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THE TALK TEST AS A MEASUREMENT OF EXERCISE INTENSITY IN CHILDREN'S NATURAL MOVEMENT PATTERNS

A Manuscript Style Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science

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THE TALK TEST AS A MEASUREMENT OF EXERCISE INTENSITY IN CHILDREN'S NATURAL MOVEMENT PATTERNS

By Bryana Petersin

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

The candidate has completed the oral defense of the thesis.

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ABSTRACT

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The Talk Test (TT) has been shown to be a valid tool to subjectively measure exercise intensity in children while in a laboratory setting, but the TT has not been studied in a field setting with children's natural play movements. The purpose of this study was to identify if the TT is an appropriate measure of exercise intensity during children's real-world movement patterns. Specifically, this study looked at the TT as a measurement of exercise intensity in children ages 8 to 12. Eight children were recruited for this study. Subjects completed two sessions, one exercise TT was completed, in which subjects read The Pledge of Allegiance three times and responded whether they could speak comfortably. The second session consisted of the TT during 30 minutes of the subject's natural physical activity play pattern. Chi-square analysis found a significant relationship in the children's exercise field session between predicted ability to speak comfortably and observed ability to speak comfortably. This study found the TT to be a reliable and appropriate measure of intensity with children's natural exercise patterns.

ACKNOWLEDGEMENTS

I would first like to thank my advisor, Dr. Sazama, for her guidance, time commitment, and finding children to participate in this study. Thank you for helping me when I had questions and concerns. Thank you to Dr. Foster for his guidance and willingness to help me understand. I would like to thank Dr. Beddoes and Dr. Gillette for their input and for being on my thesis committee.

To my family, thank you for your constant love and support. Nate, thank you for your support and believing in me even when I didn’t believe in myself.

TABLE OF CONTENTS

PAGE

LIST OF FIGURES

FIGURE PAGE

LIST OF APPENDICES

APPENDIX PAGE

INTRODUCTION

According to the Centers for Disease Control and Prevention (CDC, 2019), data from 2015-2016 show that nearly one in five school age children and young people (six to nineteen years old) in the United States are obese. The prevalence of childhood obesity has been increasing over the last two decades and is linked to many different factors including physical inactivity. On average, children spend about seven and a half hours per day in front of a screen (e.g., TV, videogames, computer) and only six states (Illinois, Hawaii, Massachusetts, Mississippi, New York, and Vermont) require physical education in every grade, K-12 (U.S. Department of Human & Health Services, 2017). The American College of Sports Medicine (ACSM) recommends children and adolescents participate in aerobic exercise at a moderate intensity for 60 minutes daily (ACSM, 2018). It is also recommended that children and adolescents participate in aerobic exercise at a vigorous intensity at least 3 days a week.

In order to meet the recommended guidelines, it is important to be able to identify when an individual is performing at a vigorous intensity. In a clinical setting, it is possible to perform physiological exercise tests to establish exercise capacity and intensity. In a non-clinical setting, it is difficult to determine exercise capacity and intensity without laboratory metabolic equipment to measure these variables. Consequently, subjective methods to measure and determine exercise intensity have been created for the general public to use to identify exercise intensity. One method, the Talk

Test (TT), is a simple exercise test that asks the question “can you speak comfortably?” while the individual is exercising.

Previous studies have established the TT as a valid measure of exercise intensity (Foster et al., 2018), that is reliable with healthy, young adults (Ballweg et al., 2013), sedentary individuals (Foster et al., 2009), and trained athletes (Gillespie, McCormick, Mermier, & Gibson, 2015 & Rodriguez-Marroyo et al., 2013). The TT has also been validated in special populations, such as patients with cardiovascular disease. The TT accurately measured exercise intensity in patients with clinically stable ischemic heart disease (Voelker et al., 2002 & Brawner et al., 2006), exertional ischemia (Cannon et al., 2004), and myocardial revascularization (Zanettini et al., 2012). The TT has been established as an accurate and valid measure of exercise intensity in children (Giddings, 2018), and recent evidence suggests that the physiological response of children, when using the TT, is similar to that observed in adults (Van Galen, 2019).

