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The Effect of External Heat and Humidity on Levels of Perceived Exertion While Performing a Submaximal Bicycle Test

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THE EFFECTS OF EXTERNAL HEAT AND HUMIDITY ON LEVELS OF PERCEIVED EXERTION WHILE PERFORMING A SUBMAXIMAL BICYCLE TEST

by

Erika E. Hanselman

A Thesis
Submitted to the Faculty of The Graduate College in partial fulfillment of the requirements for the Degree of Master of Arts
Department of Health, Physical Education and Recreation

Western Michigan University
Kalamazoo, Michigan
April 1995
ACKNOWLEDGMENTS

"Nothing you write, if you hope to be any good, will ever come out as you first hoped" - Lillian Hellman

As I quickly discovered, writing a thesis takes more than writing a paper. It's patience, writing, explaining and rewriting. I owe a great deal to the members of my thesis committee, Dr. Roger Zabik, Dr. Mary Dawson, and Dr. Patricia Frye. Through their areas of expertise they contributed greatly toward the completion of this project.

I am very grateful to the ten subjects from the Health Physical Education, and Recreation Department that dedicated themselves to me for a long, hot three weeks. I couldn't have done it without them.

Lastly, I am deeply indebted to my parents, David and Marge Hanselman, for their continuous inspiration and encouragement throughout my entire college career. They provided me with the emotional support, and determination to make this project a reality. I dedicate this thesis to them.

Erika E. Hanselman
THE EFFECTS OF EXTERNAL HEAT AND HUMIDITY ON LEVELS OF PERCEIVED EXERTION WHILE PERFORMING A SUBMAXIMAL BICYCLE TEST

Erika E. Hanselman, M.A.
Western Michigan University, 1995

The effect of changes in environmental conditions on perception of the intensity of exercise using the Borg scale for rating of perceived exertion (RPE) was the focus of this study. Subjects (n=10) recruited opportunistically from graduate classes in the Health, Physical Education and Recreation Department performed the test in a climate control chamber located in the Exercise Physiology lab at Western Michigan University. The submaximal test followed the protocol established by the American College of Sports Medicine (ACSM, 1991).

Each subject performed each of the four conditions three times. Conditions were assigned in random order to each subject. Perceived exertion, body temperature, and workload were recorded at 55%, 65%, 75%, and 85% of the subject's predicted maximum heart rate (MHR). The conditions performed were (a) 75 °F at 50% humidity, (b) 75 °F at 90% humidity, (c) 85 °F at 50% humidity, and (d) 85 °F at 90% humidity.

Randomized block factorial analyses of variance with repeated measures design was calculated for RPE and workload. To test for trend across the percentages of MHR, orthogonal polynomials were also run on both RPE and workload.

The findings of this study showed that both RPE and workload remained relatively stable under the four environmental conditions tested.
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CHAPTER I

INTRODUCTION

The effects of external temperature and humidity on the human body while exercising has often been an issue with exercisers. Exercisers need to learn how to monitor their bodies while performing under variations of high temperature and humidity. Without careful monitoring, the exerciser runs a risk of overheating, which can cause serious damage to the body, including shock, cardiac arrhythmia, and sudden death.

Thermal comfort for a human being exists when the core temperature is between 36.6 °C to 37.1 °C. When an exerciser reaches a core temperature beyond the comfort level, the perception of the level of exertion may be different than if the body is at a normal body core temperature.

Rating of perceived exertion (RPE) is a psychophysical method used in exercise testing to estimate exercise intensity (Borg, 1982). Scientists are finding a need to understand the subjective feelings of the subjects they are testing. RPE results can be compared to the more objective physiological findings collected during exercise.

In the present study, the researcher investigated the effects of external heat and humidity on subjects abilities to perceive their exertion levels while performing a
submaximal bicycle test. Heart rate and RPE levels were used to help determine the effect of changes in environmental conditions on perception of the intensity of exercise. The use of the RPE measure in exercise settings is dependent on its stability in a variety of exercise conditions. This investigation should contribute information concerning this issue.

Statement of the Problem

The problem in this study was to determine the effects of external heat and humidity on perception of exertion while performing a submaximal bicycle test. The external heat and humidity were controlled by a climate control chamber.

Purpose of the Study

The purpose of the study was to test the stability of Borg's perceived exertion rating scale under different environmental conditions. If RPE is a stable measure, it is expected that, when exercising at a percentage of their maximum heart rate; subjects will indicate similar RPE values independent of the environmental conditions.

Need for the Study

RPE scales have been used for the subjective measurement of work intensity by both exercise scientists and individual exercisers. The RPE scale is often used by the exerciser as a tool for communicating the severity of exercise to another person. In adult fitness, it is important that this communication be accurate. Lack of accuracy
could place the exerciser at some risk. It is important to determine if the environment can influence the accuracy of RPE. A relationship between variations in environmental conditions and the RPE must demonstrate stability to prevent injuries and to provide positive feedback to the exerciser when the subject is not within a controlled environment, such as a climate control chamber. It is also important to continually add to the body of knowledge as it relates to the environmental conditions in which training programs are run.

The temperatures and humidities used in this study reflect temperatures and humidities occurring in the Southwest region of Michigan during the summer months of June, July, and August. Participants benefit from this research by gaining knowledge of how they perform under these controlled environmental conditions.

Delimitations

This study was delimited to the following characteristics:

1. All data were collected in a climate control chamber located in the Exercise Physiology Lab at Western Michigan University.

