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MEASURING PHYSIOLOGICAL CHANGES IN PREGNANT WOMEN DURING HOT YOGA

Degree of Master of Sciences in Clinical Exercise Physiology

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MEASURING PHYSIOLOGICAL CHANGES IN PREGNANT WOMEN DURING HOT YOGA

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We recommend acceptance of this thesis of the candidate's requirements for the degree of Master of Science in Clinical Exercise Physiology.

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ABSTRACT

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One of the concerns surrounding the practice of hot yoga is a potentially dangerous increase in core temperature, notably pregnant women. Previous research has shown that a core temperature in excess of 102.2 ºF, or an increase in core temperature greater than 2.7-3.6 ºF from rest, may result in abnormal fetal development. The main purpose of this study was to evaluate and compare the core temperature responses in pregnant and non-pregnant women during a 60-minute hot-yoga class. Four pregnant and five non-pregnant women served as subjects and all subjects were regular participants in hot yoga. Prior to the class, subjects ingested a CorTemp Ingestible Core Body Temperature Sensor (HQ Inc, Palmetto, FL). Core temperature was recorded every 10 minutes during the class. Room temperature and humidity averaged 95.7ºF and 56.7% respectively, during the class. The highest core temperature recorded during a class averaged 99.5 ºF in the pregnant subjects and 99.9 ºF for the non-pregnant subjects. The highest single core temperature in a pregnant subject was 100.1 ºF, while one non-pregnant volunteer reached 101.4ºF. None of the pregnant subjects had a change in core temperature during a class in excess of 1.2ºF and the largest change for a non-pregnant subject was 2.8 ºF. Based upon the results of this study, it appears that women who are participating in hot yoga at the time of their pregnancy can safely continue their practice. However, it is still not recommended that women start a yoga practice after they become pregnant.

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INTRODUCTION

Yoga is an extremely popular form of group exercise. A 2016 survey estimated that 36 million Americans practice some form of yoga, with women making up 72% of participants (Scott, 2019). There are many known health benefits of yoga including improvements in strength, flexibility, respiration, and exercise capacity (Quandt, Porcari, Steffen, Felix, Foster, 2015). Yoga has also been shown to help decrease symptoms of anxiety and depression and improve "mindfulness" (Corliss, 2014).

Hot yoga has also become more popular in recent years. Hot yoga is conducted in a room heated to between 90°F to 100°F, with humidity ranging between 40-60%. Bikram yoga is a specialized type of hot yoga in which the room is heated to 105°F (Quandt et al., 2015). One of the main concerns surrounding hot yoga is the potential for overheating and associated heat-related illnesses. When a person exercises, their body is going to produce heat, which needs to be mitigated somehow in order to keep homeostasis of the body. This excess heat is going to be distributed to the surrounding tissue of the active muscles. It will happen via the circulatory system via conduction or convection. Then the heat can be dissipated from the skin either by drying or evaporation, such as sweating. While core temperature may initially increase rapidly at the onset of exercise, thermoregulatory effector responses for heat dissipation respond more slowly. Thermoregulatory responses such as radiation, convection, and evaporation will be enabled in order to reduce the body's heat. Eventually, these heat loss mechanisms will increase enough to balance out heat production, allowing a person's core temperature to reach steady-state (Sawka, Wegner, Young, Pandolf, 1993).

A number of studies have evaluated core temperature during various hot yoga classes. A study conducted by Nereng, Porcari, Camic, Gillette, and Foster (2014) found no significant difference in the change in core temperature between basic yoga and hot yoga classes. Compared with resting values, core temperature increased by 1.1°F for the basic yoga class and 0.9°F for the hot yoga class. Pate and Buono (2014) compared core temperature in novice and experienced practitioners during a Bikram yoga class. The experienced practitioners had a 1.8°F increase in core temperature versus a 1.0°F increase in the novice subjects. Fritz, Grossman, Mukherjee, Hunter, and Tracy (2014) also studied the thermal responses to a single session of Bikram yoga. It was found that the peak temperature during the class averaged 100.8°F. In contrast to the abovementioned studies, Quandt, Porcari, Steffen, Felix, and Foster (2015) found worrisome increases in core temperature during a 90-minute Bikram yoga class. Core temperature steadily increased throughout the class, peaking at an average of 102.4°F by the end of the class. In that study, eight subjects had a core temperature over 103°F and one subject had a core temperature of 104.1°F by the end of the class. Core temperatures in excess of 104°F are often associated with signs and symptoms of heat exhaustion or heat stroke (Quandt et al., 2015).

One group of participants for whom an increase in core temperature may be problematic is pregnant women. There is evidence to suggest that core temperatures in excess of 102.2°F during the first trimester of pregnancy may result in fetal neural tube defects. (Ravanelli, Casasola, English, Edwards & Jay, 2018). Heat transfer during pregnancy between the mother and the fetus takes place through the placental wall and uterine blood flow. (Ravenelli et al., 2018). When maternal CT increases, there is evidence to show uterine blood flow decreases. Overall, the fetus is fully dependent on the mother's body to be able to regulate temperature. Thus, it is recommended that pregnant women avoid using hot tubs or saunas during this time

(Ravanelli et al., 2018). While there are well-established exercise guidelines for pregnant women in regard to aerobic exercise (Ravanelli et al., 2018), there are no guidelines or recommendations regarding whether or not they can safely participate in hot yoga. Therefore, the purpose of this study was to evaluate the core temperature (CT), heart rate (HR), and rating of perceived exertion (RPE) responses of pregnant women during hot yoga classes in order to determine if it safe for them to participate in this activity.

