothing (unpublished research).

*Significantly higher than baseline value, $p < 0.05$.

†Significantly higher than control value, $p < 0.05$.

Figure 2.1. Changes in mean skin (T_{skin}) (A) and esophageal temperatures (T_{es}) (B) as well as rates of heat production ($\dot{H}_{prod}$) (C) measured in men during passive heat exposure and subsequent exercise in the heat (●) compared to control (○).

*Significantly higher than CON, $p < 0.05$.

Figure 2.2. Changes in heart rate (A) and ventilation (B) measured in men during passive heat exposure and subsequent exercise in the heat (●) compared to control (○).

*Significantly higher than CON, $p < 0.05$.

Figure 2.3. Total external work (A) and rate of perceived exertion (B) for men walking on a treadmill at 50% VO_{2peak} in the heat (●) and in control (○).

*Significantly lower than CON, $p < 0.05$.

CHAPTER 1: GENERAL INTRODUCTION

INTRODUCTION

Although the human body is highly adapted to dissipate heat, this can be impeded by extreme heat, heavy clothing (McLellan, Jacobs & Bain 1993), and high humidity (Maughan, Otani & Watson 2012). These factors create an environment of uncompensable heat stress which limits the amount of heat that can be lost through evaporation. When the human body's ability to dissipate heat is minimized, core temperature will increase, resulting in several physiological and metabolic alterations. Although carbohydrate metabolism during exercise in the heat is fairly well understood, carbohydrates represent only a small portion (2-8%) of endogenously stored energy. Lipids, on the other hand, account for 92-98% of endogenously stored fuel (Jeukendrup 2003). In addition, a greater oxidation of lipids can extend work capacity and exercise performance by sparring muscle glycogen (Brooks, Fahey & Baldwin 2005).

Though lipids are a very important energy source in the body, alterations in lipid metabolism can have negative health consequences. Overly high concentrations of NEFA lead to the development of atherosclerotic plaques and insulin resistance (Wood, Scott, Garg & Gibson 2009) and alter glucose metabolism (Groop, Saloranta, Shank, Bonadonna, Ferrannini & DeFronzo 1991). NEFA, in particular saturated and n-6 polyunsaturated NEFA, have also been shown to cause inflammation by stimulating the immune response. This leads to the development of chronic, inflammatory diseases such as diabetes, cardiovascular and respiratory disease (Wood *et al*. 2009). Further, perturbations in blood lipids are an important risk factor in cardiovascular disease (Yusuf, Hawken, Ôunpuu, Dans, Avezum, Lanas, McQueen, Budaj, Pais, Varigos & Lisheng 2004). Given the importance of lipids in energy metabolism, and the negative health consequences of altered lipid metabolism, it is important to understand how heat exposure affects whole-body lipid utilization and plasma lipids.

When humans are exposed to heat stress, behavioural changes such as minimizing movement and removing clothing allow for lower heat production and increased heat dissipation (Fanger 1970). However, certain occupations like mining, industrial work and the military require employees to work in high ambient temperatures while wearing heavy, protective clothing. Despite being exposed to heat stress, miners, industrial workers and military personnel still need to be able to perform. It is well documented that exercise performance and work capacity are reduced in environments of heat stress (Arngrimsson, Petitt, Borrani, Skinner & Cureton 2004; Gregson, Drust, Batterham & Cable 2002; MacDougal, Reddan, Layton & Dempsey 1974; Morris, Nevill, Boobis, MacDonald & Williams 2005). Less understood are the exact mechanisms behind the lower work capacity observed in the heat, although several ideas have been postulated.

This review will focus on physiological and metabolic changes that occur during passive heat stress and exercise in the heat. Specific emphasis will be placed on alterations in whole-body lipid metabolism and plasma lipids. The current knowledge on the effects of heat stress on lipid metabolism will be reviewed, along with potential mechanisms behind the alterations observed during heat stress at rest and during exercise. In addition, the effects of hyperthermia on exercise performance will be addressed, with a detailed review of how the physiological changes that occur during heat stress act to reduce exercise performance.

CARDIORESPIRATORY RESPONSE AND WHOLE BODY METABOLISM DURING PASSIVE HEAT EXPOSURE

Cardiorespiratory response

Passive heat exposure leads to increases in core temperature, which, in turn, causes alterations in cardiovascular and respiratory function. Specifically, under conditions of heat stress, heart rate (HR) is significantly increased (Cabanac & White 1995; Eddy, Sparks & Turner 1976; Ganio, Brothers, Shibata, Hastings & Crandall 2011). As a result, cardiac output (CO) is elevated. When skin temperature (T_{skin}) is maximally elevated, CO can increase by as much as 7-10 litres/min, with minimal increases in stroke volume (Rowell, Brengelmann & Murray 1969). Blood flow patterns are also altered during passive heat exposure, in order to allow heat to be transferred from the body's core to the skin and increase evaporative heat loss. Cutaneous blood flow increases by as much as 7.6 litres/min (Rowell 1974). This increase in cutaneous blood flow is offset by reductions in splanchnic and renal blood flow (Rowell, Brengelmann, Blackmon, Twiss & Kusumi 1968) and skeletal muscle blood flow through increases in sympathetically-mediated vasoconstriction (Niimi, Matsukawa, Sugiyama, Shamsuzzaman, Ito, Sobue & Mano 1997).

Once core temperature (T_{core}) rises above a certain threshold, ventilation will increase (Cabanac & White, 1995; Fujii, Honda, Hayashi, Soya, Kondo & Nishiyasu 2008). The temperature threshold for increased ventilation during passive heat exposure has varied slightly between authors and has been reported as an esophageal temperature of 37.8°C - 38.5°C (Cabanac & White 1995; Fujii *et al*. 2008) or a tympanic temperature of 38.1°C (Cabanac & White 1995). Based on observations of higher ventilation rates without an increase in oxygen consumption (VO_2), it has been suggested that hyperthermia-induced hyperpnea is a thermoregulatory rather than a metabolic response, which likely contributes to selective brain cooling (Cabanac & White 1995). However, the concept of selective brain cooling in humans has not been directly proven. Authors have contested this notion, based on research that shows hyperventilation reduces cerebral blood flow, which in turn decreases heat removal from the brain (Nybo, Secher & Nielsen 2002).

Whole body metabolism

The majority of literature exploring the effects of heat exposure on whole body metabolism has focused on changes occurring during exercise, with limited research regarding metabolic alterations at rest. Studies that have quantified VO_2 during and/or following passive heating have obtained differing results. Some authors have reported increases in VO_2 during passive heat exposure (Fujii *et al*. 2008; Saxton 1981) while others observed no change (Cabanac & White 1995). Respiratory exchange ratio (RER) has sometimes been reported as higher (Cabanac & White 1995; Fujii *et al*. 2008), which could suggest an increased reliance on carbohydrates during passive heat exposure. This would be in line with observations made during exercise of an increase in carbohydrate oxidation at the expense of lipid oxidation (Febbraio 2000).

PERFORMANCE, CARDIORESPIRATORY RESPONSE AND WHOLE BODY METABOLISM DURING EXERCISE IN THE HEAT

Performance and perceived exertion

It is well documented that exercise performance is reduced in the heat (Arngrimsson *et al.* 2004; Gregson *et al.* 2002; MacDougal *et al.*1974; Morris *et al.* 2005). During exercise at a fixed intensity, time to volitional exhaustion is significantly shorter in hyperthermic conditions (Arngrimsson *et al.* 2004; Gregson *et al*. 2002; MacDougall *et al.* 1974; Morris *et al*. 2005). When exercise is self-paced, intensity and power output are decreased in the heat. As a result, a longer time period is required to complete a given amount of work (Schlader, Raman, Morton, Stannard & Mündel 2011). The limits of exercise performance in the heat have been extensively studied. Authors have explored several potential mechanisms to determine if and how they contribute to reductions in performance. These mechanisms are: (i) alterations in energy metabolism, (ii) alterations in muscle blood flow, (iii) altered neuromuscular function, (iv) cardiovascular strain, (v) hydration status, (vi) a decrease in maximal oxygen consumption (VO_{2max}), and (vii) T_{core} threshold.

While glycogen depletion and altered blood flow have been suggested as potential causes for performance decrements in the heat, both have generally been ruled out. Heat stress tends to increase reliance on carbohydrate metabolism, specifically muscle glycogen utilization (Febbraio, Snow, Hargreaves, Stathis, Martin & Carey, 1994*b*; Febbraio 2000). However, substrate depletion does not appear to be a performance limiting factor. Researchers have shown that when exercising to volitional exhaustion in the heat, fatigue occurs before muscle glycogen availability is compromised (Morris *et al*. 2005; Nielsen, Savard, Richter, Hargreaves & Saltin 1990) and when carbohydrates are still readily available (Febbraio, Murton, Selig, Clark, Lambert, Angus & Carey 1996*b*; Maughan *et al.*2012). Further, when cycling to exhaustion in hot (40°C), neutral (20°C) and cold (3°C) ambient temperatures, muscle glycogen levels at exhaustion were higher in the hot compared to cooler temperatures, likely due to the shorter exercise duration in the heat (Parkin, Carey, Zhao & Febbraio 1999). This clearly indicates that fatigue during prolonged exercise in hot conditions is not related to carbohydrate availability.

During passive heat exposure, blood flow is redistributed to the skin (Rowell 1974) at the expense of skeletal muscle blood flow (Niimi *et al*. 1997). However, exercise presents a unique challenge as exercising skeletal muscle requires blood flow for the delivery of metabolic substrates and oxygen (Brooks *et al.* 2005). Hence, if blood flow to working muscle is compromised during exercise in the heat, this could contribute to the reductions in performance observed in hyperthermic conditions. However, authors have shown that, unless dehydration is also present, muscle blood flow is not reduced during submaximal exercise in the heat (Savard, Nielsen, Laszczynska, Larsen & Saltin 1988) or during exercise to exhaustion in the heat (Nielsen *et al*.1990). It appears then, as long as hydration status is maintained, altered muscle blood flow is not a performance limiting factor. Other mechanisms must therefore play a role.

Authors have postulated that hyperthermia during exercise affects the central nervous system (CNS) which in turn reduces motivation to exercise and diminishes motor centre function and motor unit recruitment (Nielsen *et al*. 1990). Since then, researchers have shown that altered CNS activity contributes to the development of fatigue during prolonged exercise in the heat (Nybo & Nielsen 2001). This finding is based on observations that subjectively perceived exertion is highly associated with increases in core temperature and with frequency changes in an electroencephalography (EEG) obtained over the pre-frontal cortex. However, these authors ruled out a role of altered muscle activity in performance reductions since perceived exertion was not correlated with any measured electromyography (EMG) parameters. In contrast, others have determined that peripheral factors do play a role.

Périard, Caillaud & Thompson (2011) observed a decline in maximal voluntary contraction (MVC) from hyperthermia, but < 42% of the decline in MVC could be attributed to central fatigue. As a result, the authors concluded that altered muscular activity was also involved. Despite the disagreement over the contribution of peripheral factors to fatigue, the evidence suggests that some degree of altered neuromuscular function does play a role in performance decrements during heat stress. It is of note, however, that a recent study by Racinais & Girard (2012) concluded that neuromuscular failure is not a likely reason for shortened exercise duration in the heat. Participants in their study reached exhaustion earlier in the heat, but with lower levels of peripheral fatigue compared to in thermoneutral temperatures. Although EMG readings were lower at fatigue in the heat, the authors determined that there was still no evidence of neural drive failure as other measurements were maintained. The exercise duration in this study was much shorter (~33 min) and the highest T_{core} attained was lower (~38.9°C) compared to the studies of Périard *et al*. (~64 min; ~39.8°C) and Nybo & Nielsen (~50 min; ~40.0°C), which could account for the differing conclusions.

Cardiovascular strain contributes to fatigue during exercise in the heat. Heat stress results in a thermoregulatory rise in heart rate, along with decreases in stroke volume (SV) and CO (González-Alonso, Teller, Andersen, Jensen, Hyldig & Nielsen 1999, Périard, Cramer, Chapman, Caillaud & Thompson 2010; Rowell, Marx, Bruce, Conn & Kusumi 1966). Together, these alterations cause cardiovascular strain which reduces performance by attenuating sustainable work rate, peak power output and peak oxygen uptake (Périard *et al*. 2010).

It is well known that dehydration has a negative impact on exercise performance in the heat (Cheung & McLellan 1998; González-Alonso, Mora-Rodriguez, Below & Coyle

1997; Kenefick, Cheuvront, Palombo & Ely 2010; Sawka *et al*. 1992). Dehydration combined with hyperthermia shortens exercise duration by lowering the core temperature that can be tolerated (Sawka, Young, Latzka, Neufer, Quigley & Pandolf 1992) and by reducing blood pressure and cardiac output (González-Alonso *et al*. 1997). While fluid replacement can extend performance time during low intensity exercise in the heat, it appears that during higher intensities, hydration status at the start of exercise is the more important determinant of performance (Cheung & McLellan 1998). During low intensity exercise in uncompensable heat stress, participants who were euhydrated prior to the start of exercise and replaced fluid losses were able to sustain exercise for longer than participants who did not replace fluid losses, and participants who were hypohydrated prior to the start of exercise. When intensity was increased, fluid replacement was no longer able to extend exercise duration; however, participants who were euhydrated at the start of exercise were able to perform longer than participants who started exercise in a hypohydrated state. These findings indicate that for light and heavy exercise with uncompensable heat stress, hydration status at the start of exercise affects work tolerance time and that fluid replacement prolongs exercise duration for lighter exercise intensities only (Cheung & McLellan 1998).

A hyperthermia-induced reduction in VO_{2max} has also been shown to contribute to decreased exercise performance in the heat. Decrements of 16% to 25% have been reported (Arngrimsson *et al*. 2004; Nybo, Jensen, Nielsen & González-Alonso 2001; Pirnay, Deroanne & Petit 1970). The reduction in VO_{2max} is amplified as T_{core} increases above 39.0°C. Reductions of ~9% have been reported for a T_{core} of 39.1°C - 39.2°C, and when T_{core} increased to 39.3°C - 39.7°C, the reduction in VO_{2max} also increased to 17-19% (Arngrimsson *et al*. 2004). Consequently, a lower VO_{2max} means that the same absolute work intensity requires a higher percentage of VO_{2max}, making it more difficult to sustain work in the heat.

Despite the range of contributing factors, the majority of authors have found that fatigue during exercise in the heat occurs at the same T_{core} of ~40°C (Galloway & Maughan 1997; González-Alonso *et al.* 1999; McDougall *et al.* 1974; Nielsen, Hales, Strange, Juel, Christensen, Warberg & Saltin 1993; Nielsen, Hyldig, Bidstrup, González-Alonso & Christoffersen 2001). This has led to the concept of a "critical" core temperature which limits or slows performance in the heat. Evidence for this concept comes from studies that have shown fatigue occurs at the same T_{core} of ~40°C despite different initial core temperatures (36°C, 37°C, 38°C) and/or different rates of heat storage (González-Alonso *et al*. 1999). In addition, authors have shown that fatigue occurs at the same T_{core} (~39.7°C) before and after heat acclimation, although acclimation extends time until fatigue (Nielsen, Hales, Strange, Christensen, Warberg & Saltin 1993).

However, not all researchers agree with the concept of a performance-limiting T_{core} threshold. Authors have found that an anticipatory reduction in muscle fibre recruitment is responsible for impaired performance during a 20km cycling time trial in the heat, and that this reduction in muscle fibre recruitment occurred well before a critical T_{core} of 40°C was reached (Tucker, Rauch, Harley, Noakes 2004). Further, the decreases in power output and muscle fibre recruitment were not associated with altered rectal temperature, HR or perception of effort. The authors concluded that impaired performance in the heat was caused not by a limiting T_{core}, but as part of a central regulation of skeletal muscle recruitment that controls heat storage in order to lessen the development of thermoregulatory strain during self-paced exercise in the heat. Others have found that gross-efficiency (the ratio between mechanical and metabolic power output) is lower when cycling in the heat compared to neutral temperatures, and this reduction is beyond what can be explained by increases in T_{core} alone (Hettinga, Koning, de Vrijer, Wüst, Daanen & Foster 2007).

In addition, some study participants have been able to maintain exercise even when T_{core} is above the threshold. Core temperatures in excess of 40°C have been reported in runners, without symptoms of heat illness (Byrne, Lee, Chew, Lim & Tan 2006) or decreases in running velocity (Ely, Ely, Cheuvront, Kenefick, DeGroot & Montain 2009). It is of note, however, that these final two studies where core temperatures > 40°C were observed were conducted outdoors in lower ambient temperatures (26.5°C and 27°C respectively) than most of the studies previously discussed. T_{skin} is influenced by ambient temperature and has important effects on performance-related factors (Cheuvront, Kenefick, Montain & Sawka 2010). Ely and researchers (2009) reported a T_{skin} range, measured only on the chest, of 30-34°C, and T_{skin} was not reported by Byrne *et al*. (2006). Given that a high T_{skin} can be defined as >35°C (Cheuvront *et al*. 2010), it could be that a lower T_{skin} allowed participants in these studies to continue to perform even when T_{core} rose above 40°C.

Several mechanisms have been shown to explain, at least in part, reductions in exercise performance in the heat. Thus, it is reasonable to assume that the decrease in exercise capacity cannot be explained by a single factor, but by a combination of several of the mechanisms discussed above.

Cardiorespiratory response

Heat exposure results in an increased demand on the heart and the respiratory system during exercise. For a given exercise intensity, HR is consistently higher when performed in the heat compared to in neutral temperatures (Kamon & Belding 1971; Kamon 1972; Rowell 1974; Williams, Brendell, Wyndham, Strydom, Morrison, Peter, Fleming & Ward 1962). The higher HR in the heat is thought to arise in part due to the lower VO_{2max} associated with hyperthermia. A lower VO_{2max} results in an increased HR during submaximal exercise in the heat because a higher percentage of VO_{2max} is required for the same absolute work intensity. However, this only explains a small part of the increase in HR (Arngrimsson, Stewart, Borrani, Skinner & Cureton 2002). Additional factors such as vagal withdrawal (Gorman & Proppe 1984), and increased sympathetic activation (Gorman & Proppe 1984; Rowell 1974) also contribute.

Stoke volume is reduced when exercise is performed in the heat compared to in comfortable temperatures (Périard *et al*. 2010; Rowell *et al.* 1966; Rowell 1974; Trinity, Pahnke, Leff & Coyle 2010;Williams *et al*. 1962).The lower SV results from the increase in HR, which leads to a shorter ventricular filling time (González-Alonso *et al*. 1999). Reductions in CO are also observed during hyperthermic exercise (Rowell *et al.* 1966; Périard *et al*. 2010; Rowell 1974) although some authors have reported a tendency towards increased CO (Nielsen *et al*. 1990). At lower exercise intensities, a higher HR is able to offset a lower SV and reductions in CO are somewhat attenuated. However, at higher exercise intensities (> 63% VO_{2max}), HR is not able to compensate and the reduction in CO is significantly greater, in part because HR_{max} is attained at a lower absolute work intensity (Rowell *et al*. 1966). Together, the higher HR and lower SV and CO lead to cardiovascular strain and reductions in VO_{2max} (Wingo, Lafrenz, Ganio, Edwards & Cureton 2005), which in turn decrease exercise performance (Périard *et al.* 2010).

In addition to the cardiovascular changes, ventilation is higher when exercise is performed in the heat compared to neutral temperatures (Hayashi, Honda, Ogawa, Kondo & Nishiyasu 2006; Hettinga, De Koning, de Vrijer, Wüst, Daanen & Foster 2007). The increase in ventilation under hyperthermic conditions is directly related to increases in core temperature (Fujii *et al*. 2008; Hayashi *et al*. 2006; White and Cabanac 1996; Sancheti & White 2005) and is a result of increases in breathing frequency as opposed to increases in tidal volume (Hyashi *et al*. 2006; Sancheti & White 2006). Core temperature thresholds for hyperthermic hyperventilation have been reported for prolonged, constant load exercise (Tsuji, Honda, Fujii, Kondo & Nishiyasu 2011) and for incremental exercise (Sancheti & White 2006; White & Cabanac 1996) above which ventilation increases linearly in proportion to core temperature. However, other authors have reported no threshold in 11 out of 13 subjects during submaximal exercise, but acknowledged that since ventilation data was not collected or available until the 10th minute of exercise, it would have been difficult to detect a threshold during this time period. Regardless, a threshold was detected in 2 of the 13 subjects, along with a large degree of individual variability for all participants when ventilation, tidal volume and breathing frequency were plotted against core temperature (Hayashi *et al*. 2006). Thus it appears the ventilatory response during exercise with hyperthermia is highly variable among individuals.

The reasons for hyperthermia-induced hyperventilation are unclear. As detailed by Hayashi *et al.* (2006), potential mechanisms could include: (i) augmented signaling from central command; (ii) augmented input from chemoreceptors; or (iii) activity of group III and IV muscle afferents, as a result of increases in muscle temperature and ventral respiratory group activity, caused by an increase in brain temperature. The exact cause, however, remains to be elucidated.

Whole body metabolism

Compared to thermoneutral conditions, VO_2 during submaximal exercise in the heat has been reported as increased (Dolny & Lemon 1988; Fink, Costill & Van Handel 1975; Hettinga *et al.* 2007; MacDougal *et al*. 1974; Nielsen *et al*. 1990; Wells & Paolone 1977), unchanged (1993Angus, Febbraio, Lasini & Hargreaves 2001; Febbraio, Snow, Stathis, Hargreaves & Carey 1994*a*; Gregson *et al.* 2002; Snow, Febbraio, Carey & Hargreaves 1993; Yaspelis, Scroop, Wilmore & Ivy) and decreased (Smolander, Kolari, Korhonen & Ilmarinen1986; Williams, Brendell, Wyndham, Strydom, Morrison, Peter, Fleming & Ward 1962; Young, Sawka, Levine, Cadarette & Pandolf 1985). Researchers who did observe a higher VO_2 have attributed the increase to three possible factors: (i) the additional energy required to support higher rates of sweating, and increased circulatory and respiratory strain (MacDougal *et al.* 1974); (ii) the Q_{10} effect, thus a higher overall metabolic rate (Nielsen *et al*. 1990); or (iii) a decrease in efficiency due to localized muscular exhaustion (Fink *et al*. 1975). Authors who reported a reduction in VO_2 during exercise in the heat have attributed the change to the increase in anaerobic metabolism (Williams *et al.* 1962) which has been observed during exercise in hot environments (Dimri, Malhotra, Gupta, Kumar & Arora 1980).

It is important to note that even if VO_2 during submaximal exercise is unchanged for the same absolute workload in the heat, it would still represent a greater percentage of VO_{2max} due to a hyperthermia-induced reduction in VO_{2max} (Arngrimsson *et al.* 2004;

Arngrimsson *et al*. 2003; Dimri *et al*. 1980; Lafrenz, Wingo, Ganio & Cureton 2008; Nybo et al. 2010; Pirnay *et al.* 1970; Saltin, Gagge, Bergh & Stolwijk 1972; Sawka, Young, Cadarette, Levine & Pandolf 1985).

Much of the previous research investigating changes in fuel selection during heat exposure has focused on changes in carbohydrate (CHO) metabolism during exercise. The majority of studies have found an increase in RER during exercise in the heat (Febbraio *et al.* 1994*a*; Hargreaves, Angus, Howlett, Conus, & Febbraio 1996; Young *et al*. 1985) suggesting a greater reliance on CHO over lipid metabolism, although others have reported that RER was unchanged (Parkin, Carey, Zhao & Febbraio 1999; Snow, Febbraio, Carey & Hargreaves 1993). The ambient temperature, length of heat exposure, rate and degree of change in T_{core}, exercise mode/intensity/duration, method of heating, and acclimation and fitness status of participants' have varied greatly between studies, which likely accounts for these discrepancies. Still, researchers generally agree that exercise in the heat results in an increase in CHO oxidation, specifically from muscle glycogen (Febbraio *et al.* 1994b; Hargreaves *et al.* 1996; Marino, Mbambo, Kortekaas, Wilson, Lambert, Noakes & Dennis 2001; Starkie, Hargreaves, Lambert, Proietto & Febbraio 1999) and probably at the expense of lipid oxidation (Febbraio 2000; Fink *et al.* 1975). Numerous authors have reported an increase in muscle glycogen use during exercise in the heat (Febbraio *et al*. 1994*a*; Febbraio, Carey, Snow, Stathis & Hargreaves 1996*a*; Fink *et al*. 1975; Jentjens, Wagenmakers & Jeukendrup 2001; Morris *et al*. 2005; Starkie *et al.* 1999). The increase in muscle glycogen utilization is observed when the whole body is heated (Fink *et al*. 1975; Jentjens *et al*. 2001) and when the thigh muscles are directly heated with a water-perfused cuff (Starkie *et al*. 1999) or an electric heating blanket (Febbraio *et al*. 1996*a*).

Plasma glucose concentrations are higher during and immediately after exercise in the heat (Fink *et al.* 1975; Hargreaves *et al.* 1996; Jentjens *et al*. 2001; Morris *et al*. 2005; Yaspelis *et al*. 1993). Tracer studies have determined that the hyperglycemia is due to an increase in hepatic glucose production, without a change in the rate of glucose clearance (Hargreaves *et al*. 1996). Exogenous glucose oxidation is also reduced in the heat compared to a cooler environment, with reductions of ~10% (Jentjens *et al.* 2001). Therefore, the increase in CHO oxidation seems to come solely from an increase in muscle glycogen use.

As a result, higher lactate concentrations have repeatedly been observed during and after exercise in the heat compared to cooler environments (Dolny & Lemon 1988; Fink *et al*. 1975; Febbraio *et al*. 1994*a*; Febbraio *et al.* 1994*b*; Hargreaves *et al*. 1996; Jentjens *et al*. 2001; Morris *et al*. 2005; Young *et al.* 1985). The rate at which lactate increases is accelerated in the heat. As a result, the maximum lactate steady state occurs at a lower absolute workload in hot compared to in temperate conditions. Consequently, the blood lactate concentration observed at the lactate threshold is lower in the heat compared to thermoneutral temperatures (de Barros, Mendes, Mortimer, Simões, Prado & Wisloff 2011). The increase in plasma lactate accumulation has been attributed to a reduction in muscle blood flow (Fink *et al*. 1975), a reduced rate of hepatic lactate clearance (Rowell *et al.* 1968), and an increase in adrenaline concentrations (de Barros *et al.* 2011; Febbraio 2000) although it is unclear which mechanism is correct.

Although carbohydrates are an important fuel for the human body, lipids represent the vast majority of endogenously stored energy (Jeukendrup 2003). While the changes in CHO metabolism during exercise in the heat are well understood, alterations in whole-body lipid metabolism and circulating lipids during heat exposure are less clear.

LIPID METABOLISM AND HEAT STRESS

Lipid oxidation and circulating lipids at rest

At rest, most of the energy is supplied to the body from lipids, with smaller contributions from carbohydrates and proteins. Very few studies have focused on alterations in fuel selection during passive heat exposure. RER has sometimes been reported to increase during heat stress at rest (Cabanac & White 1995; Fujii *et al*. 2008) indicating an increased reliance on carbohydrates. However, these studies focused on the changes in ventilation during heat exposure, therefore, fuel oxidation was not calculated.

To the best of this author's knowledge, only two studies have focused specifically on changes in plasma lipids during passive heat stress. Eddy *et al*. (1976) examined the effects of an increased T_{core} on circulating NEFA when participants were dehydrated and rehydrated during passive heat exposure. Heat exposure resulted in an increase in NEFA in both conditions, suggesting an adipokinetic effect of high temperatures. The increase was significantly higher when subjects were dehydrated (175%) compared to euhydrated (40%), implying that both hydration status and heat stress contribute to an increase in circulating NEFA. In agreement, Yamamoto, Zheng & Ariizumi (2003) also found that ambient temperatures altered NEFA concentrations, with an increase of 25% after 60 min of passive heat exposure to 35.5ºC compared to 25.2ºC. However, after 60 min of heat stress at 39.5ºC, NEFA concentrations were unchanged. Unpublished research from our laboratory has observed an effect of passive heat exposure on plasma NEFA. In this study, participants were exposed to 180 min of passive heat stress at 42ºC while wearing two levels of protective clothing: (i) light protective clothing consisting of military fatigues and a bulletproof vest, and (i) heavy protective clothing, consisting of a Copola assemble, or protective exoskeleton of ceramic plates (Allen Vanguard, Ottawa, ON, Canada). Following passive heat exposure wearing light protective clothing, NEFA concentrations increased 3-fold. The increase in circulating NEFA was even greater when participants wore heavy protective clothing, resulting in concentrations 7-fold higher than baseline values. A summary of the changes in NEFA concentrations observed in these three studies are presented in Figure 1.1. Given that circulating NEFA represent the balance between the rate of appearance (R_a) (i.e. lipolysis) and rate of disappearance (R_d) (i.e. NEFA disposal), the increased plasma concentrations observed in the heat would result from an imbalance between R_a and R_d.

Circulating NEFA that are taken up from the plasma can be utilized for energy. Eddy *et al*. (1976) and Yamamoto *et al*. (2003) did not calculate fuel selection, so it is unclear if an increase or decrease in lipid oxidation could have contributed to the increase in plasma NEFA in these studies. In the previously mentioned unpublished study from our lab, an increased contribution of lipids was observed. Lipid oxidation increased from 59% to 76% with a concurrent decrease in CHO oxidation from 17% to 5%. This appears to indicate an increase in R_d during passive heat exposure; however, these results have yet to be confirmed.

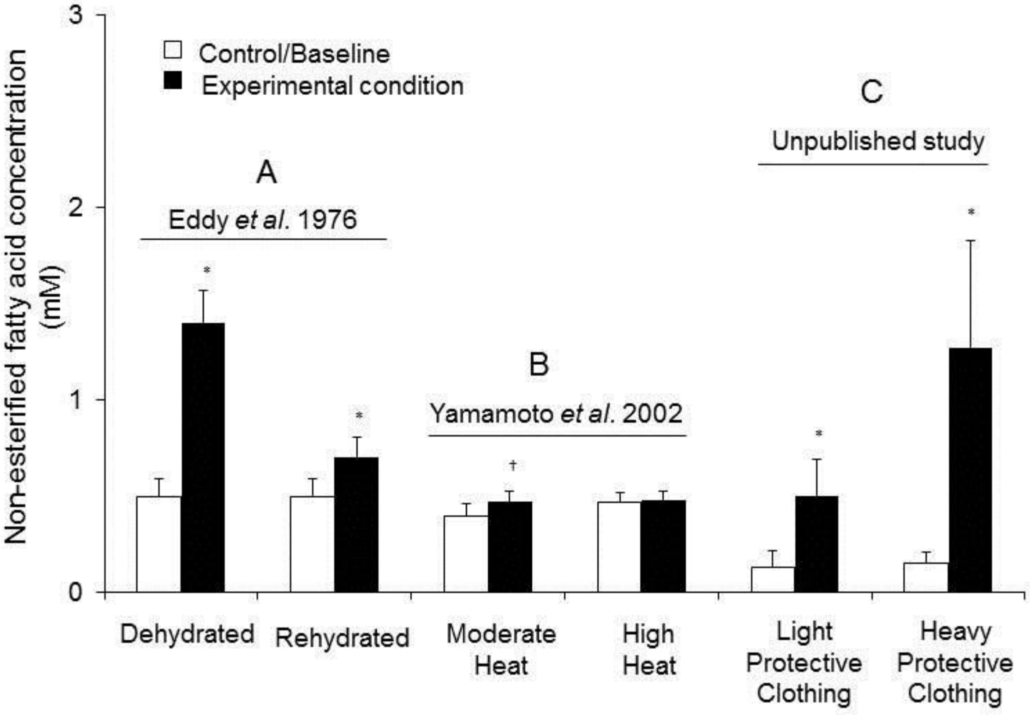

Figure1.1. Total non-esterified fatty acid (NEFA) concentration in plasma (A) before (Baseline) and after passive heat stress to increase T_{core} by 1.4°C when dehydrated and when rehydrated (Eddy *et al.* 1976); (B) after 60 min exposure to 25.2°C (Control), moderate heat (35.5°C) and high heat (39.8°C) (Yamamoto *et al.* 2003); and (C) before (Baseline) and after 180 min exposure at 42°C while wearing light protective clothing and heavy protective clothing (unpublished research).

*Significantly higher than baseline value, $p < 0.05$.

†Significantly higher than control value, $p < 0.05$.

R_a is dependent on the rate of lipolysis occurring predominantly in adipose tissue. Passive heat stress increases the levels of circulating catecholamines, both norepinephrine (NE) (Iguchi, Littman, Chang, Wester, Knipper & Shields 2012; Powers, Howley & Cox

1982) and epinephrine (EPI) (Power *et al*. 1982). Catecholamines are important regulators of NEFA mobilization (Brooks *et al.* 2005). When circulating levels of NE (Klein, Estes & Bogdonoff 1961) or EPI (Galster, Clutter, Cryer & Collins 1981) are increased at rest via infusions, NEFA concentrations increase due to an accelerated rate of lipolysis. In addition to catecholamines, plasma growth hormone (GH) concentrations are increased by passive heat exposure (Ftaiti, Jemni, Kacem, Zaouali, Tabka, Zbidi & Grélot 2008; Leppäluoto, Huttunen, Hirvonen & Väänänen 1986). Growth hormone is also known to stimulate lipolysis (Brooks *et al.* 2005). Therefore, it is possible that the increased levels of NE, EPI and GH observed during passive heat stress could result in an increase in R_a.

The effect of heat exposure on other circulating lipids is also limited. In the same study mentioned previously, Yamamoto *et al*. (2003) also quantified the changes in circulating triacylglycerol (TG) and cholesterol. TG and total cholesterol decreased after heat exposure at 39.5°C, but did not change at 35.5°C, while HDL-cholesterol increased significantly following exposure at 35.5°C. Research comparing industrial workers in hot environments and non-hot environments has found increased levels of total cholesterol and LDL-cholesterol in men who worked extensively in hot environments, suggesting a long-term effect of heat stress on plasma cholesterol (Vangelova, Deyanov & Ivanova 2006).

Lipid oxidation and circulating lipids during exercise

Researchers agree that exercise in the heat results in an increased reliance on CHO oxidation (Febbraio *et al.* 1994*b*; Hargreaves *et al.* 1996; Marino *et al.* 2001; Starkie *et al.* 1999) likely at the expense of lipid oxidation (Febbraio 2000; Fink *et al*.1975). In support of the idea that lipid metabolism is attenuated in the heat, it has been reported that intramuscular triglyceride (IMTG) use is lower in the heat (41°C) than in the cold (9°C). Following exercise, IMTG was reduced by 23% in the cold, and only 11% in the heat. Circulating NEFA were not different between conditions. However, IMTG data were based on only 4 participants, and the effects of heat were compared to the effects of cold. It cannot be assumed that IMTG use in the heat would have also been reduced if compared to thermoneutral temperatures.

Several authors have quantified changes in NEFA concentrations during exercise in hyperthermic conditions (Fink *et al*. 1975; Gregson *et al.* 2002; Jentjens *et al*. 2002; Nielsen *et al.* 1990). Generally, no significant differences have been found compared to control temperatures. While Irondelle & Freund (1977) also found no difference in NEFA concentrations during cycling at 40°C compared to 23°C, the mean decrease of NEFA during exercise tended to be smaller in the heat, although this trend did not reach significance. In addition, glycerol concentrations were higher in the heat, indicating an accelerated rate of lipolysis. During 125 min exercise recovery in the same ambient temperatures, NEFA concentrations were higher at 40°C, suggesting that heat exposure influences circulating lipids during recovery from exercise.

Greater plasma concentrations of lipolytic hormones have been observed when exercise is performed in the heat compared to in ambient temperatures. Catecholamines (Febbraio *et al.* 1994b, Hargreaves *et al.* 1996; Powers *et al.* 1982) and GH (Ftaiti *et al.* 2008; Hargreaves *et al.* 1996) are increased by heat stress during exercise and could potentially accelerate lipolysis. Interestingly, when EPI is infused during exercise at 20-22° to match the increased level observed during exercise at 40°, glycogen use, glycolysis, CHO oxidation and plasma lactate concentrations are increased, mimicking the changes observed during exercise in the heat. NEFA levels, however, remain unchanged (Febbraio *et al.* 1998).

The higher lactate concentrations observed in this study could explain why NEFA concentrations were unchanged since lactate has been shown by several authors to inhibit lipolysis (Boyd, Giamber, Mager & Lebovitz 1974; Green, Houston & Thomson 1979; Issekutz, Shaw & Issekutz 1975). Like lactate, elevated glucose concentrations have also been shown to inhibit lipolysis (Carlson, Snead, Hill, Nurjhan & Campbell 1991). Since higher concentrations of both lactate and glucose are observed during exercise in the heat, this could also explain why higher plasma NEFA have been reported following passive heat stress, when lactate and glucose concentrations are not elevated, but not during exercise.

MECHANISMS OF CHANGE

Although it is clear that heat exposure alters metabolism, the explanation for these changes are less clear. To date, several mechanisms have been proposed to explain heat-induced changes in metabolism such as alterations in blood flow, higher levels of circulating catecholamines, and an increased muscle temperature.

Alterations in blood flow

Researchers have proposed that a redistribution of blood flow from the working muscles to the skin to dissipate heat could limit the amount of oxygen delivered to active muscle, thus altering the fuel sources used during exercise (Fink *et al.* 1975). However, this does not appear to be the case, as, unless dehydration is also existent, blood flow to active muscle during exercise in the heat does not appear to be compromised (Nielsen *et al*. 1990;

Savard *et al.* 1988). However, blood flow to internal organs like the liver is attenuated during exercise in the heat (Rowell 1974; Rowell *et al.* 1968), and it has been proposed that this could slow the clearance of metabolites such as glycerol (Irondelle *et al*. 1977) and lactate (Yaspelis *et al*.1993). In agreement, Rowell *et al.* (1968) have shown that during exercise to exhaustion in the heat, lactate clearance by the liver is reduced by 42%, which the authors hypothesized was due to hepatic-splanchnic hypoxia.