2. Volunteers (n=10) age 21 to 40 years, were selected from the graduate program in the Department of Health, Physical Education, and Recreation on the campus of Western Michigan University, Kalamazoo.

3. A submaximal bike test was performed on a Bosch bicycle ergometer, using the American College of Sports Medicine (ACSM) protocol (ACSM, 1991).
4. All participants had no previous incident with heat illness requiring medical treatment.

5. The experimental conditions were delimited to; (a) 75 °F at 50% humidity, (b) 75 °F at 90% humidity, (c) 85 °F at 50% humidity, and (d) 85 °F at 90% humidity.

6. The dependent variables were perceived exertion as measured by Borg’s 15-point categorical scale and workload measured in watts.

Limitations

The interpretations of the outcomes of this investigation was limited by the following:

1. Data were collected opportunistically from those attending Western Michigan University during the 1994-1995 academic school year.

2. Only data gathered on the bicycle ergometer were used. These data may not reflect the performance of a submaximal test performed on other modes of exercise.

Basic Assumptions

This study was conducted under the following assumptions:

1. Each subject gave a maximal effort.

2. Each subject understood and followed directions.

3. Each subject was rested and ready to be tested.
Hypotheses

This study was conducted to test the following hypotheses:

1. Increases in environmental temperature did not affect subjects RPEs during the performance of the ACSM submaximal bicycle test.

2. Increases in environmental humidity did not affect subjects RPEs during the performance of the ACSM submaximal bicycle test.

3. The interaction between environmental heat and humidity did not affect subjects RPEs during the performance of the ACSM submaximal bicycle test.

4. Increases in environmental heat decreased subjects workloads during the performance of the ACSM submaximal bicycle test.

5. Increases in environmental humidity decreased subjects workloads during the performance of the ACSM submaximal bicycle test.

6. The interaction between environmental heat and humidity decreased subjects workloads during the performance of the ACSM submaximal bicycle test.

Definitions

The following terms and their definitions are important to the understanding of this study:

1. Rating of Perceived Exertion (RPE): A subjective psychophysical ratio-scaling method of rating physical strain. The subject integrates various signals from the peripheral working muscles and joints, from central cardiovascular and respiratory
functions, and from the central nervous system to correspond to objective physiological responses (Borg, 1982). Used in this study was Borg's Rating of Perceived Exertion scale, a 15-point scale with verbal anchors. The scale values range from 6 to 20 and can be used to denote heart rates ranging from 60-200 beats per minute. The scale was constructed to increase linearly with the exercise intensity (Borg, 1982).

2. **Relative Humidity**: The amount of water vapor in the air, expressed as a percentage of the maximum amount that the air could hold at a given temperature (Random House, 1987).

3. **Submaximal Graded Bicycle Exercise Test**: A widely used test of cardiorespiratory endurance and an estimate of maximum oxygen intake (VO₂) derived from heart rate response performed on a calibrated cycle ergometer. The test increases in intensity every 2 minutes until the subject reaches a prescribed percentage of his or her maximum heart rate (ACSM, 1991).

4. **Predicted Maximum Heart Rate**: A measure established by subtracting a person's age from 220. The values are independent of race and gender (McArdle, Katch, & Katch, 1991).
CHAPTER II
REVIEW OF RELATED LITERATURE

Introduction

The human body has many mechanisms to control the temperature of its internal environment. Human beings are classified into a group called homeotherms, which refers to the constant core temperature within the body. The body core temperature is maintained within 0.6° of its normal value 37 °C (99.6 °F). To keep the body at a steady state, the heat loss must match heat gain. This thermostat-type reaction found in body temperature regulation is controlled by the hypothalamus.

There is a need by exercise scientists to understand the subjective symptoms of their patients. The psychophysical ratio-scaling and category methods have been established for measuring perceived exertion. Perceived exertion ratings integrate various signals from the subject's muscles, joints, and cardiovascular responses. The Borg scale was introduced in 1967 and modified in 1968 (Borg, 1982).

The purpose of this study was to determine the effects of environmental heat and humidity on level of perceived exertion while exercising. The review of literature will give an overview of the major topics involved in this study. Topics include the following: effects of heat and humidity on the body, perceived exertion, effects of heat
Effects of Heat and Humidity on the Body

Many physiological events occur in the body when a person exercises in heat and humidity. The two most important factors are (1) muscles must receive enough oxygen to sustain energy metabolism (McArdle et al., 1991), and (2) heat produced within the body must be transported to the periphery of the body (McArdle et al., 1991).

At Rest

Thermal capacity refers to the total quantity of heat stored within the body. Thermal capacity varies little from person to person, approximately 1 kilocalorie of heat retained per kilogram of body weight (Schafer, 1992). Thermal capacity is a fixed number, but heat is constantly being produced by biochemical reactions that take place in all body cells. One example would be basal metabolism, which is the lowest degree of chemical oxidation occurring within the body at rest (Cannon, 1967).

The nude body can maintain temperatures within the normal range over an environmental temperature range of 1 °C to 53 °C (Schafer, 1992). As mentioned, the hypothalamus acts to increase heat loss in the body after being exposed to a hot environment by causing vasodilatation and sweating. This produces a balance between the heat produced by metabolism and the heat lost to the environment at rest.
The body has three ways to exchange body heat with the environment; (1) radiation, (2) conduction, and (3) evaporation. A combination of these elements produces an effective cooling method for the external surface of the body.

**During Exercise**

Even at rest the body is constantly producing heat, but when exercise occurs the body temperature may rise 2-3 °C (Schafer, 1992). Heat production during exercise can raise the body core temperature to fever levels but external heat may not affect the body's core temperature (McArdle et al., 1991).