METHODS

Four apparently-healthy, pregnant female volunteers and five apparently-healthy, non-pregnant volunteers participated in this study. All subjects were between 22 to 33 years of age. All the participants were regular practitioners of hot yoga for at least 3 months prior to enrolling in the study. The participants could not have a history of gastric problems, which is a contraindication for ingestion of the core temperature pill. Prior to participating in the study, all subjects provided written informed consent (Appendix A). The study was approved by the University's Institutional Review Board for the Protection of Human Subjects.

PROCEDURES

During each yoga session, core temperature was measured using an ingestible CorTemp pill. (HQ, Inc., Palmetto, FL). The pill was ingested 6 hours prior to the start of the yoga class. Prior to beginning the yoga class, subjects completed a questionnaire asking about their yoga habits, focusing on changes to their yoga practice due to their pregnancy (Appendix B). Subjects were then weighed using a Rice Lake Digital Scale (Rice Lake Weighing Systems, Rice Lake, WI) and had a HR monitor attached (Polar, HRM USA INC., Warminster, PA). The yoga classes were approximately 60 minutes in duration. Throughout the class, the researcher sat next to the subjects. Every 10 minutes during the class, HR , CT , and RPE using the Borg 6-20

scale (Borg, 1982) were assessed. Additionally, the temperature and humidity of the room were recorded at this time using a Model 45815 Hydro-thermometer Humidity Alert II (Nashua, NH). At the conclusion of the class, subjects were once again weighed to determine any changes in body weight. The amount of fluid consumed during the class was also recorded.

STATISTICAL ANALYSIS

Standard descriptive statistics were used to characterize the subject population and to summarize responses during the yoga class. Differences between pregnant and non-pregnant groups were compared using two-way ANOVA with repeated measures. When there was a significant interaction, Tukey's post-hoc tests were used to isolate pairwise differences. Alpha was set at $p<.05$ to determine a significant difference. All analyses were conducted using the Statistical Package for the Social Sciences (SPSS, Version 19; SPSS Inc., Chicago, IL).

RESULTS

Descriptive characteristics of the subjects are presented in Table 1. For the pregnant women, Subject 1 completed 3 sessions, Subject 2 completed 1 session, Subject 3 completed 2 sessions, and Subject 4 completed 1 session. For the non-pregnant women, Subject 5 completed 3 sessions, Subject 6 completed 2 sessions, and Subjects 6-8 each completed 1 session. Since two of the pregnant subjects completed multiple sessions at different points in their pregnancy, the actual weight of subjects is presented for each session. On average, the weight of the pregnant subjects prior to yoga session was 144.7 ± 15.36 lbs and was144.7 ± 15.19 lbs at the end of the yoga session. The change in body weight ranged from -.6 to +.8 lbs for the pregnant subjects. The average weight of the non-pregnant volunteers prior to the yoga session was 156.0 ± 15.11 and was 156.1 ± 15.15 at the end of the class. The change in body weight for individual subjects

ranged from -1.4 to + 1.0 lbs. The amount of water consumed by the pregnant and non-pregnant subjects is presented in Table 2.

Table 1. Descriptive characteristics of the subjects.

	Age (years)	Height (in)	Gestational Term	Pre-Weight (lb)	Post-Weight (lb)
Pregnant (n=4)					
Subject 1 Session 1	33	63	27 weeks	139.6	139.2
Subject 1 Session 2	-	-	30 weeks	142.4	141.8
Subject 1 Session 3	-	-	32 weeks	146.2	146.6
Subject 2 Session 1	29	66	37 weeks	170.8	170.6
Subject 3 Session 1	27	62	30 weeks	124.8	125.6
Subject 3 Session 2	-	-	32 weeks	132.5	132.4
Subject 4 Session 1	26	68	25 weeks	157.2	157.2
Non-Pregnant (n=5)					
Subject 5 Session 1	27	69	-	154.0	152.6
Subject 5 Session 2	-	-	-	154.0	154.2
Subject 5 Session 3	-	-	-	155.0	156.0
Subject 6 Session 1	22	68	-	138.4	138.4
Subject 6 Session 2	-	-	-	137.6	138.0
Subject 7 Session 1	26	65	-	155.4	155.0
Subject 8 Session 1	29	66	-	171.0	171.8
Subject 9 Session 1	22	68	-	182.8	182.6

Table 2. Volume of fluid consumed during the yoga sessions by pregnant and non-pregnant subjects.

	Ounces During	Ounce Range
Pregnant	9.1 ± 8.15	0 – 24 oz
Non-Pregnant	9.2 ± 6.94	3 – 20 oz

Mean = ± SD

Average room temperature and humidity of the hot yoga studio are presented in Table 3. As can be seen, the temperature and humidity of the room increased steadily throughout the class and averaged 95.7ºF and 56.7% humidity.

Table 3. Average temperature and humidity of the yoga studio.

	0 min	10 min	20 min	30 min	40 min	50 min	60 min
Temp (ºF)	93.6 ± 3.04	94.5 ± 2.71	95.8 ± 2.44	96.1 ± 1.91	97.0 ± 2.00	96.3 ± 1.88	97.2 ± 1.77
Humidity (%)	50.1 ± 6.91	51.0 ± 6.61	53.7 ± 6.66	57.1 ± 6.35	59.7 ± 6.72	62.6 ± 6.28	62.6 ± 6.97

Mean = ± SD

Average HR and RPE for the pregnant and non-pregnant subjects are presented in Table 4. For the pregnant subjects, HR averaged 103.6 bpm over the entire class, with one subject reaching a peak of 133 bpm 20 minutes into the class. For the non-pregnant subjects, HR averaged 94.6 bpm over the entire class, with one subject reaching a peak of 154 bpm 20 minutes into the class. For the pregnant subjects, RPE averaged 10.5, while the non-pregnant subjects RPE averaged 9.9. Both pregnant and non-pregnant subjects recorded their highest average RPE values (13.1 and 13.4, respectively) 30 minutes into the class.