Catecholamines

Compared to comfortable temperatures, levels of circulating catecholamines are increased during exercise in the heat (Febbraio *et al.* 1994*b;* Hargreaves *et al*. 1996; Powers *et al*.1982) and during passive heating (Powers *et al*. 1982). Catecholamines influence energy substrate availability by stimulating lipolysis, muscle and liver glycogenolysis, and lactate production (Brooks *et al.* 2005). This has led several authors to speculate that increased levels of catecholamines play a role in many of the metabolic changes observed in the heat both during exercise (Febbraio *et al*. 1994b; Hargreaves *et al.* 1996; Morris *et al*. 2005; Yaspelis *et al.* 1993;) and at rest (Eddy *et al.* 1976). Several authors have observed a relationship between catecholamine levels and increases in glycogen use. During exercise in the heat, there is a positive correlation between glycogen use and circulating EPI (Morris *et al*. 2005). In addition, when participants are acclimatized to heat over a period of seven days, the increase in catecholamines is attenuated, as is the higher reliance on carbohydrate metabolism usually observed during exercise in the heat (Febbraio *et al*. 1994*b*).

Elevated muscle temperature

In addition to increasing T_{core}, heat stress also results in increased muscle temperature (Febbraio *et al.* 1994*b;* Parkin *et al.* 1999). Several authors have proposed a direct role of muscle temperature in heat-induced alterations in metabolism (Febbraio *et al.* 1996*b*; Parkin *et al.* 1999; Starkie *et al.*1999; Young *et al.* 1985). This idea is supported by authors who found increases in glycogen use when skeletal muscle is heated directly prior to or during exercise. When one thigh muscle is heated before and during exercise in neutral ambient temperatures, muscle glycogen use in the heated thigh is higher compared to the unheated leg (Starkie *et al.* 1999). This observation was made without any differences in intramuscular ATP, leading the authors to speculate that high muscle temperature directly effects muscle glycogen use. Heating the thigh muscle before two intense cycling trials increased muscle glycogen use and lactate accumulation, despite a lack of change in rectal temperature or plasma catecholamines (Febbraio *et al.* 1996*a*).

The exact mechanism by which elevated muscle temperature influences metabolism is unknown. Authors have proposed that the increase in temperature alters the activity of important enzymes involved in CHO metabolism, through the Q_{10} effect (Young *et al.* 1985). However, others have calculated that the Q_{10} value associated with enzyme reactions (2.0-3.0) is too low to fully account for the increase in muscle glycogen use observed in the heat (Febbraio *et al.* 1994*b*). Authors have also proposed a role of reduced mitochondrial function (Febbraio *et al.* 1994*a*; Parkin *et al.* 1999; Starkie *et al*. 1999) based in part on research by Brooks, Hittleman, Faulkner & Beyer (1971). Brooks and co-workers examined the ratio between ADP production and mitochondrial VO_2 in isolated skeletal muscle over a wide range of muscle temperatures. They found that the ratio is held constant until muscle temperature reaches 40°C, after which point the ratio declines linearly with further increases in temperature. At this time, the mechanisms responsible for the changes in metabolism observed during heat stress are not fully understood. Reductions in hepatic blood flow, catecholamines, and direct muscle temperature likely all contribute in some way.

SUMMARY

Heat stress, both at rest and during exercise, has many effects on the human body. Cardiovascular and respiratory function, blood flow, aerobic capacity, circulating hormone levels and neuromuscular function are all influenced by heat exposure. During exercise in the heat, the resulting changes in these areas significantly reduce performance and work capacity. In addition, energy metabolism is altered in the heat. The limited research available suggests that plasma lipids are affected by heat exposure at rest and during exercise recovery. In addition, heat stress increases the level of circulating hormones known to regulate lipolysis. Given the importance of lipids as an energy source, a better understanding of how high environmental temperatures influence lipid metabolism is required.

REFERENCES

Angus, DJ, Febbraio, MA, Lasini, D & Hargreaves, M (2001). Effect of carbohydrate ingestion on glucose kinetics during exercise in the heat. *J Appl Physiol* 90, 601-605.

Arngrimsson, SÁ, Stewart, DJ, Borrani, F, Skinner, KA & Cureton, KJ (2003). Relation of heart rate to percent VO_{2peak} during submaximal exercise in the heat. *J Appl Physiol* 94, 1162-1168.

Arngrimsson, SÁ, Petitt, DS, Borrani, F, Skinner, KA & Cureton, KJ (2004). Hyperthermia and maximal oxygen uptake in men and women. *Eur J Appl Physiol* 92, 524-532.

Boyd, AE, Giamber, SR, Mager, M & Lebovitz, HE (1974). Lactate inhibition of lipolysis in exercising man. *Metabolis* 23(6), 531-542.

Brooks, GA, Hittleman, KJ, Faulkner, JA & Beyer, RE (1971). Temperature, skeletal muscle mitochondrial functions and oxygen debt. *Am J Physiol* 220, 1053-1059.

Brooks, GA, Fahey, TD & Baldwin, KM (2005). *Exercise physiology: Human bioenergetics and its applications*. The McGraw-Hill Companies, New York, NY.

Byrne, C, Lee, JKW, Chew, SAN, Lim, CL, Tan, EYM (2006). Continuous thermoregulatory responses to mass-participation distance running in heat. *Med Sci Sports Exerc* 38(5), 803-810.

Cabanac, M & White, MD (1995). Core temperature thresholds for hyperpnea during passive hyperthermia. *Eur J Appl Physiol* 71, 71-76.

Carlson, MG, Snead, WL, Hill, JO, Nurjhan, N & Campbell, PJ (1991). Glucose regulation of lipid metabolism in humans. *Am Journal Physiol Endocrinol* Metab 261, E815-E820.

Cheung, SS & McLellan, TM (1998). Influence of hydration status and fluid replacement on heat tolerance while wearing NBC protective clothing. *Eur J Appl Physiol* 77, 139-148.

Cheuvront, SN, Kenefick, RW, Montain, SJ & Sawka, MN (2010). Mechanisms of aerobic performance impairment with heat stress and dehydration. *J Appl Physiol* 109, 1989-1995.

de Barros, CLM, Mendes, TT, Mortimer, ACF, Simões, HG, Prado, LS &Wisloff, U (2011). Maximal lactate steady state is altered in the heat. *Int J Sports Med* 32, 749-753.

Dimri, GP, Malhotra, MS, Gupta, JS, Kumar, TS, &Arora, BS (1980). Alterations in aerobic-anaerobic proportions of metabolism during work in heat. *Eur J Appl Physiol* 45, 43-50.

Dolny, DG & Lemon, PWR (1988). Effect of ambient temperature on protein breakdown during prolonged exercise. *J Appl Physiol* 64(2), 550-555.

Eddy, DO, Sparks, KE & Turner, CL (1976). The adipokinetic effect of hyperthermic stress in man. *Eur J Appl Physiol* 35, 103-110.

Ely, BR, Ely, MR, Cheuvront, SN, Kenefick, RW, DeGroot, DW & Montain, SJ (2009). Evidence against a 40°C core temperature threshold for fatigue in humans. *J Appl Physiol* 107, 1519-1525.

Fanger, P.O. (1970). Thermal comfort. *Danish Technical Press*. Copenhagen.

Febbraio, MA, Snow, RJ, Stathis, CG, Hargreaves, M & Carey, MF (1994*a*). Effect of heat stress on muscle energy metabolism during exercise. *J Appl Physiol* 77(6), 2827-2831.

Febbraio, MA, Snow, RJ, Hargreaves, M, Stathis, CG, Martin, IK & Carey, MF (1994*b*). Muscle metabolism during exercise and heat stress in trained men: effect of acclimation. *J Appl Physiol* 76(2), 589-597.

Febbraio, MA, Carey, MF, Snow, RJ, Stathis, CG & Hargreaves, M (1996*a*). Influence of elevated muscle temperature on metabolism during intense, dynamic exercise. *Am J Physiol Regul Intergr Comp Physiol* 271, R1251-R1255.

Febbraio, MA, Murton, P, Selig, SE, Clark, SA, Lambert, DL, Angus, DJ & Carey, MF (1996*b*). Effect of CHO ingestion on exercise metabolism and performance in different ambient temperatures. *Med Sci Sports Exerc* 28(11), 1380-1387.

Febbraio, MA, Lambert, DL, Starkie, RL, Proietto, J & Hargreaves, M (1998). Effect of epinephrine on muscle glycogenolysis during exercise in trained men. *J Appl Physiol* 84, 465-470.

Febbraio, MA (2000). Does muscle function and metabolism affect exercise performance in the heat? *Exerc Sport Sci Rev* 28(4), 171-176.

Fink, WJ, Costill, DL & Van Handel, PJ (1975). Leg muscle metabolism during exercise in the heat and cold. *Eur J Appl Physiol* 34, 183-190.

Ftaiti, F, Jemni, M, Kacem, A, Zaouali, MA, Tabka, Z, Zbidi, A & Grélot, L (2008). Effect of hyperthermia and physical activity on circulating growth hormone. *Appl Physiol Nutr Metab* 33, 880-887.

Fujii, N, Honda, Y, Hayashi, K, Soya, H, Kondo, N & Nishiyasu, T (2008). Comparison of hyperthermic hyperpnea elicited during rest and submaximal, moderate-intensity exercise. *J Appl Physiol* 104, 998-1005.

Galloway, SDR & Maughan, RJ (1997). Effects of ambient temperature on the capacity to perform prolonged cycle exercise in man. *Med Sci Sports Exerc* 29(9), 1240-1249.

Galster, AD, Clutter, WE, Cryer, PE, Collins, JA & Bier, DM (1981), Plasma thresholds for lipolytic effects in man: Measurements of fatty acid transport with [1-^{13}C] palmitic acid. *J Clin Invest* 67, 1729-1738.

Ganio, MS, Brothers, RM, Shibata, S, Hastings, JL & Crandall, CG (2011). Effect of passive heat stress on arterial stiffness. *Exp Physiol* 96(9), 919-926.

González-Alonso, J, Mora-Rodriguez, R, Below, PR & Coyle EF (1997). Dehydration markedly impairs cardiovascular function in hyperthermic endurance athletes during exercise. *J Appl Physiol* 82, 1229-1236.

González-Alonso, J, Teller, C, Andersen, SL, Jensen, FB, Hyldig, T & Nielsen, B (1999). Influence of body temperature on the development of fatigue during prolonged exercise in the heat. *J Appl Physiol* 86, 1032-1039.

Gorman, AJ & Proppe, DW (1984). Mechanisms producing tachycardia in conscious baboons during environmental heat stress. *J Appl Physiol Respir Environ Exercise Physiol* 56(2), 441-446.

Green, HJ, Houston, ME & Thomson, JA (1979). Metabolic consequences of supramaximal arm work performed during prolonged submaximal leg work. *J Appl Physiol Respir Environ Exercise Physiol* 46 (2), 249-255.

Gregson, WA, Drust, B, Batterham, A & Cable, NT (2002). The effects of pre-warming on the metabolic and thermoregulatory responses to prolonged submaximal exercise in moderate ambient temperatures. *Eur J Appl Physiol* 86, 526-533.

Groop, LC, Saloranta, C, Shank, M, Bonadonna, RC, Ferrannini, E & DeFronzo, RA (1991). The role of free fatty acid metabolism in the pathogenesis of insulin resistance in obesity and noninsulin-dependent diabetes mellitus. *J Clin Endocrinol Metab* 71(1), 96-107.

Hargreaves, M, Angus, D, Howlett, K, Conus, NM & Febbraio, M (1996). Effect of heat stress on glucose kinetics during exercise. *J Appl Physiol* 81, 1594-1597.

Hayashi, K, Honda, Y, Ogawa, T, Kondo, N & Nishiyasu, T (2006). Relationship between ventilator response and body temperature during prolonged submaximal exercise. *J Appl Physiol* 100, 414-420.

Hettinga, FJ, De Koning, JJ, de Vrijer, A, Wüst, RCI, Daanen, HAM & Foster, C (2007). The effect of ambient temperature on gross-efficiency in cycling. *Eur J Appl Physiol* 101, 465-471.

Iguchi, M, Littmann, AE, Chang, SH, Wester, LA, Knipper, JS & Shields, RK (2012). Heat stress and cardiovascular, hormonal, and heat shock proteins in humans. *J Athl Train* 47(2), 184-190.

Irondelle, M & Freund, H (1976). Carbohydrate and fat metabolism of unacclimatized men during and after submaximal exercise in cool and hot environments. *Eur J Appl Physiol* 37, 27-38.

Issekutz, B Jr., Shaw, WA & Issekutz, TB (1975). Effect of lactate on FFA and glycerol turnover in resting and exercising dogs. *J Appl Physiol* 39, 349-353.

Jentjens, RLPG, Wagenmakers, AJM & Jeukendrup, AE (2002). Heat stress increases muscle glycogen use but reduces the oxidation of ingested carbohydrates during exercise. *J Appl Physiol* 92, 1562-1572.

Jeukendrup, AE (2003). Modulation of carbohydrate and fat utilization by diet, exercise and environment. *Biochem Soc T* 31(6), 1270-1273.

Ježová, D, Kvetňanský, R & Vigaš, M (1994). Sex differences in endocrine response to hyperthermia in sauna. *Acta Physiol Scand* 150, 293-298.

Kamon, E & Belding, HS (1971). Heart rate and rectal temperature relationships during work in hot humid environments. *J Appl Physiol* 31(3), 472-477.

Kamon, E (1972). Relationship of physiological strain to change in heart rate during work in the heat. *Am Ind Hyg Assoc* 33, 701-708.

Kenefick, RW, Cheuvront, SN, Palombo, LJ, Ely, BR & Sawka, MN (2010). Skin temperature modifies the impact of hypohydration on aerobic performance. *J Appl Physiol* 109, 79-86.

Klein, RF, Estes, EH Jr., Bogdonoff, MD (1961). Effect of norepinephrine on plasma free fatty acids level in man. *J Appl Physiol* 16, 342-344.

Lafrenz, AJ, Wingo, JE, Ganio, MS & Cureton, KJ (2008). Effect of ambient temperature on cardiovascular drift and maximal oxygen uptake. *Med Sci Sports Exerc* 40(6), 1065-1071.

Leppäluoto, J, Huttunen, P, Hirvonen, J & Väänänen, A (1986). Endocrine effects of repeated sauna bathing. *Acta Physiol Scand* 128, 467-470.

MacDougall, J.D., Reddan, W.G., Layton, C.R. & Dempsey, J.A. (1974).Effects of metabolic hyperthermia on performance during heavy prolonged exercise. *J Appl Physiol* 36(5), 538-544.

Marino, FE, Mbambo, Z, Kortekaas, E, Wilson, G, Lambert, MI, Noakes, TD & Dennis, SC (2001). Influence of ambient temperature on plasma ammonia and lactate accumulation during prolonged submaximal and self-paced running. *Eur J Appl Physiol* 86, 71-78.

Maughan, RJ, Otani, H & Watson, P (2012). Influence of relative humidity on prolonged exercise capacity in a warm environment. *Eur J Appl Physiol* 112, 2313-2321.

McLellan, TM, Jacobs, I & Bain, JB (1993). Influence of temperature and metabolic rate on work performance with Canadian Forces NBC clothing. *Aviat Space Environ Med* 64(7), 587-594.

Morris, JG, Nevill, ME, Boobis, LH, Macdonald, IA & Williams, C (2005). Muscle metabolism, temperature, and function during prolonged, intermittent, high-intensity running in air temperatures of 33° and 17°C. *Int J Sports Med* 26, 805-814.

Nielsen, B, Savard, G, Richter, EA, Hargreaves, M & Saltin, B (1990). Muscle blood flow and muscle metabolism during exercise and heat stress. *J Appl Physiol* 69(3), 1040-1046.

Nielsen, B, Hales, JRS, Strange, S, Christensen, NJ, Warberg, J & Saltin, B (1993). Human circulatory and thermoregulatory adaptations with heat acclimation and exercise in a hot, dry environment. *J Physiol* 460, 467-485.

Nielsen, B, Hyldig, T, Bidstrup, F, González-Alonso, J, Christoffersen, GRJ (2001). Brain activity and fatigue during prolonged exercise in the heat. *Eur J Physiol* 442, 41-48.

Niimi, Y, Matsukawa, T, Sugiyama, Y, Shamsuzzaman, ASM, Ito, H, Sobue, G, & Mano, T (1997). Effect of heat stress on muscle sympathetic nerve activity in humans. *J Auton Nerv Syst* 63, 61-67.

Nybo, L & Nielsen, B (2001). Perceived exertion is associated with an altered brain activity during exercise with progressive hyperthermia. *J Appl Physiol* 91, 2017-2023.

Nybo, L, Jensen, T, Nielsen, B & González-Alonso, J (2001). Effects of marked hyperthermia with and without dehydration on VO_2 kinetics during intense exercise. *J Appl Physiol* 90, 1057-1064.

Nybo, L, Secher, NH, & Nielsen, B (2002). Inadequate heat release from the human brain during prolonged exercise with hyperthermia. *J Appl Physiol* 545(2), 697-704.

Parkin, JM, Carey, MF, Zhao, S & Febbraio, MA (1999). Effect of ambient temperature on human skeletal muscle metabolism during fatiguing submaximal exercise. *J Appl Physiol* 86(3), 902-908.

Périard, JD, Cramer, MN, Chapman, PG, Caillaud, C & Thompson, MW (2010). Cardiovascular strain impairs prolonged self-paced exercise in the heat. *Exp Physiol*, 96(2), 134-144.

Périard, JD, Caillaud, C & Thompson, MW (2011). Central and peripheral fatigue during passive and exercise-induced hyperthermia. *Med Sci Sports Exerc* 43(9), 1657-1665.

Pirnay, F, Deroanne, R & Petit, JM (1970). Maximal oxygen consumption in a hot environment. *J Appl Physiol* 28(5), 642-645.

Powers, SK, Howley, ET & Cox, R (1982). A differential catecholamine response during prolonged exercise and passive heating. *Med Sci Sports Exerc* 14(6), 435-439.

Racinais, S & Girard, O (2012). Neuromuscular failure is unlikely to explain the early exercise cessation in hot ambient conditions. *Psychophysiology* 49, 853-865.

Rowell, LB, Marx, HJ, Bruce, RA, Conn, RD & Kusumi, F (1966). Reductions in cardiac output, central blood volume and stroke volume with thermal stress in normal men during exercise. *J Clin Invest* 45(11) 1801-1816.

Rowell, LB, Brengelmann, GL, Blackmon, JR, Twiss, RD, Kusumi, F (1968). Splanchnic blood flow and metabolism in heat stressed man. *J Appl Physiol* 24, 475-484.

Rowell, LB, Brengelmann, GL & Murray, JA (1969). Cardiovascular responses to sustained high skin temperature in resting man. *J Appl Physiol* 27, 673-680.

Rowell, LB (1974). Human cardiovascular adjustments to exercise and thermal stress. *Physiol Rev* 54(1), 75-158.

Saltin, B, Gagge, P, Bergh, U & Stolwijk, JAJ (1972). Body temperatures and sweating during exhaustive exercise. *J Appl Physiol* 32(5), 635-643.

Sancheti, A & White, MD (2006). Reproducibility of relationships between human ventilation, its components, and oesophageal temperature during incremental exercise. *Eur J Appl Physiol* 96, 495-504.

Savard, GK, Nielsen, B, Laszczynska, J, Larsen, BE & Saltin, B (1988). Muscle blood flow is not reduced in humans during moderate exercise and heat stress. *J Appl Physiol* 64(2), 649-657.

Sawka, MN, Young, AJ, Latzka, WA, Neufer, PD, Quigley, MD & Pandolf, KB (1992). Human tolerance to heat strain during exercise: influence of hydration. *J Appl Physiol* 73(1), 368-375.

Sawka, MN, Young, AJ, Cadarette, BS, Levine, L & Pandolf, KB (1985). Influence of heat stress and acclimation on maximal aerobic power. *Eur J Appl Physiol* 53, 294-298.

Saxton, C (1981). Effects of severe heat stress on respiration and metabolic rate in resting man. *Aviat Space and Environ Med* 52(5), 281-286.

Schlader, ZJ, Raman, A, Morton, RH, Stannard, SR & Mündel, T (2011). Exercise modality modulates body temperature regulation during exercise in uncompensable heat stress. *Eur J Appl Physiol* 111, 757-766.

Smolander, J, Kolari, P, Korhonen, O & Ilmarinen, R (1986). Aerobic and anaerobic responses to incremental exercise in a thermoneutral and a hot dry environment. *Acta Phsyiol Scand* 128, 15-21.

Snow, RJ, Febbraio, MA, Carey, MF & Hargreaves, M (1993). Heat stress increases ammonia accumulation during exercise in humans. *Exp Physiol* 78, 847-850.

Starkie, RL, Hargreaves, M, Lambert, DL, Proietto, J & Febbraio, MA (1999). Effect of temperature on muscle metabolism during submaximal exercise in humans. *Exp Physiol* 84, 775-784.

Trinity, JD, Pahnke, MD, Lee, JF & Coyle, EF (2010). Interaction of hyperthermia and heart rate on stroke volume during prolonged exercise. *J Appl Physiol* 109, 745-751.

Tsuji, B, Honda, Y, Fujii, N, Kondo, N & Nishiyasu, T (2012). Effect of initial core temperature on hyperthermic hyperventilation during prolonged submaximal exercise in the heat. *Am J Physiol Regul Integr Comp Physiol* 302, R94-R102.

Tucker, R, Rauch, L, Harley, YXR, & Noakes, TD (2004). Impaired exercise performance in the heat is associated with an anticipatory reduction in skeletal muscle recruitment. *Eur J Appl Physiol* 448, 422-430.

Vangelova, K, Deyanov, C, Ivanova, M (2006). Dyslipidemia in industrial workers in hot environments. *Cent Eur J Publ Health* 14(1), 15-17.

Wells, CL & Paolone, AM (1977). Metabolic responses to exercise in three thermal environments. *Aviat Space Environ Med* 48(10), 989-993.

White, MD & Cabanac, M (1996). Exercise hyperpnea and hyperthermia in humans. *J Appl Physiol* 81(3), 1249-1254.

Williams, CG, Bredell, AG, Wyndham, CH, Strydom, NB, Morrison, JF, Peter, J, Fleming, PW & Ward, JS (1962). Circulatory and metabolic reactions to work in the heat. *J Appl Physiol* 17, 625-638.

Wingo, JE, Lafrenz, AJ, Ganio, MS, Edwards, GL, Cureton, KJ (2005). Cardiovascular drift is related to reduced maximal oxygen uptake during heat stress. *Med Sci Sports Exerc* 37(2), 248-255.

Wood, LG, Scott, HA, Garg, ML & Gibson, PG (2009). Innate immune mechanisms linking non-esterified fatty acids and respiratory disease. *Prog Lipid Res* 48, 27-43.

Yamamoto, H, Zheng, K & Ariizumi, M (2003). Influence of heat exposure on serum lipid and lipoprotein cholesterol in young male subjects. *Ind Health* 41, 1-7.

Yaspelis III, BB, Scroop, GC, Wilmore, KM & Ivy, JL (1993). Carbohydrate metabolism during exercise in hot and thermoneutral environments. *Int J Sports Med* 14(1), 13-19.

Young, AJ, Sawka, MN, Levine, L, Cadarette, BS & Pandolf, KB (1985). Skeletal muscle metabolism during exercise is influenced by heat acclimation. *J Appl Physiol* 59, 1929-1935.

Yusuf, S, Hawken, S, Ôunpuu, S, Dans, T, Avezum, A, Lanas, F, McQueen, M, Budaj, A, Pais, P, Varigos, & Lisheng, L (2004). Effect of potentially modifiable risk factors associated with myocardial infraction in 52 countries (the INTERHEART study): case-control study. *Lancet* 364, 937-952.

GOALS OF THE INVESTIGATION

Investigating the effects of heat stress at rest and during exercise on lipid metabolism and on exercise performance is the main purpose of this thesis. More precisely, this study seeks to accomplish two objectives: (i) quantify changes in whole-body lipid metabolism and plasma lipids during passive heat exposure and subsequent exercise in the heat, and (ii) to determine the reduction in work capacity during exercise in the heat subsequent to an extended passive pre-heating period. While previous studies have generally focused on alterations in carbohydrate metabolism during exercise in the heat, available research into the effects of heat stress on lipid metabolism during exercise or in resting conditions is very limited. Lipids are the most abundant energy source in the human body. Despite this, changes in lipid metabolism in hyperthermic conditions have generally been ignored.

To achieve the thesis objective, a study was designed: (i) to quantify changes in whole-body lipid metabolism and plasma lipids during passive heat exposure and subsequent exercise in the heat, and (ii) to determine the reduction in total external work performed during exercise in the heat following passive heat exposure. The following findings are presented: (i) plasma NEFA concentrations are higher following passive heat exposure and exercise in the heat compared to neutral ambient temperatures without significant changes in whole-body lipid utilization, and (ii) thermal stress achieved during passive pre-heating and subsequent exercise in the heat significantly reduce external work and increases the perceived intensity of a given workload. In this study, whole-body lipid utilization was measured by indirect calorimetry. Plasma samples were used to determine changes in plasma lipids. Participants exercised for 30 min or until exhaustion, and the amount of external work performed was calculated to quantify work capacity. Interpretation of the results and the possible mechanisms for higher NEFA concentrations in the heat and lower work capacity are discussed.

CHAPTER 2: ALTERATIONS IN LIPID METABOLISM DURING PASSIVE HEAT EXPOSURE AND IN PERFORMANCE DURING SUBSEQUENT EXERCISE IN THE HEAT

Based in part on

Katharine O’Hearn & François Haman

ABSTRACT

The study sought to examine: (i) the effects of heat exposure on lipid metabolism during passive heating and subsequent exercise in the heat by focusing on changes in whole-body lipid utilization and plasma lipids, and (ii) the effects of extended passive pre-heating on exercise performance in the heat. Male participants (n = 8) were passively heated for 120 min at 42°C, then exercised on a treadmill in the heat at 50% VO_{2peak} for 30 min (HEAT). This same procedure was followed on a separate occasion at 23°C (CON). Results showed that whole-body lipid utilization rates were not different between HEAT and CON during passive heating or during exercise. At rest, non-esterified fatty acid (NEFA) concentrations were significantly higher following passive heating (618 ± 59 µM) compared to CON (391 ± 51 µM). The same trend was observed following exercise (2036 ± 183 µM and 1351 ± 147 µM for HEAT and CON respectively). Triacylglycerol, phospholipid and cholesterol levels were not different between HEAT and CON at rest or during exercise. Four of 8 participants were unable to complete 30 min of exercise in HEAT, resulting in a 13% decline in total external work. Rate of perceived exertion over the final 5 min of exercise was higher in HEAT (10, or maximal) than CON (5, or hard). We conclude that: (i) heat exposure results in higher circulating NEFA both at rest and during exercise without significant changes in whole-body lipid utilization, and (ii) passive pre-heating reduces work capacity during subsequent exercise in the heat and increases the perceived intensity of a given workload.

Keywords: non-esterified fatty acids, hyperthermia, lipid metabolism, work capacity

Abbreviations: NEFA, non-esterified fatty acid; PL, phospholipid; R_a, rate of appearance; R_d, rate of disappearance; TG, triacylglycerol

INTRODUCTION

Extreme heat, heavy clothing (McLellan, Jacobs, & Bain 1993) and high humidity (Maughan, Otani & Watson 2012) create an environment of uncompensable heat stress that limits the amount of heat that can be lost through evaporation. As a result, core temperature will increase, leading to alterations in energy metabolism (Febbraio, Snow, Stathis, Hargreaves & Carey 1994*a*; Fink, Costill & Van Handel 1975; Hargreaves, Angus, Howlett, Conus & Febbraio 1996; Jentjens , Wagenmakers & Jeukendrup 2001; Starkie, Hargreaves, Lambert, Proietto & Febbraio 1999) and a decrease in exercise performance (Arngrimsson, Petitt, Borrani, Skinner & Cureton 2004; Gregson, Drust, Batterham & Cable 2002; MacDougall, Reddan, Layton & Dempsey 1974; Morris, Nevill, Boobis, Macdonald & Williams 2005).

Previous research investigating heat-induced changes in metabolism has mostly focused on changes occurring during exercise, specifically with regards to carbohydrate (CHO) metabolism. As a result, very little is known about the effects of heat stress on lipid metabolism during exercise or at rest. To date, lipid oxidation has not been quantified during passive heat exposure. However, there is evidence that lipid metabolism is altered, as two authors have reported a higher concentration of circulating non-esterified fatty acids (NEFA) following passive heat stress compared to baseline values (Eddy, Sparks & Turner 1976) or thermoneutral conditions (Yamamoto, Zheng & Ariizumi 2003). Plasma concentrations, however, do not give the whole picture, as they only represent the balance between the rate of appearance (R_a) of NEFA to the blood (i.e. lipolysis), and the rate of disappearance (R_d; i.e. disposal). Since the R_a and R_d of NEFA have never been quantified during passive heat exposure, it is impossible to know which is affected by heat stress. However, hormones that play an important role in lipolysis – catecholamines (Ježová, Kvetňanský & Vigaš 1994; Powers, Howley & Cox 1982) and growth hormone (Ftaiti, Jemni, Kacem, Zaouali, Tabka, Zbidi & Grélot 2008; Leppäluoto, Huttunen, Hirvonen, Väänänen, Tuominen & Vuori 1986) – are increased following passive heat exposure and could contribute to an increase in R_a.

Researchers generally agree that, compared to neutral temperatures, exercise in the heat results in an increased reliance on CHO oxidation based on repeated observations of accelerated muscle glycogen utilization (Febbraio *et al.*1994*a*; Fink *et al.* 1975; Jentjens *et al.* 2001; Starkie *et al.*1999), higher concentrations of plasma and muscle lactate (Dolny & Lemon 1988; Febbraio *et al.* 1994*a*; Fink *et al.* 1975; Hargreaves *et al.* 1996), and a higher RER (Dolny & Lemon 1988; Febbraio *et al.* 1994*a*; Hargreaves *et al.*1996; Young, Sawka, Levine, Cadarette & Pandolf 1985). And although CHO metabolism in the heat is fairly well understood, carbohydrates only represent 2-8% of endogenously stored energy. Lipids, on the other hand, account for 92-98% (Jeukendrup 2003), yet far less information is available on alterations in lipid utilization and circulating lipids during exercise in the heat.

It has been reported that intramuscular triglyceride (IMTG) use is reduced during exercise in the heat (Fink *et al.* 1975). However, these observations were based on muscle biopsies from only 4 participants. Since heat exposure (40°C) was compared to cold exposure (9°), it cannot be assumed that the same reduction in IMTG use would be observed when comparing hot to thermoneutral temperatures. NEFA concentrations following exercise in the heat have generally not been different than control temperatures (Fink *et al.* 1975; Gregson *et al.* 2002; Jentjens *et al.* 2002; Nielsen, Savard, Richter, Hargreaves & Saltin 1990) although they do appear to be increased during exercise recovery in the heat (Irondelle & Freund 1976).

Similar to passive heating, exercise in the heat elevates circulating growth hormone (Ftaiti *et al.* 2008; Hargreaves *et al.* 1996) and catecholamines (Febbraio, Snow, Hargreaves, Stathis, Martin & Carey 1994b; Hargreaves *et al.* 1996; Powers *et al.* 1982), hormones shown to accelerate lipolysis (Brooks, Fahey & Baldwin 2005; Galster, Clutter, Cryer, Collins & Bier 1981; Klein, Estes & Bogdonoff 1961). At the same time, however, exercise in the heat results in higher plasma concentrations of lactate (Dolny & Lemon 1988; Fink *et al.* 1975; Hargreaves *et al.* 1996) and glucose (Febbraio *et al.* 1994*b;* Hargreaves *et al.* 1996), both of which have been shown to inhibit lipolysis (Boyd, Giamber, Mager & Lebovitz 1974; Carlson, Snead, Hill, Nurjhan & Campbell 1991; Green, Houston & Thomson 1979; Issekutz, Shaw & Issekutz 1975). Given the importance of lipids to energy metabolism, and how little is known about the effects of heat stress on lipid metabolism, more research in this area is required.

In addition to altering metabolism, heat stress results in decreases in exercise performance (Arngrimsson *et al*. 2004; MacDougall *et al*. 1974; Morris *et al.* 2005). Passive or active heating prior to exercise also shortens exercise tolerance time, even when exercise is performed in thermoneutral conditions. Although passive and active pre-heating were both shown to reduce performance, alterations in exercise metabolism (elevated plasma glucose and lactate) were only observed following passive heating (Gregson *et al.* 2002). The pre-heating period in this study was relatively short (29.6 ± 5.3 min). Since heat has been shown to affect metabolism (Febbraio *et al*. 1994*a*, 1994*b*; Jentjens *et al*. 2002; Hargreaves *et al*. 1996; Starkie *et al*. 1999), cardiovascular function (Périard, Cramer, Chapman, Caillaud & Thompson 2010), circulating hormones (Ftiati *et al.* 2008; Powers *et al.* 1982), and neuromuscular function (Périard, Caillaud, & Thompson 2011), it follows that a longer pre-heating period would intensify the metabolic and physiological changes induced by hyperthermia. As a result, it is likely we would observe altered substrate availability and fuel selection during exercise after extended passive heat exposure, and a greater decline in performance.

The main goals of this study were to determine the effects of heat exposure on changes in lipid metabolism, and to determine the effects of passive pre-heating on exercise performance in the heat. Specifically, (i) changes in heat production as well as total lipid, CHO and protein oxidation, (ii) changes in circulating plasma NEFA, TG, phospholipid (PL) and cholesterol, (iii) decline in external work, and (iv) changes in rate of perceived exertion were quantified in unacclimatized adult men during 120 min rest and 30 min exercise. These experiments were conducted in an environmental chamber at 23°C (CON) and 42° (HEAT).

It was firstly expected that heat stress would alter lipid metabolism. As a result it was hypothesized that:

(i) H_1: During passive heat stress the contribution of lipids would increase and the contribution of carbohydrates will decrease compared to CON, and that this pattern will be reversed during exercise

H_0: During passive heat stress and exercise in the heat, the contributions of lipids and carbohydrates will be unchanged and will not differ between HEAT and CON

(ii) H_1: Total plasma NEFA concentrations will be higher following passive heat exposure and exercise in the heat compared to CON.

H_0: Total plasma NEFA concentrations will not be different between HEAT and CON

Secondly, it was expected that the level of heat stress achieved during passive pre-heating and exercise in the heat would reduce work capacity. Specifically, it was hypothesized that:

(i) H_1: The amount of total external work performed will be significantly lower during exercise in the heat compared to CON

H_0: The amount of external work performed will not be different between HEAT and CON

(ii) H_1: The rate of perceived exertion will be higher in HEAT that CON for the same absolute workload.

H_0: The rate of perceived exertion will not be different between HEAT and CON

.

METHODS AND MATERIALS

Subjects

Eight healthy, non-heat acclimatized active males volunteered for this study, which conformed to the standards set by the latest revision of the Declaration of Helsinki and was approved by the Health Sciences Ethics Committee of the University of Ottawa. Written informed consent was obtained from all participants. Exclusion criteria were as follows: heat acclimatized (e.g. outdoor workers), smokers, and/or physically active less than 3 days/week. Anthropometric measurements (height, weight, percent body fat) and maximal oxygen consumption (Bruce Ramp treadmill protocol) were obtained prior to the first experimental session (Table 2.1).

Experimental Protocol

Each subject participated in two experimental trials, separated by at least 7 days. The trials consisted of a 90 min baseline period in ambient temperatures, followed by 120 min passive rest and 30 min exercise at 50% VO_{2max} at either 42°C (HEAT) or 23°C (CON). The order of the trials was randomly assigned in a balanced, cross-over design.

Experiments were conducted between 8h00 and 13h00. Participants were asked to refrain from consuming caffeine or alcohol for 12h, and to avoid heavy physical activity for 48h prior to the experiments. The last evening meal was standardized (~ 900 kcal, ~51% CHO, ~27% lipids, ~22% proteins). Participants were instructed to drink at least 1 litre of water the evening before the trial, and to continue drinking water the morning of the trial to ensure they were hydrated prior to the start of heat exposure. Participants reported to the laboratory at 8h00 after a 12-14h fast. Care was taken to minimize thermal stresses between awakening and the start of the experiment (avoiding exposure to heat or cold, only very low-intensity exercise when travelling from home to the laboratory).

Upon arrival at the laboratory, participants were instrumented with skin temperature transducers, esophageal probe and heart rate monitor while wearing shorts and a t-shirt. Afterwards, participants were asked to void their bladder, and nude weight was recorded. Participants then sat quietly for 90 min at ambient temperature (23.8 ± 0.5°C, 35.5 ± 3.6 % RH) for baseline measurements. At the end of the baseline period, participants again voided their bladder and were transferred to a thermal chamber (t = 0) for 120 min passive sitting at either 42 ± 0.3 °C, 24.1 ± 2.8 % RH (HEAT) or at 23.2 ± 0.4 °C, 34.8 ± 5 % RH (CON). During HEAT, participants also donned a sauna suit with elastic waist, wrists, neck and ankles (Training Sauna Suit, TKO Sports Group, Houston, TX, USA) to minimize evaporative heat loss. Throughout the passive period, participants consumed 1.5 litres of water to replenish fluids lost through sweating. Heart rate and thermal response were measured throughout the passive and baseline periods. Metabolic data and ventilation were measured every 30 min. Blood samples were drawn prior to (Baseline), midway (T_{60}) and after (T_{120}) the passive period to obtain information on changes in concentrations of NEFA, TG, phospholipids and cholesterol. After 120 min, participants removed the sauna suit and toweled off, then exited the thermal chamber for a maximum of 5 min while nude weight was recorded. Participants then returned to the thermal chamber and walked on a treadmill for 30 min or until exhaustion. Speed was set at 3.5 miles per hour and the treadmill incline was adjusted to a pre-determined level equivalent to 50% of the participant’s VO_{2peak}. Metabolic data, heart rate, thermal response and ventilation were recorded throughout the exercise period and a 10-point category scale (Borg 1982) was used every 5 min to determine the participants' rating of perceived exertion. At the end of exercise, nude weight was again recorded and a final blood sample was drawn.

Thermal Response

Changes in heat production ($\dot{H}$) were calculated by indirect calorimetry and corrected for protein oxidation (see below). Esophageal (T_{es}) and mean skin temperature (T_{skin}) were monitored continuously throughout the baseline period and experimental trial using a pediatric probe (Mon-a-therm general purpose, Mallinckrodt Medical Inc., St. Louis, MO, USA) and skin temperature transducers from 12 sites weighed in the following proportions: forehead 7%, chest 9.5%, biceps 9%, forearm 7%, abdomen 9.5%, lower back 9.5%, upper back 9.5%, front calf 8.5%, back calf 7.5%, hamstrings 9.5% and hand 4% (Hardy & Dubois 1938). The esophageal probe was inserted through the nose and the tip of the thermocouple placed at the level of the left atrium, or to a depth of one-quarter the standing height of the subject (Mekjavic & Rempel 1990).