Copping and Gisolfi (1993) showed that marathon runners experience a rise in body core temperature to as high as 103 °F to 105.5 °F. Because the body is only approximately 20-25% efficient, 75-80% of the energy expended during exercise is lost as heat (Howley & Powers, 1990).

During exercise the clothing worn is a significant factor related to heat regulation. Heavy insulating clothes help maintain the internal core temperature of the body (Falls & Humphrey, 1976). The rate of heat loss or gain is directly proportional to the temperature of the surface of the skin and inversely proportional to the thickness of the insulating layer (Schafer, 1992). Studies have indicated that the exerciser's body exchanges as much heat as possible with the environment. Heavy clothing acts to reduce heat exchange due to its low thermal conductivity. Heat conduction away from the skin occurs more rapidly when the clothing is wet than when it is dry (Gonzalez, 1988).
When a person chooses to over-dress during physical activity, the person risks the chance of heat illness, which ranges from minor nausea to fainting, comas, and sudden death (Siegel, 1988). Heavy, nonbreathable clothing makes the cooling system work harder and at a lower level of efficiency (Falls & Humphrey, 1976). When this occurs, advanced stages of heat stress may begin.

When comparing men and women who exercised in the heat, researchers found that women appear to be less tolerant than men. The higher percentage of body fat found in women reduces effective heat loss within the body (Howley & Powers, 1990).

Studies have also shown that men and women become acclimatized to the heat by living or training in areas of high heat and humidity (Howley & Powers, 1990). Howley and Powers showed that acclimatized people have lower heart rates and core temperatures at rest and during submaximal exercise. Adaptations can occur within 7 to 12 days of being exposed to a hot environment.

Perceived Exertion

Perceived exertion has been used by scientists to understand the subjective feelings of their subjects. This psychophysical aspect of exercise testing has become one of the best indicators of measuring physical strain (Borg, 1982). Scientists have attempted to define subjective feelings with the same objective measurements obtained from the exercise test. While subjects perform the tests they receive physiological cues from both local and central factors. Grove and Watt (1993) found that local
factors dominated the perception of exertion. Mihevic (1983) found that the impact of central sensations on perceived exertion in comparison with local responses increased at higher exercise intensities. She also found less capable athletes were less perceptually accurate than more capable athletes, which seemed to demonstrate a greater perceptual sensitivity among more capable athletes. RPE, as a measure of work intensity, represented a useful method of regulating performance during exercise. RPE of the exerciser can then be compared to other physiological factors such as heart rate and muscular fatigue.

Many rating scales have been developed to rate levels of perceived exertion using both the ratio-scaling and category-scaling methods. The most common scale used today was developed by Gunnar Borg in 1967 and 1968. The first rating scale used ratio scaling but proved difficult to use because of the lack of intra-individual comparisons (Borg, 1982). The perception of exertion varied from subject to subject because there was no dependent variable for each subject to be compared against. For example, one subject may rate a 1-lb weight a 10 and a 2-lb weight a 25, but another would give the weights ratings of 4 and 10, respectively. To clear up confusion, Borg introduced a category scale used in applied situations for an estimation of subjective intensity. The category scale was designed to increase linearly with exercise intensity. Because heart rate and oxygen consumption also rise linearly with workload, the perceived exertion could not stray far from the objective measurements. Borg's correlations between heart rate and perceived exertion ranged from r=.80-.90. He
stated that the use of perceived exertion using central factors would better explain the psychophysical than any physiological variable alone.

The category Borg scale is a 15-point scale with verbal anchors (associated with each odd integer) ranging from very, very light to very, very hard (see Appendix A). The values in the scale can be compared against heart rates ranging from 60-100 beats per minute (bpm). This would make it easier for the tester to compare heart rate with the level of perceived exertion; for example, 13 on the rating scale would match with 130 bpm. Borg tried to use verbal expressions that were simple and easy to understand. The ACSM (1991) established a script that a tester could recite so that subjects understood how to translate their central and local cues to the proper number on the rating scale. The RPE scale did not discriminate between gender and fitness levels of subjects working at a submaximal level (Mihevic, 1983). There have been many variations of the Borg 15-point scale, but the original is still the most widely used (Borg, 1982).

Effects of Heat and Humidity on Perceived Exertion

Often subjects feel worse, perceive work to be harder, and experience greater thermal sensation in a hot humid environment than in a thermoneutral condition (Maw, Boutcher, & Nigel, 1993). As the subjects' heart rates and peripheral circulation increase due to external heat, the perception of the exercise intensity also increases (Maw et al., 1993).
Perception of exercise intensity in a subject is based on the rate of sweating and blood vessel vasodilation. These peripheral factors may intensify skin warmth and lead to a higher perception of the work being performed. Thus, the subject's ability to rate perceived exertion in hot environments can be affected by cardiac stimulus, rate of sweating, and level of tolerance to the environment. Skinner, Borg, and Buskirk (1969) stated that perceived exertion should not be affected by environmental temperature and, in turn, should not be affected by heat stress related to exercise.

Effects of Heat and Humidity on Heart Rate

When the body begins to exercise in a hot and humid environment, the most common physiological response is an increase in heart rate response. If the body were performing in a thermoneutral environment, only the increase in exercise intensity would be a factor in an increased heart rate response.