Table 4. Average heart rate and ratings of perceived exertion during the yoga sessions for the pregnant and non-pregnant subjects.

	0 min	10 min	20 min	30 min	40 min	50 min	60 min
Pregnant	(n=4)						
HR	90.1±10.97	104.7±7.99	100.4±16.83	117.7±10.61	108.9±16.02	104.1±11.44	99.0±9.38
RPE	6.0±0.00	8.8±2.27	11.7±1.79	13.1±1.78	12.4±1.78	10.4±1.51	6.7±1.13
Non-Pregnant	(n=5)						
HR	75.5±6.74	86.6±11.59	116.4±23.70	114.9±16.14	103.6±15.15	84.1±14.34	81.25±16.88
RPE	6.0±0.00	7.9±1.46	11.0±1.93	13.4±1.30	13.0±3.29	7.7±1.75	6.4±0.74

CT of the pregnant subjects for each individual session are presented in Figure 1. CT of the non-pregnant for each session are presented in Figure 2. Average CT for the pregnant and non-pregnant subjects, collapsed across sessions, are presented in Figure 3. The average highest CT for the non-pregnant women was significantly greater than the pregnant subjects (99.9 ± 0.53 ºF vs. 99.5 ± 0.47 ºF, respectively). The highest CT seen in any single pregnant subject was 100.1 ºF, while one non-pregnant volunteer had a CT of 101.4ºF. The range of change in CT for the pregnant subjects in any one class was -0.19 – 1.2ºF and for non-pregnant subjects was 0.29 – 2.77ºF.

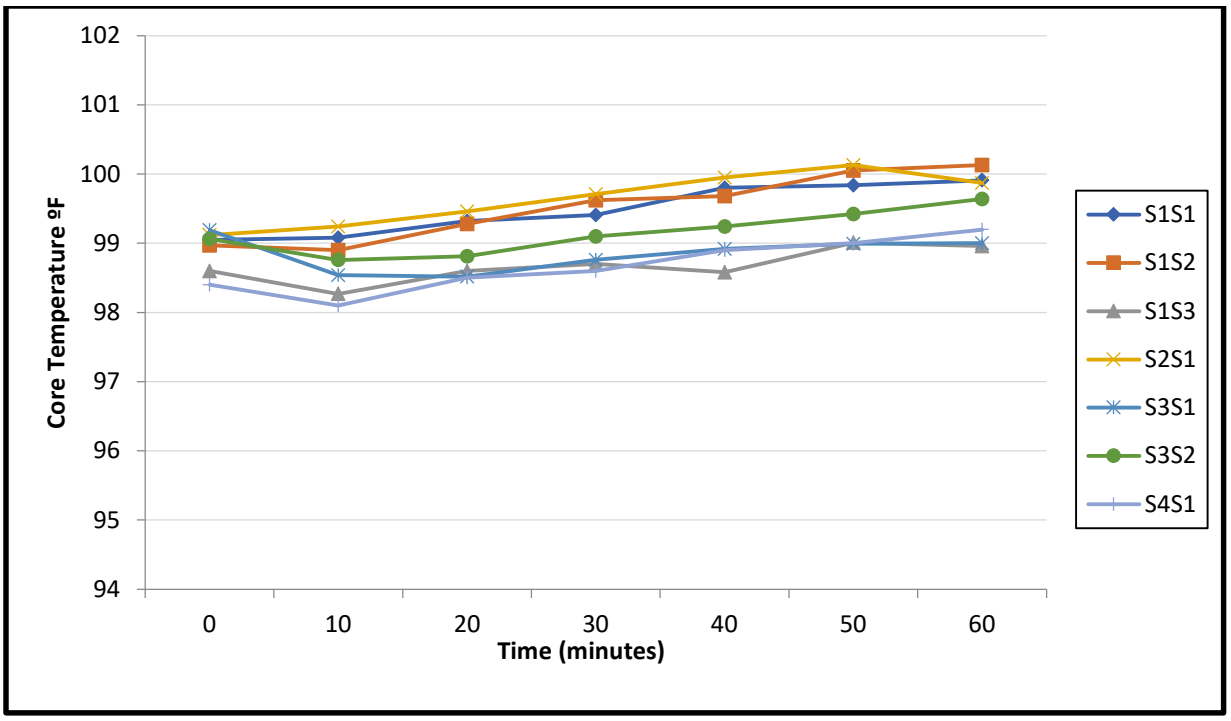

Figure 1. Core temperatures of the pregnant subjects during each yoga class. (n=4)