Cardiorespiratory response

Heart rate (HR) was measured using a Polar heart rate monitor (Polar FS2C Fitness Heart Rate Monitor System, Polar USA, Lake Success, NY, USA) and was recorded every 5 min during the baseline and passive periods, and every 1 min during exercise. Ventilation was measured using an automated metabolic cart (MOXUS, Applied Electrochemistry Inc., Pittsburgh, PA, USA) and expressed in STPD. Measurements were taken every 30 min during the baseline and passive periods and continuously during exercise.

Measurement of heat production and fuel utilization

Oxygen consumption (VO_2) and carbon dioxide production (VCO_2) were measured using the MOXUS automated metabolic cart and expressed in STPD. Total protein (RP_{ox}), carbohydrate (RG_{ox}), and lipid (RF_{ox}) oxidation rates (in g min^{-1}) were calculated as described previously by Haman *et al.* (2002, 2004):

$$RP_{ox}\ (g\ min^{-1}) = 2.9 \times UREA_{urine}\ (g\ min^{-1}) \quad (1)$$

$$RG_{ox}\ (g\ min^{-1}) = 4.59\ VCO_2\ (l\ min^{-1}) - 3.23\ VO_2\ (l\ min^{-1}) \quad (2)$$

$$RF_{ox}\ (g\ min^{-1}) = -1.70\ VCO_2\ (l\ min^{-1}) + 1.70\ VO_2\ (l\ min^{-1}) \quad (3)$$

where VCO_2 (l min^{-1}) and VO_2 (l min^{-1}) were corrected for the volumes of O_2 and CO_2 corresponding to protein oxidation (1.010 and 0.843 g $l^{-1,}$ respectively). RP_{ox} was estimated from urinary urea excretion ($UREA_{urine}$) in urine collected for 90 min during the baseline period and this value was used for the duration of the trial. Urine urea concentration was determined using a commercial urine assay kit (BioAssay Systems, CA, USA). Energy potentials of 16.3 kJg-1 (CHO), 40.8 kJg-1 (lipids), and 19.7 kJg-1 (proteins) were used to calculate the relative contributions of each fuel to total heat production (Elia 1991; Péronnet & Massicotte 1991). Area under the curve (AUC) was used to calculate total oxidation of CHO, lipids and proteins using middle Riemann sum

$$AUC\ Fuel_{ox} = \Sigma\ Fuel_{ox}\ [(y_1 - y_i)/2 \times Dt] \quad (4)$$

where $Fuel_{ox}$ represents the oxidation of CHO, lipids or proteins in mg·min^{-1}, and Dt is the time interval of 30 min. Total fuel oxidation is presented as a function of time to give the rate of utilization.

Measurement of NEFA, TG and PL concentrations

Blood samples were collected in sodium EDTA tubes at T_0, T_{60}, T_{120} and post exercise. Upon collection, blood samples were placed on ice and spun in a centrifuge. Plasma was separated and stored at -80°C until analyzed. Plasma NEFA, TG, PL and cholesterol concentrations were assessed using commercially available enzymatic assay reagents from Wako Diagnostics (Wako Chemicals, Richmond, VA, USA).

Statistical analysis

T_{skin}, T_{es}, HR, VO_2, VE, $\dot{H}$, fuel oxidation and circulating lipids were analyzed using a two-way repeated measure ANOVA to assess changes across conditions and over time (SPSS version 15.0). Significant differences were followed up by Bonferroni Post-Hoc tests. Absolute protein oxidation, quantified only during the baseline period, was analyzed using a paired T-test. The threshold for significance was set at $p<0.05$. All values are presented as mean ± standard error of the mean (SEM). A more detailed explanation of the statistical analysis performed, along with outputs from SPSS, can be found in Appendix A.

RESULTS

Thermal Response.

Changes in T_{es}, T_{skin} and $\dot{H}$ measured during baseline, passive heating and exercise are presented in Figure 2.1. T_{skin} was similar between conditions at baseline (32.6 ± 0.1°C for HEAT and 32.7 ± 0.2°C for CON) then increased during passive for HEAT and was significantly higher than CON from 30 min (35.9 ± 0.1 vs. 32.1 ± 0.2°C) to the end of passive heating (36.1 ± 0.1 vs. 32.3 ± 0.2°C; $p < 0.01$). T_{skin} increased during exercise for both conditions and was significantly higher in HEAT (37.1 ± 0.2°C) than CON (33.7 ± 0.1°C) at termination of exercise ($p < 0.01$). T_{es} was not different between conditions at baseline (36.7 ± 0.0°C for HEAT and 36.7 ± 0.0°C for CON) and for the first 60 min of passive heat exposure. T_{es} increased for HEAT over the last 60 min of passive and was significantly higher than CON at 90 min (37.3 ± 0.1 vs. 36.7 ± 0.1°C) and at 120 min (37.5 ± 0.1 vs. 36.7 ± 0.1°C; $p < 0.05$). During exercise, T_{es} increased for both conditions and was significant higher for HEAT (39.0 ± 0.2°) than CON (37.6 ± 0.1°) at termination of exercise ($p < 0.01$). $\dot{H}_{prod}$ was not different between conditions during baseline or passive ($p = 0.433$). $\dot{H}_{prod}$ increased during exercise to from 6.2 ± 0.2 kJ/min (HEAT) and 5.7 ± 0.2 kJ/min (CON) at the end of the passive period to 59.4 ± 2.9 kJ/min (HEAT) and 56.5 ± 2.5 kJ/min (CON) at the termination of exercise with no difference between conditions ($p = 0.08$).

Cardiorespiratory Response.

Changes in VE and HR are presented in Figure 2.2. HR was similar between conditions at baseline (67.5 ± 4.7 bpm for HEAT and 69.0 ± 5.9 bpm for CON) then increased for HEAT and was significantly higher than CON from 30 min (73.9 ± 5.5 vs. 65.1

± 6.4 bpm) until the end of the passive period (83.4 ± 5.3 vs. 65.3 ± 6.5 bpm). HR increased during exercise in both conditions, and was significantly higher in HEAT (181 ± 1 bpm) than CON (161 ± 3) at the termination of exercise ($p < 0.01$).VE was not different between conditions at baseline (7.9 ± 0.3 for HEAT and 8.3 ± 0.19 for CON) and for the first 90 min of passive. Over the last 30 min of passive, VE increased for HEAT and was significantly higher than CON at 120 min (9.1 ± 0.3 vs. 8.5 ± 0.3 l/min; $p < 0.05$). VE also increased throughout exercise for both HEAT and CON, and was significantly higher for HEAT (69.8 ± 5.7 l/min) than for CON (56.5 ± 1.8 l/min) at the termination of exercise ($p < 0.05$).

Changes in Weight

Changes in body mass are present in Table 2.2. Body mass was significantly lower after exercise compared to baseline values ($p < 0.05$) with reductions of 1.0 ± 0.3% for HEAT and 0.6 ± 0.1% for CON. However, there were no significant differences between conditions ($p = 0.239$).

Time to Exhaustion and Rate of Perceived Exertion.

Changes in work and perceived exertion are presented in Figure 2.3. Heat exposure resulted in a significant decrease in external work from 262 ± 8 kJ for CON to 228 ± 16 kJ for HEAT ($p < 0.05$). Four participants were unable to complete 30 min of exercise in HEAT. As a result, mean exercise duration was lower for HEAT (26 ± 1.5 min) than CON (30.0 ± 0 min) although this difference did not reach statistical significance ($p = 0.054$). At termination of exercise, rate of perceived exertion was significantly higher for HEAT (10 ± 0.2) than for CON (5 ± 0.3) ($p < 0.01$).

Fuel Selection.

The degree of thermal stress, combined with exercise, caused two participants to hyperventilate frequently during exercise and made fuel oxidation calculations for these participants impossible. Therefore, the results presented for fuel selection are based on six participants only. Changes in absolute rates of CHO and lipid oxidation are presented in Figure 2.4. Rates of CHO ($p = 0.240$) and lipid ($p = 0.846$) oxidation were not different between conditions. Absolute rates of CHO oxidation were 90.0 ± 17.6 and 100.8 ± 17.7 mg/min during baseline, and 126.5 ± 15.5 and 96.5 ± 17.2 mg/min during passive, and absolute rates of lipid oxidation were 76.2 ± 9.6 and 70.5 ± 6.6 mg/min at baseline and 66.0 ± 7.3 and 69.2 ± 6.9 mg/min during passive for HEAT and CON respectively. CHO oxidation increased during exercise for both HEAT (2572.6 ± 133.8 mg/min) and CON (2392 ± 118.0 mg/min). Lipid oxidation increased during exercise for both HEAT (244.4 ± 30.6mg/min) and CON (267.9 ± 41.3 mg/min). Absolute protein oxidation measured following the baseline period was similar between conditions (68.1 ± 6.3 mg/min for HEAT and 71.4 ± 4.4 mg/min for CON; $p = 0.549$).

Changes in relative contributions of CHO, lipids and proteins to total $\dot{H}_{prod}$ are presented in Figure 2.5. There was no effect of condition for CHO ($p = 0.984$) or lipids ($p = 0.777$). Values for relative CHO oxidation were 25.1 ± 5.0% and 27.8 ± 4.7% during baseline; and 33.9 ± 4.3% and 27.2 ± 4.6% during passive for HEAT and CON respectively. Contributions of CHO increased during exercise for both HEAT (78.8 ± 2.2%) and for CON (75.8 ± 2.8%). Lipids contributed 51.9 ± 5.4% and 48.3 ± 3.6% during baseline and 43.9 ± 4.3% and 48.5 ± 3.8% during passive for HEAT and for CON. Relative contribution of lipids decreased during exercise to 18.6 ± 2.0% for both HEAT and 20.9 ± 2.7% for CON. Protein contributions were not different between conditions ($p = 0.569$). Heat production and absolute and relative fuel oxidation are summarized in Table 2.2.

Plasma Lipids.

Changes in plasma concentrations of NEFA, TG, PL and cholesterol are presented in Table 2.3. NEFA concentrations were not different between HEAT and CON at baseline or midway through passive heating (T_{60}), but increased over time for HEAT and were significantly higher than CON at the end of passive heating (618 ± 59 and 391 ± 51 µM) and at the termination of exercise (2036 ± 183 and 1351 ± 147 µM; $p < 0.05$). TG ($p = 0.877$), PL ($p = 0.694$) and cholesterol ($p = 0.401$) concentrations were not different between conditions.

Table 2.1. Physical characteristics of subjects (n=8)

Age (years)	25	± 1
Body mass (kg)	76.2	± 2.2
Height (cm)	181	± 2
Body surface area (m^2)	2.0	± 0
Percent body fat (%)*	12	± 1
VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$)†	56	± 2

*Underwater weighing (Brosek, Grande, Andersen & Keys 1963)

† Bruce Ramp treadmill protocol

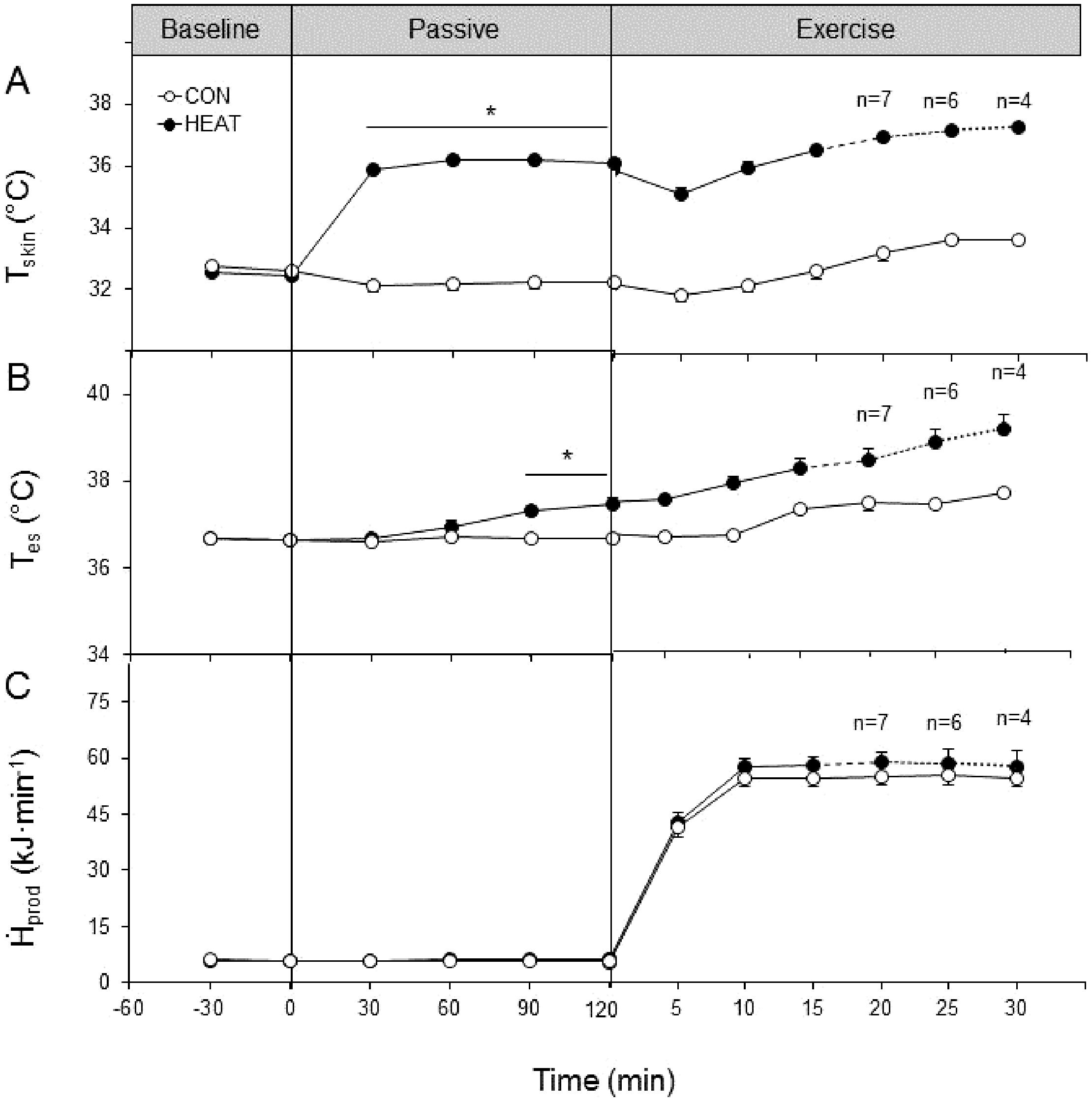

Figure 2.1. Changes in mean skin (T_{skin}) (A) and esophageal temperatures (T_{es}) (bB) as well as rates of heat production ($\dot{H}_{prod}$) (C) measured in men during passive heat exposure and subsequent exercise in the heat (●) compared to control (○).

*Significantly higher than CON, $p < 0.05$.

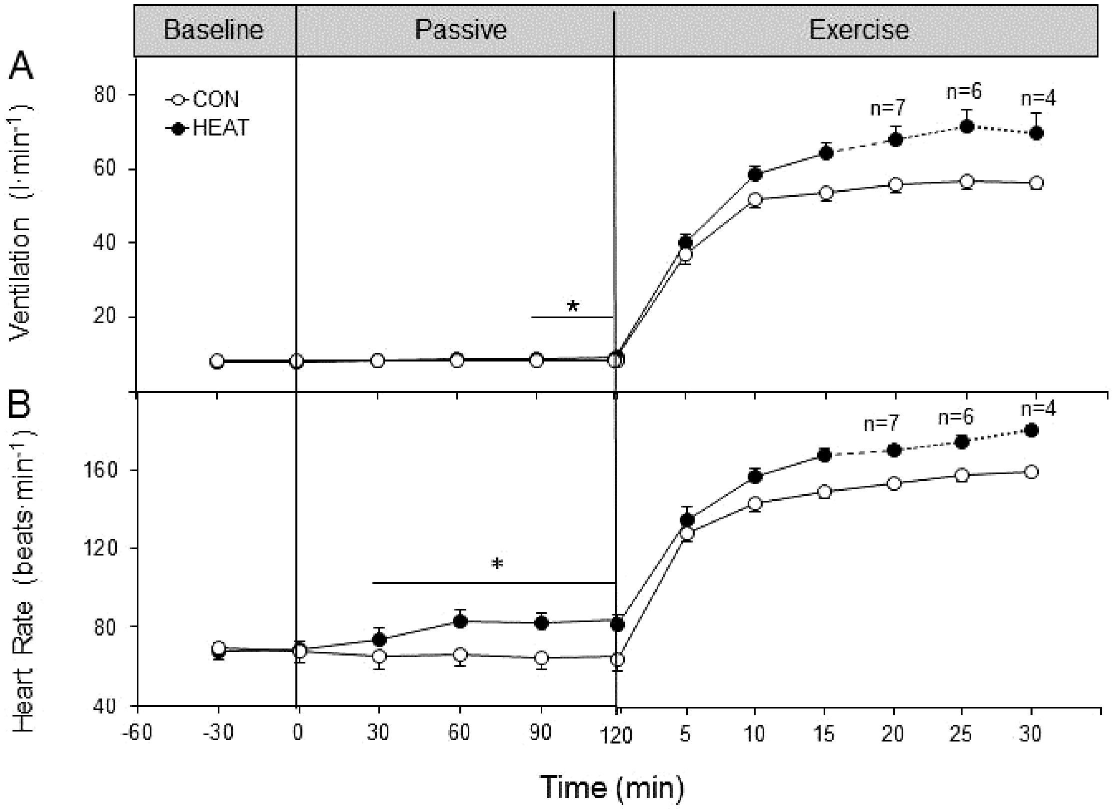

Figure 2.2. Changes in heart rate (A) and ventilation (B) measured in men during passive heat exposure and subsequent exercise in the heat (●) compared to control (○). *Significantly higher than CON, $p < 0.05$.

Table 2.2. Changes in body mass (kilograms) at before (Baseline), following passive heat exposure (End of Passive), and after exercise in the heat (Post Exercise) compared to control (CON).

	CON	HEAT
Baseline	76.8 ± 2.7	76.4 ± 2.7
End of Passive	76.8 ± 2.7	76.2 ± 2.6
Post Exercise	76.2 ± 2.7*	75.7 ± 2.6*

*Significantly lower than baseline value, ($p < 0.05$)

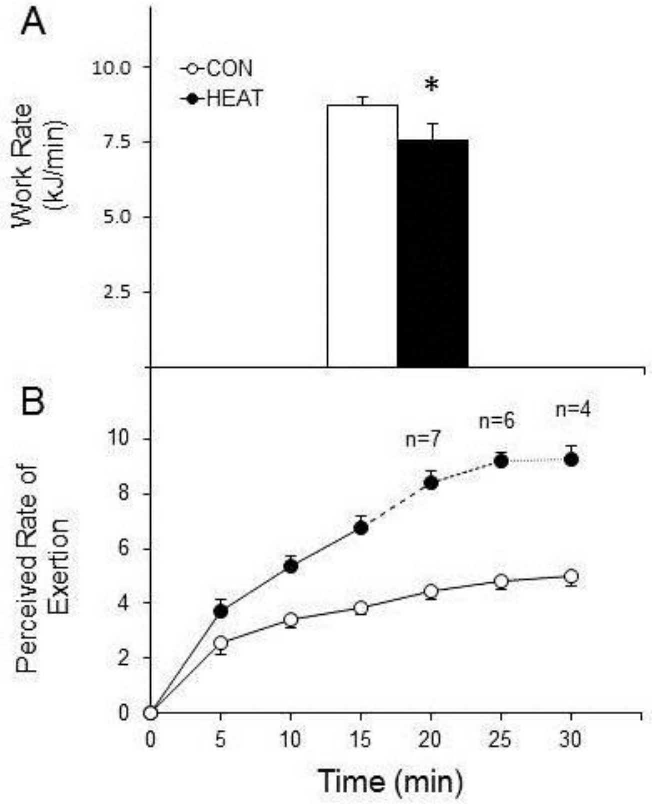

Figure 2.3. Total external work (A) and rate of perceived exertion (B) for 8 men walking on a treadmill at 50% VO_{2peak} in the heat (●) and in control (○).

*Significantly lower than CON, $p < 0.05$.

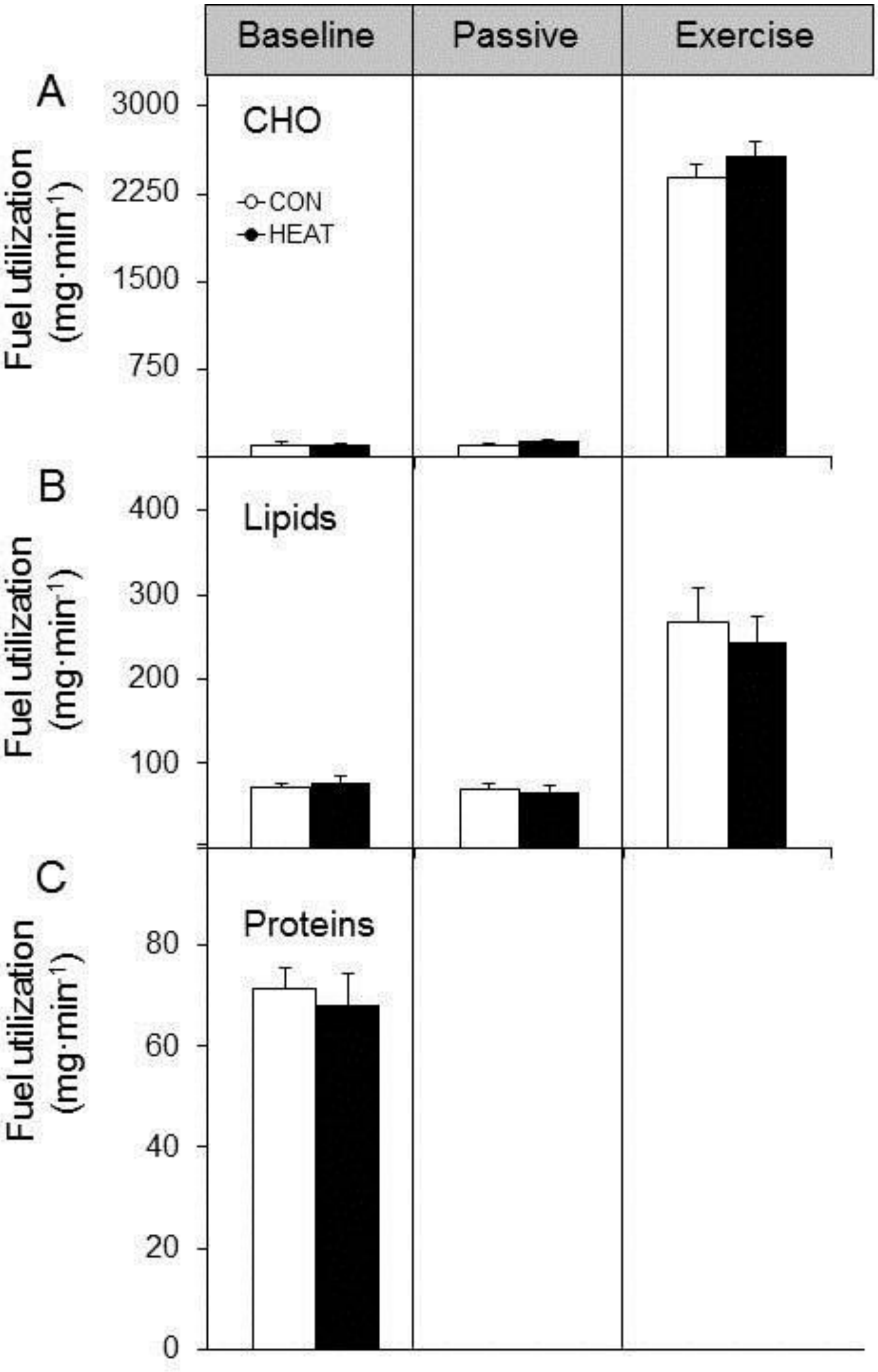

Figure2.4. Changes in absolute rates of CHO (A), lipid (B), and protein oxidation (C) measured in men during passive heat exposure and subsequent exercise in the heat (●) compared to control (○).

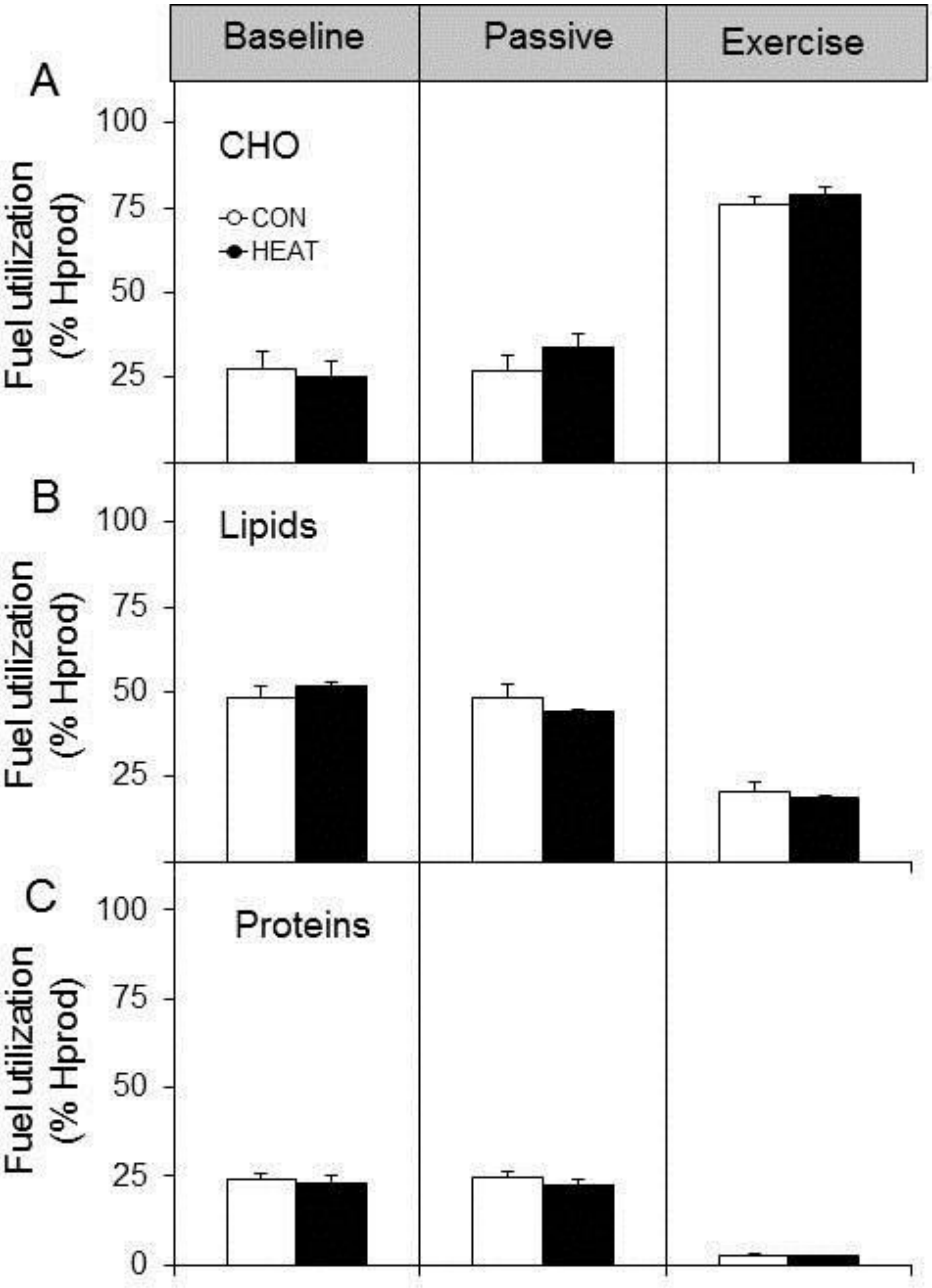

Figure2.5. Changes in the relative contribution of CHO (A), lipid (B) and protein oxidation (C) to total heat production measured in men during passive heat exposure and subsequent exercise in the heat (●) compared to control (○).

Table 2.3. Absolute oxidation rates and relative contributions of lipids, carbohydrates and proteins to total heat production before heat exposure (23°C), during passive heat exposure (42°C) and during exercise in the heat (42°C) compared to control (CON; 23°C).

	CON			HEAT		
	Baseline 23°C	Passive 23°C	Exercise 23°C	Baseline 23°C	Passive 42°C	Exercise 42°C
$\dot{H}_{prod}$						
kJ/min	5.9 ± 0.2	5.8 ± 0.2	51.6 ± 2.4	5.9 ± 0.2	6.1 ± 0.2	53.3 ± 2.5
Lipids						
mg/min	70.5 ± 6.6	69.2 ± 6.9	268 ± 41	76.2 ± 9.6	66.0 ± 7.3	244 ± 31
$\%\dot{H}_{prod}$	48.3 ± 3.6	48.5 ± 3.8	20.9 ± 2.7	51.9 ± 5.4	43.9 ± 4.3	18.6 ± 2.0
CHO						
mg/min	101 ± 18	96.5 ± 17.2	2393 ± 118	90.0 ± 17.6	127 ± 16	2573 ± 134
$\%\dot{H}_{prod}$	27.8 ± 4.7	27.2 ± 4.6	75.8 ± 2.5	25.1 ± 5.0	33.9 ± 4.3	78.8 ± 2.2
Proteins						
mg/min	71.4 ± 4.4			68.1 ± 6.3		
$\%\dot{H}_{prod}$	23.9 ± 1.6	24.4 ± 1.6	2.8 ± 0.2	23.1 ± 2.4	22.2 ± 2.2	2.6 ± 0.3

Values are means ± SE; n=8 subjects (baseline and passive), n = 6 subjects (exercise). $\dot{H}_{prod}$, total heat production.

Table 2.4. Plasma NEFA, TG, PL and cholesterol concentrations before (Baseline), during (T_{60}), and after (T_{120}) passive heat exposure and after exercise in the heat (Post Ex) compared to control (CON).

	CON				HEAT			
	Baseline T_0	Passive T_{60}	Passive T_{120}	Post Ex	Baseline T_0	Passive T_{60}	Passive T_{120}	Post Ex
NEFA (μM)	277 ± 35	426 ± 31	391 ± 51	1351 ± 147	420 ± 77	598 ± 73	618 ± 59*	2036 ± 183*
TG (μM)	777 ± 146	739 ± 130	759 ± 166	719 ± 145	773 ± 155	746 ± 162	783 ± 177	745 ± 171
PL (g/L)	1.48 ± 0.1	1.52 ± 0.0	1.62 ± 0.1	1.60 ± 0.1	1.54 ± 0.1	1.45 ± 0.1	1.57 ± 0.1	1.59 ± 0.1
Cholesterol (μM)	4241 ± 241	3987 ± 309	3949 ± 335	4332 ± 349	4024 ± 350	3854 ± 276	3743 ± 233	4207 ± 255

*Significantly higher than CON, $p < 0.05$.

DISCUSSION

This study quantifies alterations in whole-body lipid utilization and circulating plasma lipids during passive heat exposure and subsequent exercise in the heat. It shows that, following passive heat exposure, circulating NEFA concentrations are higher ~37% compared to thermoneutral temperatures. The same pattern is observed following exercise, with a ~34% higher NEFA concentration in the heat compared to control (Table 2.3). At the same time, whole-body lipid utilization is unchanged (Figure 2.4, Figure 2.5, Table 2.2). The increase in NEFA concentrations following passive heating is consistent with observations made by previous researchers (Eddy *et al.* 1976; Yamamoto *et al.* 2003) who found similar concentrations following exposure to heat at rest. In contrast with our results, researchers who have quantified alterations in NEFA concentrations following exercise in the heat have not found significant differences compared to thermoneutral temperatures (Fink *et al.* 1975; Gregson *et al.* 2002; Jentjens *et al.* 2002; Nielson *et al.* 1990). An examination of the methodology used in these studies could explain the discrepancy with our results.

The exercise intensity employed by Fink *et al.* (1975) and Gregson *et al.* (2002) was considerably higher than that used in our study (70-85% VO_{2max} vs.50% VO_{2max}). Plasma NEFA turnover is reduced at higher exercise intensities. R_a of plasma NEFA has been shown to be inversely related to exercise intensity, and does not increase above resting values at intensities of 85% VO_{2max} despite simulation of lipolysis (Romijn, Coyle, Sidossis, Gastaldelli, Horowitz, Endert & Wolfe 1993). In addition, muscle glycogen becomes the most important substrate at higher exercise intensities (Romijn *et al.* 1993; van Loon, Greenhaff, Constantin-Teodosiu, Saris & Wagenmakers 2001) resulting in a greater production of lactate. Lactate accumulation is repeatedly observed to be even greater when exercise of the same intensity is performed in the heat as opposed to comfortable temperatures (Dolny & Lemon 1988; Febbraio *et al.* 1994*b*; Fink *et al*. 1975; Hargreaves *et al*.1996; Morris *et al*. 2005; Jentjens *et al*. 2001; Young *et al.* 1985). Lactate has been shown by several authors to inhibit lipolysis (Boyd *et al*. 1974; Green *et al.* 1979; Issekutz *et al.* 1975). Therefore, at the exercise intensities used by Fink *et al*. and Gregson *et al*., the greater reliance on carbohydrate metabolism and higher lactate concentration, which was even higher with heat stress, could have attenuated an increase in plasma NEFA in the heat.

Although Jentjens and co-workers (2001) used a similar exercise intensity of 55% maximum power output, participants in this study consumed an 8% glucose solution prior to and every 15 min during exercise. Consumption of carbohydrates prior to exercise is known to inhibit fat oxidation and lipolysis (Coyle, Jeukendrup, Wagenmakers & Saris 1997) and could have counteracted the effects of heat stress on plasma lipid alterations. Finally, Nielsen *et al*. (1990) used a counterbalanced study design where exercise started in neutral temperature for the first 30 min, then continued in heat for an additional 60 min. Exercise metabolism changes with increasing duration (Ahlborg, Felig, Hagenfeldt, Hendler & Wahren 1974). Therefore, it is difficult to draw conclusions about metabolism from this study since exercise in the heat was not compared to a true control condition. The present study is unique in that an extended passive pre-heating period was employed prior to exercise in the heat. The degree of heat stress during passive heating resulted in elevated NEFA concentrations. As a result NEFA concentrations were already higher in HEAT prior to starting exercise.

Contrary to our hypothesis, fuel selection was not affected by heat stress at rest or during exercise. Although there was a trend towards an increase in CHO oxidation during exercise in the heat, this did not reach statistical significance. The exercise duration in this study was relatively short, so it could be that if exercise had continued beyond 30 minutes, the increase in CHO oxidation would have become more distinct. We had expected to see an increase in lipid oxidation during passive heat to match the increase in plasma NEFA, but this was not the case. This is intriguing, because increases in plasma NEFA concentrations are usually matched by an increase in lipid oxidation and a decrease in glucose uptake and oxidation (Ferrannini, Barrett, Bevilacqua & DeFronzo 1983; Groop, Bonadonna, Shank, Petrides & DeFronzo 1991; Johnson, Argyraki, Thow, Cooper, Fulcher & Taylor 1992).

Although the exact mechanism behind the elevation in NEFA concentrations in the heat is unclear, a number of mechanisms could be proposed. Plasma concentrations represent the balance between R_a and R_d, thus any factor that increases or decreases R_a or R_d can alter the concentrations. NEFA taken up from the plasma can either be oxidized or re-esterified back into TG (Jensen 2003). Based on previous research, and results from this study, whole-body lipid oxidation is not increased during heat stress, and may even be reduced (Febbraio 2000; Fink *et al*. 1975). If lipid oxidation is reduced in the heat, this could contribute in part to greater NEFA concentrations, but a reduction in lipid oxidation remains to be definitively shown. Although circulating NEFA are the main energy source for lipid oxidation, IMTG can also contribute, particularly in trained subjects (Brooks *et al.* 2005) and at higher exercise intensities (Romijn *et al.* 1993). The indirect calorimetry used in this study measures whole-body lipid oxidation, and does not distinguish between oxidation of NEFA or IMTG. It is therefore not known if the relative proportions of these fuel sources are affected by heat stress. There is evidence that IMTG use is reduced in the heat compared to cooler temperatures (9°) (Fink *et al*. 1975), but whether this also holds true when heat is compared to ambient temperatures is unknown. The effects of heat exposure on NEFA re-esterification have not been previously determined. As a result, it is unknown if this process is altered in the heat.

If R_d is unchanged during heat stress, an increased R_a would be required to explain the elevated NEFA concentrations observed in this study. The large majority of circulating NEFA comes from lipolysis in adipose tissue (Jensen 2003). Catecholamines are important regulators of lipolysis. Although not measured in this study, several authors have confirmed higher circulating levels of both catecholamines following passive heat exposure (Iguchi, Littman, Chang, Wester, Knipper & Shields 2012; Powers *et al*. 1982) and exercise in the heat (Febbraio *et al*. 1994b; Hargreaves *et al*. 1996; Powers *et al*. 1982). An increase in catecholamines could be responsible for the higher NEFA concentrations via an increase in R_a. During rest, a small infusion of epinephrine, 3-fold above resting values, has been show to increase plasma NEFA (Galster *et al.* 1981). An infusion of norepinephrine at rest will also increase lipolysis (Klein *et al.* 1961) but, compared to epinephrine, a much greater infusion is required before lipolysis is increased (Galster *et al*. 1981). Taken together, these findings indicate that catecholamines could explain the increase in NEFA concentrations observed in this study during passive heat exposure. However, the same may not hold true for exercise. When epinephrine is infused during exercise at 20°C to replicate the increases in epinephrine observed during exercise at 40°C, glycogenolysis, lactate accumulation, glycolysis and heart rate are accelerated, mimicking the physiological changes observed during exercise in the heat. Circulating NEFA, on the other hand, remain unchanged (Febbraio, Lambert, Starkie, Proietto & Hargreaves 1998). So while it appears that epinephrine can explain the increased reliance on CHO metabolism during exercise in the heat, it may not explain the alterations in plasma NEFA observed in this study.

It could be suggested that altered patterns of blood flow contributed to the higher NEFA concentrations observed in the heat. If blood flow to skeletal muscle was attenuated during exercise due to an increased blood flow to the skin to dissipate heat, NEFA delivery to skeletal muscle could be compromised. However, this does not appear to be the case, because unless dehydration is also present, blood flow to skeletal muscle is not reduced (Nielsen *et al*. 1990; Savard, Nielsen, Laszczynska, Larsen & Saltin 1988). Although body mass in the current study was lower following exercise, the reduction was small ~0.6 - 1.0%, and was observed in both HEAT and CON. Therefore, it is unlikely that skeletal muscle blood flow was affected. Visceral blood flow, on the other hand, is reduced during exercise in the heat (Rowell 1974; Rowell, Brengelmann, Blackmon, Twiss & Kusumi 1968). A reduction in blood flow could attenuate NEFA disposal by the splanchnic bed. However, during exercise, splanchnic disposal of NEFA represents a relatively small proportion (<20%) of total NEFA uptake (Ahlborg *et al*.1974).