At Rest

In a resting state, the body uses 60% of VO₂ maximum regardless of the state of fitness (Londeree & Moeschberger, 1982). The body is adversely affected by any increases in external heat. Any change in body temperature can influence heart rate, and an increase in body temperature above normal will result in an increase in heart rate (Howley & Powers, 1990).
During Exercise

As the subject begins to exercise, heart rate increases linearly with exercise intensity (Borg, 1982). The body reacts to external heat and strenuous exercise with a higher heart rate (Schafer, 1992). According to Londeree and Moeschberger (1982), the heat factor only causes fatigue and poor performance at an earlier rate.

Cooling Mechanisms of the Body

The body possesses a mechanism for keeping itself cool during exposure to hot, humid environments. Within the body, two main physiological responses occur in response to high heat and/or high humidity; (1) cutaneous vasodilation and (2) sweating. To complement these responses, the exerciser should be adequately hydrated and wear proper clothing while exercising.

Cutaneous Vasodilation

When the hypothalamus is stimulated by an increase in body core temperature, the first response is cutaneous vasodilation (Schafer, 1992). This moves the blood from the inner core to the periphery (McArdle et al., 1991). The blood is cooled by the external environment. This, in turn, reduces the blood's ability to deliver oxygen to the working muscles.
Sweating

Water loss from the blood affects cardiovascular functioning (McArdle et al., 1991). Fluid loss is much greater during exercise in hot and humid environments. The rate of evaporation of fluid away from the skin is determined partially by the vapor pressure in the air. Excessive sweating in humid environments will contribute little to cooling the body, because the vapor pressure is much lower.

Fluid loss during exercise can equal up to 1.0% of a person's body mass (McArdle et al., 1991). Dehydration can occur quickly in hot, humid environments due to fluid lost through the skin. This can result in a larger reduction of work capacity than in a thermoneutral environment (Pandolf & Young, 1992). Furthermore, hours of sweating can cause sweat-gland fatigue and ultimately lead to the body's inability to regulate core temperature (McArdle et al., 1991).

Summary

Many different physiological variables are known to be affected by external heat and humidity while a person exercises. This includes cardiac responses, vasodilatation, sweating, and higher perceptions of work intensity.

Borg established a 15-point scale with verbal anchors, which in applied situations, became a simple estimation of subjective exercise intensity. The scale values from 6 to 20 were used to denote heart rates ranging from 60 to 200 beats per
minute. The RPE scale was constructed to increase linearly with the exercise intensity (Borg, 1982).
CHAPTER III

METHODS AND PROCEDURES

The purpose of this study was to determine the effects of external heat and humidity on subjects levels of perceived exertion while performing a submaximal bicycle test. This chapter includes five sections; (1) human subjects approval, (2) subject selection, (3) instrumentation, (4) data collection, and (5) statistical analysis.

Human Subjects Approval

Approval to conduct this study was required by Western Michigan University's Human Subjects Institutional Review Board (HSIRB). The appropriate forms were submitted by the principal investigator to the HSIRB. After the proposal was reviewed by the full board and revisions were made and resubmitted, the board granted approval for this study (see Appendix B).

Subject Selection

This study involved 10 subjects, ages 21-40 years, both males and females. The subjects were recruited opportunistically from graduate classes in the Health, Physical Education, and Recreation Department (HPER) at Western Michigan University. The principal investigator explained the project in graduate classes.
conducted by the HPER Department. A sign-up sheet for graduate students was made available, and interested graduate students were able to directly contact the investigator. All potential subjects were interviewed and screened concerning any previous experience with heat illness. Individuals who had experienced a heat incident requiring hospitalization were eliminated from the study. Only apparently healthy individuals were used for this study (ACSM, 1991). Each subject signed an informed consent stating the conditions and the involvement required (see Appendix C).

Instrumentation

The temperature and humidity were manipulated according to the selected experimental condition in the climate control chamber. The chamber was controlled by a Barber-Colman thermostat and humidistat. The subject performed the submaximal test on a Bosch ERG model 551 bicycle ergometer. ACSM's submaximal bicycle protocol was used. During the submaximal test

1. Heart rate was measured at four percentages of the subject's maximum heart rate using a Polar heart rate monitor model 61210.

2. Body temperature was monitored with an oral digital thermometer placed under the tongue.

3. Perceived exertion was monitored using Borg's 15-point category scale with verbal anchors, which was mounted on the wall before the subject and the subject indicated his/her rating with a verbal response.
Data Collection Procedures

Subjects came to the lab dressed for warm weather activity. Subjects entered the climate control chamber and were allowed to adjust to the environment before beginning the test. Subjects began the test within 5 min of entering the climate control chamber. The subjects' heart rates, oral temperatures, and RPEs were measured continuously throughout the duration of the test. Subjects were also instructed that a rating of 6 corresponded with feelings of exertion while sitting quietly on the bicycle and a rating of 20 reflected maximal exertion. During the tests, cool water was offered ad libitum, and drinking was encouraged.

Each subject performed each of the four conditions three times. Conditions were assigned in a random order to each subject. RPE, body temperature, and workload were recorded at 55%, 65%, 75%, and 85% of each subject's predicted maximum heart rate for the three trials under each condition. The four conditions performed were (1) 75 °F at 50% humidity, (2) 75 °F at 90% humidity, (3) 85 °F at 50% humidity, and (4) 85 °F at 90% humidity.