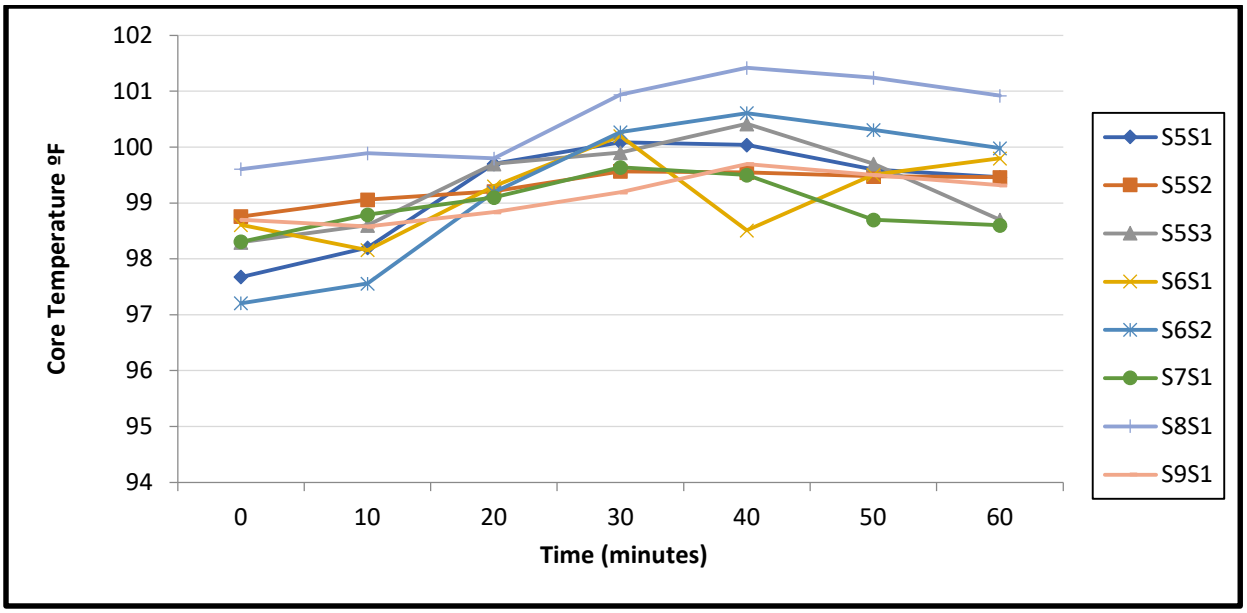

Figure 2. Core temperature of the non-pregnant subjects during each yoga class. (n=5)

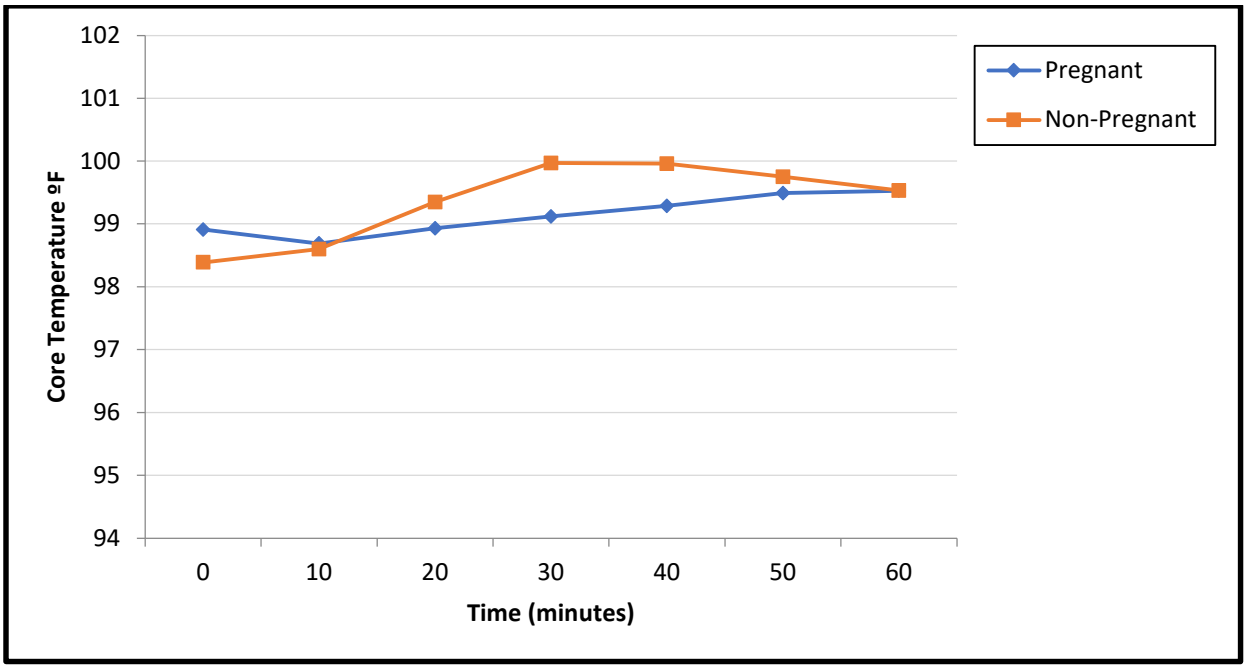

Figure 3. Mean core temperatures of the pregnant and non-pregnant subjects collapsed across all sessions for each group. (n=9)

DISCUSSION

One of the main concerns regarding the practice of hot yoga by pregnant women is a potentially high increase in CT during a class. A maternal CT exceeding 102.2ºF or an increase of 2.7 - 3.6ºF from baseline has been suggested to augment risk for abnormal fetal development (Ravanelli, et al., 2019). The present study evaluated HR, CT, and RPE in four pregnant women and five non-pregnant women. The highest CT in pregnant subjects averaged 99.5 ºF compared to a value of 99.9 ºF for the non-pregnant subjects. One pregnant subject had a single CT of 100.1 ºF, while one non-pregnant volunteer reached 101.4ºF. In addition, none of the pregnant subjects had a change in CT during a single class in excess of 1.2ºF. The non-pregnant subjects did not reach a change in CT exceeding 2.8 ºF. The core temperatures reached by both the pregnant and non-pregnant volunteers are not concerning because they are below the critical

threshold of 102.2ºF and did not exceed a change of 2.7 - 3.6ºF. It is interesting to note that in Figure 3 there was difference in the pattern of CT over the course of the class for the pregnant and non-pregnant subjects. Non-pregnant subjects reached a peak 30 minutes into the class, but the CT of pregnant subjects continually increased over the entire session. Whether or not this has any significance could be explored in future studies.