Children’s exercise patterns are different than the other populations studied because children’s patterns are naturally stochastic. Stochastic physical activity refers to the randomness and unpredictability of children’s playing pattern. Armstrong & Bray (1991) investigated physical activity patterns in 137 (65 girls & 67 boys) British schoolchildren aged seven to ten years old to determine whether their intensity and duration of physical activity was meeting cardiopulmonary fitness guidelines. They found that 66.3% of children’s physical activity sessions lasted five minutes or fewer (HR > 139 bpm), 29.2% of physical activity sessions lasted >10 minutes, and 4.5% of physical

activity sessions lasted >20 minutes. Thus, sustained periods of physical activity >20 minutes and occasionally >10 minutes are not characteristic of children's habitual physical activity.

The purpose of this study was to determine if the TT can determine exercise intensity during children's natural movement patterns in children age eight to twelve.

METHODS

Subjects

This study was approved by the Institutional Review Board at the University of Wisconsin-La Crosse. All subjects provided written informed consent, signed by the parents, along with written assent signed by the child. In addition, all subjects completed the Physical Activity Readiness Questionnaire (PAR-Q) and an Exercise History Questionnaire to determine any contraindications or limitations that would disqualify them from participating. Participants included eight children aged eight to twelve years old (2 female and 6 male) and were either children of university staff, or children that were known by the university staff.

Protocol

The subjects visited campus on two separate occasions. The first visit included orientation to the laboratory, familiarizing the subject with the treadmill, and completing a maximal exercise test using the TT. The TT was completed on a motorized treadmill and followed a modified Balke protocol. This protocol required the walking speed to remain constant while the slope increased at each interval. Speed remained constant at three mph and percent grade began at zero and increased by two percent every two-minutes. This allowed the children to begin at a slower speed, and since the speed remained constant, exercise intensity increased via grade increases. The TT was

performed the last 30 seconds of each stage by having the subject read the Pledge of Allegiance three times. After the Pledge of Allegiance was read, the subject was asked "can you speak comfortably?" Answers that indicated the subject could still speak comfortably (by responding with "yes") were recorded as (+), when the subject was not unequivocally comfortable speaking ("yes, but") were recorded as (+/-), and when the subject was unable to speak comfortably ("no") were recorded as (-). Heart rate and Rate of Perceived Exertion (RPE) were documented during the last 10 seconds of each stage. Heart rate was assessed via radio telemetry (Polar Vantage XL, Polar USA, Lake Success, New York) and the Rating of Perceived Exertion scale (Nye & Todd, 2013) was used to assess the child's perceived exertion level.

On the final visit, participants completed the TT during 30 minutes of stochastic physical activity in a gym setting. Prior to the subject's arrival, activity zones were set up in the gym with different activities associated with each zone such as basketballs and footballs in zone one, soccer balls and volleyballs in zone 2, and jump ropes and frisbees in zone 3. This equipment is representative of what may typically be provided on a school playground at recess and provided some choice for the children. Zoned playgrounds have been found to be effective at decreasing sedentary behaviors by dividing the recess area into distinct zones with each zone having a specific activity and equipment associated with it. This design allows freedom of choice by the children who can facilitate their own activity (Barnas et al., 2018).

As subjects arrived in the gym, they were given a wireless microphone, pedometer, and heart rate watch to wear. Before the 30-minute gym session began, the principal investigator gave instructions on how to perform the TT while continuing to

play, how to use the RPE scale, and how to indicate their RPE. A 30-minute timer was then started, and the subjects were not given any instruction on what activities to engage in from the principal investigator. The children completed the TT at each two-minute interval just as they did in the lab. The Pledge of Allegiance was spoken three times while the children continued to play. After the children completed speaking the Pledge aloud, they responded to "can you speak comfortably?" with "yes", "yes, but…", or "no". After the TT was completed, they were asked "how hard do you feel you are working?" to indicate their RPE. Four large RPE posters were placed around the gym for the children to glance at, as well as, one poster that the investigator carried around while the children were playing. The subjects spoke their RPE out loud. The purpose of each subject's response being spoken out loud was to record it on a microphone clipped to the subject's shirt collar. Recordings could then be played back to record each child's TT and RPE responses.