The most likely explanation is that passive heat stress increased NEFA concentrations through the actions of elevated catecholamines, and the higher NEFA levels at the end of passive heat exposure were maintained during exercise in the heat, resulting in greater concentrations at termination of exercise in the heat compared to control.

Hyperthermia and Exercise Performance

The second objective of this study was to quantify the effects of passive heat stress on subsequent exercise performance in the heat. Passive heat exposure resulted in thermal and physiological stress, as evidenced by increases in T_{skin} (~3.6°C), T_{es} (~0.8°C), ventilation (~1.2 $l \cdot min^{-1}$) and heart rate (~15 bpm). The degree of hyperthermia achieved during passive heat exposure, in addition to the heat stress during exercise, resulted in a reduction in work capacity of 13%. While all subjects were able to easily complete the exercise portion in CON, only 4 of 8 participants were able to tolerate 30 min of exercise in HEAT. These findings are in agreement with other authors who have observed shorter work durations during fixed-intensity exercise in hyperthermic conditions (Gregson *et al.* 2002; McDougall *et al.* 1974; Morris *et al*. 2005).

The increase in core temperature during exercise was nearly 2-fold greater in the heat. Among the four participants who were unable to complete 30 min of exercise in the heat, T_{es} at exhaustion ranged from 38.5 to 39.3°C. This is slightly lower than core temperatures (39.7°C, 40°C) previously associated with a critical performance limiting threshold (González-Alonso, Teller, Andersen, Jensen, Hyldig & Nielsen 1999; Nielsen, Hales, Strange, Christensen, Warberg & Saltin 1993). The remaining four participants who were able to complete 30 min of exercise in the heat exhibited similar core temperatures (38.2 to 39.5°C) over the final 5 min of exercise. T_{skin} was 9% higher at exercise termination in the heat. It has been proposed that high T_{skin} (defined as >35°C), alone or in conjunction with a high core temperature, diminishes aerobic performance by decreasing VO_{2max}, thus increasing the relative intensity of exercise at a given work load (Cheuvront, Kenefick, Montain & Sawka 2010). Rating of perceived exertion (RPE) from participants in this study indicated that the same workload felt much harder in the heat. While RPE over the final 5 min of exercise in CON was rated as 5, or Hard, RPE in the final 5 min of exercise in the heat was rated as 10, or Maximal. It could be that the reduction in performance and increased perception of effort observed in this study are due, at least in part, to the combination of an elevated T_{es} and T_{skin}.

Cardiovascular strain is also a contributing factor in reduced performance under hyperthermic conditions (Périard *et al.* 2010). Heart rate was 20 beats per minute higher at termination of exercise in the heat compared to control. The elevated HR observed during exercise in the heat is typically found in conjunction with reductions in cardiac output and stroke volume (Périard *et al.* 2010). Together, these alterations in cardiovascular function are proposed as factors leading to a decrease in decrease VO_{2max} (Wingo, Lafrenz, Ganio, Edwards & Cureton, 2005), which increases the relative intensity of exercise and diminishes exercise tolerance time in the heat. It is possible that, in addition to high T_{es} and T_{skin}, impairment in cardiovascular function also contributed to the reduction in performance and increased ratings of exertion observed during this study.

In summary, this study shows that plasma NEFA concentrations are elevated by heat exposure, both at rest and during exercise. At the same time, whole-body lipid oxidation is unchanged. In addition, passive heat stress combined with heat exposure during exercise reduces work capacity and increases the perceived exertion associated with a given exercise intensity. Future research should focus on quantifying the R_a and R_d of plasma NEFA during heat stress and on determining the mechanisms responsible for the changes observed.

ACKNOWLEDGMENTS

The authors would like to acknowledge the contribution and assistance provided by Denis Blondin, Jean-François Mauger and Bernard Pinet. We would also like to thank the participants for their collaboration. A special thanks to Elizabeth Lavoie and Mathieu Lebreton for their assistance with blood sampling. This work was funded by grants from the Natural Sciences and Engineering Research Council of Canada (NSERC Canada) to F. Haman, and a scholarship from the Canadian Institutes of Health Research (CIHR) to K. O’Hearn as well as from the Ontario Graduate Scholarship (OGS).

REFERENCES

Ahlborg, G, Felig, P, Hagenfeldt, L, Hendler, R & Wahren, J (1974). Substrate turnover during prolonged exercise in man: Splanchnic and leg metabolism of glucose, free fatty acids, and amino acids. *J Clin Invest* 53, 1080-1090.

Arngrimsson, SÁ, Petitt, DS, Borrani, F, Skinner, KA &Cureton, KJ (2004). Hyperthermia and maximal oxygen uptake in men and women. *Eur J Appl Physiol* 92, 524-532.

Boyd, AE, Giamber, SR, Mager, M & Lebovitz, HE (1974). Lactate inhibition of lipolysis in exercising man. *Metabolis* 23(6), 531-542.

Borg G (1982). Psychophysical bases of perceived exertion. *Med Sci Sports Exerc* 14(5), 377-381.

Brooks, GA, Fahey, TD & Baldwin, KM (2005). *Exercise physiology: Human bioenergetics and its applications*. The McGraw-Hill Companies, New York, NY.

Brosek, JF, Grande, JT, Andersen, JT & Keys, A (1963). Densitometry analysis of body composition: review of some quantitative assumptions. *Ann N Y Acad Sci* 110, 113-140.

Carlson, MG, Snead, WL, Hill, JO, Nurjhan, N & Campbell, PJ (1991). Glucose regulation of lipid metabolism in humans. *Am Journal Physiol Endocrinol* Metab 261, E815-E820.

Cheuvront, SN, Kenefick, RW, Montain, SJ & Sawka, MN (2010). Mechanisms of aerobic performance impairment with heat stress and dehydration. *J Appl Physiol* 109, 1989-1995.

Coyle, EF, Jeukendrup, AE, Wagenmakers, AJ & Saris, WH (1997). Fatty acid oxidation is directly regulated by carbohydrate metabolism during exercise. *Am J Physiol Endocrinol Metab* 273, E268-E275.

Dolny, DG & Lemon, PWR (1988). Effect of ambient temperature on protein breakdown during prolonged exercise. *J Appl Physiol* 64(2), 550-555.

Eddy, DO, Sparks, KE & Turner, CL (1976). The adipokinetic effect of hyperthermic stress in man. *Eur J Appl Physiol* 35, 103-110.

Elia, M (1991). Energy equivalents of CO_2 and their importance in assessing energy expenditure when using tracer techniques. *Am J Physiol Endocrinol Metab* 260, E75-E88.

Febbraio, MA, Snow, RJ, Stathis, CG, Hargreaves, M & Carey, MF (1994*a*). Effect of heat stress on muscle energy metabolism during exercise. *J Appl Physiol* 77(6), 2827-2831.

Febbraio, MA, Snow, RJ, Hargreaves, M, Stathis, CG, Martin, IK & Carey, MF (1994*b*). Muscle metabolism during exercise and heat stress in trained men: effect of acclimation. *J Appl Physiol* 76(2), 589-597.

Febbraio, MA, Lambert, DL, Starkie, RL, Proietto, J & Hargreaves, M (1998). Effect of epinephrine on muscle glycogenolysis during exercise in trained men. *J Appl Physiol* 84, 465-470.

Febbraio, MA (2000). Does muscle function and metabolism affect exercise performance in the heat? *Exerc Sport Sci Rev* 28(4), 171-176.

Ferrannini, E, Barrett, EJ, Bevilacqua, S & DeFronza, RA (1983). Effect of fatty acids on glucose production and utilization in man. *J Clin Invest* 72, 1737-1747.

Fink, WJ, Costill, DL & Van Handel, PJ (1975). Leg muscle metabolism during exercise in the heat and cold. *Eur J Appl Physiol* 34, 183-190.

Ftaiti, F, Jemni, M, Kacem, A, Zaouali, MA, Tabka, Z, Zbidi, A & Grélot, L (2008). Effect of hyperthermia and physical activity on circulating growth hormone. *Appl Physiol Nutr Metab* 33, 880-887.

Galster, AD, Clutter, WE, Cryer, PE, Collins, JA & Bier, DM (1981). Plasma thresholds for lipolytic effects in man: Measurements of fatty acid transport with [1-^{13}C] palmitic acid. *J Clin Invest* 67, 1729-1738.

González-Alonso, J, Teller, C, Andersen, SL, Jensen, FB, Hyldig, T & Nielsen, B (1999). Influence of body temperature on the development of fatigue during prolonged exercise in the heat. *J Appl Physiol* 86, 1032-1039.

Green, HJ, Houston, ME & Thomson, JA (1979). Metabolic consequences of supramaximal arm work performed during prolonged submaximal leg work. *J Appl Physiol Respir Environ Exercise Physiol* 46 (2), 249-255.

Gregson, WA, Drust, B, Batterham, A & Cable, NT (2002).The effects of pre-warming on the metabolic and thermoregulatory responses to prolonged submaximal exercise in moderate ambient temperatures. *Eur J Appl Physiol* 86, 526-533.

Groop, LC, Bonadonna, RC, Shank, M, Petrides, AS & DeFronzo, RA (1991). Role of free fatty acids and insulin in determining free fatty acid and lipid oxidation in man. *J Clin Invest* 87, 83-89.

Haman, F, Péronnet, F, Kenny, GP, Massicotte, D, Lavoie, C, Scott, C, Weber, J-M. (2002). Effect of cold exposure on fuel selection in humans: plasma glucose, muscle glycogen, and lipids. *J Appl Physiol* 93, 77-84.

Haman, F, Péronnet, F, Kenny, GP, Doucet, E, Massicotte, D, Lavoie, C, Weber, J-M (2004). Effects of carbohydrate availability on sustained shivering I: oxidation of plasma glucose, muscle glycogen and proteins. *J Appl Physiol* 96, 32-40.

Hardy, J & Dubois, E (1938). The technique of measuring radiation and convection. *J Nutr* 15, 461-475.

Hargreaves, M, Angus, D, Howlett, K, Conus, NM &Febbraio, M (1996). Effect of heat stress on glucose kinetics during exercise. *J Appl Physiol* 81, 1594-1597.

Iguchi, M, Littmann, AE, Chang, SH, Wester, LA, Knipper, JS & Shields, RK (2012). Heat stress and cardiovascular, hormonal and heat shock proteins in humans. *J Athl Train* 47(2) 184-190.

Irondelle, M & Freund, H (1976). Carbohydrate and fat metabolism of unacclimatized men during and after submaximal exercise in cool and hot environments. *Europ J Appl Physiol* 37, 27-38.

Issekutz, B Jr., Shaw, WA & Issekutz, TB (1975). Effect of lactate on FFA and glycerol turnover in resting and exercising dogs. *J Appl Physiol* 39, 349-353.

Jensen, MD (2003). Fate of fatty acids at rest and during exercise: regulatory mechanisms. *Acta Physiol Scand* 178, 385-390.

Jentjens, RLPG, Wagenmakers, AJM & Jeukendrup, AE (2002). Heat stress increases muscle glycogen use but reduces the oxidation of ingested carbohydrates during exercise. *J Appl Physiol* 92, 1562-1572.

Jeukendrup, AE (2003). Modulation of carbohydrate and fat utilization by diet, exercise and environment. *Biochem Soc T* 31(6), 1270-1273.

Ježová, D, Kvetňanský, R & Vigaš, M (1994). Sex differences in endocrine response to hyperthermia in sauna. *Acta Physiol Scand* 150, 293-298.

Johnson, AB, Argyraki, M, Thow, JC, Cooper, BG, Fulcher, G & Taylor, R (1992). Effect of increased free fatty acid supply on glucose metabolism and skeletal muscle glycogen synthase activity in normal man. *Clin Sci* 82(2), 219-226.

Klein, RF, Estes, EH Jr., Bogdonoff, MD (1961). Effect of norepinephrine on plasma free fatty acids level in man. *J Appl Physiol* 16, 342-344.

Leppäluoto, J, Huttunen, P, Hirvonen, J & Väänänen, A (1986). Endocrine effects of repeated sauna bathing. *Acta Physiol Scand* 128, 467-470.

MacDougall, J.D., Reddan, W.G., Layton, C.R. & Dempsey, J.A. (1974).Effects of metabolic hyperthermia on performance during heavy prolonged exercise. *J Appl Physiol* 36(5), 538-544.

Maughan, RJ, Otani, H & Watson, P (2012). Influence of relative humidity on prolonged exercise capacity in a warm environment. *Eur J Appl Physiol* 112, 2313-2321.

McLellan, TM, Jacobs, I & Bain, JB (1993). Influence of temperature and metabolic rate on work performance with Canadian Forces NBC clothing. *Aviat Space Environ Med* 64(7), 587-594.

Mekjavic, IB & Rempel, ME (1990). Determination of esophageal probe insertion length based on standing and sitting height. *J Appl Physiol* 69, 376-379.

Morris, JG, Nevill, ME, Boobis, LH, Macdonald, IA & Williams, C (2005). Muscle metabolism, temperature, and function during prolonged, intermittent, high-intensity running in air temperatures of 33° and 17°C. *Int J Sports Med* 26, 805-814.

Nielsen, B, Savard, G, Richter, EA, Hargreaves, M &Saltin, B (1990). Muscle blood flow and muscle metabolism during exercise and heat stress. *J Appl Physiol* 69(3), 1040-1046.

Nielsen, B, Hales, JRS, Strange, S, Christensen, NJ, Warberg, J & Saltin, B (1993). Human circulatory and thermoregulatory adaptations with heat acclimation and exercise in a hot, dry environment. *J Physiol* 460, 467-485.

Parkin, JM, Carey, MF, Zhao, S &Febbraio, MA (1999). Effect of ambient temperature on human skeletal muscle metabolism during fatiguing submaximal exercise. Journal of Applied Physiology 86(3), 902-908.

Périard, JD, Cramer, MN, Chapman, PG, Caillaud, C & Thompson, MW (2010). Cardiovascular strain impairs prolonged self-paced exercise in the heat. *Exp Physiol*, 96(2), 134-144.

Périard, JD, Caillaud, C & Thompson, MW (2011).Central and peripheral fatigue during passive and exercise-induced hyperthermia. *Med Sci Sports Exerc* 43(9), 1657-1665.

Péronnet, F & Massicotte, D (1991). Table of nonprotein respiratory quotient: an update. *Can J Sport Sci* 16, 23-29.

Powers, SK, Howley, ET & Cox, R (1982). A differential catecholamine response during prolonged exercise and passive heating. *Med Sci Sports Exerc* 14(6), 435-439.

Romijn, JA, Coyle, EF, Sidossis, LS, Gastaldelli, A, Horowitz, JF, Endert, E & Wolfe, RR (1993). Regulation of endogenous fat and carbohydrate metabolism in relation to exercise intensity and duration. *Am J Physiol Endocrinol Metab* 265, E380-E391.

Rowell, LB, Brengelmann, GL, Blackmon, JR, Twiss, RD, Kusumi, F (1968). Splanchnic blood flow and metabolism in heat stressed man. *J Appl Physiol* 24, 475-484.

Rowell, LB (1974). Human cardiovascular adjustments to exercise and thermal stress. *Physiol Rev* 54(1), 75-158.

Savard, GK, Nielsen, B, Laszczynska, J, Larsen, BE & Saltin, B (1988). Muscle blood flow is not reduced in humans during moderate exercise and heat stress. *J Appl Physiol* 64(2), 649-657.

Starkie, RL, Hargreaves, M, Lambert, DL, Proietto, J & Febbraio, MA (1999). Effect of temperature on muscle metabolism during submaximal exercise in humans. *Exp Physiol* 84, 775-784.

van Loon, LJC, Greenhaff, PL, Constantin-Teodosiu, D, Saris, WHM & Wagenmakers, AJM (2001). The effects of increasing exercise intensity on muscle fuel utilization in humans. *J Physiol* 536(1), 295-304.

Yamamoto, H, Zheng, K & Ariizumi, M (2003). Influence of heat exposure on serum lipid and lipoprotein cholesterol in young male subjects. *Ind Health* 41, 1-7.

Young, AJ, Sawka, MN, Levine, L, Cadarette, BS & Pandolf, KB (1985). Skeletal muscle metabolism during exercise is influenced by heat acclimation. *J Appl Physiol* 59, 1929-1935.

Wingo, JE, Lafrenz, AJ, Ganio, MS, Edwards, GL, Cureton, KJ (2005). Cardiovascular drift is related to reduced maximal oxygen uptake during heat stress. *Med Sci Sports Exerc* 37(2), 248-255.

CHAPTER 3: GENERAL CONCLUSION

The general objectives of this thesis were: (i) to demonstrate alterations in whole-body lipid metabolism and plasma lipids during passive heat stress and subsequent exercise in the heat, and (ii) to determine the effects of passive pre-heating on exercise performance in the heat.

CHAPTER 1 reviewed the physiological and metabolic changes that occur as a result of passive heat stress and during exercise in the heat. It also examined the diminished performance observed during heat stress and how physiological and metabolic alterations induced by heat stress could contribute to decreased work capacity. In addition, this chapter examined what is currently known about the effects of heat exposure on lipid metabolism at rest and during exercise.

The trials described in CHAPTER 2 confirmed that plasma lipids, specifically NEFA, are altered during passive heat stress and exercise in the heat, resulting in greater plasma concentrations. Contrary to our hypothesis, whole-body lipid oxidation was not altered by heat exposure. The methodology used in this study has certain limitations which prevented further conclusions regarding the effects of heat stress on plasma lipids. Stable isotope tracers would have been of great use to determine whether changes in NEFA R_a or R_d accounted for the increases in plasma concentrations. The degree of thermal stress, combined with the stress of exercise, caused two participants to hyperventilate frequently during exercise and made fuel oxidation calculations for these participants impossible. Finally, information on plasma catecholamines would have been useful to provide support for the suggestion that elevated plasma catecholamines contributed to the increased NEFA concentrations during passive heat stress.

At this time, the exact mechanism behind the alterations in plasma NEFA observed following heat exposure are unclear. It is, however, well established that heat stress increases plasma catecholamines and that increased catecholamines accelerate adipose tissue lipolysis. Taken together, these findings strongly suggest that catecholamines likely played a role in increasing NEFA concentrations during heat stress.

The importance of lipids in energy metabolism requires a better understanding of how lipid oxidation and plasma lipids are altered in individuals exposed to heat. In addition, higher levels of plasma NEFA are associated with inflammation and several chronic diseases. The findings of this study can be applied to better understand changes in energy metabolism and possible health risks in individuals who work in environments of heat stress.

APPENDIX A

Statistical Analysis

The Grubb's test was used to check data for outliers. Based on the sample size of 8 participants (n=8), the critical z-value was 2.13. Potential outliers were verified to ensure that they were within the critical z-value using the following formula:

(Group mean – sample value of suspected outlier)/standard deviation of group mean

Data recorded during the baseline and passive period was averaged every 30 minutes. Data recorded during exercise was measured every 5 minutes. All data is presented as means ± s.e.m.

A two-way repeated measure ANOVA was used for statistical analysis, and was performed using SPSS (Version 15.0). This type of analysis was chosen because it allowed us to analyze changes between conditions and across time. Mauchly's Test of Sphericity was used to determine whether the assumption of sphericity was met. In cases where the assumption of sphericity was violated, Greenhouse-Geisser test was used to adjust for the violation. Significant differences were followed up by Bonferroni Post-Hoc tests. The threshold for significance was set at $p < 0.05$.

Data from the baseline and passive period was analyzed together. The within subjects factors entered into SPSS for this analysis were:

i) Condition - 2 levels: Control and Heat

ii) Time - 6 levels: Baseline(T_{-30}), T_0, T_{30}, T_{60}, T_{90}, and T_{120}.

Not all participants were able to complete the full 30 minutes of exercise, which resulted in varying exercise durations for heat. To analyze data for the exercise portion of the trial, data was compared from the start of exercise (pre-exercise value) to data from the last five minutes of exercise (termination of exercise). The within subject factors entered into SPSS for analysis of the exercise period were:

i) Condition - 2 levels: Control and Heat

ii) Time - 2 levels, Pre-Exercise and Termination of Exercise

Absolute protein oxidation, quantified only during the baseline period, was analyzed using a paired T-test.

THERMAL RESPONSE STATISTICAL ANALYSIS

Average Skin Temperature (T_{skin}): Baseline and Passive

```
GLM HB30 H0 H30 H60 H90 H120 CB30 C0 C30 C60 C90 C120
  /WSFACTOR=Condition 2 Polynomial Time 6 Polynomial
  /METHOD=SSTYPE(3)
  /EMMEANS=TABLES(Time*Condition) COMPARE(Condition) ADJ(BONFERRONI)
  /EMMEANS=TABLES(Time*Condition)
  /PRINT=DESCRIPTIVE HOMOGENEITY
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=Condition Time Condition*Time.
```

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

Condition	Time	Dependent Variable
1	1	HB30
	2	H0
	3	H30
	4	H60
	5	H90
	6	H120
2	1	CB30
	2	C0
	3	C30
	4	C60
	5	C90
	6	C120

Descriptive Statistics

	Mean	Std. Deviation	N
HB30	32.5953	.36325	8
H0	32.4598	.45419	8
H30	35.7726	.30615	8
H60	36.0935	.32596	8
H90	36.0850	.31992	8
H120	35.9534	.34834	8
CB30	32.7400	.60450	8
C0	32.6122	.65380	8
C30	32.1228	.61945	8
C60	32.1884	.65807	8

C90	32.2381	.60871	8
C120	32.2569	.52035	8

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.
Condition	Pillai's Trace	.943	115.376[b]	1.000	7.000	.000
	Wilks' Lambda	.057	115.376[b]	1.000	7.000	.000
	Hotelling's Trace	16.482	115.376[b]	1.000	7.000	.000
	Roy's Largest Root	16.482	115.376[b]	1.000	7.000	.000
Time	Pillai's Trace	.980	29.762[b]	5.000	3.000	.009
	Wilks' Lambda	.020	29.762[b]	5.000	3.000	.009
	Hotelling's Trace	49.604	29.762[b]	5.000	3.000	.009
	Roy's Largest Root	49.604	29.762[b]	5.000	3.000	.009
Condition * Time	Pillai's Trace	.999	563.226[b]	5.000	3.000	.000
	Wilks' Lambda	.001	563.226[b]	5.000	3.000	.000
	Hotelling's Trace	938.711	563.226[b]	5.000	3.000	.000
	Roy's Largest Root	938.711	563.226[b]	5.000	3.000	.000

a. Design: Intercept

Within Subjects Design: Condition + Time + Condition * Time

b. Exact statistic

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]
					Greenhouse-Geisser
Condition	1.000	.000	0	.	1.000
Time	.005	27.465	14	.027	.334
Condition * Time	.020	19.936	14	.170	.508

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Epsilon	
	Huynh-Feldt	Lower-bound
Condition	1.000	1.000
Time	.427	.200
Condition * Time	.821	.200

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.[a]

a. Design: Intercept

Within Subjects Design: Condition + Time + Condition * Time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F
Condition	Sphericity Assumed	146.049	1	146.049	115.376
	Greenhouse-Geisser	146.049	1.000	146.049	115.376
	Huynh-Feldt	146.049	1.000	146.049	115.376
	Lower-bound	146.049	1.000	146.049	115.376
Error(Condition)	Sphericity Assumed	8.861	7	1.266	
	Greenhouse-Geisser	8.861	7.000	1.266	
	Huynh-Feldt	8.861	7.000	1.266	
	Lower-bound	8.861	7.000	1.266	
Time	Sphericity Assumed	47.762	5	9.552	104.913
	Greenhouse-Geisser	47.762	1.671	28.579	104.913
	Huynh-Feldt	47.762	2.134	22.385	104.913
	Lower-bound	47.762	1.000	47.762	104.913
Error(Time)	Sphericity Assumed	3.187	35	.091	
	Greenhouse-Geisser	3.187	11.699	.272	
	Huynh-Feldt	3.187	14.936	.213	
	Lower-bound	3.187	7.000	.455	
Condition * Time	Sphericity Assumed	82.259	5	16.452	319.507
	Greenhouse-Geisser	82.259	2.540	32.391	319.507
	Huynh-Feldt	82.259	4.106	20.032	319.507
	Lower-bound	82.259	1.000	82.259	319.507
Error(Condition*Time)	Sphericity Assumed	1.802	35	.051	
	Greenhouse-Geisser	1.802	17.777	.101	
	Huynh-Feldt	1.802	28.745	.063	
	Lower-bound	1.802	7.000	.257	

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source	Sig.

Condition	Sphericity Assumed	.000
	Greenhouse-Geisser	.000
	Huynh-Feldt	.000
	Lower-bound	.000
Error(Condition)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Time	Sphericity Assumed	.000
	Greenhouse-Geisser	.000
	Huynh-Feldt	.000
	Lower-bound	.000
Error(Time)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Condition * Time	Sphericity Assumed	.000
	Greenhouse-Geisser	.000
	Huynh-Feldt	.000
	Lower-bound	.000
Error(Condition*Time)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Condition	Time	Type III Sum of Squares	df	Mean Square	F
Condition	Linear		146.049	1	146.049	115.376
Error(Condition)	Linear		8.861	7	1.266	
Time		Linear	34.342	1	34.342	114.621
		Quadratic	5.127	1	5.127	140.467
		Cubic	2.191	1	2.191	34.866
		Order 4	4.666	1	4.666	145.398
		Order 5	1.437	1	1.437	59.335
Error(Time)		Linear	2.097	7	.300	
		Quadratic	.255	7	.036	
		Cubic	.440	7	.063	

		Order 4	.225	7	.032	
		Order 5	.170	7	.024	
Condition * Time	Linear	Linear	56.552	1	56.552	1477.840
		Quadratic	12.429	1	12.429	101.013
		Cubic	2.139	1	2.139	34.292
		Order 4	8.204	1	8.204	316.783
		Order 5	2.937	1	2.937	372.068
Error(Condition*Time)	Linear	Linear	.268	7	.038	
		Quadratic	.861	7	.123	
		Cubic	.437	7	.062	
		Order 4	.181	7	.026	
		Order 5	.055	7	.008	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Condition	Time	Sig.
Condition	Linear		.000
Error(Condition)	Linear		
Time		Linear	.000
		Quadratic	.000
		Cubic	.001
		Order 4	.000
		Order 5	.000
Error(Time)		Linear	
		Quadratic	
		Cubic	
		Order 4	
		Order 5	
Condition * Time	Linear	Linear	.000
		Quadratic	.000
		Cubic	.001
		Order 4	.000
		Order 5	.000
Error(Condition*Time)	Linear	Linear	
		Quadratic	
		Cubic	
		Order 4	
		Order 5	

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	108336.038	1	108336.038	104745.110	.000
Error	7.240	7	1.034		

Estimated Marginal Means

1. Time * Condition

Estimates

Measure: MEASURE_1

Time	Condition	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	1	32.595	.128	32.292	32.899
	2	32.740	.214	32.235	33.245
2	1	32.460	.161	32.080	32.840
	2	32.612	.231	32.066	33.159
3	1	35.773	.108	35.517	36.029
	2	32.123	.219	31.605	32.641
4	1	36.093	.115	35.821	36.366
	2	32.188	.233	31.638	32.739
5	1	36.085	.113	35.818	36.352
	2	32.238	.215	31.729	32.747
6	1	35.953	.123	35.662	36.245
	2	32.257	.184	31.822	32.692

Pairwise Comparisons

Measure: MEASURE_1

Time	(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]
						Lower Bound
1	1	2	-.145	.188	.467	-.590
	2	1	.145	.188	.467	-.301
2	1	2	-.152	.242	.549	-.724
	2	1	.152	.242	.549	-.420
3	1	2	3.650*	.286	.000	2.974

	2	1	-3.650*	.286	.000	-4.326
4	1	2	3.905*	.284	.000	3.233
	2	1	-3.905*	.284	.000	-4.578
5	1	2	3.847*	.241	.000	3.277
	2	1	-3.847*	.241	.000	-4.417
6	1	2	3.696*	.257	.000	3.089
	2	1	-3.696*	.257	.000	-4.304

Pairwise Comparisons

Measure: MEASURE_1

Time	(I) Condition	(J) Condition	95% Confidence Interval for Difference
			Upper Bound
1	1	2	.301
	2	1	.590
2	1	2	.420
	2	1	.724
3	1	2	4.326*
	2	1	-2.974*
4	1	2	4.578*
	2	1	-3.233*
5	1	2	4.417*
	2	1	-3.277*
6	1	2	4.304*
	2	1	-3.089*

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Multivariate Tests

Time		Value	F	Hypothesis df	Error df	Sig.
1	Pillai's trace	.078	.591[a]	1.000	7.000	.467
	Wilks' lambda	.922	.591[a]	1.000	7.000	.467
	Hotelling's trace	.084	.591[a]	1.000	7.000	.467
	Roy's largest root	.084	.591[a]	1.000	7.000	.467
2	Pillai's trace	.054	.397[a]	1.000	7.000	.549
	Wilks' lambda	.946	.397[a]	1.000	7.000	.549
	Hotelling's trace	.057	.397[a]	1.000	7.000	.549
	Roy's largest root	.057	.397[a]	1.000	7.000	.549

3	Pillai's trace	.959	162.883[a]	1.000	7.000	.000
	Wilks' lambda	.041	162.883[a]	1.000	7.000	.000
	Hotelling's trace	23.269	162.883[a]	1.000	7.000	.000
	Roy's largest root	23.269	162.883[a]	1.000	7.000	.000
4	Pillai's trace	.964	188.537[a]	1.000	7.000	.000
	Wilks' lambda	.036	188.537[a]	1.000	7.000	.000
	Hotelling's trace	26.934	188.537[a]	1.000	7.000	.000
	Roy's largest root	26.934	188.537[a]	1.000	7.000	.000
5	Pillai's trace	.973	254.386[a]	1.000	7.000	.000
	Wilks' lambda	.027	254.386[a]	1.000	7.000	.000
	Hotelling's trace	36.341	254.386[a]	1.000	7.000	.000
	Roy's largest root	36.341	254.386[a]	1.000	7.000	.000
6	Pillai's trace	.967	206.960[a]	1.000	7.000	.000
	Wilks' lambda	.033	206.960[a]	1.000	7.000	.000
	Hotelling's trace	29.566	206.960[a]	1.000	7.000	.000
	Roy's largest root	29.566	206.960[a]	1.000	7.000	.000

Each F tests the multivariate simple effects of Condition within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

2. Time * Condition

Measure: MEASURE_1

Time	Condition	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	1	32.595	.128	32.292	32.899
	2	32.740	.214	32.235	33.245
2	1	32.460	.161	32.080	32.840
	2	32.612	.231	32.066	33.159
3	1	35.773	.108	35.517	36.029
	2	32.123	.219	31.605	32.641
4	1	36.093	.115	35.821	36.366
	2	32.188	.233	31.638	32.739
5	1	36.085	.113	35.818	36.352
	2	32.238	.215	31.729	32.747
6	1	35.953	.123	35.662	36.245
	2	32.257	.184	31.822	32.692

Average Skin Temperature (T_{skin}): Exercise

```
GLM Hpre Hterm Cpre Cterm
  /WSFACTOR=Condition 2 Polynomial Time 2 Polynomial
  /METHOD=SSTYPE(3)
  /EMMEANS=TABLES(Condition) COMPARE ADJ(BONFERRONI)
  /EMMEANS=TABLES(Time) COMPARE ADJ(BONFERRONI)
  /EMMEANS=TABLES(Condition*Time)
  /PRINT=DESCRIPTIVE
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=Condition Time Condition*Time.
```

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

Condition	Time	Dependent Variable
1	1	Hpre
	2	Hterm
2	1	Cpre
	2	Cterm

Descriptive Statistics

	Mean	Std. Deviation	N
Hpre	35.0529	1.23410	8
Hterm	37.0904	.56226	8
Cpre	32.1568	.57022	8
Cterm	33.6700	.37918	8

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.
Condition	Pillai's Trace	.964	188.726[b]	1.000	7.000	.000
	Wilks' Lambda	.036	188.726[b]	1.000	7.000	.000
	Hotelling's Trace	26.961	188.726[b]	1.000	7.000	.000
	Roy's Largest Root	26.961	188.726[b]	1.000	7.000	.000
Time	Pillai's Trace	.827	33.532[b]	1.000	7.000	.001
	Wilks' Lambda	.173	33.532[b]	1.000	7.000	.001
	Hotelling's Trace	4.790	33.532[b]	1.000	7.000	.001
	Roy's Largest Root	4.790	33.532[b]	1.000	7.000	.001
Condition * Time	Pillai's Trace	.199	1.744[b]	1.000	7.000	.228
	Wilks' Lambda	.801	1.744[b]	1.000	7.000	.228

	Hotelling's Trace	.249	1.744[b]	1.000	7.000	.228
	Roy's Largest Root	.249	1.744[b]	1.000	7.000	.228

a. Design: Intercept

Within Subjects Design: Condition + Time + Condition * Time

b. Exact statistic

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]
					Greenhouse-Geisser
Condition	1.000	.000	0	.	1.000
Time	1.000	.000	0	.	1.000
Condition * Time	1.000	.000	0	.	1.000

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Epsilon	
	Huynh-Feldt	Lower-bound
Condition	1.000	1.000
Time	1.000	1.000
Condition * Time	1.000	1.000

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.[a]

a. Design: Intercept

Within Subjects Design: Condition + Time + Condition * Time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F
Condition	Sphericity Assumed	79.799	1	79.799	188.726
	Greenhouse-Geisser	79.799	1.000	79.799	188.726
	Huynh-Feldt	79.799	1.000	79.799	188.726
	Lower-bound	79.799	1.000	79.799	188.726
Error(Condition)	Sphericity Assumed	2.960	7	.423	

	Greenhouse-Geisser	2.960	7.000	.423	
	Huynh-Feldt	2.960	7.000	.423	
	Lower-bound	2.960	7.000	.423	
Time	Sphericity Assumed	25.215	1	25.215	33.532
	Greenhouse-Geisser	25.215	1.000	25.215	33.532
	Huynh-Feldt	25.215	1.000	25.215	33.532
	Lower-bound	25.215	1.000	25.215	33.532
Error(Time)	Sphericity Assumed	5.264	7	.752	
	Greenhouse-Geisser	5.264	7.000	.752	
	Huynh-Feldt	5.264	7.000	.752	
	Lower-bound	5.264	7.000	.752	
Condition * Time	Sphericity Assumed	.550	1	.550	1.744
	Greenhouse-Geisser	.550	1.000	.550	1.744
	Huynh-Feldt	.550	1.000	.550	1.744
	Lower-bound	.550	1.000	.550	1.744
Error(Condition*Time)	Sphericity Assumed	2.207	7	.315	
	Greenhouse-Geisser	2.207	7.000	.315	
	Huynh-Feldt	2.207	7.000	.315	
	Lower-bound	2.207	7.000	.315	

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Sig.
Condition	Sphericity Assumed	.000
	Greenhouse-Geisser	.000
	Huynh-Feldt	.000
	Lower-bound	.000
Error(Condition)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Time	Sphericity Assumed	.001
	Greenhouse-Geisser	.001
	Huynh-Feldt	.001
	Lower-bound	.001
Error(Time)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	

Condition * Time	Sphericity Assumed	.228
	Greenhouse-Geisser	.228
	Huynh-Feldt	.228
	Lower-bound	.228
Error(Condition*Time)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Condition	Time	Type III Sum of Squares	df	Mean Square	F
Condition	Linear		79.799	1	79.799	188.726
Error(Condition)	Linear		2.960	7	.423	
Time		Linear	25.215	1	25.215	33.532
Error(Time)		Linear	5.264	7	.752	
Condition * Time	Linear	Linear	.550	1	.550	1.744
Error(Condition*Time)	Linear	Linear	2.207	7	.315	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Condition	Time	Sig.
Condition	Linear		.000
Error(Condition)	Linear		
Time		Linear	.001
Error(Time)		Linear	
Condition * Time	Linear	Linear	.228
Error(Condition*Time)	Linear	Linear	

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	38071.493	1	38071.493	46543.277	.000
Error	5.726	7	.818		

Estimated Marginal Means

1. Condition

Estimates

Measure: MEASURE_1

Condition	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	36.072	.239	35.506	36.638
2	32.913	.142	32.577	33.250

Pairwise Comparisons

Measure: MEASURE_1

(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	3.158[*]	.230	.000	2.615	3.702
2	1	-3.158[*]	.230	.000	-3.702	-2.615

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.
Pillai's trace	.964	188.726[a]	1.000	7.000	.000
Wilks' lambda	.036	188.726[a]	1.000	7.000	.000
Hotelling's trace	26.961	188.726[a]	1.000	7.000	.000
Roy's largest root	26.961	188.726[a]	1.000	7.000	.000

Each F tests the multivariate effect of Condition. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

2. Time

Estimates

Measure: MEASURE_1

Time	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	33.605	.290	32.919	34.291
2	35.380	.118	35.101	35.659

Pairwise Comparisons

Measure: MEASURE_1

(I) Time	(J) Time	Mean Difference	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]

		(I-J)			Lower Bound	Upper Bound
1	2	-1.775[*]	.307	.001	-2.500	-1.050
2	1	1.775[*]	.307	.001	1.050	2.500

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.
Pillai's trace	.827	33.532[a]	1.000	7.000	.001
Wilks' lambda	.173	33.532[a]	1.000	7.000	.001
Hotelling's trace	4.790	33.532[a]	1.000	7.000	.001
Roy's largest root	4.790	33.532[a]	1.000	7.000	.001

Each F tests the multivariate effect of Time. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

3. Condition * Time

Measure: MEASURE_1

Condition	Time	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	1	35.053	.436	34.021	36.085
	2	37.090	.199	36.620	37.560
2	1	32.157	.202	31.680	32.633
	2	33.670	.134	33.353	33.987

Esophageal Temperature (Tes): Baseline and Passive

```
GLM HB30 H0 H30 H60 H90 H120 CB30 C0 C30 C60 C90 C120
  /WSFACTOR=Condition 2 Polynomial Time 6 Polynomial
  /METHOD=SSTYPE(3)
  /EMMEANS=TABLES(Time*Condition) COMPARE(Condition) ADJ(BONFERRONI)
  /EMMEANS=TABLES(Time*Condition)
  /PRINT=DESCRIPTIVE HOMOGENEITY
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=Condition Time Condition*Time.
```

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

Condition	Time	Dependent Variable
1	1	HB30
	2	H0
	3	H30
	4	H60
	5	H90
	6	H120
2	1	CB30
	2	C0
	3	C30
	4	C60
	5	C90
	6	C120

Descriptive Statistics

	Mean	Std. Deviation	N
HB30	36.7138	.14010	8
H0	36.7013	.14584	8
H30	36.7375	.16688	8
H60	36.8790	.38345	8
H90	37.2317	.26542	8
H120	37.3789	.34632	8
CB30	36.6689	.06614	8
C0	36.6506	.07655	8
C30	36.6086	.19749	8
C60	36.7122	.30578	8

C90	36.7010	.26981	8
C120	36.6783	.27243	8

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.
Condition	Pillai's Trace	.782	25.171[b]	1.000	7.000	.002
	Wilks' Lambda	.218	25.171[b]	1.000	7.000	.002
	Hotelling's Trace	3.596	25.171[b]	1.000	7.000	.002
	Roy's Largest Root	3.596	25.171[b]	1.000	7.000	.002
Time	Pillai's Trace	.931	8.113[b]	5.000	3.000	.058
	Wilks' Lambda	.069	8.113[b]	5.000	3.000	.058
	Hotelling's Trace	13.522	8.113[b]	5.000	3.000	.058
	Roy's Largest Root	13.522	8.113[b]	5.000	3.000	.058
Condition * Time	Pillai's Trace	.952	11.832[b]	5.000	3.000	.034
	Wilks' Lambda	.048	11.832[b]	5.000	3.000	.034
	Hotelling's Trace	19.719	11.832[b]	5.000	3.000	.034
	Roy's Largest Root	19.719	11.832[b]	5.000	3.000	.034

a. Design: Intercept

Within Subjects Design: Condition + Time + Condition * Time

b. Exact statistic

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]
					Greenhouse-Geisser
Condition	1.000	.000	0	.	1.000
Time	.002	31.189	14	.009	.493
Condition * Time	.002	32.477	14	.006	.347

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Epsilon	
	Huynh-Feldt	Lower-bound
Condition	1.000	1.000
Time	.782	.200
Condition * Time	.452	.200

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.[a]

a. Design: Intercept

Within Subjects Design: Condition + Time + Condition * Time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F
Condition	Sphericity Assumed	1.755	1	1.755	25.171
	Greenhouse-Geisser	1.755	1.000	1.755	25.171
	Huynh-Feldt	1.755	1.000	1.755	25.171
	Lower-bound	1.755	1.000	1.755	25.171
Error(Condition)	Sphericity Assumed	.488	7	.070	
	Greenhouse-Geisser	.488	7.000	.070	
	Huynh-Feldt	.488	7.000	.070	
	Lower-bound	.488	7.000	.070	
Time	Sphericity Assumed	1.969	5	.394	7.874
	Greenhouse-Geisser	1.969	2.467	.798	7.874
	Huynh-Feldt	1.969	3.912	.503	7.874
	Lower-bound	1.969	1.000	1.969	7.874
Error(Time)	Sphericity Assumed	1.751	35	.050	
	Greenhouse-Geisser	1.751	17.267	.101	
	Huynh-Feldt	1.751	27.383	.064	
	Lower-bound	1.751	7.000	.250	
Condition * Time	Sphericity Assumed	1.531	5	.306	6.753
	Greenhouse-Geisser	1.531	1.737	.881	6.753
	Huynh-Feldt	1.531	2.261	.677	6.753
	Lower-bound	1.531	1.000	1.531	6.753
Error(Condition*Time)	Sphericity Assumed	1.587	35	.045	
	Greenhouse-Geisser	1.587	12.162	.130	
	Huynh-Feldt	1.587	15.827	.100	
	Lower-bound	1.587	7.000	.227	

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source	Sig.