The pregnant subjects' weight pre to post yoga session did not show much change. The average weight differences from pre to post testing for pregnant subjects were -0.01 ± 0.477 lbs., and non-pregnant subjects were 0.00 ± 0.756 lbs. Not seeing a significant change in weight pre to post yoga session is normal because almost all the subjects drank water during their session, thus compensating for water loss.

The difference in CT between pregnant and non-pregnant subjects is most likely due to the pregnant subjects modifying their yoga practice because of their pregnancy. Each pregnant subject filled out a questionnaire (Appendix B) that asked how they had modified their yoga practice as a result of their pregnancy. It was found that the pregnant subjects either modified or avoided specific poses. Poses that were avoided were upward facing dog, wheel or bridge, and any pose involving core work or twists. The poses that were modified were high-to-low plank (subjects preferred to do this from their knees), straight leg/forward fold, and wrap around breathing to protect doming and the linea alba. The linea alba is responsible for keeping the abdominal muscles at a close proximity to each other. Doming can occur when lifting, getting out of bed, or leaning backwards. This would indicate that the mother is straining the abdomen too much. One subject commented that she makes modifications because otherwise she feels an overall tightening in her core and hip flexors.

The present study has some limitations due to its small sample size. We only had four pregnant subjects and the earliest stage of pregnancy where a subject was tested was 27 weeks. The latest gestational stage in which we were able to test a subject was 37 weeks. Such limitations make it difficult to generalize for the pregnant population across the span of their 9-month gestation.

In summary, the main purpose of this study was to evaluate evaluated CT in pregnant volunteers during a hot yoga class. None of the pregnant women had an increase in CT that was over the critical threshold of 102.2ºF and none of the subjects had a change in CT from baseline that would be considered dangerous. While it is still not recommended that women *start* a yoga practice after they become pregnant, based on the results of this study it appears that women who are participating in hot yoga at the time of their pregnancy can safely continue their practice.

Appendix A

Project: Heart Rate and Core Temperature in Pregnant Women during Hot Yoga

I, _____, volunteer to participate in a research study being conducted by the University of Wisconsin – La Crosse.

Purpose and Procedures

- The purpose of this study is to evaluate the core temperature, heart rate, and perceived exertion of pregnant women during a hot yoga class.
- My participation in this study will involve one testing session, lasting 90 minutes.
- Prior to the hot yoga class, I will swallow an ingestible core temperature pill that will measure my core temperature response.
- I will wear a chest strap in order to record and measure my heart rate responses.
- At the end of class, I will be asked to rate my exertion level during the class.
- Graduate students will be conducting the research under the direction of John Porcari, a Professor in the Department of Exercise and Sport Science at the University of

  Wisconsin – La Crosse.

Potential Risks

- Muscle fatigue, muscle soreness, and dizziness are possible risks associated with participating in this study.
- Individuals trained in CPR will be present for all testing sessions and the testing will be terminated if complications occur.

Rights and Confidentiality

- My participation is voluntary, and I can withdraw or refuse to answer any question without consequences at any time.
- I can withdraw from the study at any time for any reason without penalty.
- The results of this study may be shared in scientific literature or presented at professional conferences.
- All data and information will be kept confidential using number codes.
- By completing the survey tools provided, I am constituting informed consent.

Benefits of this Study

- I will gain knowledge about my core temperature and heart rate responses during hot yoga.
- The general public and health professionals will gain insight about the safety of participating in hot yoga while pregnant.

I have read the information provided on this consent form. I have been informed of the purpose of this test, the procedures, and expectations, of myself as well as the testers, and of the potential risks and benefits that may be associated with volunteering for this study. I have asked any and all questions that concerned me and received clear answers so as to fully understand all aspects of this study.

Questions regarding study procedures may be directed to Amber Patterman (608-387-2620), the principal investigator, or the faculty advisor John Porcari, PhD., Department of Exercise and Sport Science, UW-L (608-386-5416). Questions regarding the protection of human subjects may be addressed to the UW-La Crosse Informed Consent Institutional Review Board for the Protection of Human Subjects at irb@uwlax.edu.

Participant _____ Date _____

Researcher _____ Date _____

Appendix B

Core Temperature Questionnaire

Name: _____ Age: _____

Date: _____ Height: _____

PRE-WT: _____

POST-WT: _____

Please answer the following questions in as much detail as possible.

1. How many years have you been practicing yoga?

2. How far along are you in your pregnancy?

3. Are there any specific yoga positions you avoid now that you are pregnant? If so, which ones?

4. What have you changed about your practice since becoming pregnant?

5. Have you experienced different symptoms during hot yoga while pregnant, versus when you were not pregnant? If so, what are they?

6. Have you ever experienced any digestive problems? If so, please explain.

7. Did you consume any water prior to today's yoga session? If so, how much?

8. Did you consume any water during today's yoga session? If so, how much?

Data Collection

Time	Room Temp	Humidity	Core Temp	RPE	Heart Rate
0 minutes					
10 minutes					
20 minutes					
30 minutes					
40 minutes					
50 minutes					
60 minutes					

REFERENCES

Bongers CC, Daanen HA, Bogerd CP, Hopman MT, Ejisyogels TM. (2018). Validity, reliability, and inertia of four different temperature capsule systems. *Med Sci Sports Exerc,* 50(1), 169-175.

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

Corliss J. (2014). Mindfulness meditation may ease anxiety, mental stress. *Harvard Heart Letter.* Retrieved from https://www.health.hardvard.edu/blog/mindfulness-meditation-may-ease-anxiety-mental-stress-201401086967

Fritz, M. L., Grossman, A. M., Mukherjee, A., Hunter, S. D., & Tracy, B. L. (2014). Acute metabolic, cardiovascular, and thermal responses to a single session of bikram yoga. *Medicine & Science in Sports and Exercise*, *46*(5), 146-147. doi:10.1249/01.mss.0000493613.83031.88

Nereng AN, Porcari JP, Camic JL, Gillete CM, Foster C. (2014). Heart rate and core temperature responses during basic yoga compared with those during hot yoga. *Gund Med J,* 8(2), 113-115.