Each test was halted when the subject reached 85% of his or her maximum heart rate or RPE rose to 18. The test was also halted if oral temperature reached 102 °F.
Statistical Analysis

All the data gathered by the investigators were entered into the computer for statistical analysis. The BMDP statistical package (Dixon, Brown, Engelman, & Jennrich, 1990) was used for data analysis. The data were first tested for reliability. Randomized block factorial ANOVAS with repeated measures design were calculated for RPE and for workload at each percentage of maximum heart rate, 55%, 65%, 75%, and 85%. To test for trend, orthogonal polynomials were run on both RPE and workload. The .05 level was used to evaluate the significance of the statistical hypotheses tested.
CHAPTER IV

RESULTS AND DISCUSSION

This study was conducted to determine the effects of variations of external heat and humidity on level of perceived exertion while performing a submaximal bicycle test. The purpose was to test the stability of the RPE scale when subjects were exposed to different environmental conditions. RPE and workload were compared at 55%, 65%, 75%, and 85% of the maximum heart rate (MHR) for each subject as measures of work intensity at both a subjective and objective level. This study was conducted to provide information concerning the clinical and individual use of RPE. This chapter includes the results and discussion.

Results

Reliability

The reliability was estimated using intraclass correlation (R). This technique was preferable to other correlation techniques when reliability was based on repeated measures. Two major advantages exist with this approach:

1. The magnitude of the sources of variability that are of interest to the investigator can be examined.
2. Several intraclass correlation coefficients, used to estimate reliability and objectivity, can be computed from the same set of data on the basis of wanted and unwanted sources of variance (Safrit, 1976).

A two-way nested ANOVA-random model developed by Feldt and McKee in 1958 was used for determining the $R$ value (Safrit, 1976). This design was utilized because the days, trials, and subjects were assumed to be random variables (Safrit, 1976).

The $R$ values for the two dependent variables, RPE and workload were calculated at each percentage. The formula used was $R = (\text{MSs} - \text{MScws}) / \text{MSs}$. $\text{MScws}$ is the mean square for condition within subjects and $\text{MSs}$ is the mean square for subjects. This formula represents model IV as indicated by Safrit (1976). All the intraclass correlations were found to be .95 or greater. The correlations, as well as the descriptive data for RPE and workload across the four environmental conditions at each percentage of MHR are presented in Table 1. The means generally increased across the four percentages of MHR in both RPE and workload. The standard deviation also increased in a similar manner for both dependent variables, RPE and workload.

**Analysis of Variance**

Randomized block factorial ANOVAs with repeated measures were calculated for RPE and workload at each percentage of MHR, 55%, 65%, 75%, and 85%. In the ANOVAs, the mean square residual was used in a randomized block factorial design
as an estimate of experimental error. To utilize this ANOVA design, one must meet
the assumption of sphericity (independence of repeated variables). The result of the
sphericity tests are presented in Tables 2 and 3. The tests indicated that this basic
assumption was not met in the following variables. For RPE, between subjects was
significant, \( F(9, 135) = 89.77, p < .05 \). For RPE, percent of MHR, was significant,
\( F(1.37, 61.64) = 861.89, p < .05 \). For workload, between subjects was significant,
\( F(9, 135) = 105.18, p < .05 \). For workload, percent of MHR was significant, \( F(1.37,
61.64) = 412.76, p < .05 \). As a result, the Greenhouse-Geisser correction was used
to adjust the degrees of freedom for the affected variables in the ANOVA design.

Table 1

Descriptive Data and Intraclass Correlations for RPE and Workload

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>( M^a )</th>
<th>SD</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>RPE at 55% MHR</td>
<td>8.85</td>
<td>1.41</td>
<td>.96</td>
</tr>
<tr>
<td>RPE at 65% MHR</td>
<td>11.43</td>
<td>1.55</td>
<td>.97</td>
</tr>
<tr>
<td>RPE at 75% MHR</td>
<td>13.61</td>
<td>1.70</td>
<td>.97</td>
</tr>
<tr>
<td>RPE at 85% MHR</td>
<td>15.88</td>
<td>1.72</td>
<td>.97</td>
</tr>
<tr>
<td>Workload at 55% MHR</td>
<td>72.71</td>
<td>29.96</td>
<td>.96</td>
</tr>
<tr>
<td>Workload at 65% MHR</td>
<td>111.04</td>
<td>36.42</td>
<td>.98</td>
</tr>
<tr>
<td>Workload at 75% MHR</td>
<td>146.04</td>
<td>41.04</td>
<td>.98</td>
</tr>
<tr>
<td>Workload at 85% MHR</td>
<td>185.42</td>
<td>48.55</td>
<td>.99</td>
</tr>
</tbody>
</table>

\( ^a n = 10 \)
The mean of the trials for each of the four conditions; (1) 75 °F at 50% humidity, (2) 75 °F at 90% humidity, (3) 85 °F at 50% humidity, and (4) 85 °F at 90% humidity for each dependent variable was calculated for each subject. Table 2 presents the ANOVA summary table for workload, and Table 3 presents the ANOVA summary table for RPE.

Workload

In the ANOVA summary table for workload, the subject source of variation was significant, $F(9, 135) = 105.18$, $p < .05$. This was expected because the range of ability among the subjects was different. The percent source of variation (% MHR)
was significant, $E(1.37, 61.64) = 412.76, p < .05$. This was also expected. Increases in heart rate were the result of an increased exercise intensity.