Condition	Sphericity Assumed	.002
	Greenhouse-Geisser	.002
	Huynh-Feldt	.002
	Lower-bound	.002
Error(Condition)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Time	Sphericity Assumed	.000
	Greenhouse-Geisser	.002
	Huynh-Feldt	.000
	Lower-bound	.026
Error(Time)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Condition * Time	Sphericity Assumed	.000
	Greenhouse-Geisser	.013
	Huynh-Feldt	.006
	Lower-bound	.035
Error(Condition*Time)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Condition	Time	Type III Sum of Squares	df	Mean Square	F
Condition	Linear		1.755	1	1.755	25.171
Error(Condition)	Linear		.488	7	.070	
Time		Linear	1.641	1	1.641	13.082
		Quadratic	.223	1	.223	3.904
		Cubic	.062	1	.062	2.751
		Order 4	.042	1	.042	2.318
		Order 5	.001	1	.001	.029
Error(Time)		Linear	.878	7	.125	
		Quadratic	.400	7	.057	
		Cubic	.158	7	.023	

		Order 4	.125	7	.018	
		Order 5	.188	7	.027	
Condition * Time	Linear	Linear	1.293	1	1.293	20.614
		Quadratic	.183	1	.183	4.009
		Cubic	.001	1	.001	.020
		Order 4	.024	1	.024	2.549
		Order 5	.030	1	.030	.628
Error(Condition*Time)	Linear	Linear	.439	7	.063	
		Quadratic	.320	7	.046	
		Cubic	.433	7	.062	
		Order 4	.065	7	.009	
		Order 5	.330	7	.047	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Condition	Time	Sig.
Condition	Linear		.002
Error(Condition)	Linear		
Time		Linear	.009
		Quadratic	.089
		Cubic	.141
		Order 4	.172
		Order 5	.870
Error(Time)		Linear	
		Quadratic	
		Cubic	
		Order 4	
		Order 5	
Condition * Time	Linear	Linear	.003
		Quadratic	.085
		Cubic	.893
		Order 4	.154
		Order 5	.454
Error(Condition*Time)	Linear	Linear	
		Quadratic	
		Cubic	
		Order 4	
		Order 5	

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	130043.352	1	130043.352	870529.468	.000
Error	1.046	7	.149		

Estimated Marginal Means
1. Time * Condition

Estimates

Measure: MEASURE_1

Time	Condition	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	1	36.714	.050	36.597	36.831
	2	36.669	.023	36.614	36.724
2	1	36.701	.052	36.579	36.823
	2	36.651	.027	36.587	36.715
3	1	36.738	.059	36.598	36.877
	2	36.609	.070	36.443	36.774
4	1	36.879	.136	36.558	37.200
	2	36.712	.108	36.457	36.968
5	1	37.232	.094	37.010	37.454
	2	36.701	.095	36.475	36.927
6	1	37.379	.122	37.089	37.668
	2	36.678	.096	36.451	36.906

Pairwise Comparisons

Measure: MEASURE_1

Time	(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]
						Lower Bound
1	1	2	.045	.054	.432	-.082
	2	1	-.045	.054	.432	-.172
2	1	2	.051	.061	.434	-.094
	2	1	-.051	.061	.434	-.195
3	1	2	.129	.099	.235	-.106

	2	1	-.129	.099	.235	-.364
4	1	2	.167	.198	.426	-.301
	2	1	-.167	.198	.426	-.634
5	1	2	.531*	.117	.003	.255
	2	1	-.531*	.117	.003	-.806
6	1	2	.701*	.070	.000	.534
	2	1	-.701*	.070	.000	-.867

Pairwise Comparisons

Measure: MEASURE_1

Time	(I) Condition	(J) Condition	95% Confidence Interval for Difference
			Upper Bound
1	1	2	.172
	2	1	.082
2	1	2	.195
	2	1	.094
3	1	2	.364
	2	1	.106
4	1	2	.634
	2	1	.301
5	1	2	.806*
	2	1	-.255*
6	1	2	.867*
	2	1	-.534*

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Multivariate Tests

Time		Value	F	Hypothesis df	Error df	Sig.
1	Pillai's trace	.090	.694[a]	1.000	7.000	.432
	Wilks' lambda	.910	.694[a]	1.000	7.000	.432
	Hotelling's trace	.099	.694[a]	1.000	7.000	.432
	Roy's largest root	.099	.694[a]	1.000	7.000	.432
2	Pillai's trace	.089	.688[a]	1.000	7.000	.434
	Wilks' lambda	.911	.688[a]	1.000	7.000	.434
	Hotelling's trace	.098	.688[a]	1.000	7.000	.434
	Roy's largest root	.098	.688[a]	1.000	7.000	.434

3	Pillai's trace	.194	1.686[a]	1.000	7.000	.235
	Wilks' lambda	.806	1.686[a]	1.000	7.000	.235
	Hotelling's trace	.241	1.686[a]	1.000	7.000	.235
	Roy's largest root	.241	1.686[a]	1.000	7.000	.235
4	Pillai's trace	.092	.713[a]	1.000	7.000	.426
	Wilks' lambda	.908	.713[a]	1.000	7.000	.426
	Hotelling's trace	.102	.713[a]	1.000	7.000	.426
	Roy's largest root	.102	.713[a]	1.000	7.000	.426
5	Pillai's trace	.747	20.714[a]	1.000	7.000	.003
	Wilks' lambda	.253	20.714[a]	1.000	7.000	.003
	Hotelling's trace	2.959	20.714[a]	1.000	7.000	.003
	Roy's largest root	2.959	20.714[a]	1.000	7.000	.003
6	Pillai's trace	.934	98.765[a]	1.000	7.000	.000
	Wilks' lambda	.066	98.765[a]	1.000	7.000	.000
	Hotelling's trace	14.109	98.765[a]	1.000	7.000	.000
	Roy's largest root	14.109	98.765[a]	1.000	7.000	.000

Each F tests the multivariate simple effects of Condition within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

2. Time * Condition

Measure: MEASURE_1

Time	Condition	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	1	36.714	.050	36.597	36.831
	2	36.669	.023	36.614	36.724
2	1	36.701	.052	36.579	36.823
	2	36.651	.027	36.587	36.715
3	1	36.738	.059	36.598	36.877
	2	36.609	.070	36.443	36.774
4	1	36.879	.136	36.558	37.200
	2	36.712	.108	36.457	36.968
5	1	37.232	.094	37.010	37.454
	2	36.701	.095	36.475	36.927
6	1	37.379	.122	37.089	37.668
	2	36.678	.096	36.451	36.906

Esophageal Temperature (T_{es}): Exercise

```
GLM Hpre Hterm Cpre Cterm
  /WSFACTOR=Condition 2 Polynomial Time 2 Polynomial
  /METHOD=SSTYPE(3)
  /EMMEANS=TABLES(Condition) COMPARE ADJ(BONFERRONI)
  /EMMEANS=TABLES(Time) COMPARE ADJ(BONFERRONI)
  /EMMEANS=TABLES(Condition*Time)
  /PRINT=DESCRIPTIVE
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=Condition Time Condition*Time.
```

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

Condition	Time	Dependent Variable
1	1	Hpre
	2	Hterm
2	1	Cpre
	2	Cterm

Descriptive Statistics

	Mean	Std. Deviation	N
Hpre	37.1847	.29476	8
Hterm	38.7875	.49009	8
Cpre	36.2805	.28232	8
Cterm	37.3791	.24987	8

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.
Condition	Pillai's Trace	.937	104.867[b]	1.000	7.000	.000
	Wilks' Lambda	.063	104.867[b]	1.000	7.000	.000
	Hotelling's Trace	14.981	104.867[b]	1.000	7.000	.000
	Roy's Largest Root	14.981	104.867[b]	1.000	7.000	.000
Time	Pillai's Trace	.963	184.208[b]	1.000	7.000	.000
	Wilks' Lambda	.037	184.208[b]	1.000	7.000	.000
	Hotelling's Trace	26.315	184.208[b]	1.000	7.000	.000
	Roy's Largest Root	26.315	184.208[b]	1.000	7.000	.000
Condition * Time	Pillai's Trace	.385	4.389[b]	1.000	7.000	.074
	Wilks' Lambda	.615	4.389[b]	1.000	7.000	.074

	Hotelling's Trace	.627	4.389[b]	1.000	7.000	.074
	Roy's Largest Root	.627	4.389[b]	1.000	7.000	.074

a. Design: Intercept

Within Subjects Design: Condition + Time + Condition * Time

b. Exact statistic

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]
					Greenhouse-Geisser
Condition	1.000	.000	0	.	1.000
Time	1.000	.000	0	.	1.000
Condition * Time	1.000	.000	0	.	1.000

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Epsilon	
	Huynh-Feldt	Lower-bound
Condition	1.000	1.000
Time	1.000	1.000
Condition * Time	1.000	1.000

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.[a]

a. Design: Intercept

Within Subjects Design: Condition + Time + Condition * Time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F
Condition	Sphericity Assumed	10.696	1	10.696	104.867
	Greenhouse-Geisser	10.696	1.000	10.696	104.867
	Huynh-Feldt	10.696	1.000	10.696	104.867
	Lower-bound	10.696	1.000	10.696	104.867

Error(Condition)	Sphericity Assumed	.714	7	.102	
	Greenhouse-Geisser	.714	7.000	.102	
	Huynh-Feldt	.714	7.000	.102	
	Lower-bound	.714	7.000	.102	
Time	Sphericity Assumed	14.594	1	14.594	184.208
	Greenhouse-Geisser	14.594	1.000	14.594	184.208
	Huynh-Feldt	14.594	1.000	14.594	184.208
	Lower-bound	14.594	1.000	14.594	184.208
Error(Time)	Sphericity Assumed	.555	7	.079	
	Greenhouse-Geisser	.555	7.000	.079	
	Huynh-Feldt	.555	7.000	.079	
	Lower-bound	.555	7.000	.079	
Condition * Time	Sphericity Assumed	.509	1	.509	4.389
	Greenhouse-Geisser	.509	1.000	.509	4.389
	Huynh-Feldt	.509	1.000	.509	4.389
	Lower-bound	.509	1.000	.509	4.389
Error(Condition*Time)	Sphericity Assumed	.811	7	.116	
	Greenhouse-Geisser	.811	7.000	.116	
	Huynh-Feldt	.811	7.000	.116	
	Lower-bound	.811	7.000	.116	

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Sig.
Condition	Sphericity Assumed	.000
	Greenhouse-Geisser	.000
	Huynh-Feldt	.000
	Lower-bound	.000
Error(Condition)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Time	Sphericity Assumed	.000
	Greenhouse-Geisser	.000
	Huynh-Feldt	.000
	Lower-bound	.000
Error(Time)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	

	Lower-bound	
Condition * Time	Sphericity Assumed	.074
	Greenhouse-Geisser	.074
	Huynh-Feldt	.074
	Lower-bound	.074
Error(Condition*Time)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Condition	Time	Type III Sum of Squares	df	Mean Square	F
Condition	Linear		10.696	1	10.696	104.867
Error(Condition)	Linear		.714	7	.102	
Time		Linear	14.594	1	14.594	184.208
Error(Time)		Linear	.555	7	.079	
Condition * Time	Linear	Linear	.509	1	.509	4.389
Error(Condition*Time)	Linear	Linear	.811	7	.116	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Condition	Time	Sig.
Condition	Linear		.000
Error(Condition)	Linear		
Time		Linear	.000
Error(Time)		Linear	
Condition * Time	Linear	Linear	.074
Error(Condition*Time)	Linear	Linear	

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	44779.344	1	44779.344	260164.110	.000
Error	1.205	7	.172		

Estimated Marginal Means
1. Condition

Estimates

Measure: MEASURE_1

Condition	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	37.986	.110	37.726	38.246
2	36.830	.071	36.661	36.998

Pairwise Comparisons

Measure: MEASURE_1

(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	1.156*	.113	.000	.889	1.423
2	1	-1.156*	.113	.000	-1.423	-.889

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.
Pillai's trace	.937	104.867[a]	1.000	7.000	.000
Wilks' lambda	.063	104.867[a]	1.000	7.000	.000
Hotelling's trace	14.981	104.867[a]	1.000	7.000	.000
Roy's largest root	14.981	104.867[a]	1.000	7.000	.000

Each F tests the multivariate effect of Condition. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

2. Time

Estimates

Measure: MEASURE_1

Time	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	36.733	.071	36.565	36.900
2	38.083	.103	37.839	38.328

Pairwise Comparisons

Measure: MEASURE_1

(I) Time	(J) Time	Mean Difference	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]

		(I-J)			Lower Bound	Upper Bound
1	2	-1.351[*]	.100	.000	-1.586	-1.115
2	1	1.351[*]	.100	.000	1.115	1.586

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.
Pillai's trace	.963	184.208[a]	1.000	7.000	.000
Wilks' lambda	.037	184.208[a]	1.000	7.000	.000
Hotelling's trace	26.315	184.208[a]	1.000	7.000	.000
Roy's largest root	26.315	184.208[a]	1.000	7.000	.000

Each F tests the multivariate effect of Time. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

3. Condition * Time

Measure: MEASURE_1

Condition	Time	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	1	37.185	.104	36.938	37.431
	2	38.787	.173	38.378	39.197
2	1	36.281	.100	36.045	36.517
	2	37.379	.088	37.170	37.588

Heat Production (H_{prod}): Baseline and Passive

```
GLM HB30 H0 H30 H60 H90 H120 CB30 C0 C30 C60 C90 C120
  /WSFACTOR=Condition 2 Polynomial Time 6 Polynomial
  /METHOD=SSTYPE(3)
  /EMMEANS=TABLES(Time) COMPARE ADJ(BONFERRONI)
  /EMMEANS=TABLES(Time*Condition)
  /PRINT=DESCRIPTIVE HOMOGENEITY
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=Condition Time Condition*Time.
```

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

Condition	Time	Dependent Variable
1	1	HB30
	2	H0
	3	H30
	4	H60
	5	H90
	6	H120
2	1	CB30
	2	C0
	3	C30
	4	C60
	5	C90
	6	C120

Descriptive Statistics

	Mean	Std. Deviation	N
HB30	5.9011	.58499	8
H0	5.9335	.75687	8
H30	5.9599	.51164	8
H60	6.2478	.49128	8
H90	6.0989	.50674	8
H120	6.2390	.60327	8
CB30	6.0145	.72607	8
C0	5.8368	.60057	8
C30	5.8899	.77191	8
C60	5.8382	.72470	8
C90	5.6948	.56920	8

C120	5.6958	.68067	8

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.
Condition	Pillai's Trace	.090	.693[b]	1.000	7.000	.433
	Wilks' Lambda	.910	.693[b]	1.000	7.000	.433
	Hotelling's Trace	.099	.693[b]	1.000	7.000	.433
	Roy's Largest Root	.099	.693[b]	1.000	7.000	.433
Time	Pillai's Trace	.773	2.049[b]	5.000	3.000	.295
	Wilks' Lambda	.227	2.049[b]	5.000	3.000	.295
	Hotelling's Trace	3.415	2.049[b]	5.000	3.000	.295
	Roy's Largest Root	3.415	2.049[b]	5.000	3.000	.295
Condition * Time	Pillai's Trace	.770	2.009[b]	5.000	3.000	.300
	Wilks' Lambda	.230	2.009[b]	5.000	3.000	.300
	Hotelling's Trace	3.348	2.009[b]	5.000	3.000	.300
	Roy's Largest Root	3.348	2.009[b]	5.000	3.000	.300

a. Design: Intercept

Within Subjects Design: Condition + Time + Condition * Time

b. Exact statistic

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]
					Greenhouse-Geisser
Condition	1.000	.000	0	.	1.000
Time	.010	23.549	14	.074	.379
Condition * Time	.089	12.351	14	.625	.571

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Epsilon	
	Huynh-Feldt	Lower-bound
Condition	1.000	1.000
Time	.516	.200
Condition * Time	1.000	.200

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.[a]

a. Design: Intercept

Within Subjects Design: Condition + Time + Condition * Time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F
Condition	Sphericity Assumed	1.326	1	1.326	.693
	Greenhouse-Geisser	1.326	1.000	1.326	.693
	Huynh-Feldt	1.326	1.000	1.326	.693
	Lower-bound	1.326	1.000	1.326	.693
Error(Condition)	Sphericity Assumed	13.396	7	1.914	
	Greenhouse-Geisser	13.396	7.000	1.914	
	Huynh-Feldt	13.396	7.000	1.914	
	Lower-bound	13.396	7.000	1.914	
Time	Sphericity Assumed	.265	5	.053	.493
	Greenhouse-Geisser	.265	1.896	.140	.493
	Huynh-Feldt	.265	2.580	.103	.493
	Lower-bound	.265	1.000	.265	.493
Error(Time)	Sphericity Assumed	3.766	35	.108	
	Greenhouse-Geisser	3.766	13.274	.284	
	Huynh-Feldt	3.766	18.063	.208	
	Lower-bound	3.766	7.000	.538	
Condition * Time	Sphericity Assumed	1.288	5	.258	2.686
	Greenhouse-Geisser	1.288	2.856	.451	2.686
	Huynh-Feldt	1.288	5.000	.258	2.686
	Lower-bound	1.288	1.000	1.288	2.686
Error(Condition*Time)	Sphericity Assumed	3.355	35	.096	
	Greenhouse-Geisser	3.355	19.990	.168	
	Huynh-Feldt	3.355	35.000	.096	
	Lower-bound	3.355	7.000	.479	

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Sig.
Condition	Sphericity Assumed	.433
	Greenhouse-Geisser	.433

	Huynh-Feldt	.433
	Lower-bound	.433
Error(Condition)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Time	Sphericity Assumed	.779
	Greenhouse-Geisser	.612
	Huynh-Feldt	.665
	Lower-bound	.505
Error(Time)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Condition * Time	Sphericity Assumed	.037
	Greenhouse-Geisser	.076
	Huynh-Feldt	.037
	Lower-bound	.145
Error(Condition*Time)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Condition	Time	Type III Sum of Squares	df	Mean Square	F
Condition	Linear		1.326	1	1.326	.693
Error(Condition)	Linear		13.396	7	1.914	
Time		Linear	.009	1	.009	.029
		Quadratic	.000	1	.000	.002
		Cubic	.023	1	.023	.641
		Order 4	.152	1	.152	1.967
		Order 5	.081	1	.081	2.114
Error(Time)		Linear	2.232	7	.319	
		Quadratic	.476	7	.068	
		Cubic	.249	7	.036	
		Order 4	.539	7	.077	
		Order 5	.269	7	.038	

Condition * Time	Linear	Linear	1.181	1	1.181	7.365
		Quadratic	.003	1	.003	.035
		Cubic	.001	1	.001	.026
		Order 4	.002	1	.002	.013
		Order 5	.100	1	.100	2.689
Error(Condition*Time)	Linear	Linear	1.122	7	.160	
		Quadratic	.691	7	.099	
		Cubic	.312	7	.045	
		Order 4	.969	7	.138	
		Order 5	.261	7	.037	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Condition	Time	Sig.
Condition	Linear		.433
Error(Condition)	Linear		
Time		Linear	.870
		Quadratic	.964
		Cubic	.450
		Order 4	.204
		Order 5	.189
Error(Time)		Linear	
		Quadratic	
		Cubic	
		Order 4	
		Order 5	
Condition * Time	Linear	Linear	.030
		Quadratic	.856
		Cubic	.877
		Order 4	.912
		Order 5	.145
Error(Condition*Time)	Linear	Linear	
		Quadratic	
		Cubic	
		Order 4	
		Order 5	

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	3393.916	1	3393.916	1782.467	.000
Error	13.328	7	1.904		

Estimated Marginal Means

1. Time

Estimates

Measure: MEASURE_1

Time	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	5.958	.172	5.551	6.364
2	5.885	.185	5.448	6.323
3	5.925	.146	5.581	6.269
4	6.043	.130	5.736	6.351
5	5.897	.141	5.563	6.231
6	5.967	.175	5.553	6.382

Pairwise Comparisons

Measure: MEASURE_1

(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	.073	.089	1.000	-.317	.462
	3	.033	.118	1.000	-.480	.546
	4	-.085	.143	1.000	-.710	.539
	5	.061	.155	1.000	-.612	.734
	6	-.010	.157	1.000	-.694	.674
2	1	-.073	.089	1.000	-.462	.317
	3	-.040	.142	1.000	-.657	.578
	4	-.158	.144	1.000	-.784	.468
	5	-.012	.146	1.000	-.645	.622
	6	-.082	.147	1.000	-.724	.559
3	1	-.033	.118	1.000	-.546	.480
	2	.040	.142	1.000	-.578	.657
	4	-.118	.057	1.000	-.367	.131
	5	.028	.074	1.000	-.296	.352
	6	-.042	.089	1.000	-.430	.345

4	1	.085	.143	1.000	-.539	.710
	2	.158	.144	1.000	-.468	.784
	3	.118	.057	1.000	-.131	.367
	5	.146	.049	.298	-.066	.358
	6	.076	.076	1.000	-.257	.408
5	1	-.061	.155	1.000	-.734	.612
	2	.012	.146	1.000	-.622	.645
	3	-.028	.074	1.000	-.352	.296
	4	-.146	.049	.298	-.358	.066
	6	-.071	.048	1.000	-.278	.137
6	1	.010	.157	1.000	-.674	.694
	2	.082	.147	1.000	-.559	.724
	3	.042	.089	1.000	-.345	.430
	4	-.076	.076	1.000	-.408	.257
	5	.071	.048	1.000	-.137	.278

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.
Pillai's trace	.773	2.049[a]	5.000	3.000	.295
Wilks' lambda	.227	2.049[a]	5.000	3.000	.295
Hotelling's trace	3.415	2.049[a]	5.000	3.000	.295
Roy's largest root	3.415	2.049[a]	5.000	3.000	.295

Each F tests the multivariate effect of Time. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

2. Time * Condition

Measure: MEASURE_1

Time	Condition	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	1	5.901	.207	5.412	6.390
	2	6.015	.257	5.408	6.622
2	1	5.933	.268	5.301	6.566
	2	5.837	.212	5.335	6.339
3	1	5.960	.181	5.532	6.388
	2	5.890	.273	5.245	6.535
4	1	6.248	.174	5.837	6.659

	2	5.838	.256	5.232	6.444
5	1	6.099	.179	5.675	6.523
	2	5.695	.201	5.219	6.171
6	1	6.239	.213	5.735	6.743
	2	5.696	.241	5.127	6.265

Heat Production (Hprod): Exercise

```
GLM Starth Endh Startc Endc
  /WSFACTOR=Condition 2 Polynomial Time 2 Polynomial
  /METHOD=SSTYPE(3)
  /EMMEANS=TABLES(Time) COMPARE ADJ(BONFERRONI)
  /EMMEANS=TABLES(Condition*Time)
  /PRINT=DESCRIPTIVE
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=Condition Time Condition*Time.
```

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

Condition	Time	Dependent Variable
1	1	Starth
	2	Endh
2	1	Startc
	2	Endc

Descriptive Statistics

	Mean	Std. Deviation	N
Starth	6.2390	.60327	8
Endh	59.4258	8.27782	8
Startc	5.6958	.68067	8
Endc	56.4883	7.05325	8

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.
Condition	Pillai's Trace	.375	4.200[b]	1.000	7.000	.080
	Wilks' Lambda	.625	4.200[b]	1.000	7.000	.080
	Hotelling's Trace	.600	4.200[b]	1.000	7.000	.080
	Roy's Largest Root	.600	4.200[b]	1.000	7.000	.080
Time	Pillai's Trace	.984	441.710[b]	1.000	7.000	.000
	Wilks' Lambda	.016	441.710[b]	1.000	7.000	.000
	Hotelling's Trace	63.101	441.710[b]	1.000	7.000	.000
	Roy's Largest Root	63.101	441.710[b]	1.000	7.000	.000
Condition * Time	Pillai's Trace	.179	1.531[b]	1.000	7.000	.256
	Wilks' Lambda	.821	1.531[b]	1.000	7.000	.256
	Hotelling's Trace	.219	1.531[b]	1.000	7.000	.256

	Roy's Largest Root	.219	1.531[b]	1.000	7.000	.256

a. Design: Intercept

Within Subjects Design: Condition + Time + Condition * Time

b. Exact statistic

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]
					Greenhouse-Geisser
Condition	1.000	.000	0	.	1.000
Time	1.000	.000	0	.	1.000
Condition * Time	1.000	.000	0	.	1.000

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Epsilon	
	Huynh-Feldt	Lower-bound
Condition	1.000	1.000
Time	1.000	1.000
Condition * Time	1.000	1.000

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.[a]

a. Design: Intercept

Within Subjects Design: Condition + Time + Condition * Time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F
Condition	Sphericity Assumed	24.232	1	24.232	4.200
	Greenhouse-Geisser	24.232	1.000	24.232	4.200
	Huynh-Feldt	24.232	1.000	24.232	4.200
	Lower-bound	24.232	1.000	24.232	4.200
Error(Condition)	Sphericity Assumed	40.384	7	5.769	
	Greenhouse-Geisser	40.384	7.000	5.769	
	Huynh-Feldt	40.384	7.000	5.769	

	Lower-bound	40.384	7.000	5.769	
Time	Sphericity Assumed	21623.381	1	21623.381	441.710
	Greenhouse-Geisser	21623.381	1.000	21623.381	441.710
	Huynh-Feldt	21623.381	1.000	21623.381	441.710
	Lower-bound	21623.381	1.000	21623.381	441.710
Error(Time)	Sphericity Assumed	342.676	7	48.954	
	Greenhouse-Geisser	342.676	7.000	48.954	
	Huynh-Feldt	342.676	7.000	48.954	
	Lower-bound	342.676	7.000	48.954	
Condition * Time	Sphericity Assumed	11.466	1	11.466	1.531
	Greenhouse-Geisser	11.466	1.000	11.466	1.531
	Huynh-Feldt	11.466	1.000	11.466	1.531
	Lower-bound	11.466	1.000	11.466	1.531
Error(Condition*Time)	Sphericity Assumed	52.426	7	7.489	
	Greenhouse-Geisser	52.426	7.000	7.489	
	Huynh-Feldt	52.426	7.000	7.489	
	Lower-bound	52.426	7.000	7.489	

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Sig.
Condition	Sphericity Assumed	.080
	Greenhouse-Geisser	.080
	Huynh-Feldt	.080
	Lower-bound	.080
Error(Condition)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Time	Sphericity Assumed	.000
	Greenhouse-Geisser	.000
	Huynh-Feldt	.000
	Lower-bound	.000
Error(Time)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Condition * Time	Sphericity Assumed	.256
	Greenhouse-Geisser	.256

	Huynh-Feldt	.256
	Lower-bound	.256
Error(Condition*Time)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Condition	Time	Type III Sum of Squares	df	Mean Square	F
Condition	Linear		24.232	1	24.232	4.200
Error(Condition)	Linear		40.384	7	5.769	
Time		Linear	21623.381	1	21623.381	441.710
Error(Time)		Linear	342.676	7	48.954	
Condition * Time	Linear	Linear	11.466	1	11.466	1.531
Error(Condition*Time)	Linear	Linear	52.426	7	7.489	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Condition	Time	Sig.
Condition	Linear		.080
Error(Condition)	Linear		
Time		Linear	.000
Error(Time)		Linear	
Condition * Time	Linear	Linear	.256
Error(Condition*Time)	Linear	Linear	

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	32690.691	1	32690.691	574.675	.000
Error	398.199	7	56.886		

Estimated Marginal Means

1. Time

Estimates

Measure: MEASURE_1

Time	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	5.967	.175	5.553	6.382
2	57.957	2.566	51.890	64.025

Pairwise Comparisons

Measure: MEASURE_1

(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	-51.990*	2.474	.000	-57.839	-46.140
2	1	51.990*	2.474	.000	46.140	57.839

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.
Pillai's trace	.984	441.710[a]	1.000	7.000	.000
Wilks' lambda	.016	441.710[a]	1.000	7.000	.000
Hotelling's trace	63.101	441.710[a]	1.000	7.000	.000
Roy's largest root	63.101	441.710[a]	1.000	7.000	.000

Each F tests the multivariate effect of Time. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

2. Condition * Time

Measure: MEASURE_1

Condition	Time	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	1	6.239	.213	5.735	6.743
	2	59.426	2.927	52.505	66.346
2	1	5.696	.241	5.127	6.265
	2	56.488	2.494	50.592	62.385

CARDIORESPIRATORY RESPONSE STATISTICAL ANALYSIS

Ventilation: Baseline and Passive

```
GLM HB30 H0 H30 H60 H90 H120 CB30 C0 C30 C60 C90 C120
  /WSFACTOR=Condition 2 Polynomial Time 6 Polynomial
  /METHOD=SSTYPE(3)
  /EMMEANS=TABLES(Condition) COMPARE ADJ(BONFERRONI)
  /EMMEANS=TABLES(Time*Condition) COMPARE(Condition) ADJ(BONFERRONI)
  /EMMEANS=TABLES(Condition*Time)
  /PRINT=DESCRIPTIVE
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=Condition Time Condition*Time.
```

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

Condition	Time	Dependent Variable
1	1	HB30
	2	H0
	3	H30
	4	H60
	5	H90
	6	H120
2	1	CB30
	2	C0
	3	C30
	4	C60
	5	C90
	6	C120

Descriptive Statistics

	Mean	Std. Deviation	N
HB30	8088.8676	794.31813	8
H0	8174.8977	973.66997	8
H30	8525.2665	784.36506	8
H60	8828.4113	926.33050	8
H90	8902.6976	848.42464	8
H120	9134.5149	733.48254	8
CB30	8411.8220	1129.35379	8
C0	8278.9980	527.55554	8

C30	8294.0303	962.03736	8
C60	8388.2280	775.48173	8
C90	8449.8373	1001.70303	8
C120	8468.3870	875.88664	8

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.
Condition	Pillai's Trace	.146	1.195[b]	1.000	7.000	.311
	Wilks' Lambda	.854	1.195[b]	1.000	7.000	.311
	Hotelling's Trace	.171	1.195[b]	1.000	7.000	.311
	Roy's Largest Root	.171	1.195[b]	1.000	7.000	.311
Time	Pillai's Trace	.602	.907[b]	5.000	3.000	.570
	Wilks' Lambda	.398	.907[b]	5.000	3.000	.570
	Hotelling's Trace	1.511	.907[b]	5.000	3.000	.570
	Roy's Largest Root	1.511	.907[b]	5.000	3.000	.570
Condition * Time	Pillai's Trace	.966	16.875[b]	5.000	3.000	.021
	Wilks' Lambda	.034	16.875[b]	5.000	3.000	.021
	Hotelling's Trace	28.124	16.875[b]	5.000	3.000	.021
	Roy's Largest Root	28.124	16.875[b]	5.000	3.000	.021

a. Design: Intercept

Within Subjects Design: Condition + Time + Condition * Time

b. Exact statistic

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]
					Greenhouse-Geisser
Condition	1.000	.000	0	.	1.000
Time	.051	15.211	14	.417	.469
Condition * Time	.012	22.694	14	.091	.499

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Epsilon	
	Huynh-Feldt	Lower-bound
Condition	1.000	1.000
Time	.719	.200

Condition * Time	.797	.200

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.[a]

a. Design: Intercept

Within Subjects Design: Condition + Time + Condition * Time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F
Condition	Sphericity Assumed	1239154.164	1	1239154.164	1.195
	Greenhouse-Geisser	1239154.164	1.000	1239154.164	1.195
	Huynh-Feldt	1239154.164	1.000	1239154.164	1.195
	Lower-bound	1239154.164	1.000	1239154.164	1.195
Error(Condition)	Sphericity Assumed	7258504.730	7	1036929.247	
	Greenhouse-Geisser	7258504.730	7.000	1036929.247	
	Huynh-Feldt	7258504.730	7.000	1036929.247	
	Lower-bound	7258504.730	7.000	1036929.247	
Time	Sphericity Assumed	4457646.933	5	891529.387	3.293
	Greenhouse-Geisser	4457646.933	2.343	1902255.256	3.293
	Huynh-Feldt	4457646.933	3.596	1239503.885	3.293
	Lower-bound	4457646.933	1.000	4457646.933	3.293
Error(Time)	Sphericity Assumed	9474699.749	35	270705.707	
	Greenhouse-Geisser	9474699.749	16.403	577604.465	
	Huynh-Feldt	9474699.749	25.174	376365.357	
	Lower-bound	9474699.749	7.000	1353528.536	
Condition * Time	Sphericity Assumed	2805552.990	5	561110.598	3.160
	Greenhouse-Geisser	2805552.990	2.495	1124639.813	3.160
	Huynh-Feldt	2805552.990	3.986	703908.244	3.160
	Lower-bound	2805552.990	1.000	2805552.990	3.160
Error(Condition*Time)	Sphericity Assumed	6214809.804	35	177565.994	
	Greenhouse-Geisser	6214809.804	17.462	355897.371	
	Huynh-Feldt	6214809.804	27.900	222754.957	
	Lower-bound	6214809.804	7.000	887829.972	

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Sig.
Condition	Sphericity Assumed	.311
	Greenhouse-Geisser	.311
	Huynh-Feldt	.311
	Lower-bound	.311
Error(Condition)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Time	Sphericity Assumed	.015
	Greenhouse-Geisser	.056
	Huynh-Feldt	.030
	Lower-bound	.112
Error(Time)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Condition * Time	Sphericity Assumed	.019
	Greenhouse-Geisser	.058
	Huynh-Feldt	.029
	Lower-bound	.119
Error(Condition*Time)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Condition	Time	Type III Sum of Squares	df	Mean Square	F
Condition	Linear		1239154.164	1	1239154.164	1.195
Error(Condition)	Linear		7258504.730	7	1036929.247	
Time		Linear	4230533.876	1	4230533.876	5.781
		Quadratic	15351.285	1	15351.285	.164
		Cubic	124691.861	1	124691.861	.684
		Order 4	81685.166	1	81685.166	.638
		Order 5	5384.745	1	5384.745	.025
Error(Time)		Linear	5122604.714	7	731800.673	

		Quadratic	656226.811	7	93746.687	
		Cubic	1276493.118	7	182356.160	
		Order 4	896505.230	7	128072.176	
		Order 5	1522869.876	7	217552.839	
Condition * Time	Linear	Linear	2661937.584	1	2661937.584	8.695
		Quadratic	82791.935	1	82791.935	.637
		Cubic	988.407	1	988.407	.007
		Order 4	58465.391	1	58465.391	.380
		Order 5	1369.673	1	1369.673	.008
Error(Condition*Time)	Linear	Linear	2143121.543	7	306160.220	
		Quadratic	909455.523	7	129922.218	
		Cubic	951118.011	7	135874.002	
		Order 4	1077822.713	7	153974.673	
		Order 5	1133292.016	7	161898.859	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Condition	Time	Sig.
Condition	Linear		.311
Error(Condition)	Linear		
Time		Linear	.047
		Quadratic	.698
		Cubic	.436
		Order 4	.451
		Order 5	.879
Error(Time)		Linear	
		Quadratic	
		Cubic	
		Order 4	
		Order 5	
Condition * Time	Linear	Linear	.021
		Quadratic	.451
		Cubic	.934
		Order 4	.557
		Order 5	.929
Error(Condition*Time)	Linear	Linear	
		Quadratic	
		Cubic	
		Order 4	