The subjects wore IHT ZONE wrist heart rate monitors that were designed specifically for children (Interactive Health Technologies, LLC, Austin, TX). Heart rate was monitored continuously during the 30 minutes of free play. Heart rate was recorded every five seconds on the IHT ZONE wrist heart rate monitors and data was downloaded onto the IHT Spirit System when the watch was returned following the end of the session.

Statistical Analysis

A chi square was used to test for statistical significance for predicted and observed TT responses during the field session. A p-value of <0.05 was considered statistically significant.

RESULTS

Analysis was performed using N = 8 (6 boys, 2 girls). Descriptive statistics are presented in Table 1.

Table 1. Descriptive characteristics of the children.

Variable	Boys (n=6)	Girls (n=2)	Total (N=8)
Age (years)	10.3±1.21	11±0.0	10.5±1.0
Height (cm)	145.3±8.11	147.4±2.69	145.9±6.55
Weight (kg)	45.1±11.89	41.8±8.39	44.3±9.96

Values represented by mean ± standard deviation.

After the subject's VT was extrapolated from the equivocal TT responses in the lab, percent time above the HR associated with the VT during the free play session was calculated. On average, the boys spent 37.1% ± 11.38% of their time above their VT or 11.2 minutes. On average, the girls spent 2.4% ± 0.49% of their time above their VT or 1.2 minutes. Altogether, the average time spent above VT was 8.31 minutes. Individual responses of HR over time are provided in Figures 1a – 1h. The horizontal line represents the individual's VT.