Table 3

ANOVA Summary Table for RPE

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjects</td>
<td>338.46</td>
<td>9</td>
<td>237.61</td>
<td>89.77*</td>
</tr>
<tr>
<td>Treatment</td>
<td>1087.49</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Condition</td>
<td>2.73</td>
<td>3</td>
<td>0.91</td>
<td>2.17</td>
</tr>
<tr>
<td>Percent</td>
<td>1083.30</td>
<td>3</td>
<td>361.10</td>
<td>861.89*</td>
</tr>
<tr>
<td>C X P</td>
<td>1.46</td>
<td>9</td>
<td>0.16</td>
<td>0.39</td>
</tr>
<tr>
<td>Residual</td>
<td>56.56</td>
<td>135</td>
<td>0.41896</td>
<td></td>
</tr>
</tbody>
</table>

*Significant at $p < .05$ using original df. \(\overset{\wedge}{v}\)Significant at $p < .05$ level using Greenhouse-Geisser adjusted df ($1.37, 61.64$).

RPE

In the ANOVA summary table for the RPE, the subject source of variation was significant, $F(9, 135) = 89.77, p < .05$. This was expected because the range of ability among the subjects was different. The percent source of variation ($\%$ MHR) was significant, $F(1.37, 61.64) = 861.89, p < .05$. This was also expected. Increases in exercise intensity resulted in a higher RPE score.
Orthogonal Polynomials

In the original ANOVA for workload, the means were graphed for each condition across the percentages of MHR (see Figure 1). The pattern found for the means at high temperatures was different than that found at low temperatures, and then patterns were shown to be significantly different by a test for trend. The test for trend was a test for orthogonal polynomials. The results of that test are presented in Table 4. The RPE means, graphed in Figure 2, indicated a pattern similar to the pattern for workload means. Results of the orthogonal polynomials test for RPE are presented in Table 5.

![Graph of Workload Means](image)

Figure 1. Workload Means Plotted Across the Percentage of Maximum Heart Rate for Each Condition.
Table 4
Test for Orthogonal Polynomials for Workload

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Condition</td>
<td>7.81</td>
<td>1</td>
<td>7.81</td>
<td>0.01</td>
</tr>
<tr>
<td>Error</td>
<td>5660.59</td>
<td>9</td>
<td>628.95</td>
<td></td>
</tr>
<tr>
<td>Linear</td>
<td>149189.07</td>
<td>1</td>
<td>149189.07</td>
<td>142.69*</td>
</tr>
<tr>
<td>Error</td>
<td>9409.90</td>
<td>9</td>
<td>1045.54</td>
<td></td>
</tr>
<tr>
<td>Quadratic</td>
<td>0.867</td>
<td>1</td>
<td>0.87</td>
<td>0.01</td>
</tr>
<tr>
<td>Error</td>
<td>632.81</td>
<td>9</td>
<td>70.31</td>
<td></td>
</tr>
<tr>
<td>Cubic</td>
<td>0.17</td>
<td>1</td>
<td>0.17</td>
<td>0.02</td>
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<tr>
<td>Error</td>
<td>98.78</td>
<td>9</td>
<td>10.98</td>
<td></td>
</tr>
<tr>
<td>High Condition</td>
<td>170.14</td>
<td>1</td>
<td>170.14</td>
<td>0.49</td>
</tr>
<tr>
<td>Error</td>
<td>3093.75</td>
<td>9</td>
<td>343.75</td>
<td></td>
</tr>
<tr>
<td>Linear</td>
<td>129600.00</td>
<td>1</td>
<td>129600.00</td>
<td>190.74*</td>
</tr>
<tr>
<td>Error</td>
<td>6115.28</td>
<td>9</td>
<td>579.48</td>
<td></td>
</tr>
<tr>
<td>Quadratic</td>
<td>13.89</td>
<td>1</td>
<td>13.89</td>
<td>0.34</td>
</tr>
<tr>
<td>Error</td>
<td>368.06</td>
<td>9</td>
<td>40.90</td>
<td></td>
</tr>
<tr>
<td>Cubic</td>
<td>250.70</td>
<td>1</td>
<td>250.90</td>
<td>10.51*</td>
</tr>
<tr>
<td>Error</td>
<td>214.58</td>
<td>9</td>
<td>23.84</td>
<td></td>
</tr>
</tbody>
</table>

* p < .05.
Workload

For workload, the linear trend observed in Figure 1 was significant for both the high and low temperatures. For high temperatures, the cubic trend was also significant. This was seen in Figure 1 as an increase from 55% to 65% MHR, a leveling off between 65% and 75% MHR, and another increase from 75% to 85% MHR.

RPE

In Figure 2, RPE shows the linear trend for all four of the percentages of MHR. It can be seen that the linear trend observed in Figure 2 was also significant for both high and low temperatures. For high temperatures, the cubic trend was also significant. This was seen in Figure 2 as a steady increase between 55% MHR through 85% MHR.

Figure 2. RPE Means Plotted Across the Percentage of Maximum Heart Rate for Each Condition.
<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Condition</td>
<td>0.01</td>
<td>1</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Error</td>
<td>5.69</td>
<td>9</td>
<td>0.63</td>
<td></td>
</tr>
<tr>
<td>Linear</td>
<td>512.27</td>
<td>1</td>
<td>512.27</td>
<td>516.48*</td>
</tr>
<tr>
<td>Error</td>
<td>8.93</td>
<td>9</td>
<td>0.99</td>
<td></td>
</tr>
<tr>
<td>Quadratic</td>
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<td>1</td>
<td>0.56</td>
<td>2.02</td>
</tr>
<tr>
<td>Error</td>
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<td>9</td>
<td>0.27</td>
<td></td>
</tr>
<tr>
<td>Cubic</td>
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<td>0.07</td>
<td>1.25</td>
</tr>
<tr>
<td>Error</td>
<td>0.51</td>
<td>9</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>High Condition</td>
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<td>1</td>
<td>2.57</td>
<td>2.22</td>
</tr>
<tr>
<td>Error</td>
<td>10.39</td>
<td>9</td>
<td>1.15</td>
<td></td>
</tr>
<tr>
<td>Linear</td>
<td>570.41</td>
<td>1</td>
<td>570.41</td>
<td>512.79*</td>
</tr>
<tr>
<td>Error</td>
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<td>9</td>
<td>1.11</td>
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</tr>
<tr>
<td>Quadratic</td>
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<td>1</td>
<td>0.40</td>
<td>1.23</td>
</tr>
<tr>
<td>Error</td>
<td>2.95</td>
<td>9</td>
<td>0.33</td>
<td></td>
</tr>
<tr>
<td>Cubic</td>
<td>0.47</td>
<td>1</td>
<td>0.47</td>
<td>6.08*</td>
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<tr>
<td>Error</td>
<td>0.69</td>
<td>9</td>
<td>0.08</td>
<td></td>
</tr>
</tbody>
</table>