Pate, J. L., & Buono, M. J. (2014). The physiological responses to Bikram yoga in novice and experienced practitioners. *Alternative therapies in health and medicine*, *20*(4), 12–18.

Quandt E, Porcari JP, Steffen J, Felix M, Foster C. (2015). Heart rate and core temperature responses to Bikram Yoga. *Gund Med J,* 9(1), 3-6.

Ravanelli N, Casasola W, English T, Edwards KM, Jay O. (2018). Environmental limits for exercise and passive heat stress during pregnancy: A systemic review with best evidence synthesis. *Br J Sports Med,* 53(13), 799-805.

Sawka, M. N., Wenger, B., Young, A. J., & Pandolf, K. B. (1993). Physiological responses to exercise in the heat. *Institute of Medicine (US) Committee on Military Nutrition Research*.

Scott C. (2019). Hot yoga: Is it super-heated exercise or a health danger? Retrieved from https://www.healthline.com/health-news/hot-yoga-booming-but-it-may-be-bad-for-you-051515#1

REVIEW OF THE LITERATURE

Introduction

Yoga has been around for centuries both as a form of exercise and meditation practice. It is a mind-body exercise that combines static postures with fluid, low-impact motions. A 2016 survey estimated that 36 million Americans practice some form of yoga, with women making up 72% of participants (Scott, 2019). Due to there being different styles of yoga available all over the country, how do you know which option is best suited for you? Women who are pregnant ask this very question to instructors frequently. There are prenatal yoga classes available, but what if the women have been practicing hot yoga for years and do not want to give up their practice? There is little to no research available documenting if hot yoga is safe for expecting mothers. It is important to determine if the core temperature of pregnant women is reaching hyperthermic conditions, because if it is, that could challenge fetal development.

Definition of Hot Yoga

Hot yoga involves practicing yoga in a room with temperatures ranging from 90ºF to 105ºF, with 40-60% humidity. The high temperature of the room is supposed to make it easier to stretch deeper into certain poses, and most advocates suggest it further improves the mind-body connection, allowing the participants to focus more intently on breathing and posture (Nereng, Porcari, Camic, Gillette, Foster, 2014). The postures require lengthy, forceful, and well-controlled contractions of all major muscle groups (Tracy and Hart, 2013). The combination of rapid transition between postures and environmental heat stress produces a substantial cardiovascular response and muscle fatigue (Tracy and Hart, 2013).

Benefits of Doing Yoga in the Heat

Yoga increases overall strength, flexibility, lung function, and may help control blood pressure, respiration, heart rate (HR), metabolic rate, and overall exercise capacity (Quandt, Porcari, Steffen, Felix, Foster, 2015). Several intervention studies have demonstrated the positive effects of yoga on blood-lipid profile, coronary artery disease, obesity, and diabetes mellitus (Pate and Buono, 2014). Many people even use it for therapeutic intervention for chronic illness and degenerative diseases (Quandt et al., 2015). Tracy and Hart (2013) reported yoga has also been shown to help cancer survivors with weight maintenance after treatment and improve physical function in stroke survivors. Hunter, Dhindsa, Cunningham, Tarumi, Alkatan, and Tanaka (2013) found hot yoga to be beneficial for improving glucose tolerance and insulin resistance in older, obese adults.

Hot yoga enthusiasts suggest that doing the exercise in a heated room strengthens the heart, clears out the veins, cleanses impurities from the body, and boosts the immune system (Scott, 2019). A person will likely experience an elevated heart rate when working out in high ambient temperatures. This can be explained as a reactive mechanism that shifts blood flow toward the cutaneous vessels, which helps maintain thermal homeostasis (Rowell, 1987) The blood shift that takes place will reduced stroke volume, and therefore, heart rate becomes elevated in order to maintain cardiac output during exercise (Rowell, 1987). The most highlighted benefit of hot yoga is the ability to stretch through a greater range of motion, since the muscles are more “warmed-up” and elastic due to the higher room temperature (Nereng et al., 2014). Tracy and Hart (2013) found hot yoga to increase participants’ deadlift strength, lower back/hamstring flexibility, and shoulder flexibility after 8 weeks of training. Yoga is also thought to decrease feelings of stress, depression, and anxiety due to its similar techniques like meditation, relaxation, and exercise.

Potential Dangers of Doing Yoga in the Heat

Hyperthermia is a large concern when it comes to practicing hot yoga. Exercise generates heat, making thermoregulation increasingly difficult. Since the air temperature of the room is potentially higher than body temperature, it is difficult to expel this heat, as radiative heat exchange favors heat gain. Normally, the body can cool itself through sweating and evaporation, but with high heat and humidity, the body is not able to rid itself of the excess heat. Exertional heat stroke (core temperature ≥ 104°F) occurs when the temperature regulation system is overwhelmed due to excessive endogenous heat production or inhibited heat loss in challenging environmental conditions and can progress to complete thermoregulatory system failure (Binkley, Beckett, Casa, Kleiner, Plummer, 2002). Common signs and symptoms of heat-related illness include hypotension, tachycardia, dizziness, syncope, hyperventilation, nausea, vomiting, muscle cramps, and seizures (Quandt et al., 2015).