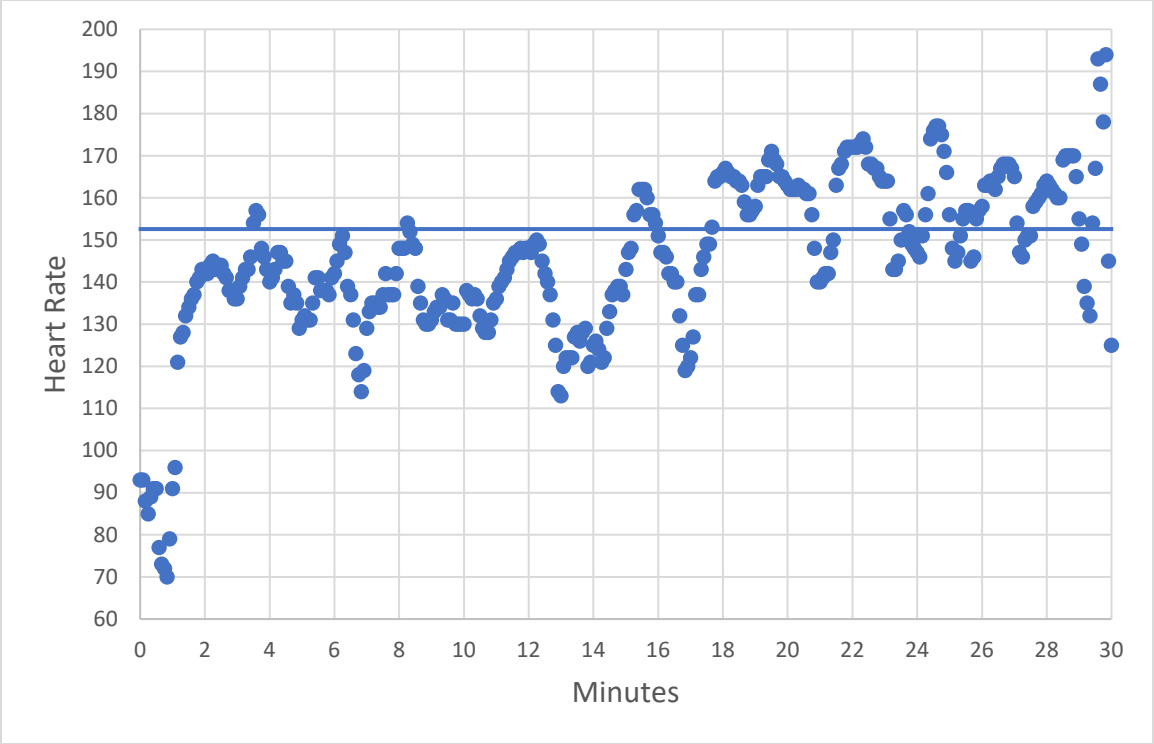


Figure 1a. Heart rate versus time during subject 01's free play session (male).

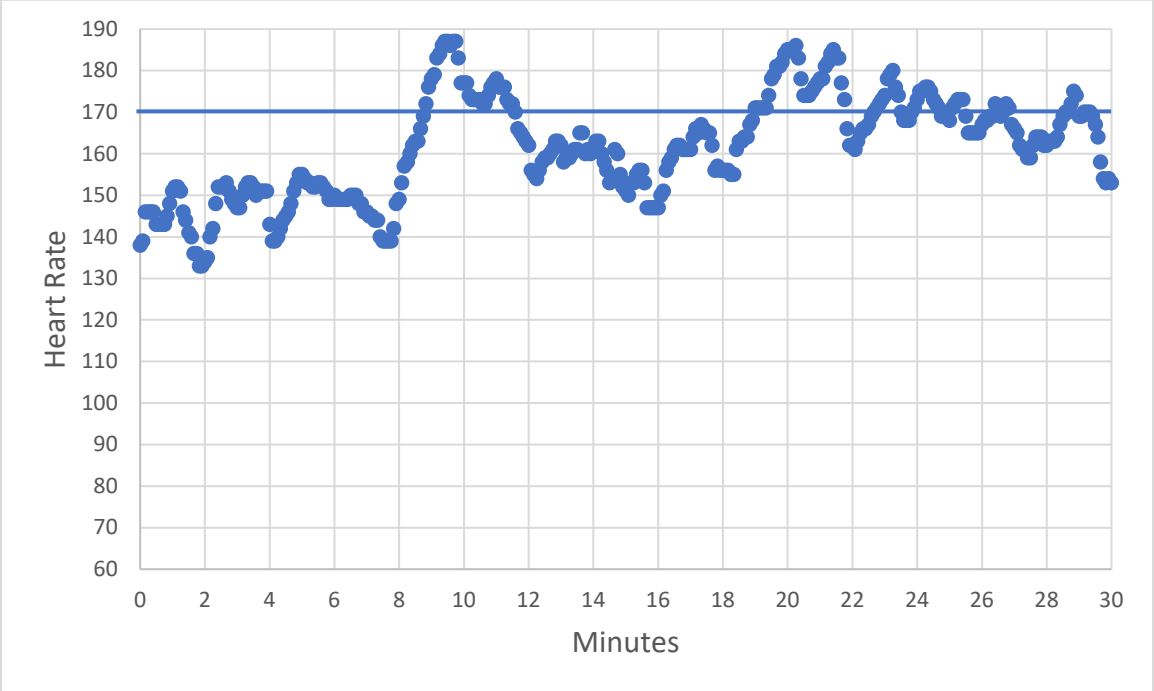


Figure 1b. Heart rate versus time during subject 02's free play session (male).