* p < .05
Discussion

Maw et al. (1993) stated that subjects exposed to a high temperature felt worse, perceived work to be harder, and experienced greater thermal sensation. Other researchers have found evidence supporting the stability of the RPE scale in a hot, humid environment. The current study supported these findings. Skinner et al. (1969) contended that RPE is unaltered by environmental temperature, and similarly, RPE does not seem to be affected by heat stress (Grove & Watt, 1993).

In the current study, RPEs at four different environmental conditions were compared. All of these conditions occur commonly during the summer months of June, July, and August in Southwest Michigan. To promote the use of RPE by the common exerciser and the exercise tester, RPE must be stable in these conditions. Inaccurate RPE measures could contribute to overexertion resulting in heat illness. Maw et al. (1993) and Grove and Watt (1993) stated that subjects performing in a hot, humid condition had higher heart rates than subjects in a more thermoneutral environment. This results in an increase in the perception of exertion during exercise.

Some researchers indicated the use of the RPE scale may be limited, due to the lack of sensitivity when exercising in the heat (Maw et al., 1993). Borg (1982) reported that some of the physiological differences reflected at low intensities of exercise in a variety of environmental conditions were due to "noise" in the perceptual system. It may be argued that, in this study, the narrow range between the extremes
of the environmental conditions studied failed to challenge the temperature regulatory mechanisms sufficiently to see a difference in perception between the conditions.

The results of this study showed some inconsistency in RPE across the conditions at all levels of percentage of MHR. When compared against workload, differences were also found between the percentages of MHR. Figure 1 shows a leveling off between 65% and 75% of the subjects' percent MHR in the high temperature conditions, which could be attributed either to the failure to distinguish perception of exertion between 65% and 75% MHR or the reduction of exercise capacity due to the hot environment. At these percentages of MHR, subjects had the greatest inaccuracy in perceiving the exertion. Subjects felt most comfortable exercising at this level because, in fact, it is the most common level at which the average exerciser is recommended to work to achieve his/her maximum fitness goals (ACSM, 1991). Maintenance of a steady state condition may be necessary for the subject to distinguish exertion levels accurately between 65% and 75% of MHR on the RPE scale (Mihevic, 1983).

Workload did increase as RPE increased, with a slight deviation at the higher temperatures in this study. Maw et al. (1993) stated that the exerciser must experience a higher thermal drive to rate perceived exertion in hot environments, which may not have occurred in the subjects involved with this study.
CHAPTER V

SUMMARY, FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

Summary

This study was conducted to determine the stability of Borg's PRE scale under different environmental conditions. In order to determine this, data were collected from 10 subjects. The subjects performed a submaximal bicycle test for each of the four environmental conditions, in a random order. The four environmental conditions used in this study were; (1) 75 °F at 50% humidity, (2) 75 °F at 90% humidity, (3) 85 °F at 50% humidity, and (4) 85 °F at 90% humidity. The study took place in the climate control chamber located in the exercise physiology laboratory at Western Michigan University. Variations in workload the subjects performed during each of the environmental conditions were also compared and discussed.

Findings

The BMDP statistical program was used to run repeated measures, randomized block factorial ANOVAs on both RPE and workload. To test for trend, tests for orthogonal polynomials were used. The following were indicated:

1. No significant difference was found among the environmental conditions for workload, $F(3, 135) = 0.28, p < .05$. 

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2. No significant difference was found for the interactional effect of environmental conditions and percent of MHR for workload, $F(9, 135) = 0.39, p < .05$.

3. No significant difference was found among the environmental conditions for RPE, $F(3, 135) = 2.17, p < .05$.

4. No significant difference was found for the interactional effect of environmental conditions and percentage of MHR for RPE, $F(9, 135) = 0.39, p < .05$.

5. In the test for orthogonal polynomials for workload, the low and high linear trend was significant, $F(1, 9) = 142.69, p < .05$ and $F(1, 9) = 190.74, p < .05$, respectively.

6. In the test for orthogonal polynomials for watts in the high condition, the cubic trend was significant, $F(9, 9) = 10.51, p < .05$.

7. In the test for orthogonal polynomials for RPE, the linear trends for both low and high temperatures was significant, $F(9, 9) = 516.48, p < .05$ and $F(9, 9) = 512.79, p < .05$, respectively.

8. In the test for orthogonal polynomials for RPE at high temperatures, the cubic trend was significant, $F(9, 9) = 6.08, p < .05$.