Order 5	

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	6928652253.104	1	6928652253.104	1177.731	.000
Error	41181374.551	7	5883053.507		

Estimated Marginal Means
1. Condition

Estimates

Measure: MEASURE_1

Condition	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	8609.109	244.892	8030.033	9188.186
2	8381.884	290.163	7695.758	9068.010

Pairwise Comparisons

Measure: MEASURE_1

(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	227.225	207.859	.311	-264.283	718.734
2	1	-227.225	207.859	.311	-718.734	264.283

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.
Pillai's trace	.146	1.195[a]	1.000	7.000	.311
Wilks' lambda	.854	1.195[a]	1.000	7.000	.311
Hotelling's trace	.171	1.195[a]	1.000	7.000	.311
Roy's largest root	.171	1.195[a]	1.000	7.000	.311

Each F tests the multivariate effect of Condition. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

2. Time * Condition

Estimates

Measure: MEASURE_1

Time	Condition	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	1	8088.868	280.834	7424.801	8752.934
	2	8411.822	399.287	7467.659	9355.985
2	1	8174.898	344.244	7360.889	8988.906
	2	8278.998	186.519	7837.951	8720.045
3	1	8525.266	277.315	7869.521	9181.012
	2	8294.030	340.132	7489.747	9098.314
4	1	8828.411	327.507	8053.980	9602.843
	2	8388.228	274.174	7739.909	9036.547
5	1	8902.698	299.963	8193.397	9611.998
	2	8449.837	354.156	7612.393	9287.282
6	1	9134.515	259.325	8521.308	9747.722
	2	8468.387	309.673	7736.127	9200.647

Pairwise Comparisons

Measure: MEASURE_1

Time	(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]
						Lower Bound
1	1	2	-322.954	295.018	.310	-1020.561
	2	1	322.954	295.018	.310	-374.653
2	1	2	-104.100	284.657	.725	-777.208
	2	1	104.100	284.657	.725	-569.007
3	1	2	231.236	316.792	.489	-517.857
	2	1	-231.236	316.792	.489	-980.330
4	1	2	440.183	305.466	.193	-282.129
	2	1	-440.183	305.466	.193	-1162.496
5	1	2	452.860	221.466	.080	-70.823
	2	1	-452.860	221.466	.080	-976.544
6	1	2	666.128[*]	265.350	.040	38.675
	2	1	-666.128[*]	265.350	.040	-1293.581

Pairwise Comparisons

Measure: MEASURE_1

Time	(I) Condition	(J) Condition	95% Confidence Interval for Difference
			Upper Bound
1	1	2	374.653
	2	1	1020.561
2	1	2	569.007
	2	1	777.208
3	1	2	980.330
	2	1	517.857
4	1	2	1162.496
	2	1	282.129
5	1	2	976.544
	2	1	70.823
6	1	2	1293.581*
	2	1	-38.675*

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Multivariate Tests

Time		Value	F	Hypothesis df	Error df	Sig.
1	Pillai's trace	.146	1.198[a]	1.000	7.000	.310
	Wilks' lambda	.854	1.198[a]	1.000	7.000	.310
	Hotelling's trace	.171	1.198[a]	1.000	7.000	.310
	Roy's largest root	.171	1.198[a]	1.000	7.000	.310
2	Pillai's trace	.019	.134[a]	1.000	7.000	.725
	Wilks' lambda	.981	.134[a]	1.000	7.000	.725
	Hotelling's trace	.019	.134[a]	1.000	7.000	.725
	Roy's largest root	.019	.134[a]	1.000	7.000	.725
3	Pillai's trace	.071	.533[a]	1.000	7.000	.489
	Wilks' lambda	.929	.533[a]	1.000	7.000	.489
	Hotelling's trace	.076	.533[a]	1.000	7.000	.489
	Roy's largest root	.076	.533[a]	1.000	7.000	.489
4	Pillai's trace	.229	2.077[a]	1.000	7.000	.193
	Wilks' lambda	.771	2.077[a]	1.000	7.000	.193
	Hotelling's trace	.297	2.077[a]	1.000	7.000	.193
	Roy's largest root	.297	2.077[a]	1.000	7.000	.193
5	Pillai's trace	.374	4.181[a]	1.000	7.000	.080

	Wilks' lambda	.626	4.181[a]	1.000	7.000	.080
	Hotelling's trace	.597	4.181[a]	1.000	7.000	.080
	Roy's largest root	.597	4.181[a]	1.000	7.000	.080
6	Pillai's trace	.474	6.302[a]	1.000	7.000	.040
	Wilks' lambda	.526	6.302[a]	1.000	7.000	.040
	Hotelling's trace	.900	6.302[a]	1.000	7.000	.040
	Roy's largest root	.900	6.302[a]	1.000	7.000	.040

Each F tests the multivariate simple effects of Condition within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

3. Condition * Time

Measure: MEASURE_1

Condition	Time	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	1	8088.868	280.834	7424.801	8752.934
	2	8174.898	344.244	7360.889	8988.906
	3	8525.266	277.315	7869.521	9181.012
	4	8828.411	327.507	8053.980	9602.843
	5	8902.698	299.963	8193.397	9611.998
	6	9134.515	259.325	8521.308	9747.722
2	1	8411.822	399.287	7467.659	9355.985
	2	8278.998	186.519	7837.951	8720.045
	3	8294.030	340.132	7489.747	9098.314
	4	8388.228	274.174	7739.909	9036.547
	5	8449.837	354.156	7612.393	9287.282
	6	8468.387	309.673	7736.127	9200.647

Ventilation: Exercise

```
GLM Hpre Hterm Cpre Cterm
  /WSFACTOR=Condition 2 Polynomial Time 2 Polynomial
  /METHOD=SSTYPE(3)
  /EMMEANS=TABLES(Condition) COMPARE ADJ(BONFERRONI)
  /EMMEANS=TABLES(Time*Condition) COMPARE(Condition) ADJ(BONFERRONI)
  /EMMEANS=TABLES(Condition*Time)
  /PRINT=DESCRIPTIVE
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=Condition Time Condition*Time.
```

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

Condition	Time	Dependent Variable
1	1	Hpre
	2	Hterm
2	1	Cpre
	2	Cterm

Descriptive Statistics

	Mean	Std. Deviation	N
Hpre	9134.5143	733.48156	8
Hterm	71047.6331	9164.20608	8
Cpre	8468.3870	875.88664	8
Cterm	56547.7379	5088.44715	8

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.
Condition	Pillai's Trace	.777	24.421[b]	1.000	7.000	.002
	Wilks' Lambda	.223	24.421[b]	1.000	7.000	.002
	Hotelling's Trace	3.489	24.421[b]	1.000	7.000	.002
	Roy's Largest Root	3.489	24.421[b]	1.000	7.000	.002
Time	Pillai's Trace	.992	829.080[b]	1.000	7.000	.000
	Wilks' Lambda	.008	829.080[b]	1.000	7.000	.000
	Hotelling's Trace	118.440	829.080[b]	1.000	7.000	.000
	Roy's Largest Root	118.440	829.080[b]	1.000	7.000	.000
Condition * Time	Pillai's Trace	.729	18.822[b]	1.000	7.000	.003

	Wilks' Lambda	.271	18.822[b]	1.000	7.000	.003
	Hotelling's Trace	2.689	18.822[b]	1.000	7.000	.003
	Roy's Largest Root	2.689	18.822[b]	1.000	7.000	.003

a. Design: Intercept

Within Subjects Design: Condition + Time + Condition * Time

b. Exact statistic

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]
					Greenhouse-Geisser
Condition	1.000	.000	0	.	1.000
Time	1.000	.000	0	.	1.000
Condition * Time	1.000	.000	0	.	1.000

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Epsilon	
	Huynh-Feldt	Lower-bound
Condition	1.000	1.000
Time	1.000	1.000
Condition * Time	1.000	1.000

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.[a]

a. Design: Intercept

Within Subjects Design: Condition + Time + Condition * Time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F
Condition	Sphericity Assumed	460016473.673	1	460016473.673	24.421

	Greenhouse-Geisser	460016473.673	1.000	460016473.673	24.421
	Huynh-Feldt	460016473.673	1.000	460016473.673	24.421
	Lower-bound	460016473.673	1.000	460016473.673	24.421
Error(Condition)	Sphericity Assumed	131858042.419	7	18836863.203	
	Greenhouse-Geisser	131858042.419	7.000	18836863.203	
	Huynh-Feldt	131858042.419	7.000	18836863.203	
	Lower-bound	131858042.419	7.000	18836863.203	
Time	Sphericity Assumed	24196686764.307	1	24196686764.307	829.080
	Greenhouse-Geisser	24196686764.307	1.000	24196686764.307	829.080
	Huynh-Feldt	24196686764.307	1.000	24196686764.307	829.080
	Lower-bound	24196686764.307	1.000	24196686764.307	829.080
Error(Time)	Sphericity Assumed	204294809.475	7	29184972.782	
	Greenhouse-Geisser	204294809.475	7.000	29184972.782	
	Huynh-Feldt	204294809.475	7.000	29184972.782	
	Lower-bound	204294809.475	7.000	29184972.782	
Condition * Time	Sphericity Assumed	382746270.635	1	382746270.635	18.822
	Greenhouse-Geisser	382746270.635	1.000	382746270.635	18.822
	Huynh-Feldt	382746270.635	1.000	382746270.635	18.822
	Lower-bound	382746270.635	1.000	382746270.635	18.822
Error(Condition*Time)	Sphericity Assumed	142347799.099	7	20335399.871	
	Greenhouse-Geisser	142347799.099	7.000	20335399.871	
	Huynh-Feldt	142347799.099	7.000	20335399.871	
	Lower-bound	142347799.099	7.000	20335399.871	

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Sig.
Condition	Sphericity Assumed	.002
	Greenhouse-Geisser	.002
	Huynh-Feldt	.002
	Lower-bound	.002
Error(Condition)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Time	Sphericity Assumed	.000
	Greenhouse-Geisser	.000
	Huynh-Feldt	.000
	Lower-bound	.000

Error(Time)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Condition * Time	Sphericity Assumed	.003
	Greenhouse-Geisser	.003
	Huynh-Feldt	.003
	Lower-bound	.003
Error(Condition*Time)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Condition	Time	Type III Sum of Squares	df	Mean Square	F
Condition	Linear		460016473.673	1	460016473.673	24.421
Error(Condition)	Linear		131858042.419	7	18836863.203	
Time		Linear	24196686764.307	1	24196686764.307	829.080
Error(Time)		Linear	204294809.475	7	29184972.782	
Condition * Time	Linear	Linear	382746270.635	1	382746270.635	18.822
Error(Condition*Time)	Linear	Linear	142347799.099	7	20335399.871	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Condition	Time	Sig.
Condition	Linear		.002
Error(Condition)	Linear		
Time		Linear	.000
Error(Time)		Linear	
Condition * Time	Linear	Linear	.003
Error(Condition*Time)	Linear	Linear	

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	42165076503.433	1	42165076503.433	984.638	.000
Error	299760330.024	7	42822904.289		

Estimated Marginal Means

1. Condition

Estimates

Measure: MEASURE_1

Condition	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	40091.074	1726.707	36008.060	44174.087
2	32508.062	933.926	30299.678	34716.447

Pairwise Comparisons

Measure: MEASURE_1

(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	7583.011*	1534.473	.002	3954.559	11211.464
2	1	-7583.011*	1534.473	.002	-11211.464	-3954.559

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.
Pillai's trace	.777	24.421[a]	1.000	7.000	.002
Wilks' lambda	.223	24.421[a]	1.000	7.000	.002
Hotelling's trace	3.489	24.421[a]	1.000	7.000	.002
Roy's largest root	3.489	24.421[a]	1.000	7.000	.002

Each F tests the multivariate effect of Condition. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

2. Time * Condition

Estimates

Measure: MEASURE_1

Time	Condition	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	1	9134.514	259.325	8521.308	9747.720
	2	8468.387	309.673	7736.127	9200.647
2	1	71047.633	3240.036	63386.165	78709.101
	2	56547.738	1799.038	52293.690	60801.786

Pairwise Comparisons

Measure: MEASURE_1

Time	(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]
						Lower Bound
1	1	2	666.127*	265.350	.040	38.675
	2	1	-666.127*	265.350	.040	-1293.580
2	1	2	14499.895*	3118.117	.002	7126.719
	2	1	-14499.895*	3118.117	.002	-21873.071

Pairwise Comparisons

Measure: MEASURE_1

Time	(I) Condition	(J) Condition	95% Confidence Interval for Difference
			Upper Bound
1	1	2	1293.580*
	2	1	-38.675*
2	1	2	21873.071*
	2	1	-7126.719*

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Multivariate Tests

Time		Value	F	Hypothesis df	Error df	Sig.
1	Pillai's trace	.474	6.302[a]	1.000	7.000	.040

	Wilks' lambda	.526	6.302[a]	1.000	7.000	.040
	Hotelling's trace	.900	6.302[a]	1.000	7.000	.040
	Roy's largest root	.900	6.302[a]	1.000	7.000	.040
2	Pillai's trace	.755	21.624[a]	1.000	7.000	.002
	Wilks' lambda	.245	21.624[a]	1.000	7.000	.002
	Hotelling's trace	3.089	21.624[a]	1.000	7.000	.002
	Roy's largest root	3.089	21.624[a]	1.000	7.000	.002

Each F tests the multivariate simple effects of Condition within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

3. Condition * Time

Measure: MEASURE_1

Condition	Time	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	1	9134.514	259.325	8521.308	9747.720
	2	71047.633	3240.036	63386.165	78709.101
2	1	8468.387	309.673	7736.127	9200.647
	2	56547.738	1799.038	52293.690	60801.786

Heart Rate: Passive and Exercise

```
GLM HB30 H0 H30 H60 H90 H120 CB30 C0 C30 C60 C90 C120
  /WSFACTOR=Condition 2 Polynomial Time 6 Polynomial
  /METHOD=SSTYPE(3)
  /EMMEANS=TABLES(Time*Condition) COMPARE(Condition) ADJ(BONFERRONI)
  /EMMEANS=TABLES(Time*Condition)
  /PRINT=DESCRIPTIVE HOMOGENEITY
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=Condition Time Condition*Time.
```

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

Condition	Time	Dependent Variable
1	1	HB30
	2	H0
	3	H30
	4	H60
	5	H90
	6	H120
2	1	CB30
	2	C0
	3	C30
	4	C60
	5	C90
	6	C120

Descriptive Statistics

	Mean	Std. Deviation	N
HB30	68.3750	13.31087	8
H0	68.4250	12.69452	8
H30	73.1000	15.58901	8
H60	81.2156	15.84497	8
H90	81.5375	15.00333	8
H120	82.8292	15.08405	8
CB30	68.9659	16.67779	8
C0	68.0125	17.46765	8
C30	65.0563	18.05055	8

C60	65.9167	17.24947	8
C90	64.4631	17.85060	8
C120	65.3264	18.35656	8

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.
Condition	Pillai's Trace	.749	20.840[b]	1.000	7.000	.003
	Wilks' Lambda	.251	20.840[b]	1.000	7.000	.003
	Hotelling's Trace	2.977	20.840[b]	1.000	7.000	.003
	Roy's Largest Root	2.977	20.840[b]	1.000	7.000	.003
Time	Pillai's Trace	.976	24.447[b]	5.000	3.000	.012
	Wilks' Lambda	.024	24.447[b]	5.000	3.000	.012
	Hotelling's Trace	40.745	24.447[b]	5.000	3.000	.012
	Roy's Largest Root	40.745	24.447[b]	5.000	3.000	.012
Condition * Time	Pillai's Trace	.970	19.098[b]	5.000	3.000	.018
	Wilks' Lambda	.030	19.098[b]	5.000	3.000	.018
	Hotelling's Trace	31.830	19.098[b]	5.000	3.000	.018
	Roy's Largest Root	31.830	19.098[b]	5.000	3.000	.018

a. Design: Intercept

Within Subjects Design: Condition + Time + Condition * Time

b. Exact statistic

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]
					Greenhouse-Geisser
Condition	1.000	.000	0	.	1.000
Time	.028	18.246	14	.241	.492
Condition * Time	.040	16.436	14	.339	.487

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Epsilon	
	Huynh-Feldt	Lower-bound

Condition	1.000	1.000
Time	.778	.200
Condition * Time	.765	.200

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.[a]

a. Design: Intercept

Within Subjects Design: Condition + Time + Condition * Time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F
Condition	Sphericity Assumed	2222.721	1	2222.721	20.840
	Greenhouse-Geisser	2222.721	1.000	2222.721	20.840
	Huynh-Feldt	2222.721	1.000	2222.721	20.840
	Lower-bound	2222.721	1.000	2222.721	20.840
Error(Condition)	Sphericity Assumed	746.584	7	106.655	
	Greenhouse-Geisser	746.584	7.000	106.655	
	Huynh-Feldt	746.584	7.000	106.655	
	Lower-bound	746.584	7.000	106.655	
Time	Sphericity Assumed	589.638	5	117.928	12.341
	Greenhouse-Geisser	589.638	2.458	239.929	12.341
	Huynh-Feldt	589.638	3.888	151.661	12.341
	Lower-bound	589.638	1.000	589.638	12.341
Error(Time)	Sphericity Assumed	334.445	35	9.556	
	Greenhouse-Geisser	334.445	17.203	19.441	
	Huynh-Feldt	334.445	27.215	12.289	
	Lower-bound	334.445	7.000	47.778	
Condition * Time	Sphericity Assumed	1365.930	5	273.186	42.052
	Greenhouse-Geisser	1365.930	2.434	561.119	42.052
	Huynh-Feldt	1365.930	3.827	356.890	42.052
	Lower-bound	1365.930	1.000	1365.930	42.052
Error(Condition*Time)	Sphericity Assumed	227.374	35	6.496	
	Greenhouse-Geisser	227.374	17.040	13.343	
	Huynh-Feldt	227.374	26.791	8.487	

	Lower-bound	227.374	7.000	32.482	

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Sig.
Condition	Sphericity Assumed	.003
	Greenhouse-Geisser	.003
	Huynh-Feldt	.003
	Lower-bound	.003
Error(Condition)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Time	Sphericity Assumed	.000
	Greenhouse-Geisser	.000
	Huynh-Feldt	.000
	Lower-bound	.010
Error(Time)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Condition * Time	Sphericity Assumed	.000
	Greenhouse-Geisser	.000
	Huynh-Feldt	.000
	Lower-bound	.000
Error(Condition*Time)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Condition	Time	Type III Sum of Squares	df	Mean Square	F
Condition	Linear		2222.721	1	2222.721	20.840
Error(Condition)	Linear		746.584	7	106.655	
Time		Linear	480.911	1	480.911	23.877

		Quadratic	.721	1	.721	.073
		Cubic	52.861	1	52.861	19.667
		Order 4	10.961	1	10.961	1.008
		Order 5	44.184	1	44.184	10.416
Error(Time)		Linear	140.991	7	20.142	
		Quadratic	68.792	7	9.827	
		Cubic	18.815	7	2.688	
		Order 4	76.154	7	10.879	
		Order 5	29.693	7	4.242	
Condition * Time	Linear	Linear	1246.747	1	1246.747	146.591
		Quadratic	32.934	1	32.934	7.794
		Cubic	67.677	1	67.677	10.032
		Order 4	17.717	1	17.717	1.669
		Order 5	.854	1	.854	.357
Error(Condition*Time)	Linear	Linear	59.535	7	8.505	
		Quadratic	29.578	7	4.225	
		Cubic	47.225	7	6.746	
		Order 4	74.303	7	10.615	
		Order 5	16.732	7	2.390	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Condition	Time	Sig.
Condition	Linear		.003
Error(Condition)	Linear		
Time		Linear	.002
		Quadratic	.794
		Cubic	.003
		Order 4	.349
		Order 5	.015
Error(Time)		Linear	
		Quadratic	
		Cubic	
		Order 4	
		Order 5	
Condition * Time	Linear	Linear	.000
		Quadratic	.027
		Cubic	.016
		Order 4	.237
		Order 5	.569

Error(Condition*Time)	Linear	Linear	
		Quadratic	
		Cubic	
		Order 4	
		Order 5	

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	485326.410	1	485326.410	163.941	.000
Error	20722.557	7	2960.365		

Estimated Marginal Means

1. Time * Condition

Estimates

Measure: MEASURE_1

Time	Condition	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	1	68.375	4.706	57.247	79.503
	2	68.966	5.896	55.023	82.909
2	1	68.425	4.488	57.812	79.038
	2	68.013	6.176	53.409	82.616
3	1	73.100	5.512	60.067	86.133
	2	65.056	6.382	49.966	80.147
4	1	81.216	5.602	67.969	94.462
	2	65.917	6.099	51.496	80.338
5	1	81.538	5.304	68.994	94.081
	2	64.463	6.311	49.540	79.387
6	1	82.829	5.333	70.219	95.440
	2	65.326	6.490	49.980	80.673

Pairwise Comparisons

Measure: MEASURE_1

Time	(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]
						Lower Bound
1	1	2	-.591	2.324	.807	-6.086
	2	1	.591	2.324	.807	-4.904
2	1	2	.412	2.460	.872	-5.405
	2	1	-.412	2.460	.872	-6.230
3	1	2	8.044*	1.947	.004	3.440
	2	1	-8.044*	1.947	.004	-12.647
4	1	2	15.299*	2.241	.000	10.000
	2	1	-15.299*	2.241	.000	-20.598
5	1	2	17.074*	2.979	.001	10.031
	2	1	-17.074*	2.979	.001	-24.118
6	1	2	17.503*	2.377	.000	11.883
	2	1	-17.503*	2.377	.000	-23.122

Pairwise Comparisons

Measure: MEASURE_1

Time	(I) Condition	(J) Condition	95% Confidence Interval for Difference
			Upper Bound
1	1	2	4.904
	2	1	6.086
2	1	2	6.230
	2	1	5.405
3	1	2	12.647*
	2	1	-3.440*
4	1	2	20.598*
	2	1	-10.000*
5	1	2	24.118*
	2	1	-10.031*
6	1	2	23.122*
	2	1	-11.883*

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Multivariate Tests

Time		Value	F	Hypothesis df	Error df	Sig.
1	Pillai's trace	.009	.065[a]	1.000	7.000	.807
	Wilks' lambda	.991	.065[a]	1.000	7.000	.807
	Hotelling's trace	.009	.065[a]	1.000	7.000	.807
	Roy's largest root	.009	.065[a]	1.000	7.000	.807
2	Pillai's trace	.004	.028[a]	1.000	7.000	.872
	Wilks' lambda	.996	.028[a]	1.000	7.000	.872
	Hotelling's trace	.004	.028[a]	1.000	7.000	.872
	Roy's largest root	.004	.028[a]	1.000	7.000	.872
3	Pillai's trace	.709	17.073[a]	1.000	7.000	.004
	Wilks' lambda	.291	17.073[a]	1.000	7.000	.004
	Hotelling's trace	2.439	17.073[a]	1.000	7.000	.004
	Roy's largest root	2.439	17.073[a]	1.000	7.000	.004
4	Pillai's trace	.869	46.606[a]	1.000	7.000	.000
	Wilks' lambda	.131	46.606[a]	1.000	7.000	.000
	Hotelling's trace	6.658	46.606[a]	1.000	7.000	.000
	Roy's largest root	6.658	46.606[a]	1.000	7.000	.000
5	Pillai's trace	.824	32.857[a]	1.000	7.000	.001
	Wilks' lambda	.176	32.857[a]	1.000	7.000	.001
	Hotelling's trace	4.694	32.857[a]	1.000	7.000	.001
	Roy's largest root	4.694	32.857[a]	1.000	7.000	.001
6	Pillai's trace	.886	54.240[a]	1.000	7.000	.000
	Wilks' lambda	.114	54.240[a]	1.000	7.000	.000
	Hotelling's trace	7.749	54.240[a]	1.000	7.000	.000
	Roy's largest root	7.749	54.240[a]	1.000	7.000	.000

Each F tests the multivariate simple effects of Condition within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

2. Time * Condition

Measure: MEASURE_1

Time	Condition	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound

1	1	68.375	4.706	57.247	79.503
	2	68.966	5.896	55.023	82.909
2	1	68.425	4.488	57.812	79.038
	2	68.013	6.176	53.409	82.616
3	1	73.100	5.512	60.067	86.133
	2	65.056	6.382	49.966	80.147
4	1	81.216	5.602	67.969	94.462
	2	65.917	6.099	51.496	80.338
5	1	81.538	5.304	68.994	94.081
	2	64.463	6.311	49.540	79.387
6	1	82.829	5.333	70.219	95.440
	2	65.326	6.490	49.980	80.673

Heart Rate: Exercise

```
GLM Hpre Hterm Cpre Cterm
  /WSFACTOR=Condition 2 Polynomial Time 2 Polynomial
  /METHOD=SSTYPE(3)
  /EMMEANS=TABLES(Condition) COMPARE ADJ(BONFERRONI)
  /EMMEANS=TABLES(Time) COMPARE ADJ(BONFERRONI)
  /EMMEANS=TABLES(Condition*Time)
  /PRINT=DESCRIPTIVE
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=Condition Time Condition*Time.
```

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

Condition	Time	Dependent Variable
1	1	Hpre
	2	Hterm
2	1	Cpre
	2	Cterm

Descriptive Statistics

	Mean	Std. Deviation	N
Hpre	79.7875	18.16955	8
Hterm	179.6500	6.74664	8
Cpre	65.3264	18.35656	8
Cterm	160.5000	8.00000	8

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.
Condition	Pillai's Trace	.842	37.250[b]	1.000	7.000	.000
	Wilks' Lambda	.158	37.250[b]	1.000	7.000	.000
	Hotelling's Trace	5.321	37.250[b]	1.000	7.000	.000
	Roy's Largest Root	5.321	37.250[b]	1.000	7.000	.000
Time	Pillai's Trace	.974	265.461[b]	1.000	7.000	.000
	Wilks' Lambda	.026	265.461[b]	1.000	7.000	.000
	Hotelling's Trace	37.923	265.461[b]	1.000	7.000	.000
	Roy's Largest Root	37.923	265.461[b]	1.000	7.000	.000

Condition * Time	Pillai's Trace	.231	2.107[b]	1.000	7.000	.190
	Wilks' Lambda	.769	2.107[b]	1.000	7.000	.190
	Hotelling's Trace	.301	2.107[b]	1.000	7.000	.190
	Roy's Largest Root	.301	2.107[b]	1.000	7.000	.190

a. Design: Intercept

Within Subjects Design: Condition + Time + Condition * Time

b. Exact statistic

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]
					Greenhouse-Geisser
Condition	1.000	.000	0	.	1.000
Time	1.000	.000	0	.	1.000
Condition * Time	1.000	.000	0	.	1.000

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Epsilon	
	Huynh-Feldt	Lower-bound
Condition	1.000	1.000
Time	1.000	1.000
Condition * Time	1.000	1.000

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.[a]

a. Design: Intercept

Within Subjects Design: Condition + Time + Condition * Time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source	Type III Sum of Squares	df	Mean Square	F

Condition	Sphericity Assumed	2259.414	1	2259.414	37.250
	Greenhouse-Geisser	2259.414	1.000	2259.414	37.250
	Huynh-Feldt	2259.414	1.000	2259.414	37.250
	Lower-bound	2259.414	1.000	2259.414	37.250
Error(Condition)	Sphericity Assumed	424.590	7	60.656	
	Greenhouse-Geisser	424.590	7.000	60.656	
	Huynh-Feldt	424.590	7.000	60.656	
	Lower-bound	424.590	7.000	60.656	
Time	Sphericity Assumed	76078.169	1	76078.169	265.461
	Greenhouse-Geisser	76078.169	1.000	76078.169	265.461
	Huynh-Feldt	76078.169	1.000	76078.169	265.461
	Lower-bound	76078.169	1.000	76078.169	265.461
Error(Time)	Sphericity Assumed	2006.125	7	286.589	
	Greenhouse-Geisser	2006.125	7.000	286.589	
	Huynh-Feldt	2006.125	7.000	286.589	
	Lower-bound	2006.125	7.000	286.589	
Condition * Time	Sphericity Assumed	43.971	1	43.971	2.107
	Greenhouse-Geisser	43.971	1.000	43.971	2.107
	Huynh-Feldt	43.971	1.000	43.971	2.107
	Lower-bound	43.971	1.000	43.971	2.107
Error(Condition*Time)	Sphericity Assumed	146.068	7	20.867	
	Greenhouse-Geisser	146.068	7.000	20.867	
	Huynh-Feldt	146.068	7.000	20.867	
	Lower-bound	146.068	7.000	20.867	

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Sig.
Condition	Sphericity Assumed	.000
	Greenhouse-Geisser	.000
	Huynh-Feldt	.000
	Lower-bound	.000
Error(Condition)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Time	Sphericity Assumed	.000
	Greenhouse-Geisser	.000
	Huynh-Feldt	.000

	Lower-bound	.000
Error(Time)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Condition * Time	Sphericity Assumed	.190
	Greenhouse-Geisser	.190
	Huynh-Feldt	.190
	Lower-bound	.190
Error(Condition*Time)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Condition	Time	Type III Sum of Squares	df	Mean Square	F
Condition	Linear		2259.414	1	2259.414	37.250
Error(Condition)	Linear		424.590	7	60.656	
Time		Linear	76078.169	1	76078.169	265.461
Error(Time)		Linear	2006.125	7	286.589	
Condition * Time	Linear	Linear	43.971	1	43.971	2.107
Error(Condition*Time)	Linear	Linear	146.068	7	20.867	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Condition	Time	Sig.
Condition	Linear		.000
Error(Condition)	Linear		
Time		Linear	.000
Error(Time)		Linear	
Condition * Time	Linear	Linear	.190
Error(Condition*Time)	Linear	Linear	

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	470962.084	1	470962.084	1152.902	.000
Error	2859.509	7	408.501		

Estimated Marginal Means

1. Condition

Estimates

Measure: MEASURE_1

Condition	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	129.719	3.662	121.060	138.377
2	112.913	3.989	103.480	122.346

Pairwise Comparisons

Measure: MEASURE_1

(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	16.806*	2.754	.000	10.294	23.317
2	1	-16.806*	2.754	.000	-23.317	-10.294

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.
Pillai's trace	.842	37.250[a]	1.000	7.000	.000
Wilks' lambda	.158	37.250[a]	1.000	7.000	.000
Hotelling's trace	5.321	37.250[a]	1.000	7.000	.000
Roy's largest root	5.321	37.250[a]	1.000	7.000	.000

Each F tests the multivariate effect of Condition. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

2. Time

Estimates

Measure: MEASURE_1

Time	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	72.557	6.271	57.728	87.386
2	170.075	2.029	165.277	174.873

Pairwise Comparisons

Measure: MEASURE_1

(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	-97.518*	5.985	.000	-111.671	-83.365
2	1	97.518*	5.985	.000	83.365	111.671

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.
Pillai's trace	.974	265.461[a]	1.000	7.000	.000
Wilks' lambda	.026	265.461[a]	1.000	7.000	.000
Hotelling's trace	37.923	265.461[a]	1.000	7.000	.000
Roy's largest root	37.923	265.461[a]	1.000	7.000	.000

Each F tests the multivariate effect of Time. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

3. Condition * Time

Measure: MEASURE_1

Condition	Time	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	1	79.788	6.424	64.597	94.978
	2	179.650	2.385	174.010	185.290
2	1	65.326	6.490	49.980	80.673
	2	160.500	2.828	153.812	167.188

CHANGES IN MASS AND RATE OF PERCEIVED EXERTION STATISTICAL ANALYSIS

Changes in Mass

```
GLM Preh Posth Exh Prec Postc Exc
  /WSFACTOR=Condition 2 Polynomial Time 3 Polynomial
  /METHOD=SSTYPE(3)
  /EMMEANS=TABLES(Condition) COMPARE ADJ(BONFERRONI)
  /EMMEANS=TABLES(Time) COMPARE ADJ(BONFERRONI)
  /EMMEANS=TABLES(Condition*Time)
  /PRINT=DESCRIPTIVE
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=Condition Time Condition*Time.
```

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

Condition	Time	Dependent Variable
1	1	Preh
	2	Posth
	3	Exh
2	1	Prec
	2	Postc
	3	Exc

Descriptive Statistics

	Mean	Std. Deviation	N
Preh	76.4162	7.53655	8
Posth	76.2287	7.35865	8
Exh	75.6638	7.39404	8
Prec	76.8438	7.55415	8
Postc	76.7762	7.53422	8
Exc	76.2000	7.56852	8

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.
Condition	Pillai's Trace	.192	1.660[b]	1.000	7.000	.239
	Wilks' Lambda	.808	1.660[b]	1.000	7.000	.239
	Hotelling's Trace	.237	1.660[b]	1.000	7.000	.239
	Roy's Largest Root	.237	1.660[b]	1.000	7.000	.239
Time	Pillai's Trace	.832	14.875[b]	2.000	6.000	.005

	Wilks' Lambda	.168	14.875[b]	2.000	6.000	.005
	Hotelling's Trace	4.958	14.875[b]	2.000	6.000	.005
	Roy's Largest Root	4.958	14.875[b]	2.000	6.000	.005
Condition * Time	Pillai's Trace	.167	.602[b]	2.000	6.000	.578
	Wilks' Lambda	.833	.602[b]	2.000	6.000	.578
	Hotelling's Trace	.201	.602[b]	2.000	6.000	.578
	Roy's Largest Root	.201	.602[b]	2.000	6.000	.578

a. Design: Intercept

Within Subjects Design: Condition + Time + Condition * Time

b. Exact statistic

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]
					Greenhouse-Geisser
Condition	1.000	.000	0	.	1.000
Time	.265	7.965	2	.019	.576
Condition * Time	.348	6.331	2	.042	.605

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Epsilon	
	Huynh-Feldt	Lower-bound
Condition	1.000	1.000
Time	.618	.500
Condition * Time	.664	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.[a]

a. Design: Intercept

Within Subjects Design: Condition + Time + Condition * Time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F
Condition	Sphericity Assumed	3.045	1	3.045	1.660
	Greenhouse-Geisser	3.045	1.000	3.045	1.660
	Huynh-Feldt	3.045	1.000	3.045	1.660
	Lower-bound	3.045	1.000	3.045	1.660
Error(Condition)	Sphericity Assumed	12.840	7	1.834	
	Greenhouse-Geisser	12.840	7.000	1.834	
	Huynh-Feldt	12.840	7.000	1.834	
	Lower-bound	12.840	7.000	1.834	
Time	Sphericity Assumed	4.423	2	2.211	21.939
	Greenhouse-Geisser	4.423	1.153	3.836	21.939
	Huynh-Feldt	4.423	1.235	3.580	21.939
	Lower-bound	4.423	1.000	4.423	21.939
Error(Time)	Sphericity Assumed	1.411	14	.101	
	Greenhouse-Geisser	1.411	8.070	.175	
	Huynh-Feldt	1.411	8.647	.163	
	Lower-bound	1.411	7.000	.202	
Condition * Time	Sphericity Assumed	.035	2	.018	.231
	Greenhouse-Geisser	.035	1.211	.029	.231
	Huynh-Feldt	.035	1.328	.026	.231
	Lower-bound	.035	1.000	.035	.231
Error(Condition*Time)	Sphericity Assumed	1.065	14	.076	
	Greenhouse-Geisser	1.065	8.475	.126	
	Huynh-Feldt	1.065	9.293	.115	
	Lower-bound	1.065	7.000	.152	

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Sig.
Condition	Sphericity Assumed	.239
	Greenhouse-Geisser	.239
	Huynh-Feldt	.239
	Lower-bound	.239
Error(Condition)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Time	Sphericity Assumed	.000

	Greenhouse-Geisser	.001
	Huynh-Feldt	.001
	Lower-bound	.002
Error(Time)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Condition * Time	Sphericity Assumed	.797
	Greenhouse-Geisser	.688
	Huynh-Feldt	.709
	Lower-bound	.645
Error(Condition*Time)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Condition	Time	Type III Sum of Squares	df	Mean Square	F
Condition	Linear		3.045	1	3.045	1.660
Error(Condition)	Linear		12.840	7	1.834	
Time		Linear	3.899	1	3.899	21.280
		Quadratic	.524	1	.524	28.510
Error(Time)		Linear	1.283	7	.183	
		Quadratic	.129	7	.018	
Condition * Time	Linear	Linear	.024	1	.024	.179
		Quadratic	.011	1	.011	.569
Error(Condition*Time)	Linear	Linear	.924	7	.132	
		Quadratic	.141	7	.020	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Condition	Time	Sig.
Condition	Linear		.239
Error(Condition)	Linear		
Time		Linear	.002
		Quadratic	.001
Error(Time)		Linear	

		Quadratic	
Condition * Time	Linear	Linear	.685
		Quadratic	.475
Error(Condition*Time)	Linear	Linear	
		Quadratic	

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	279842.602	1	279842.602	836.486	.000
Error	2341.818	7	334.545		

Estimated Marginal Means

1. Condition

Estimates

Measure: MEASURE_1

Condition	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	76.103	2.625	69.896	82.310
2	76.607	2.669	70.295	82.919

Pairwise Comparisons

Measure: MEASURE_1

(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	-.504	.391	.239	-1.428	.421
2	1	.504	.391	.239	-.421	1.428

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.
Pillai's trace	.192	1.660[a]	1.000	7.000	.239
Wilks' lambda	.808	1.660[a]	1.000	7.000	.239

Hotelling's trace	.237	1.660[a]	1.000	7.000	.239
Roy's largest root	.237	1.660[a]	1.000	7.000	.239

Each F tests the multivariate effect of Condition. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

2. Time

Estimates

Measure: MEASURE_1

Time	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	76.630	2.663	70.332	82.928
2	76.503	2.626	70.292	82.713
3	75.932	2.632	69.707	82.157

Pairwise Comparisons

Measure: MEASURE_1

(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	.127	.068	.310	-.086	.341
	3	.698*	.151	.007	.225	1.171
2	1	-.127	.068	.310	-.341	.086
	3	.571*	.101	.002	.254	.887
3	1	-.698*	.151	.007	-1.171	-.225
	2	-.571*	.101	.002	-.887	-.254