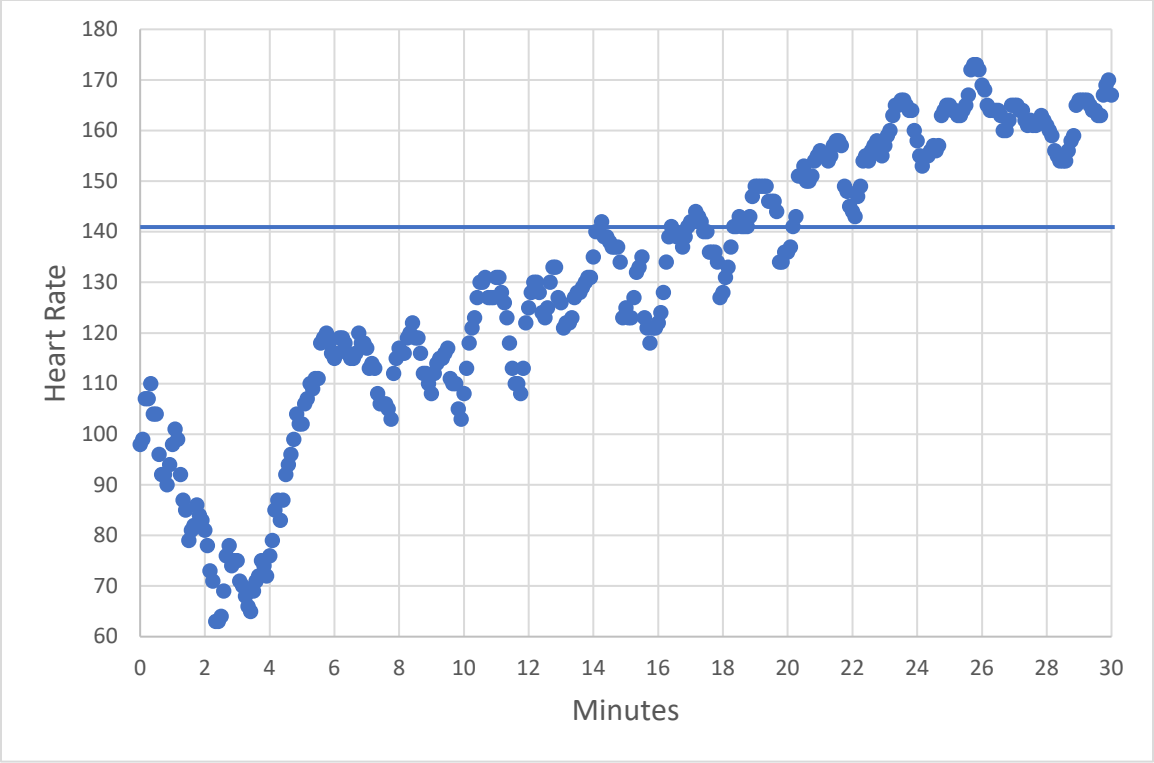


Figure 1c. Heart rate vs time during subject 03's free play session (male).