Conclusions

The above findings led the investigator to suggest the following conclusions:

1. RPE was generally stable across the four environmental conditions used in this study. However, results of the tests for orthogonal polynomials indicated that
the RPE scores across the four levels of percentage of MHR increased linearly for both high and low temperatures, but at high temperatures there was a leveling off between 65% and 75% MHR that was not evident at low temperatures.

2. Workload was stable across the four environmental conditions used in this study. However, results of the tests for orthogonal polynomials indicated that the workload scores across the four percentages of MHR increased linearly for both high and low temperatures, but at high temperatures there was a leveling off between 65% and 75% MHR that was not evident at low temperatures.

Recommendations

Based on the results of this study, the following are recommendations for further research:

1. A larger sample size should be used.

2. A larger range in experimental conditions, both heat and humidity, should be used.

3. Factors such as fitness levels and climate acclimation should be controlled.

4. Subjects should be able to choose the mode of exercise with which they feel most comfortable to perform the submaximal test.

5. More time should be spent between tests to prevent acclimatization and to control for the learning effect.
Appendix A

Borg's Rating of Perceived Exertion Scale
Another way to gauge intensity is to subjectively report how hard you feel you are working. Use the chart below to express that feeling in a number. This measure should take into account your whole body and not just one part. Try to concentrate on your total feeling of exertion. Be as accurate as you can.

6
7 Very, very light
8
9 Very light
10
11 Fairly light
12
13 Somewhat hard
14
15 Hard
16
17 Very hard
18
19 Very, very hard
20
Appendix B

Human Subjects Institutional Review Board Approval
Date: December 12, 1994
To: Erika Hanselman
From: Richard Wright, Interim Chair
Re: HSIRB Project Number 94-09-15

This letter will serve as confirmation that your research project entitled "The effects of external heat and humidity on a subject's level of perceived exertion while performing a sub maximum bike test" has been approved under the full category of review by the Human Subjects Institutional Review Board. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the application.

Please note that you must seek specific approval for any changes in this design. You must also seek reapproval if the project extends beyond the termination date. In addition if there are any unanticipated adverse or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the HSIRB for consultation.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: Dec. 12, 1995

xc: Zabik, HPER
Appendix C

Human Subjects Informed Consent
Informed Consent

I have been invited to participate in a research project entitled "The effects of external heat and humidity on a subject's level of perceived exertion while performing a submaximum bike test." I understand that this research is intended to compare the effects that different temperatures and humidity have on a subject's ability to perceive his or her own level of exertion. I further understand that this study is a thesis project conducted by Erika E. Hanselman, graduate student in the department of Health, Physical Education & Recreation at Western Michigan University, Kalamazoo.

My agreement to participate indicates that I will attend 12 half-hour sessions over a period of 3 weeks with Erika. These sessions will take place in the Exercise Physiology Laboratory in the University Recreation Center. Each session will involve exercising on a bicycle ergometer under different conditions of temperature and humidity, each condition is repeated three times, and assigned randomly by the researcher. The four treatment conditions are 50% humidity at 75 OF, 50% humidity at 85 OF, 90% humidity at 75 OF and 90% humidity at 85 OF. The actual experience will last 10-15 minutes per session.

I am aware that I will be performing in heat and humidity levels that reflect temperatures commonly found in Southwest Michigan during the summer months. However, appropriate measures will be taken to minimize any risks of heat illness. I have never been hospitalized for heat related illnesses and I do not have a cardiac, pulmonary, or metabolic disease. I will be able to dress in light clothing so that I am comfortable and will be able to drink water before, during, and after the test. During the test heart rate and body temperature will be monitored during the last 30 seconds of each 2-minute stage of the ACSM submaximum bicycle test. Heart rate will be measured using
a Polar heart rate monitor and body temperature measured using an oral thermometer placed under the tongue. The test will halt if any one of the following conditions occur: 85% of my maximum heart is reached, perceived exertion rises to 18 on the Borg scale for rating perceived exertion, or body temperature reaches 102 °F or above. If an accidental injury occurs, appropriate emergency measures will be taken; however no compensation or treatment will be made available to the subject except as otherwise stated in this consent form. I also understand that I may terminate my involvement with this research for any reason at anytime.

I may benefit from my participation by knowing how my body reacts to the heat and humidity in a controlled environment. I may also evaluate my own level of perceived exertion in the four different variations of heat and humidity used in this study.

I am aware that all information and data pertaining to my participation is confidential. I will be assigned an identification number, and no individual names will be printed on any paper or reports. The researcher will retain a master list containing the names of participants and corresponding identification number. At the end of data collection, the master list will be destroyed. All other data will be retained for a period of three years in a locked file controlled by the principal investigator.

If I have any questions or concerns about this study I may contact either Erika Hanselman at 387-2689, or Dr. Zabik at 387-2705. I may also contact the chair of the Human Subjects Institutional Review Board at 387-8293 or the Vice President for Research at 387-8298. My signature below indicates that I understand the purpose and requirements of the study and I agree to participate.
Appendix D

Data Collection Sheet
Data Collection Sheet

Subject ID# ______  Age: ______  Gender: ______

Predicted MHR: ______

Submaximal Test

<table>
<thead>
<tr>
<th>IIR %</th>
<th>IHR (BPM)</th>
<th>Stage Workload (Watts)</th>
<th>Time (Min)</th>
<th>RPE (Borg)</th>
<th>Body Temp (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>55%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>65%</td>
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<tr>
<td>75%</td>
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<tr>
<td>85%</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Notes

Day # ______  Condition # ______  Trial # ______  Time of Day ______  Date ______
BIBLIOGRAPHY