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.
Pillai's trace	.832	14.875[a]	2.000	6.000	.005
Wilks' lambda	.168	14.875[a]	2.000	6.000	.005
Hotelling's trace	4.958	14.875[a]	2.000	6.000	.005
Roy's largest root	4.958	14.875[a]	2.000	6.000	.005

Each F tests the multivariate effect of Time. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

3. Condition * Time

Measure: MEASURE_1

Condition	Time	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	1	76.416	2.665	70.116	82.717
	2	76.229	2.602	70.077	82.381
	3	75.664	2.614	69.482	81.845
2	1	76.844	2.671	70.528	83.159
	2	76.776	2.664	70.477	83.075
	3	76.200	2.676	69.873	82.527

Rate of Perceived Exertion

```
GLM Hpre Hterm Cpre Cterm
  /WSFACTOR=Condition 2 Polynomial Time 2 Polynomial
  /METHOD=SSTYPE(3)
  /EMMEANS=TABLES(Condition) COMPARE ADJ(BONFERRONI)
  /EMMEANS=TABLES(Time*Condition) COMPARE(Condition) ADJ(BONFERRONI)
  /EMMEANS=TABLES(Condition*Time)
  /PRINT=DESCRIPTIVE
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=Condition Time Condition*Time.
```

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

Condition	Time	Dependent Variable
1	1	Hpre
	2	Hterm
2	1	Cpre
	2	Cterm

Descriptive Statistics

	Mean	Std. Deviation	N
Hpre	.0000	.00000	8
Hterm	9.5000	.75593	8
Cpre	.0000	.00000	8
Cterm	5.0000	1.06904	8

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.
Condition	Pillai's Trace	.953	141.750[b]	1.000	7.000	.000
	Wilks' Lambda	.047	141.750[b]	1.000	7.000	.000
	Hotelling's Trace	20.250	141.750[b]	1.000	7.000	.000
	Roy's Largest Root	20.250	141.750[b]	1.000	7.000	.000
Time	Pillai's Trace	.991	735.875[b]	1.000	7.000	.000
	Wilks' Lambda	.009	735.875[b]	1.000	7.000	.000
	Hotelling's Trace	105.125	735.875[b]	1.000	7.000	.000
	Roy's Largest Root	105.125	735.875[b]	1.000	7.000	.000
Condition * Time	Pillai's Trace	.953	141.750[b]	1.000	7.000	.000

	Wilks' Lambda	.047	141.750[b]	1.000	7.000	.000
	Hotelling's Trace	20.250	141.750[b]	1.000	7.000	.000
	Roy's Largest Root	20.250	141.750[b]	1.000	7.000	.000

a. Design: Intercept

Within Subjects Design: Condition + Time + Condition * Time

b. Exact statistic

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]
					Greenhouse-Geisser
Condition	1.000	.000	0	.	1.000
Time	1.000	.000	0	.	1.000
Condition * Time	1.000	.000	0	.	1.000

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Epsilon	
	Huynh-Feldt	Lower-bound
Condition	1.000	1.000
Time	1.000	1.000
Condition * Time	1.000	1.000

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.[a]

a. Design: Intercept

Within Subjects Design: Condition + Time + Condition * Time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F
Condition	Sphericity Assumed	40.500	1	40.500	141.750

	Greenhouse-Geisser	40.500	1.000	40.500	141.750
	Huynh-Feldt	40.500	1.000	40.500	141.750
	Lower-bound	40.500	1.000	40.500	141.750
Error(Condition)	Sphericity Assumed	2.000	7	.286	
	Greenhouse-Geisser	2.000	7.000	.286	
	Huynh-Feldt	2.000	7.000	.286	
	Lower-bound	2.000	7.000	.286	
Time	Sphericity Assumed	420.500	1	420.500	735.875
	Greenhouse-Geisser	420.500	1.000	420.500	735.875
	Huynh-Feldt	420.500	1.000	420.500	735.875
	Lower-bound	420.500	1.000	420.500	735.875
Error(Time)	Sphericity Assumed	4.000	7	.571	
	Greenhouse-Geisser	4.000	7.000	.571	
	Huynh-Feldt	4.000	7.000	.571	
	Lower-bound	4.000	7.000	.571	
Condition * Time	Sphericity Assumed	40.500	1	40.500	141.750
	Greenhouse-Geisser	40.500	1.000	40.500	141.750
	Huynh-Feldt	40.500	1.000	40.500	141.750
	Lower-bound	40.500	1.000	40.500	141.750
Error(Condition*Time)	Sphericity Assumed	2.000	7	.286	
	Greenhouse-Geisser	2.000	7.000	.286	
	Huynh-Feldt	2.000	7.000	.286	
	Lower-bound	2.000	7.000	.286	

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Sig.
Condition	Sphericity Assumed	.000
	Greenhouse-Geisser	.000
	Huynh-Feldt	.000
	Lower-bound	.000
Error(Condition)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Time	Sphericity Assumed	.000
	Greenhouse-Geisser	.000
	Huynh-Feldt	.000
	Lower-bound	.000

Error(Time)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Condition * Time	Sphericity Assumed	.000
	Greenhouse-Geisser	.000
	Huynh-Feldt	.000
	Lower-bound	.000
Error(Condition*Time)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Condition	Time	Type III Sum of Squares	df	Mean Square	F
Condition	Linear		40.500	1	40.500	141.750
Error(Condition)	Linear		2.000	7	.286	
Time		Linear	420.500	1	420.500	735.875
Error(Time)		Linear	4.000	7	.571	
Condition * Time	Linear	Linear	40.500	1	40.500	141.750
Error(Condition*Time)	Linear	Linear	2.000	7	.286	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Condition	Time	Sig.
Condition	Linear		.000
Error(Condition)	Linear		
Time		Linear	.000
Error(Time)		Linear	
Condition * Time	Linear	Linear	.000
Error(Condition*Time)	Linear	Linear	

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	420.500	1	420.500	735.875	.000

Error	4.000	7	.571		

Estimated Marginal Means

1. Condition

Estimates

Measure: MEASURE_1

Condition	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	4.750	.134	4.434	5.066
2	2.500	.189	2.053	2.947

Pairwise Comparisons

Measure: MEASURE_1

(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	2.250*	.189	.000	1.803	2.697
2	1	-2.250*	.189	.000	-2.697	-1.803

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.
Pillai's trace	.953	141.750[a]	1.000	7.000	.000
Wilks' lambda	.047	141.750[a]	1.000	7.000	.000
Hotelling's trace	20.250	141.750[a]	1.000	7.000	.000
Roy's largest root	20.250	141.750[a]	1.000	7.000	.000

Each F tests the multivariate effect of Condition. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

2. Time * Condition

Estimates

Measure: MEASURE_1

Time	Condition	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound

1	1	.000	.000	.000	.000
	2	.000	.000	.000	.000
2	1	9.500	.267	8.868	10.132
	2	5.000	.378	4.106	5.894

Pairwise Comparisons

Measure: MEASURE_1

Time	(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]
						Lower Bound
1	1	2	.000	.000	.	.000
	2	1	.000	.000	.	.000
2	1	2	4.500*	.378	.000	3.606
	2	1	-4.500*	.378	.000	-5.394

Pairwise Comparisons

Measure: MEASURE_1

Time	(I) Condition	(J) Condition	95% Confidence Interval for Difference
			Upper Bound
1	1	2	.000
	2	1	.000
2	1	2	5.394*
	2	1	-3.606*

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Multivariate Tests

Time		Value	F	Hypothesis df	Error df	Sig.
1	Pillai's trace	.	.[a]	.	.	.
	Wilks' lambda	.	.[a]	.	.	.
	Hotelling's trace	.	.[a]	.	.	.
	Roy's largest root	.	.[a]	.	.	.
2	Pillai's trace	.953	141.750[a]	1.000	7.000	.000
	Wilks' lambda	.047	141.750[a]	1.000	7.000	.000
	Hotelling's trace	20.250	141.750[a]	1.000	7.000	.000

Roy's largest root	20.250	141.750[a]	1.000	7.000	.000

Each F tests the multivariate simple effects of Condition within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

3. Condition * Time

Measure: MEASURE_1

Condition	Time	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	1	.000	.000	.000	.000
	2	9.500	.267	8.868	10.132
2	1	.000	.000	.000	.000
	2	5.000	.378	4.106	5.894

ABSOLUTE FUEL SELECTION STATISTICAL ANALYSIS

Carbohydrates (CHO)

```
NEW FILE.
DATASET NAME DataSet3 WINDOW=FRONT.
GLM Hbase Hpassive Hex Cbase Cpassive Cex
  /WSFACTOR=Condition 2 Polynomial Time 3 Polynomial
  /METHOD=SSTYPE(3)
  /EMMEANS=TABLES(Time) COMPARE ADJ(BONFERRONI)
  /EMMEANS=TABLES(Condition*Time)
  /PRINT=DESCRIPTIVE
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=Condition Time Condition*Time.
```

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

Condition	Time	Dependent Variable
1	1	Hbase
	2	Hpassive
	3	Hex
2	1	Cbase
	2	Cpassive
	3	Cex

Descriptive Statistics

	Mean	Std. Deviation	N
Hbase	68.6301	35.53717	6
Hpassive	109.2597	35.19597	6
Hex	2572.5932	327.62545	6
Cbase	95.2880	49.70397	6
Cpassive	85.3884	43.42438	6
Cex	2392.5882	289.09137	6

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.
Condition	Pillai's Trace	.262	1.774[b]	1.000	5.000	.240
	Wilks' Lambda	.738	1.774[b]	1.000	5.000	.240
	Hotelling's Trace	.355	1.774[b]	1.000	5.000	.240
	Roy's Largest Root	.355	1.774[b]	1.000	5.000	.240

Time	Pillai's Trace	.987	150.022[b]	2.000	4.000	.000
	Wilks' Lambda	.013	150.022[b]	2.000	4.000	.000
	Hotelling's Trace	75.011	150.022[b]	2.000	4.000	.000
	Roy's Largest Root	75.011	150.022[b]	2.000	4.000	.000
Condition * Time	Pillai's Trace	.895	17.031[b]	2.000	4.000	.011
	Wilks' Lambda	.105	17.031[b]	2.000	4.000	.011
	Hotelling's Trace	8.516	17.031[b]	2.000	4.000	.011
	Roy's Largest Root	8.516	17.031[b]	2.000	4.000	.011

a. Design: Intercept

Within Subjects Design: Condition + Time + Condition * Time

b. Exact statistic

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]
					Greenhouse-Geisser
Condition	1.000	.000	0	.	1.000
Time	.027	14.508	2	.001	.507
Condition * Time	.003	23.547	2	.000	.501

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Epsilon	
	Huynh-Feldt	Lower-bound
Condition	1.000	1.000
Time	.512	.500
Condition * Time	.501	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.[a]

a. Design: Intercept

Within Subjects Design: Condition + Time + Condition * Time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F
Condition	Sphericity Assumed	31406.358	1	31406.358	1.774
	Greenhouse-Geisser	31406.358	1.000	31406.358	1.774
	Huynh-Feldt	31406.358	1.000	31406.358	1.774
	Lower-bound	31406.358	1.000	31406.358	1.774
Error(Condition)	Sphericity Assumed	88528.650	5	17705.730	
	Greenhouse-Geisser	88528.650	5.000	17705.730	
	Huynh-Feldt	88528.650	5.000	17705.730	
	Lower-bound	88528.650	5.000	17705.730	
Time	Sphericity Assumed	45811060.887	2	22905530.443	371.604
	Greenhouse-Geisser	45811060.887	1.013	45201939.942	371.604
	Huynh-Feldt	45811060.887	1.024	44752139.142	371.604
	Lower-bound	45811060.887	1.000	45811060.887	371.604
Error(Time)	Sphericity Assumed	616396.190	10	61639.619	
	Greenhouse-Geisser	616396.190	5.067	121640.071	
	Huynh-Feldt	616396.190	5.118	120429.641	
	Lower-bound	616396.190	5.000	123279.238	
Condition * Time	Sphericity Assumed	69640.513	2	34820.257	4.443
	Greenhouse-Geisser	69640.513	1.001	69543.861	4.443
	Huynh-Feldt	69640.513	1.002	69471.490	4.443
	Lower-bound	69640.513	1.000	69640.513	4.443
Error(Condition*Time)	Sphericity Assumed	78365.612	10	7836.561	
	Greenhouse-Geisser	78365.612	5.007	15651.370	
	Huynh-Feldt	78365.612	5.012	15635.082	
	Lower-bound	78365.612	5.000	15673.122	

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Sig.
Condition	Sphericity Assumed	.240
	Greenhouse-Geisser	.240
	Huynh-Feldt	.240
	Lower-bound	.240
Error(Condition)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Time	Sphericity Assumed	.000

	Greenhouse-Geisser	.000
	Huynh-Feldt	.000
	Lower-bound	.000
Error(Time)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Condition * Time	Sphericity Assumed	.042
	Greenhouse-Geisser	.089
	Huynh-Feldt	.089
	Lower-bound	.089
Error(Condition*Time)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Condition	Time	Type III Sum of Squares	df	Mean Square	F
Condition	Linear		31406.358	1	31406.358	1.774
Error(Condition)	Linear		88528.650	5	17705.730	
Time		Linear	34578193.521	1	34578193.521	371.555
		Quadratic	11232867.365	1	11232867.365	371.755
Error(Time)		Linear	465317.222	5	93063.444	
		Quadratic	151078.968	5	30215.794	
Condition * Time	Linear	Linear	64064.349	1	64064.349	4.684
		Quadratic	5576.164	1	5576.164	2.793
Error(Condition*Time)	Linear	Linear	68382.629	5	13676.526	
		Quadratic	9982.983	5	1996.597	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Condition	Time	Sig.
Condition	Linear		.240
Error(Condition)	Linear		
Time		Linear	.000
		Quadratic	.000
Error(Time)		Linear	

		Quadratic	
Condition * Time	Linear	Linear	.083
		Quadratic	.156
Error(Condition*Time)	Linear	Linear	
		Quadratic	

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	28342287.690	1	28342287.690	689.392	.000
Error	205559.885	5	41111.977		

Estimated Marginal Means

1. Time

Estimates

Measure: MEASURE_1

Time	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	81.959	14.723	44.112	119.806
2	97.324	8.417	75.688	118.961
3	2482.591	115.809	2184.895	2780.286

Pairwise Comparisons

Measure: MEASURE_1

(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	-15.365	11.808	.750	-57.096	26.366
	3	-2400.632*	124.541	.000	-2840.775	-1960.488
2	1	15.365	11.808	.750	-26.366	57.096
	3	-2385.267*	123.166	.000	-2820.548	-1949.985
3	1	2400.632*	124.541	.000	1960.488	2840.775
	2	2385.267*	123.166	.000	1949.985	2820.548

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.
Pillai's trace	.987	150.022[a]	2.000	4.000	.000
Wilks' lambda	.013	150.022[a]	2.000	4.000	.000
Hotelling's trace	75.011	150.022[a]	2.000	4.000	.000
Roy's largest root	75.011	150.022[a]	2.000	4.000	.000

Each F tests the multivariate effect of Time. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

2. Condition * Time

Measure: MEASURE_1

Condition	Time	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	1	68.630	14.508	31.336	105.924
	2	109.260	14.369	72.324	146.196
	3	2572.593	133.753	2228.771	2916.415
2	1	95.288	20.292	43.127	147.449
	2	85.388	17.728	39.817	130.960
	3	2392.588	118.021	2089.205	2695.971

Lipids

```
GLM Hbase Hpassive Hex Cbase Cpassive Cex
  /WSFACTOR=Condition 2 Polynomial Time 3 Polynomial
  /METHOD=SSTYPE(3)
  /EMMEANS=TABLES(Time) COMPARE ADJ(BONFERRONI)
  /EMMEANS=TABLES(Condition*Time)
  /PRINT=DESCRIPTIVE
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=Condition Time Condition*Time.
```

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

Condition	Time	Dependent Variable
1	1	Hbase
	2	Hpassive
	3	Hex
2	1	Cbase
	2	Cpassive
	3	Cex

Descriptive Statistics

	Mean	Std. Deviation	N
Hbase	85.2582	23.59832	6
Hpassive	74.0701	16.69686	6
Hex	244.4258	75.04592	6
Cbase	72.7727	21.43966	6
Cpassive	73.9467	20.49360	6
Cex	267.9100	101.17884	6

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.
Condition	Pillai's Trace	.008	.042[b]	1.000	5.000	.846
	Wilks' Lambda	.992	.042[b]	1.000	5.000	.846
	Hotelling's Trace	.008	.042[b]	1.000	5.000	.846
	Roy's Largest Root	.008	.042[b]	1.000	5.000	.846
Time	Pillai's Trace	.950	38.253[b]	2.000	4.000	.002
	Wilks' Lambda	.050	38.253[b]	2.000	4.000	.002
	Hotelling's Trace	19.127	38.253[b]	2.000	4.000	.002
	Roy's Largest Root	19.127	38.253[b]	2.000	4.000	.002

Condition * Time	Pillai's Trace	.422	1.458[b]	2.000	4.000	.334
	Wilks' Lambda	.578	1.458[b]	2.000	4.000	.334
	Hotelling's Trace	.729	1.458[b]	2.000	4.000	.334
	Roy's Largest Root	.729	1.458[b]	2.000	4.000	.334

a. Design: Intercept

Within Subjects Design: Condition + Time + Condition * Time

b. Exact statistic

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]
					Greenhouse-Geisser
Condition	1.000	.000	0	.	1.000
Time	.022	15.224	2	.000	.506
Condition * Time	.088	9.708	2	.008	.523

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Epsilon	
	Huynh-Feldt	Lower-bound
Condition	1.000	1.000
Time	.510	.500
Condition * Time	.541	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.[a]

a. Design: Intercept

Within Subjects Design: Condition + Time + Condition * Time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F
Condition	Sphericity Assumed	118.274	1	118.274	.042
	Greenhouse-Geisser	118.274	1.000	118.274	.042

	Huynh-Feldt	118.274	1.000	118.274	.042
	Lower-bound	118.274	1.000	118.274	.042
Error(Condition)	Sphericity Assumed	14054.405	5	2810.881	
	Greenhouse-Geisser	14054.405	5.000	2810.881	
	Huynh-Feldt	14054.405	5.000	2810.881	
	Lower-bound	14054.405	5.000	2810.881	
Time	Sphericity Assumed	258360.530	2	129180.265	50.368
	Greenhouse-Geisser	258360.530	1.011	255487.631	50.368
	Huynh-Feldt	258360.530	1.020	253360.754	50.368
	Lower-bound	258360.530	1.000	258360.530	50.368
Error(Time)	Sphericity Assumed	25647.456	10	2564.746	
	Greenhouse-Geisser	25647.456	5.056	5072.453	
	Huynh-Feldt	25647.456	5.099	5030.226	
	Lower-bound	25647.456	5.000	5129.491	
Condition * Time	Sphericity Assumed	2003.953	2	1001.976	.824
	Greenhouse-Geisser	2003.953	1.046	1915.480	.824
	Huynh-Feldt	2003.953	1.082	1852.469	.824
	Lower-bound	2003.953	1.000	2003.953	.824
Error(Condition*Time)	Sphericity Assumed	12162.344	10	1216.234	
	Greenhouse-Geisser	12162.344	5.231	2325.077	
	Huynh-Feldt	12162.344	5.409	2248.592	
	Lower-bound	12162.344	5.000	2432.469	

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Sig.
Condition	Sphericity Assumed	.846
	Greenhouse-Geisser	.846
	Huynh-Feldt	.846
	Lower-bound	.846
Error(Condition)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Time	Sphericity Assumed	.000
	Greenhouse-Geisser	.001
	Huynh-Feldt	.001
	Lower-bound	.001
Error(Time)	Sphericity Assumed	

	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Condition * Time	Sphericity Assumed	.466
	Greenhouse-Geisser	.410
	Huynh-Feldt	.413
	Lower-bound	.406
Error(Condition*Time)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Condition	Time	Type III Sum of Squares	df	Mean Square	F
Condition	Linear		118.274	1	118.274	.042
Error(Condition)	Linear		14054.405	5	2810.881	
Time		Linear	188297.938	1	188297.938	55.465
		Quadratic	70062.592	1	70062.592	40.392
Error(Time)		Linear	16974.548	5	3394.910	
		Quadratic	8672.909	5	1734.582	
Condition * Time	Linear	Linear	1940.723	1	1940.723	1.014
		Quadratic	63.230	1	63.230	.122
Error(Condition*Time)	Linear	Linear	9572.352	5	1914.470	
		Quadratic	2589.992	5	517.998	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Condition	Time	Sig.
Condition	Linear		.846
Error(Condition)	Linear		
Time		Linear	.001
		Quadratic	.001
Error(Time)		Linear	
		Quadratic	
Condition * Time	Linear	Linear	.360
		Quadratic	.741
Error(Condition*Time)	Linear	Linear	

Quadratic	

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	669751.420	1	669751.420	92.872	.000
Error	36057.601	5	7211.520		

Estimated Marginal Means

1. Time

Estimates

Measure: MEASURE_1

Time	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	79.015	7.630	59.401	98.630
2	74.008	5.660	59.459	88.558
3	256.168	30.629	177.432	334.903

Pairwise Comparisons

Measure: MEASURE_1

(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	5.007	3.521	.643	-7.435	17.449
	3	-177.152*	23.787	.002	-261.218	-93.087
2	1	-5.007	3.521	.643	-17.449	7.435
	3	-182.159*	26.536	.003	-275.941	-88.378
3	1	177.152*	23.787	.002	93.087	261.218
	2	182.159*	26.536	.003	88.378	275.941

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.

Pillai's trace	.950	38.253[a]	2.000	4.000	.002
Wilks' lambda	.050	38.253[a]	2.000	4.000	.002
Hotelling's trace	19.127	38.253[a]	2.000	4.000	.002
Roy's largest root	19.127	38.253[a]	2.000	4.000	.002

Each F tests the multivariate effect of Time. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

2. Condition * Time

Measure: MEASURE_1

Condition	Time	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	1	85.258	9.634	60.493	110.023
	2	74.070	6.816	56.548	91.592
	3	244.426	30.637	165.670	323.182
2	1	72.773	8.753	50.273	95.272
	2	73.947	8.366	52.440	95.453
	3	267.910	41.306	161.729	374.091

Proteins

```
T-TEST PAIRS=Hbase WITH Cbase (PAIRED)
  /CRITERIA=CI(.9500)
  /MISSING=ANALYSIS.
```

T-Test

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Hbase	68.1473	8	17.93175	6.33983
	Cbase	71.3824	8	12.34811	4.36572

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Hbase & Cbase	8	.594	.121

Paired Samples Test

		Paired Differences				
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference	
					Lower	Upper
Pair 1	Hbase - Cbase	-3.23504	14.53052	5.13732	-15.38286	8.91278

Paired Samples Test

		t	df	Sig. (2-tailed)
Pair 1	Hbase - Cbase	-.630	7	.549

RELATIVE FUEL SELECTION

Carbohydrates (CHO)

```
GLM Hbase Hpassive Hex Cbase Cpassive Cex
  /WSFACTOR=Condition 2 Polynomial Time 3 Polynomial
  /METHOD=SSTYPE(3)
  /EMMEANS=TABLES(Time) COMPARE ADJ(BONFERRONI)
  /EMMEANS=TABLES(Condition*Time)
  /PRINT=DESCRIPTIVE
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=Condition Time Condition*Time.
```

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

Condition	Time	Dependent Variable
1	1	Hbase
	2	Hpassive
	3	Hex
2	1	Cbase
	2	Cpassive
	3	Cex

Descriptive Statistics

	Mean	Std. Deviation	N
Hbase	19.0252	10.08340	6
Hpassive	28.8254	8.94107	6
Hex	78.8033	5.27127	6
Cbase	26.3760	13.85320	6
Cpassive	24.2136	12.49799	6
Cex	75.7563	6.21253	6

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.
Condition	Pillai's Trace	.000	.000[b]	1.000	5.000	.984
	Wilks' Lambda	1.000	.000[b]	1.000	5.000	.984
	Hotelling's Trace	.000	.000[b]	1.000	5.000	.984
	Roy's Largest Root	.000	.000[b]	1.000	5.000	.984
Time	Pillai's Trace	.985	135.539[b]	2.000	4.000	.000
	Wilks' Lambda	.015	135.539[b]	2.000	4.000	.000

	Hotelling's Trace	67.769	135.539[b]	2.000	4.000	.000
	Roy's Largest Root	67.769	135.539[b]	2.000	4.000	.000
Condition * Time	Pillai's Trace	.667	4.007[b]	2.000	4.000	.111
	Wilks' Lambda	.333	4.007[b]	2.000	4.000	.111
	Hotelling's Trace	2.004	4.007[b]	2.000	4.000	.111
	Roy's Largest Root	2.004	4.007[b]	2.000	4.000	.111

a. Design: Intercept

Within Subjects Design: Condition + Time + Condition * Time

b. Exact statistic

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]
					Greenhouse-Geisser
Condition	1.000	.000	0	.	1.000
Time	.900	.422	2	.810	.909
Condition * Time	.952	.195	2	.907	.955

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Epsilon	
	Huynh-Feldt	Lower-bound
Condition	1.000	1.000
Time	1.000	.500
Condition * Time	1.000	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.[a]

a. Design: Intercept

Within Subjects Design: Condition + Time + Condition * Time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source	Type III Sum of Squares	df	Mean Square	F

Condition	Sphericity Assumed	.095	1	.095	.000
	Greenhouse-Geisser	.095	1.000	.095	.000
	Huynh-Feldt	.095	1.000	.095	.000
	Lower-bound	.095	1.000	.095	.000
Error(Condition)	Sphericity Assumed	1030.524	5	206.105	
	Greenhouse-Geisser	1030.524	5.000	206.105	
	Huynh-Feldt	1030.524	5.000	206.105	
	Lower-bound	1030.524	5.000	206.105	
Time	Sphericity Assumed	22280.351	2	11140.175	203.678
	Greenhouse-Geisser	22280.351	1.818	12254.435	203.678
	Huynh-Feldt	22280.351	2.000	11140.175	203.678
	Lower-bound	22280.351	1.000	22280.351	203.678
Error(Time)	Sphericity Assumed	546.949	10	54.695	
	Greenhouse-Geisser	546.949	9.091	60.166	
	Huynh-Feldt	546.949	10.000	54.695	
	Lower-bound	546.949	5.000	109.390	
Condition * Time	Sphericity Assumed	253.668	2	126.834	4.024
	Greenhouse-Geisser	253.668	1.909	132.878	4.024
	Huynh-Feldt	253.668	2.000	126.834	4.024
	Lower-bound	253.668	1.000	253.668	4.024
Error(Condition*Time)	Sphericity Assumed	315.158	10	31.516	
	Greenhouse-Geisser	315.158	9.545	33.018	
	Huynh-Feldt	315.158	10.000	31.516	
	Lower-bound	315.158	5.000	63.032	

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Sig.
Condition	Sphericity Assumed	.984
	Greenhouse-Geisser	.984
	Huynh-Feldt	.984
	Lower-bound	.984
Error(Condition)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Time	Sphericity Assumed	.000
	Greenhouse-Geisser	.000
	Huynh-Feldt	.000

	Lower-bound	.000
Error(Time)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Condition * Time	Sphericity Assumed	.052
	Greenhouse-Geisser	.055
	Huynh-Feldt	.052
	Lower-bound	.101
Error(Condition*Time)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Condition	Time	Type III Sum of Squares	df	Mean Square	F
Condition	Linear		.095	1	.095	.000
Error(Condition)	Linear		1030.524	5	206.105	
Time		Linear	17873.361	1	17873.361	250.442
		Quadratic	4406.990	1	4406.990	115.905
Error(Time)		Linear	356.837	5	71.367	
		Quadratic	190.113	5	38.023	
Condition * Time	Linear	Linear	162.172	1	162.172	4.859
		Quadratic	91.496	1	91.496	3.085
Error(Condition*Time)	Linear	Linear	166.880	5	33.376	
		Quadratic	148.278	5	29.656	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Condition	Time	Sig.
Condition	Linear		.984
Error(Condition)	Linear		
Time		Linear	.000
		Quadratic	.000
Error(Time)		Linear	
		Quadratic	
Condition * Time	Linear	Linear	.079

		Quadratic	.139
Error(Condition*Time)	Linear	Linear	
		Quadratic	

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	64008.947	1	64008.947	294.181	.000
Error	1087.919	5	217.584		

Estimated Marginal Means

1. Time

Estimates

Measure: MEASURE_1

Time	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	22.701	4.137	12.066	33.335
2	26.520	2.626	19.770	33.269
3	77.280	1.799	72.654	81.905

Pairwise Comparisons

Measure: MEASURE_1

(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	-3.819	2.657	.631	-13.210	5.572
	3	-54.579*	3.449	.000	-66.768	-42.391
2	1	3.819	2.657	.631	-5.572	13.210
	3	-50.760*	2.897	.000	-60.998	-40.523
3	1	54.579*	3.449	.000	42.391	66.768
	2	50.760*	2.897	.000	40.523	60.998

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.
Pillai's trace	.985	135.539[a]	2.000	4.000	.000
Wilks' lambda	.015	135.539[a]	2.000	4.000	.000
Hotelling's trace	67.769	135.539[a]	2.000	4.000	.000
Roy's largest root	67.769	135.539[a]	2.000	4.000	.000

Each F tests the multivariate effect of Time. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

2. Condition * Time

Measure: MEASURE_1

Condition	Time	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	1	19.025	4.117	8.443	29.607
	2	28.825	3.650	19.442	38.209
	3	78.803	2.152	73.271	84.335
2	1	26.376	5.656	11.838	40.914
	2	24.214	5.102	11.098	37.329
	3	75.756	2.536	69.237	82.276

Lipids

```
GLM Hbase Hpassive Hex Cbase Cpassive Cex
  /WSFACTOR=Condition 2 Polynomial Time 3 Polynomial
  /METHOD=SSTYPE(3)
  /EMMEANS=TABLES(Time) COMPARE ADJ(BONFERRONI)
  /EMMEANS=TABLES(Condition*Time)
  /PRINT=DESCRIPTIVE
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=Condition Time Condition*Time.
```

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

Condition	Time	Dependent Variable
1	1	Hbase
	2	Hpassive
	3	Hex
2	1	Cbase
	2	Cpassive
	3	Cex

Descriptive Statistics

	Mean	Std. Deviation	N
Hbase	57.8009	11.27061	6
Hpassive	48.9680	9.15724	6
Hex	18.6211	4.98377	6
Cbase	49.4669	11.13299	6
Cpassive	51.4299	11.05442	6
Cex	20.8664	6.72883	6

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.
Condition	Pillai's Trace	.017	.089[b]	1.000	5.000	.777
	Wilks' Lambda	.983	.089[b]	1.000	5.000	.777
	Hotelling's Trace	.018	.089[b]	1.000	5.000	.777
	Roy's Largest Root	.018	.089[b]	1.000	5.000	.777
Time	Pillai's Trace	.968	59.997[b]	2.000	4.000	.001
	Wilks' Lambda	.032	59.997[b]	2.000	4.000	.001
	Hotelling's Trace	29.998	59.997[b]	2.000	4.000	.001

	Roy's Largest Root	29.998	59.997[b]	2.000	4.000	.001
Condition * Time	Pillai's Trace	.607	3.083[b]	2.000	4.000	.155
	Wilks' Lambda	.393	3.083[b]	2.000	4.000	.155
	Hotelling's Trace	1.541	3.083[b]	2.000	4.000	.155
	Roy's Largest Root	1.541	3.083[b]	2.000	4.000	.155

a. Design: Intercept

Within Subjects Design: Condition + Time + Condition * Time

b. Exact statistic

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]
					Greenhouse-Geisser
Condition	1.000	.000	0	.	1.000
Time	.871	.554	2	.758	.885
Condition * Time	.835	.720	2	.698	.859

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Epsilon	
	Huynh-Feldt	Lower-bound
Condition	1.000	1.000
Time	1.000	.500
Condition * Time	1.000	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.[a]

a. Design: Intercept

Within Subjects Design: Condition + Time + Condition * Time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F
Condition	Sphericity Assumed	13.154	1	13.154	.089

	Greenhouse-Geisser	13.154	1.000	13.154	.089
	Huynh-Feldt	13.154	1.000	13.154	.089
	Lower-bound	13.154	1.000	13.154	.089
Error(Condition)	Sphericity Assumed	739.130	5	147.826	
	Greenhouse-Geisser	739.130	5.000	147.826	
	Huynh-Feldt	739.130	5.000	147.826	
	Lower-bound	739.130	5.000	147.826	
Time	Sphericity Assumed	8351.464	2	4175.732	89.117
	Greenhouse-Geisser	8351.464	1.771	4716.127	89.117
	Huynh-Feldt	8351.464	2.000	4175.732	89.117
	Lower-bound	8351.464	1.000	8351.464	89.117
Error(Time)	Sphericity Assumed	468.565	10	46.856	
	Greenhouse-Geisser	468.565	8.854	52.920	
	Huynh-Feldt	468.565	10.000	46.856	
	Lower-bound	468.565	5.000	93.713	
Condition * Time	Sphericity Assumed	228.519	2	114.259	4.550
	Greenhouse-Geisser	228.519	1.717	133.082	4.550
	Huynh-Feldt	228.519	2.000	114.259	4.550
	Lower-bound	228.519	1.000	228.519	4.550
Error(Condition*Time)	Sphericity Assumed	251.143	10	25.114	
	Greenhouse-Geisser	251.143	8.586	29.251	
	Huynh-Feldt	251.143	10.000	25.114	
	Lower-bound	251.143	5.000	50.229	

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Sig.
Condition	Sphericity Assumed	.777
	Greenhouse-Geisser	.777
	Huynh-Feldt	.777
	Lower-bound	.777
Error(Condition)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Time	Sphericity Assumed	.000
	Greenhouse-Geisser	.000
	Huynh-Feldt	.000
	Lower-bound	.000

Error(Time)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Condition * Time	Sphericity Assumed	.039
	Greenhouse-Geisser	.049
	Huynh-Feldt	.039
	Lower-bound	.086
Error(Condition*Time)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Condition	Time	Type III Sum of Squares	df	Mean Square	F
Condition	Linear		13.154	1	13.154	.089
Error(Condition)	Linear		739.130	5	147.826	
Time		Linear	6891.280	1	6891.280	148.402
		Quadratic	1460.184	1	1460.184	30.886
Error(Time)		Linear	232.183	5	46.437	
		Quadratic	236.382	5	47.276	
Condition * Time	Linear	Linear	167.883	1	167.883	4.824
		Quadratic	60.636	1	60.636	3.930
Error(Condition*Time)	Linear	Linear	174.007	5	34.801	
		Quadratic	77.136	5	15.427	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Condition	Time	Sig.
Condition	Linear		.777
Error(Condition)	Linear		
Time		Linear	.000
		Quadratic	.003
Error(Time)		Linear	
		Quadratic	
Condition * Time	Linear	Linear	.079
		Quadratic	.104

Error(Condition*Time)	Linear	Linear	
		Quadratic	

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	61084.697	1	61084.697	259.523	.000
Error	1176.864	5	235.373		

Estimated Marginal Means

1. Time

Estimates

Measure: MEASURE_1

Time	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	53.634	3.773	43.934	63.334
2	50.199	3.100	42.229	58.169
3	19.744	1.890	14.885	24.603

Pairwise Comparisons

Measure: MEASURE_1

(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	3.435	2.326	.600	-4.787	11.657
	3	33.890*	2.782	.000	24.058	43.722
2	1	-3.435	2.326	.600	-11.657	4.787
	3	30.455*	3.206	.001	19.126	41.785
3	1	-33.890*	2.782	.000	-43.722	-24.058
	2	-30.455*	3.206	.001	-41.785	-19.126

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.
Pillai's trace	.968	59.997[a]	2.000	4.000	.001
Wilks' lambda	.032	59.997[a]	2.000	4.000	.001
Hotelling's trace	29.998	59.997[a]	2.000	4.000	.001
Roy's largest root	29.998	59.997[a]	2.000	4.000	.001

Each F tests the multivariate effect of Time. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

2. Condition * Time

Measure: MEASURE_1

Condition	Time	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	1	57.801	4.601	45.973	69.629
	2	48.968	3.738	39.358	58.578
	3	18.621	2.035	13.391	23.851
2	1	49.467	4.545	37.784	61.150
	2	51.430	4.513	39.829	63.031
	3	20.866	2.747	13.805	27.928

Proteins

```
GLM Hbase Hpassive Hex Cbase Cpassive Cex
  /WSFACTOR=Condition 2 Polynomial Time 3 Polynomial
  /METHOD=SSTYPE(3)
  /EMMEANS=TABLES(Time) COMPARE ADJ(BONFERRONI)
  /EMMEANS=TABLES(Condition*Time)
  /PRINT=DESCRIPTIVE
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=Condition Time Condition*Time.
```

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

Condition	Time	Dependent Variable
1	1	Hbase
	2	Hpassive
	3	Hex
2	1	Cbase
	2	Cpassive
	3	Cex

Descriptive Statistics

	Mean	Std. Deviation	N
Hbase	23.1739	7.02436	6
Hpassive	22.2066	6.42037	6
Hex	2.5756	.73853	6
Cbase	24.1570	3.75756	6
Cpassive	24.5351	2.95407	6
Cex	2.7776	.39838	6

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.
Condition	Pillai's Trace	.069	.372[b]	1.000	5.000	.569
	Wilks' Lambda	.931	.372[b]	1.000	5.000	.569
	Hotelling's Trace	.074	.372[b]	1.000	5.000	.569
	Roy's Largest Root	.074	.372[b]	1.000	5.000	.569
Time	Pillai's Trace	.984	126.566[b]	2.000	4.000	.000
	Wilks' Lambda	.016	126.566[b]	2.000	4.000	.000
	Hotelling's Trace	63.283	126.566[b]	2.000	4.000	.000

	Roy's Largest Root	63.283	126.566[b]	2.000	4.000	.000
Condition * Time	Pillai's Trace	.251	.670[b]	2.000	4.000	.561
	Wilks' Lambda	.749	.670[b]	2.000	4.000	.561
	Hotelling's Trace	.335	.670[b]	2.000	4.000	.561
	Roy's Largest Root	.335	.670[b]	2.000	4.000	.561

a. Design: Intercept

Within Subjects Design: Condition + Time + Condition * Time

b. Exact statistic

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]
					Greenhouse-Geisser
Condition	1.000	.000	0	.	1.000
Time	.339	4.321	2	.115	.602
Condition * Time	.417	3.503	2	.174	.632