Nereng et al. (2014) conducted a study to compare heart rate and core temperature responses to regular yoga versus hot yoga. Temperature in the hot yoga classroom averaged 92.7ºF and the humidity averaged 35%. They found no significant difference in core temperature between basic yoga and hot yoga classes. Core temperature increased by 1.1ºF for the basic yoga class and by 0.9 ºF for the hot yoga class. The highest recorded temperature was 102.4 ºF for an individual, well below the critical value of 104°F (Nereng et al., 2014). Researchers found no significant difference of heart rates between the regular yoga class and hot yoga class. Exercise intensity average 56% of maximal heart rate for the basic yoga class and 57% of maximal heart rate for the hot yoga class (Nereng et al., 2014).

Bikram yoga is another version of hot yoga that combines thermal therapy and Hatha yoga. These sessions last 90 minutes and the rooms are heated to 105°F and kept at ~40%

humidity. In 2014, Pate and Buono recruited 26 volunteers aged 18 to 57 years old to do a Bikram study. The novice participants had an oral temperature increase of 1.0 ± 1.2°F and the experienced participants had an oral temperature increase of 1.8 ± 1.4°F (Pate and Buono, 2014). Fritz, Grossman, Mukherjee, Hunter, and Tracy (2014) studied thermal responses to a single session of Bikram yoga. They found that peak temperature during the class averaged at 100.8°F.

Quandt et al. (2015) conducted a similar Bikram study with 20 volunteers aged from 28 to 67 years old. At the beginning of the sessions, room temperature was 104.9°F and relative humidity was 37%. By the end of class, room temperature had increased to 105.8°F with humidity at 38%. Core temperatures increased in a linear fashion in both men and women. Peak core temperatures averaged 102.4°F. Eight subjects had a peak core temperature over 103°F and one man's core temperature reached 104.1°F by the end of the 90-minute session. These temperatures are concerning because they are at or near the critical values of 104°F, where many signs and symptoms of heat-related illness manifest themselves and may become threatening (Quandt et al., 2015).

Effects of Hot Environments While Pregnant

Exercise during pregnancy reduces the risk of infants born at extreme ends of the birth weight range, protects against preterm birth, and improves nutrient delivery to the fetus to support development (Clapp, 2006). Exercise inevitably results in the production of heat, which must be liberated to the environment to mitigate the rise in internal temperature. The excess heat produced from muscular contractions is first transferred to the surrounding tissue by a combination of conduction and convection, through the circulatory system, where it is ultimately dissipated from the skin surface to the surrounding environment through dry (i.e. radiative,

conductive or convection) or evaporative (i.e. sweating) avenues (Lotgering, Gilbert & Longo, 1983). During the pregnancy, the main avenue for heat transfer between the mother and the fetus is via the placental wall and uterine blood flow (e.g. conductive heat transfer) (Lotgering et al., 1983). With increasing maternal core temperatures, there is evidence of reduced uterine blood flow, although compensatory mechanisms exist to maintain nutrient supply to the fetus (Ziskin & Morissey, 2011).

The American Congress of Obstetrics and Gynecologists (ACOG) discourages the use of hot baths and saunas during pregnancy and suggest '…*avoiding high heat and humidity to protect against heat stress'* (Ravanelli, Casasola, English, Edwards & Jay, 2018). However, the terms 'hot' and 'humid' are ambiguous and subject to a wide scope of individual interpretation that may be further confounded by an altered perception of thermal stimuli with pregnancy (Ravenlli et al., 2018). Since hot weather is a perceived barrier to exercise, only a small proportion of pregnant women meet the recommended physical activity requirements (Ravanelli et al., 2018). Because exercise is beneficial for both mother and fetus, Ravanelli et al. (2018) conducted a systematic review of several studies to help clarify these gray areas.

The review sought to (1) determine the critical environmental and exposure limits for exercise and/or heat exposure during pregnancy, and (2) assess whether thermoregulatory capacity (indicated by changes in core temperature) during exercise and/or heat exposure is altered throughout pregnancy. It was important to the researchers to identify the combinations of climate conditions, exercise intensity, duration and mode that could be performed without exceeding a critical maternal core temperature of 102.2ºF (Ravanelli et al., 2018). Researchers found women may safely engage in: (1) exercise for up to 35 minutes at 80-90% of their maximum heart rate in 77ºF and 45% relative humidity; (2) water immersion (≤ 92.1ºF) exercise

for up to 45 minutes; (3) sitting in hot baths (104ºF) or hot/dry saunas (158ºF; 15% relative humidity) for up to 20 minutes, regardless of pregnancy stage, without reaching a core temperature that will interfere with development of the fetus (Ravanelli et al., 2018).

There is an understandable concern about potential birth defects when a mother's core temperature goes above 104ºF. Most organ systems are formed during the 3rd to 8th weeks of embryonic development (Sadler & Langman, 2004). Development of the central nervous system occurs earlier, during the 3rd to 4th weeks. Abnormal closure of neural folds during this time can result in neural tube defects (Sadler & Langman, 2004). The following studies have investigated potential causes of birth defects.

Chan, Natekar, and Koren (2014) analyzed several studies conducted in pregnant women who had documented maternal hyperthermia, specifically from saunas or hot tubs. Pregnant women had a 2-fold increased risk of neural tube defects (NTDs) when their core temperature increased to 100-102ºF. Duong, Hashmi, Ramadhani, Canfield, Scheuerle, Waller, et al. (2011) found an increased risk of esophageal atresia and omphalocele (i.e. a birth defect in which an infant's intestine or other abdominal organs are outside of the body because of a hole in the belly button) among offspring of mothers who reported using hot tubs during pregnancy more than once for longer than 30 minutes.

Duong et al. (2011) included mothers of infants with birth defects, and mothers of infants without birth defects, who participated in the multisite National Birth Defects Prevention Study between 1997 and 2005. The results found that women who used a hot tub more than once during the early stages of pregnancy and for a long period of time per session had increased risk of certain birth defect phenotypes, particularly anencephaly and gastroschisis (Duong et al., 2011). Anencephaly is when the baby is born with an underdeveloped brain and an incomplete

skull; and gastroschisis is when the baby's intestines are found outside of the baby's body, exiting through a hole beside the belly button.