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Epsilon	
	Huynh-Feldt	Lower-bound
Condition	1.000	1.000
Time	.689	.500
Condition * Time	.746	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.[a]

a. Design: Intercept

Within Subjects Design: Condition + Time + Condition * Time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F
Condition	Sphericity Assumed	12.346	1	12.346	.372

	Greenhouse-Geisser	12.346	1.000	12.346	.372
	Huynh-Feldt	12.346	1.000	12.346	.372
	Lower-bound	12.346	1.000	12.346	.372
Error(Condition)	Sphericity Assumed	166.044	5	33.209	
	Greenhouse-Geisser	166.044	5.000	33.209	
	Huynh-Feldt	166.044	5.000	33.209	
	Lower-bound	166.044	5.000	33.209	
Time	Sphericity Assumed	3475.475	2	1737.737	175.918
	Greenhouse-Geisser	3475.475	1.204	2885.555	175.918
	Huynh-Feldt	3475.475	1.377	2523.876	175.918
	Lower-bound	3475.475	1.000	3475.475	175.918
Error(Time)	Sphericity Assumed	98.781	10	9.878	
	Greenhouse-Geisser	98.781	6.022	16.403	
	Huynh-Feldt	98.781	6.885	14.347	
	Lower-bound	98.781	5.000	19.756	
Condition * Time	Sphericity Assumed	6.942	2	3.471	.456
	Greenhouse-Geisser	6.942	1.263	5.496	.456
	Huynh-Feldt	6.942	1.493	4.650	.456
	Lower-bound	6.942	1.000	6.942	.456
Error(Condition*Time)	Sphericity Assumed	76.149	10	7.615	
	Greenhouse-Geisser	76.149	6.315	12.057	
	Huynh-Feldt	76.149	7.464	10.202	
	Lower-bound	76.149	5.000	15.230	

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Sig.
Condition	Sphericity Assumed	.569
	Greenhouse-Geisser	.569
	Huynh-Feldt	.569
	Lower-bound	.569
Error(Condition)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Time	Sphericity Assumed	.000
	Greenhouse-Geisser	.000
	Huynh-Feldt	.000
	Lower-bound	.000

Error(Time)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Condition * Time	Sphericity Assumed	.646
	Greenhouse-Geisser	.568
	Huynh-Feldt	.596
	Lower-bound	.530
Error(Condition*Time)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Condition	Time	Type III Sum of Squares	df	Mean Square	F
Condition	Linear		12.346	1	12.346	.372
Error(Condition)	Linear		166.044	5	33.209	
Time		Linear	2643.192	1	2643.192	155.391
		Quadratic	832.283	1	832.283	303.069
Error(Time)		Linear	85.050	5	17.010	
		Quadratic	13.731	5	2.746	
Condition * Time	Linear	Linear	.915	1	.915	.091
		Quadratic	6.027	1	6.027	1.162
Error(Condition*Time)	Linear	Linear	50.226	5	10.045	
		Quadratic	25.923	5	5.185	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Condition	Time	Sig.
Condition	Linear		.569
Error(Condition)	Linear		
Time		Linear	.000
		Quadratic	.000
Error(Time)		Linear	
		Quadratic	
Condition * Time	Linear	Linear	.775
		Quadratic	.330

Error(Condition*Time)	Linear	Linear Quadratic	

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	9885.487	1	9885.487	215.286	.000
Error	229.590	5	45.918		

Estimated Marginal Means

1. Time

Estimates

Measure: MEASURE_1

Time	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	23.665	1.838	18.941	28.390
2	23.371	1.432	19.690	27.052
3	2.677	.211	2.134	3.219

Pairwise Comparisons

Measure: MEASURE_1

(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	.295	.721	1.000	-2.254	2.843
	3	20.989*	1.684	.000	15.038	26.939
2	1	-.295	.721	1.000	-2.843	2.254
	3	20.694*	1.259	.000	16.246	25.142
3	1	-20.989*	1.684	.000	-26.939	-15.038
	2	-20.694*	1.259	.000	-25.142	-16.246

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.
Pillai's trace	.984	126.566[a]	2.000	4.000	.000
Wilks' lambda	.016	126.566[a]	2.000	4.000	.000
Hotelling's trace	63.283	126.566[a]	2.000	4.000	.000
Roy's largest root	63.283	126.566[a]	2.000	4.000	.000

Each F tests the multivariate effect of Time. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

2. Condition * Time

Measure: MEASURE_1

Condition	Time	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	1	23.174	2.868	15.802	30.546
	2	22.207	2.621	15.469	28.944
	3	2.576	.302	1.801	3.351
2	1	24.157	1.534	20.214	28.100
	2	24.535	1.206	21.435	27.635
	3	2.778	.163	2.360	3.196

PLASMA LIPIDS STATISTICAL ANALYSIS

Non-Esterified Fatty Acids (NEFA)

```
GLM Preh Hourh Posth Exh Prec Hourc Postc Exc
  /WSFACTOR=Condition 2 Polynomial Time 4 Polynomial
  /METHOD=SSTYPE(3)
  /EMMEANS=TABLES(Condition) COMPARE ADJ(BONFERRONI)
  /EMMEANS=TABLES(Time*Condition) COMPARE(Condition) ADJ(BONFERRONI)
  /EMMEANS=TABLES(Condition*Time)
  /PRINT=DESCRIPTIVE
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=Condition Time Condition*Time.
```

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

Condition	Time	Dependent Variable
1	1	Preh
	2	Hourh
	3	Posth
	4	Exh
2	1	Prec
	2	Hourc
	3	Postc
	4	Exc

Descriptive Statistics

	Mean	Std. Deviation	N
Preh	419.9788	218.04904	8
Hourh	598.4654	207.51966	8
Posth	617.8110	166.39356	8
Exh	2036.4681	517.80414	8
Prec	276.6360	99.47828	8
Hourc	426.3214	88.49733	8
Postc	390.6584	144.19643	8
Exc	1350.6600	417.18058	8

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.
Condition	Pillai's Trace	.731	19.012[b]	1.000	7.000	.003

	Wilks' Lambda	.269	19.012[b]	1.000	7.000	.003
	Hotelling's Trace	2.716	19.012[b]	1.000	7.000	.003
	Roy's Largest Root	2.716	19.012[b]	1.000	7.000	.003
Time	Pillai's Trace	.983	97.041[b]	3.000	5.000	.000
	Wilks' Lambda	.017	97.041[b]	3.000	5.000	.000
	Hotelling's Trace	58.225	97.041[b]	3.000	5.000	.000
	Roy's Largest Root	58.225	97.041[b]	3.000	5.000	.000
Condition * Time	Pillai's Trace	.672	3.419[b]	3.000	5.000	.109
	Wilks' Lambda	.328	3.419[b]	3.000	5.000	.109
	Hotelling's Trace	2.052	3.419[b]	3.000	5.000	.109
	Roy's Largest Root	2.052	3.419[b]	3.000	5.000	.109

a. Design: Intercept

Within Subjects Design: Condition + Time + Condition * Time

b. Exact statistic

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]
					Greenhouse-Geisser
Condition	1.000	.000	0	.	1.000
Time	.019	22.593	5	.000	.395
Condition * Time	.368	5.723	5	.340	.608

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Epsilon	
	Huynh-Feldt	Lower-bound
Condition	1.000	1.000
Time	.428	.333
Condition * Time	.811	.333

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.[a]

a. Design: Intercept

Within Subjects Design: Condition + Time + Condition * Time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F
Condition	Sphericity Assumed	1509083.360	1	1509083.360	19.012
	Greenhouse-Geisser	1509083.360	1.000	1509083.360	19.012
	Huynh-Feldt	1509083.360	1.000	1509083.360	19.012
	Lower-bound	1509083.360	1.000	1509083.360	19.012
Error(Condition)	Sphericity Assumed	555633.875	7	79376.268	
	Greenhouse-Geisser	555633.875	7.000	79376.268	
	Huynh-Feldt	555633.875	7.000	79376.268	
	Lower-bound	555633.875	7.000	79376.268	
Time	Sphericity Assumed	18682753.291	3	6227584.430	82.204
	Greenhouse-Geisser	18682753.291	1.184	15774790.334	82.204
	Huynh-Feldt	18682753.291	1.285	14535957.863	82.204
	Lower-bound	18682753.291	1.000	18682753.291	82.204
Error(Time)	Sphericity Assumed	1590903.241	21	75757.297	
	Greenhouse-Geisser	1590903.241	8.290	191897.114	
	Huynh-Feldt	1590903.241	8.997	176826.969	
	Lower-bound	1590903.241	7.000	227271.892	
Condition * Time	Sphericity Assumed	779363.689	3	259787.896	8.696
	Greenhouse-Geisser	779363.689	1.824	427169.334	8.696
	Huynh-Feldt	779363.689	2.434	320232.586	8.696
	Lower-bound	779363.689	1.000	779363.689	8.696
Error(Condition*Time)	Sphericity Assumed	627361.642	21	29874.364	
	Greenhouse-Geisser	627361.642	12.771	49122.428	
	Huynh-Feldt	627361.642	17.036	36825.214	
	Lower-bound	627361.642	7.000	89623.092	

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Sig.
Condition	Sphericity Assumed	.003
	Greenhouse-Geisser	.003
	Huynh-Feldt	.003
	Lower-bound	.003
Error(Condition)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	

	Lower-bound	
Time	Sphericity Assumed	.000
	Greenhouse-Geisser	.000
	Huynh-Feldt	.000
	Lower-bound	.000
Error(Time)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Condition * Time	Sphericity Assumed	.001
	Greenhouse-Geisser	.005
	Huynh-Feldt	.002
	Lower-bound	.021
Error(Condition*Time)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Condition	Time	Type III Sum of Squares	df	Mean Square	F
Condition	Linear		1509083.360	1	1509083.360	19.012
Error(Condition)	Linear		555633.875	7	79376.268	
Time		Linear	12977322.573	1	12977322.573	112.143
		Quadratic	4204495.930	1	4204495.930	47.355
		Cubic	1500934.787	1	1500934.787	65.935
Error(Time)		Linear	810045.441	7	115720.777	
		Quadratic	621511.846	7	88787.407	
		Cubic	159345.955	7	22763.708	
Condition * Time	Linear	Linear	566096.919	1	566096.919	10.685
		Quadratic	184774.650	1	184774.650	11.946
		Cubic	28492.119	1	28492.119	1.346
Error(Condition*Time)	Linear	Linear	370873.150	7	52981.879	
		Quadratic	108273.207	7	15467.601	
		Cubic	148215.285	7	21173.612	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Condition	Time	Sig.
Condition	Linear		.003
Error(Condition)	Linear		
Time		Linear	.000
		Quadratic	.000
		Cubic	.000
Error(Time)		Linear	
		Quadratic	
		Cubic	
Condition * Time	Linear	Linear	.014
		Quadratic	.011
		Cubic	.284
Error(Condition*Time)	Linear	Linear	
		Quadratic	
		Cubic	

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	37417678.234	1	37417678.234	184.590	.000
Error	1418945.091	7	202706.442		

Estimated Marginal Means

1. Condition

Estimates

Measure: MEASURE_1

Condition	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	918.181	74.203	742.718	1093.643
2	611.069	57.524	475.047	747.091

Pairwise Comparisons

Measure: MEASURE_1

(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	307.112[*]	70.434	.003	140.561	473.663

2	1	-307.112*	70.434	.003	-473.663	-140.561

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.
Pillai's trace	.731	19.012[a]	1.000	7.000	.003
Wilks' lambda	.269	19.012[a]	1.000	7.000	.003
Hotelling's trace	2.716	19.012[a]	1.000	7.000	.003
Roy's largest root	2.716	19.012[a]	1.000	7.000	.003

Each F tests the multivariate effect of Condition. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

2. Time * Condition

Estimates

Measure: MEASURE_1

Time	Condition	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	1	419.979	77.092	237.685	602.272
	2	276.636	35.171	193.470	359.802
2	1	598.465	73.369	424.975	771.956
	2	426.321	31.289	352.336	500.307
3	1	617.811	58.829	478.702	756.919
	2	390.658	50.981	270.107	511.210
4	1	2036.468	183.071	1603.573	2469.363
	2	1350.660	147.496	1001.888	1699.432

Pairwise Comparisons

Measure: MEASURE_1

Time	(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]
						Lower Bound
1	1	2	143.343	76.125	.102	-36.665
	2	1	-143.343	76.125	.102	-323.350

2	1	2	172.144	73.824	.052	-2.422
	2	1	-172.144	73.824	.052	-346.710
3	1	2	227.153*	57.691	.006	90.734
	2	1	-227.153*	57.691	.006	-363.571
4	1	2	685.808*	166.363	.004	292.423
	2	1	-685.808*	166.363	.004	-1079.193

Pairwise Comparisons

Measure: MEASURE_1

Time	(I) Condition	(J) Condition	95% Confidence Interval for Difference
			Upper Bound
1	1	2	323.350
	2	1	36.665
2	1	2	346.710
	2	1	2.422
3	1	2	363.571*
	2	1	-90.734*
4	1	2	1079.193*
	2	1	-292.423*

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Multivariate Tests

Time		Value	F	Hypothesis df	Error df	Sig.
1	Pillai's trace	.336	3.546[a]	1.000	7.000	.102
	Wilks' lambda	.664	3.546[a]	1.000	7.000	.102
	Hotelling's trace	.507	3.546[a]	1.000	7.000	.102
	Roy's largest root	.507	3.546[a]	1.000	7.000	.102
2	Pillai's trace	.437	5.437[a]	1.000	7.000	.052
	Wilks' lambda	.563	5.437[a]	1.000	7.000	.052
	Hotelling's trace	.777	5.437[a]	1.000	7.000	.052
	Roy's largest root	.777	5.437[a]	1.000	7.000	.052
3	Pillai's trace	.689	15.503[a]	1.000	7.000	.006
	Wilks' lambda	.311	15.503[a]	1.000	7.000	.006
	Hotelling's trace	2.215	15.503[a]	1.000	7.000	.006
	Roy's largest root	2.215	15.503[a]	1.000	7.000	.006

4	Pillai's trace	.708	16.994[a]	1.000	7.000	.004
	Wilks' lambda	.292	16.994[a]	1.000	7.000	.004
	Hotelling's trace	2.428	16.994[a]	1.000	7.000	.004
	Roy's largest root	2.428	16.994[a]	1.000	7.000	.004

Each F tests the multivariate simple effects of Condition within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

3. Condition * Time

Measure: MEASURE_1

Condition	Time	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	1	419.979	77.092	237.685	602.272
	2	598.465	73.369	424.975	771.956
	3	617.811	58.829	478.702	756.919
	4	2036.468	183.071	1603.573	2469.363
2	1	276.636	35.171	193.470	359.802
	2	426.321	31.289	352.336	500.307
	3	390.658	50.981	270.107	511.210
	4	1350.660	147.496	1001.888	1699.432

Triacylglycerol (TG)

```
GLM Preh Hourh Posth Exh Prec Hourc Postc Exc
  /WSFACTOR=Condition 2 Polynomial Time 4 Polynomial
  /METHOD=SSTYPE(3)
  /EMMEANS=TABLES(Condition) COMPARE ADJ(BONFERRONI)
  /EMMEANS=TABLES(Time) COMPARE ADJ(BONFERRONI)
  /EMMEANS=TABLES(Condition*Time)
  /PRINT=DESCRIPTIVE
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=Condition Time Condition*Time.
```

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

Condition	Time	Dependent Variable
1	1	Preh
	2	Hourh
	3	Posth
	4	Exh
2	1	Prec
	2	Hourc
	3	Postc
	4	Exc

Descriptive Statistics

	Mean	Std. Deviation	N
Preh	.7727	.43820	8
Hourh	.7462	.45682	8
Posth	.7831	.50200	8
Exh	.7446	.48285	8
Prec	.7775	.41366	8
Hourc	.7389	.36713	8
Postc	.7593	.46992	8
Exc	.7189	.41053	8

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.
Condition	Pillai's Trace	.004	.026[b]	1.000	7.000	.877
	Wilks' Lambda	.996	.026[b]	1.000	7.000	.877
	Hotelling's Trace	.004	.026[b]	1.000	7.000	.877

	Roy's Largest Root	.004	.026[b]	1.000	7.000	.877
Time	Pillai's Trace	.582	2.325[b]	3.000	5.000	.192
	Wilks' Lambda	.418	2.325[b]	3.000	5.000	.192
	Hotelling's Trace	1.395	2.325[b]	3.000	5.000	.192
	Roy's Largest Root	1.395	2.325[b]	3.000	5.000	.192
Condition * Time	Pillai's Trace	.171	.345[b]	3.000	5.000	.795
	Wilks' Lambda	.829	.345[b]	3.000	5.000	.795
	Hotelling's Trace	.207	.345[b]	3.000	5.000	.795
	Roy's Largest Root	.207	.345[b]	3.000	5.000	.795

a. Design: Intercept

Within Subjects Design: Condition + Time + Condition * Time

b. Exact statistic

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]
					Greenhouse-Geisser
Condition	1.000	.000	0	.	1.000
Time	.109	12.698	5	.028	.527
Condition * Time	.306	6.780	5	.243	.626

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Epsilon	
	Huynh-Feldt	Lower-bound
Condition	1.000	1.000
Time	.655	.333
Condition * Time	.848	.333

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.[a]

a. Design: Intercept

Within Subjects Design: Condition + Time + Condition * Time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F
Condition	Sphericity Assumed	.003	1	.003	.026
	Greenhouse-Geisser	.003	1.000	.003	.026
	Huynh-Feldt	.003	1.000	.003	.026
	Lower-bound	.003	1.000	.003	.026
Error(Condition)	Sphericity Assumed	.736	7	.105	
	Greenhouse-Geisser	.736	7.000	.105	
	Huynh-Feldt	.736	7.000	.105	
	Lower-bound	.736	7.000	.105	
Time	Sphericity Assumed	.022	3	.007	1.783
	Greenhouse-Geisser	.022	1.582	.014	1.783
	Huynh-Feldt	.022	1.966	.011	1.783
	Lower-bound	.022	1.000	.022	1.783
Error(Time)	Sphericity Assumed	.086	21	.004	
	Greenhouse-Geisser	.086	11.072	.008	
	Huynh-Feldt	.086	13.764	.006	
	Lower-bound	.086	7.000	.012	
Condition * Time	Sphericity Assumed	.003	3	.001	.369
	Greenhouse-Geisser	.003	1.879	.001	.369
	Huynh-Feldt	.003	2.545	.001	.369
	Lower-bound	.003	1.000	.003	.369
Error(Condition*Time)	Sphericity Assumed	.048	21	.002	
	Greenhouse-Geisser	.048	13.153	.004	
	Huynh-Feldt	.048	17.813	.003	
	Lower-bound	.048	7.000	.007	

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Sig.
Condition	Sphericity Assumed	.877
	Greenhouse-Geisser	.877
	Huynh-Feldt	.877
	Lower-bound	.877
Error(Condition)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	

	Lower-bound	
Time	Sphericity Assumed	.181
	Greenhouse-Geisser	.214
	Huynh-Feldt	.205
	Lower-bound	.224
Error(Time)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Condition * Time	Sphericity Assumed	.776
	Greenhouse-Geisser	.686
	Huynh-Feldt	.745
	Lower-bound	.563
Error(Condition*Time)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Condition	Time	Type III Sum of Squares	df	Mean Square	F
Condition	Linear		.003	1	.003	.026
Error(Condition)	Linear		.736	7	.105	
Time		Linear	.008	1	.008	1.683
		Quadratic	.000	1	.000	.217
		Cubic	.013	1	.013	2.067
Error(Time)		Linear	.034	7	.005	
		Quadratic	.006	7	.001	
		Cubic	.045	7	.006	
Condition * Time	Linear	Linear	.002	1	.002	1.399
		Quadratic	.000	1	.000	.199
		Cubic	7.296E-005	1	7.296E-005	.016
Error(Condition*Time)	Linear	Linear	.012	7	.002	
		Quadratic	.004	7	.001	
		Cubic	.032	7	.005	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Condition	Time	Sig.
Condition	Linear		.877
Error(Condition)	Linear		
Time		Linear	.236
		Quadratic	.655
		Cubic	.194
Error(Time)		Linear	
		Quadratic	
		Cubic	
Condition * Time	Linear	Linear	.275
		Quadratic	.669
		Cubic	.904
Error(Condition*Time)	Linear	Linear	
		Quadratic	
		Cubic	

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	36.495	1	36.495	25.051	.002
Error	10.198	7	1.457		

Estimated Marginal Means

1. Condition

Estimates

Measure: MEASURE_1

Condition	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	.762	.166	.370	1.153
2	.749	.146	.403	1.094

Pairwise Comparisons

Measure: MEASURE_1

(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound

1	2	.013	.081	.877	-.179	.205
2	1	-.013	.081	.877	-.205	.179

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.
Pillai's trace	.004	.026[a]	1.000	7.000	.877
Wilks' lambda	.996	.026[a]	1.000	7.000	.877
Hotelling's trace	.004	.026[a]	1.000	7.000	.877
Roy's largest root	.004	.026[a]	1.000	7.000	.877

Each F tests the multivariate effect of Condition. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

2. Time

Estimates

Measure: MEASURE_1

Time	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	.775	.144	.434	1.117
2	.743	.140	.412	1.073
3	.771	.167	.376	1.166
4	.732	.154	.369	1.095

Pairwise Comparisons

Measure: MEASURE_1

(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	.033	.014	.342	-.019	.085
	3	.004	.028	1.000	-.098	.106
	4	.043	.020	.400	-.029	.116
2	1	-.033	.014	.342	-.085	.019
	3	-.029	.032	1.000	-.145	.087
	4	.011	.017	1.000	-.050	.072
3	1	-.004	.028	1.000	-.106	.098
	2	.029	.032	1.000	-.087	.145

	4	.039	.019	.467	-.030	.109
4	1	-.043	.020	.400	-.116	.029
	2	-.011	.017	1.000	-.072	.050
	3	-.039	.019	.467	-.109	.030

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.
Pillai's trace	.582	2.325[a]	3.000	5.000	.192
Wilks' lambda	.418	2.325[a]	3.000	5.000	.192
Hotelling's trace	1.395	2.325[a]	3.000	5.000	.192
Roy's largest root	1.395	2.325[a]	3.000	5.000	.192

Each F tests the multivariate effect of Time. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

3. Condition * Time

Measure: MEASURE_1

Condition	Time	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	1	.773	.155	.406	1.139
	2	.746	.162	.364	1.128
	3	.783	.177	.363	1.203
	4	.745	.171	.341	1.148
2	1	.777	.146	.432	1.123
	2	.739	.130	.432	1.046
	3	.759	.166	.366	1.152
	4	.719	.145	.376	1.062

Phospholipids (PL)

```
GLM Preh Hourh Posth Exh Prec Hourc Postc Exc
  /WSFACTOR=Condition 2 Polynomial Time 4 Polynomial
  /METHOD=SSTYPE(3)
  /EMMEANS=TABLES(Condition) COMPARE ADJ(BONFERRONI)
  /EMMEANS=TABLES(Time) COMPARE ADJ(BONFERRONI)
  /EMMEANS=TABLES(Condition*Time)
  /PRINT=DESCRIPTIVE
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=Condition Time Condition*Time.
```

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

Condition	Time	Dependent Variable
1	1	Preh
	2	Hourh
	3	Posth
	4	Exh
2	1	Prec
	2	Hourc
	3	Postc
	4	Exc

Descriptive Statistics

	Mean	Std. Deviation	N
Preh	1.5395	.25759	8
Hourh	1.4475	.27597	8
Posth	1.5655	.20011	8
Exh	1.5902	.29165	8
Prec	1.4819	.21179	8
Hourc	1.5199	.12582	8
Postc	1.6246	.24588	8
Exc	1.6027	.23545	8

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.
Condition	Pillai's Trace	.024	.169[b]	1.000	7.000	.694
	Wilks' Lambda	.976	.169[b]	1.000	7.000	.694

	Hotelling's Trace	.024	.169[b]	1.000	7.000	.694
	Roy's Largest Root	.024	.169[b]	1.000	7.000	.694
Time	Pillai's Trace	.813	7.237[b]	3.000	5.000	.029
	Wilks' Lambda	.187	7.237[b]	3.000	5.000	.029
	Hotelling's Trace	4.342	7.237[b]	3.000	5.000	.029
	Roy's Largest Root	4.342	7.237[b]	3.000	5.000	.029
Condition * Time	Pillai's Trace	.249	.553[b]	3.000	5.000	.668
	Wilks' Lambda	.751	.553[b]	3.000	5.000	.668
	Hotelling's Trace	.332	.553[b]	3.000	5.000	.668
	Roy's Largest Root	.332	.553[b]	3.000	5.000	.668

a. Design: Intercept

Within Subjects Design: Condition + Time + Condition * Time

b. Exact statistic

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]
					Greenhouse-Geisser
Condition	1.000	.000	0	.	1.000
Time	.577	3.146	5	.681	.812
Condition * Time	.761	1.567	5	.907	.849

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Epsilon	
	Huynh-Feldt	Lower-bound
Condition	1.000	1.000
Time	1.000	.333
Condition * Time	1.000	.333

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.[a]

a. Design: Intercept

Within Subjects Design: Condition + Time + Condition * Time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F
Condition	Sphericity Assumed	.007	1	.007	.169
	Greenhouse-Geisser	.007	1.000	.007	.169
	Huynh-Feldt	.007	1.000	.007	.169
	Lower-bound	.007	1.000	.007	.169
Error(Condition)	Sphericity Assumed	.310	7	.044	
	Greenhouse-Geisser	.310	7.000	.044	
	Huynh-Feldt	.310	7.000	.044	
	Lower-bound	.310	7.000	.044	
Time	Sphericity Assumed	.161	3	.054	4.211
	Greenhouse-Geisser	.161	2.437	.066	4.211
	Huynh-Feldt	.161	3.000	.054	4.211
	Lower-bound	.161	1.000	.161	4.211
Error(Time)	Sphericity Assumed	.268	21	.013	
	Greenhouse-Geisser	.268	17.059	.016	
	Huynh-Feldt	.268	21.000	.013	
	Lower-bound	.268	7.000	.038	
Condition * Time	Sphericity Assumed	.041	3	.014	.501
	Greenhouse-Geisser	.041	2.546	.016	.501
	Huynh-Feldt	.041	3.000	.014	.501
	Lower-bound	.041	1.000	.041	.501
Error(Condition*Time)	Sphericity Assumed	.577	21	.027	
	Greenhouse-Geisser	.577	17.824	.032	
	Huynh-Feldt	.577	21.000	.027	
	Lower-bound	.577	7.000	.082	

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Sig.
Condition	Sphericity Assumed	.694
	Greenhouse-Geisser	.694
	Huynh-Feldt	.694
	Lower-bound	.694
Error(Condition)	Sphericity Assumed	

	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Time	Sphericity Assumed	.018
	Greenhouse-Geisser	.027
	Huynh-Feldt	.018
	Lower-bound	.079
Error(Time)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Condition * Time	Sphericity Assumed	.685
	Greenhouse-Geisser	.657
	Huynh-Feldt	.685
	Lower-bound	.502
Error(Condition*Time)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Condition	Time	Type III Sum of Squares	df	Mean Square	F
Condition	Linear		.007	1	.007	.169
Error(Condition)	Linear		.310	7	.044	
Time		Linear	.109	1	.109	7.015
		Quadratic	.003	1	.003	.216
		Cubic	.049	1	.049	6.263
Error(Time)		Linear	.108	7	.015	
		Quadratic	.105	7	.015	
		Cubic	.055	7	.008	
Condition * Time	Linear	Linear	.008	1	.008	.187
		Quadratic	.031	1	.031	1.470
		Cubic	.002	1	.002	.121
Error(Condition*Time)	Linear	Linear	.289	7	.041	
		Quadratic	.149	7	.021	
		Cubic	.139	7	.020	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Condition	Time	Sig.
Condition	Linear		.694
Error(Condition)	Linear		
Time		Linear	.033
		Quadratic	.656
		Cubic	.041
Error(Time)		Linear	
		Quadratic	
		Cubic	
Condition * Time	Linear	Linear	.678
		Quadratic	.265
		Cubic	.738
Error(Condition*Time)	Linear	Linear	
		Quadratic	
		Cubic	

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	153.063	1	153.063	548.439	.000
Error	1.954	7	.279		

Estimated Marginal Means

1. Condition

Estimates

Measure: MEASURE_1

Condition	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	1.536	.081	1.345	1.727
2	1.557	.060	1.416	1.699

Pairwise Comparisons

Measure: MEASURE_1

(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	-.022	.053	.694	-.146	.103
2	1	.022	.053	.694	-.103	.146

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.
Pillai's trace	.024	.169[a]	1.000	7.000	.694
Wilks' lambda	.976	.169[a]	1.000	7.000	.694
Hotelling's trace	.024	.169[a]	1.000	7.000	.694
Roy's largest root	.024	.169[a]	1.000	7.000	.694

Each F tests the multivariate effect of Condition. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

2. Time

Estimates

Measure: MEASURE_1

Time	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	1.511	.074	1.335	1.687
2	1.484	.067	1.325	1.642
3	1.595	.069	1.431	1.759
4	1.596	.071	1.429	1.764

Pairwise Comparisons

Measure: MEASURE_1

(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	.027	.038	1.000	-.111	.165
	3	-.084	.045	.630	-.249	.080
	4	-.086	.047	.649	-.255	.084
2	1	-.027	.038	1.000	-.165	.111
	3	-.111[*]	.027	.029	-.211	-.012
	4	-.113	.034	.072	-.235	.009

	1	.084	.045	.630	-.080	.249
3	2	.111[*]	.027	.029	.012	.211
	4	-.001	.045	1.000	-.166	.163
	1	.086	.047	.649	-.084	.255
4	2	.113	.034	.072	-.009	.235
	3	.001	.045	1.000	-.163	.166

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.
Pillai's trace	.813	7.237[a]	3.000	5.000	.029
Wilks' lambda	.187	7.237[a]	3.000	5.000	.029
Hotelling's trace	4.342	7.237[a]	3.000	5.000	.029
Roy's largest root	4.342	7.237[a]	3.000	5.000	.029

Each F tests the multivariate effect of Time. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

3. Condition * Time

Measure: MEASURE_1

Condition	Time	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	1	1.539	.091	1.324	1.755
	2	1.447	.098	1.217	1.678
	3	1.566	.071	1.398	1.733
	4	1.590	.103	1.346	1.834
2	1	1.482	.075	1.305	1.659
	2	1.520	.044	1.415	1.625
	3	1.625	.087	1.419	1.830
	4	1.603	.083	1.406	1.800

Cholesterol

```
GLM Preh Hourh Posth Exh Prec Hourc Postc Exc
  /WSFACTOR=Condition 2 Polynomial Time 4 Polynomial
  /METHOD=SSTYPE(3)
  /EMMEANS=TABLES(Condition) COMPARE ADJ(BONFERRONI)
  /EMMEANS=TABLES(Time) COMPARE ADJ(BONFERRONI)
  /EMMEANS=TABLES(Condition*Time)
  /PRINT=DESCRIPTIVE
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=Condition Time Condition*Time.
```

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

Condition	Time	Dependent Variable
1	1	Preh
	2	Hourh
	3	Posth
	4	Exh
2	1	Prec
	2	Hourc
	3	Postc
	4	Exc

Descriptive Statistics

	Mean	Std. Deviation	N
Preh	4.0244	.98886	8
Hourh	3.8540	.78138	8
Posth	3.7434	.66006	8
Exh	4.2066	.72037	8
Prec	4.2412	.68248	8
Hourc	3.9870	.87532	8
Postc	3.9492	.94662	8
Exc	4.3322	.98640	8

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.
Condition	Pillai's Trace	.103	.800[b]	1.000	7.000	.401
	Wilks' Lambda	.897	.800[b]	1.000	7.000	.401

	Hotelling's Trace	.114	.800[b]	1.000	7.000	.401
	Roy's Largest Root	.114	.800[b]	1.000	7.000	.401
Time	Pillai's Trace	.770	5.570[b]	3.000	5.000	.047
	Wilks' Lambda	.230	5.570[b]	3.000	5.000	.047
	Hotelling's Trace	3.342	5.570[b]	3.000	5.000	.047
	Roy's Largest Root	3.342	5.570[b]	3.000	5.000	.047
Condition * Time	Pillai's Trace	.034	.059[b]	3.000	5.000	.979
	Wilks' Lambda	.966	.059[b]	3.000	5.000	.979
	Hotelling's Trace	.036	.059[b]	3.000	5.000	.979
	Roy's Largest Root	.036	.059[b]	3.000	5.000	.979

a. Design: Intercept

Within Subjects Design: Condition + Time + Condition * Time

b. Exact statistic

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]
					Greenhouse-Geisser
Condition	1.000	.000	0	.	1.000
Time	.711	1.952	5	.858	.807
Condition * Time	.480	4.197	5	.527	.718

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Epsilon	
	Huynh-Feldt	Lower-bound
Condition	1.000	1.000
Time	1.000	.333
Condition * Time	1.000	.333

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.[a]

a. Design: Intercept

Within Subjects Design: Condition + Time + Condition * Time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F
Condition	Sphericity Assumed	.464	1	.464	.800
	Greenhouse-Geisser	.464	1.000	.464	.800
	Huynh-Feldt	.464	1.000	.464	.800
	Lower-bound	.464	1.000	.464	.800
Error(Condition)	Sphericity Assumed	4.063	7	.580	
	Greenhouse-Geisser	4.063	7.000	.580	
	Huynh-Feldt	4.063	7.000	.580	
	Lower-bound	4.063	7.000	.580	
Time	Sphericity Assumed	1.808	3	.603	5.743
	Greenhouse-Geisser	1.808	2.420	.747	5.743
	Huynh-Feldt	1.808	3.000	.603	5.743
	Lower-bound	1.808	1.000	1.808	5.743
Error(Time)	Sphericity Assumed	2.204	21	.105	
	Greenhouse-Geisser	2.204	16.938	.130	
	Huynh-Feldt	2.204	21.000	.105	
	Lower-bound	2.204	7.000	.315	
Condition * Time	Sphericity Assumed	.027	3	.009	.059
	Greenhouse-Geisser	.027	2.155	.013	.059
	Huynh-Feldt	.027	3.000	.009	.059
	Lower-bound	.027	1.000	.027	.059
Error(Condition*Time)	Sphericity Assumed	3.216	21	.153	
	Greenhouse-Geisser	3.216	15.084	.213	
	Huynh-Feldt	3.216	21.000	.153	
	Lower-bound	3.216	7.000	.459	

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Sig.
Condition	Sphericity Assumed	.401
	Greenhouse-Geisser	.401
	Huynh-Feldt	.401
	Lower-bound	.401
Error(Condition)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	

	Lower-bound	
Time	Sphericity Assumed	.005
	Greenhouse-Geisser	.009
	Huynh-Feldt	.005
	Lower-bound	.048
Error(Time)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	
Condition * Time	Sphericity Assumed	.981
	Greenhouse-Geisser	.952
	Huynh-Feldt	.981
	Lower-bound	.815
Error(Condition*Time)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Condition	Time	Type III Sum of Squares	df	Mean Square	F
Condition	Linear		.464	1	.464	.800
Error(Condition)	Linear		4.063	7	.580	
Time		Linear	.090	1	.090	.777
		Quadratic	1.615	1	1.615	20.855
		Cubic	.103	1	.103	.850
Error(Time)		Linear	.812	7	.116	
		Quadratic	.542	7	.077	
		Cubic	.850	7	.121	
Condition * Time	Linear	Linear	.008	1	.008	.052
		Quadratic	1.342E-005	1	1.342E-005	.000
		Cubic	.019	1	.019	.128
Error(Condition*Time)	Linear	Linear	1.079	7	.154	
		Quadratic	1.093	7	.156	
		Cubic	1.044	7	.149	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Condition	Time	Sig.
Condition	Linear		.401
Error(Condition)	Linear		
Time		Linear	.407
		Quadratic	.003
		Cubic	.387
Error(Time)		Linear	
		Quadratic	
		Cubic	
Condition * Time	Linear	Linear	.826
		Quadratic	.993
		Cubic	.731
Error(Condition*Time)	Linear	Linear	
		Quadratic	
		Cubic	

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	1045.750	1	1045.750	243.802	.000
Error	30.025	7	4.289		

Estimated Marginal Means

1. Condition

Estimates

Measure: MEASURE_1

Condition	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	3.957	.266	3.328	4.587
2	4.127	.285	3.453	4.802

Pairwise Comparisons

Measure: MEASURE_1

(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	-.170	.190	.401	-.621	.280

2	1	.170	.190	.401	-.280	.621

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.
Pillai's trace	.103	.800[a]	1.000	7.000	.401
Wilks' lambda	.897	.800[a]	1.000	7.000	.401
Hotelling's trace	.114	.800[a]	1.000	7.000	.401
Roy's largest root	.114	.800[a]	1.000	7.000	.401

Each F tests the multivariate effect of Condition. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

2. Time

Estimates

Measure: MEASURE_1

Time	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	4.133	.280	3.471	4.795
2	3.921	.253	3.323	4.518
3	3.846	.263	3.224	4.469
4	4.269	.276	3.616	4.923

Pairwise Comparisons

Measure: MEASURE_1

(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	.212	.127	.831	-.249	.674
	3	.286	.104	.170	-.092	.664
	4	-.137	.137	1.000	-.635	.362
2	1	-.212	.127	.831	-.674	.249
	3	.074	.104	1.000	-.305	.453
	4	-.349[*]	.089	.034	-.671	-.027
3	1	-.286	.104	.170	-.664	.092
	2	-.074	.104	1.000	-.453	.305
	4	-.423	.119	.056	-.857	.011
4	1	.137	.137	1.000	-.362	.635
	2	.349[*]	.089	.034	.027	.671

3	.423	.119	.056	-.011	.857

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.
Pillai's trace	.770	5.570[a]	3.000	5.000	.047
Wilks' lambda	.230	5.570[a]	3.000	5.000	.047
Hotelling's trace	3.342	5.570[a]	3.000	5.000	.047
Roy's largest root	3.342	5.570[a]	3.000	5.000	.047

Each F tests the multivariate effect of Time. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

3. Condition * Time

Measure: MEASURE_1

Condition	Time	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	1	4.024	.350	3.198	4.851
	2	3.854	.276	3.201	4.507
	3	3.743	.233	3.192	4.295
	4	4.207	.255	3.604	4.809
2	1	4.241	.241	3.671	4.812
	2	3.987	.309	3.255	4.719
	3	3.949	.335	3.158	4.741
	4	4.332	.349	3.508	5.157