Measuring Core Temperature

In order to measure core temperature during exercise, researchers often use a wireless system that is noninvasive and easily applicable in field conditions. Bongers, Daanen, Bogerd, Hopman, and Eijsvogels (2017) examined the validity, reliability, and inertia characteristics of four ingestible temperature capsule systems (i.e., CorTemp, e-Celsius, myTemp, and VitalSense). The study took place in a water bath using 10 sensors per telemetric capsule (i.e. 40 in total) in three separate trials. The first two trials assessed the validity and test-retest reliability, while the third trial examined inertia characteristics of the temperature capsules. The water baths were filled with 3.5 L of distilled water and were controlled by a thermostat. In the first two trials, 12 temperature plateaus were set to ensure the stability of the water bath temperature and reliability of the temperature measurements. During the third trial that was testing for inertia, the temperature was set at specific thresholds and stabilized for five minutes. The protocol allowed researchers to calculate the time delay of the temperature measured by each temperature capsule compared with the actual temperature of the water bath during the stepwise heating phase (Bongers et al., 2017). It was found that of all the capsules were shown to be valid and reliable in terms of measuring temperature and demonstrated an acceptable responsiveness to changes in temperature (Bongers et al, 2017). The CorTemp system, which was used in the current study, was found to be accurate in normothermic and hyperthermic conditions but did not meet the criteria for excellent validity for hypothermic conditions (Bongers et al., 2017).

Conclusion

There are many well-defined benefits when practicing hot yoga including increases in flexibility and strength, and reductions in feelings of anxiety, depression and stress. Studies have shown practicing hot yoga (room temperature of ~95ºF) does not result in an unsafe increase in core temperature. However, core temperature responses to Bikram yoga (room temperature ~105ºF) could be worrisome. The core temperature responses in pregnant women during hot yoga are unknown. Research on this topic would provide guidance for expectant mothers to ensure their safety, as well as the safety of the fetus in regards to proper prenatal development.

References

American Council on Obstetrics and Gynecology (ACOG) Committee Opinion. (2020). Physical activity and exercise during pregnancy and the postpartum period. *Obst Gynecol*, 135(4), 178-188.

Binkley, H. M., Beckett, J., Casa, D. J., Kleiner, D. M., & Plummer, P. E. (2002, September). National Athletic Trainer's Association position statement: exertional heat illnesses. Journal of Athletic Training, 37(3), 329-343.

Bongers, C. C., Daanen, H. A., Bogerd, C. P., Hopman, M. T., & Eijsvogels, T. M. (2018). Validity, reliability, and inertia of four different temperature capsule systems. American College of Sports Medicine, 50 (1), 169-175. doi:10.1249/MSS0000000000001403

Chan, J., Natekar, A., & Koren, G. (2014). Hot yoga and pregnancy. Canadian Family Physician, 60, 41-42.

Clapp JF. Influence of endurance exercise and diet on human placental development and fetal growth. *Placenta* 2006; 27:527-534.

Duong HT, Shahrukh Hashmi S, Ramadhani T, Canfield MA, Scheuerie A, Kim Waller D, et al. Maternal use of hot tub and major structural birth defects. *Birth Defects Res A Clin Mol Teratol* 2011; 91(9):836-841. Epub 2011 Jun 6.

Hunter SD, Dhindsa M, Cunningham E, Tarumi T, Alkatan M, Tanaka H. Improvements in glucose tolerance with Bikram yoga in older obese adults: a pilot study. *J Bodyw Mov Ther.* 2013;17(4):404-407

Lotgering FK, Gilbert Rd, Longo LD. Exercise responses in pregnant sheep: blood gases, temperature, and fetal cardiovascular system. *J Appl Physiol Respir Environ Exerc Physiol* 1983; 55:842-850.

Nereng, A. N., Porcari, J. P., Camic, C. L., Gillette, C. M., & Foster, C. (2014). Heart rate and core temperature responses during basic yoga compared with those during hot yoga. *Gundersen Medical Journal*, *8* (2), 113-115.

Pate, J. L., & Buono, M. J. (2014). The physiological responses to bikram yoga in novice and experienced practitioners. *Alternative Therapies in Health & Medicine*, *20*(4), 12-18.

Quandt, E., Porcari, J. P., Steffen, J., Felix, M., & Foster, C. (2015). Heart rate and core temperature responses to Bikram Yoga. *Gundersen Medical Journal*, *9* (1), 3-6.

Ravanelli, N., Casasola, W., English, T., Edwards, K. M., & Jay, O. (2018). Heat stress and fetal risk. Environmental limits for exercise and passive heat stress during pregnancy: a systematic review with best evidence synthesis. *British Journal Sports Medicine*, *53*(13), 799-805. doi:10.1136/bjsports-2017-097914

Rowell, L. B. (1987). Human circulation: regulation during physical stress. *Journal of the American Medical Association*. doi:10.1001/jama.1987.03400220116052

Sadler TW, Langman J. 2004. Langman's medical embryology. 9th ed. Philadelphia: Lippincott Williams and Wilkins.

Scott, C. (2019). Hot yoga: is it super-heated exercise or a health danger? In *Healthline.*

Tracy BL, Hart CE. Bikram yoga training and physical fitness in healthy young adults. *J Strength and Cond Res.* 2013; 27(3):822-830

Ziskin MC, Morrissey J. Thermal thresholds for teratogenicity, reproduction, and development. *Int J Hyperthermia* 2011; 27:374-387.