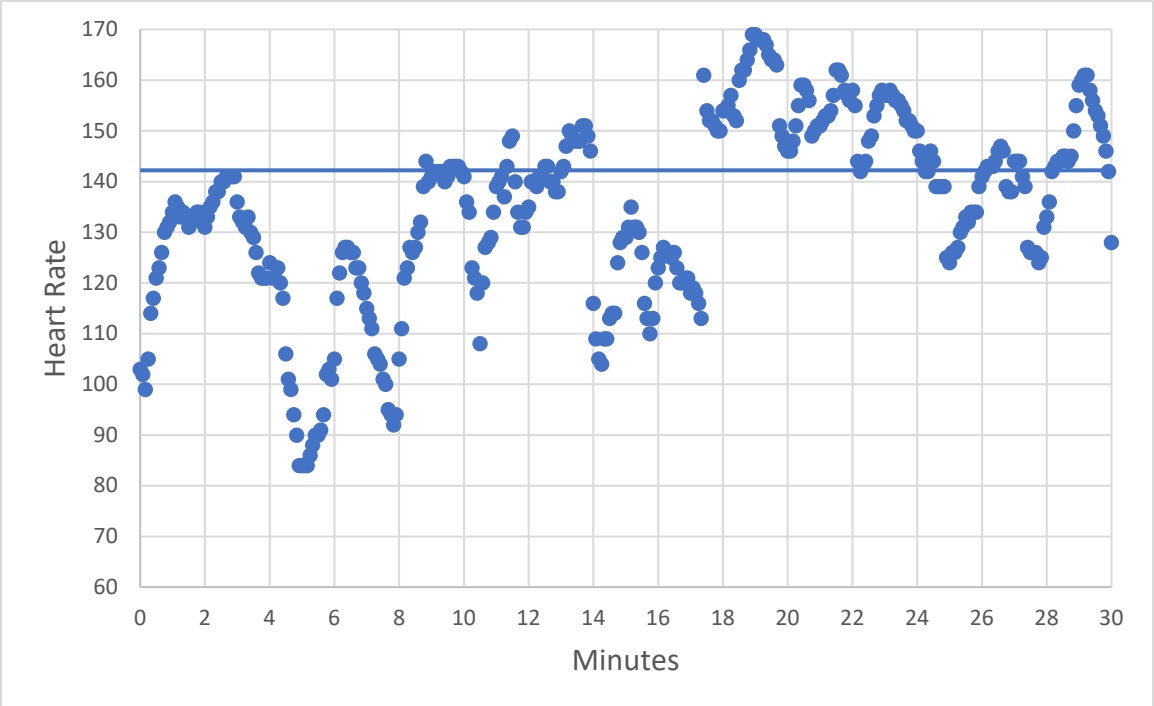


Figure 1d. Heart rate versus time during subject 04's free play session (male).

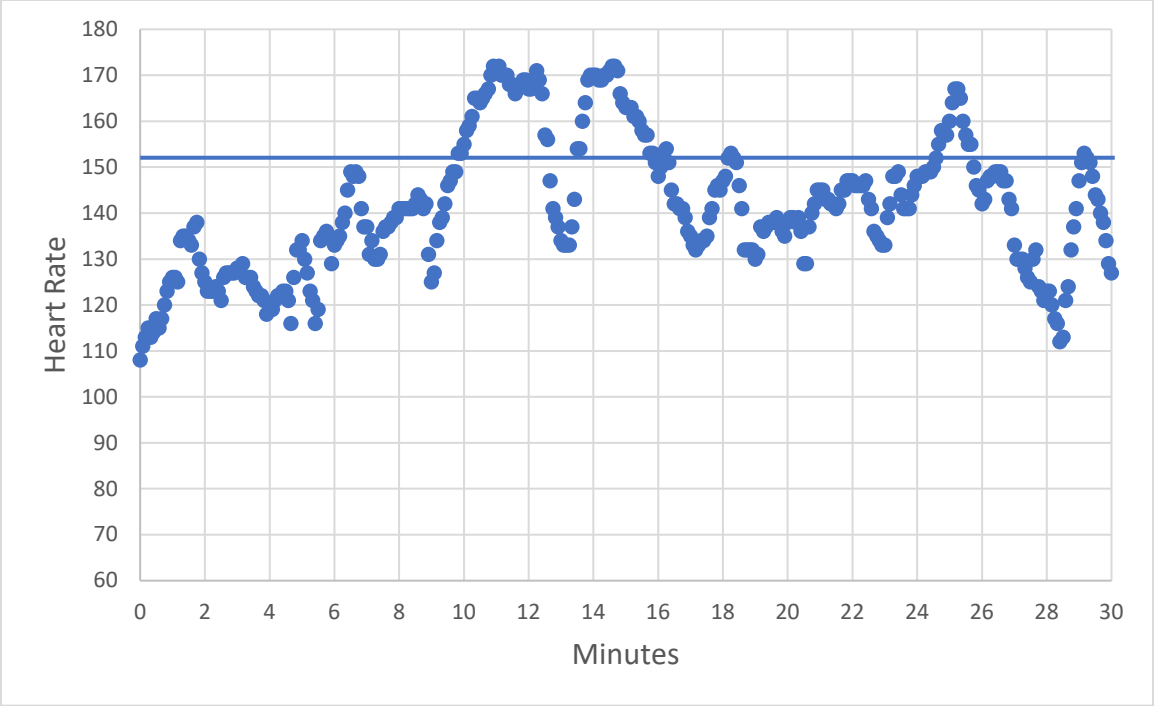


Figure 1e. Heart rate versus time during subject 05's free play session (male).

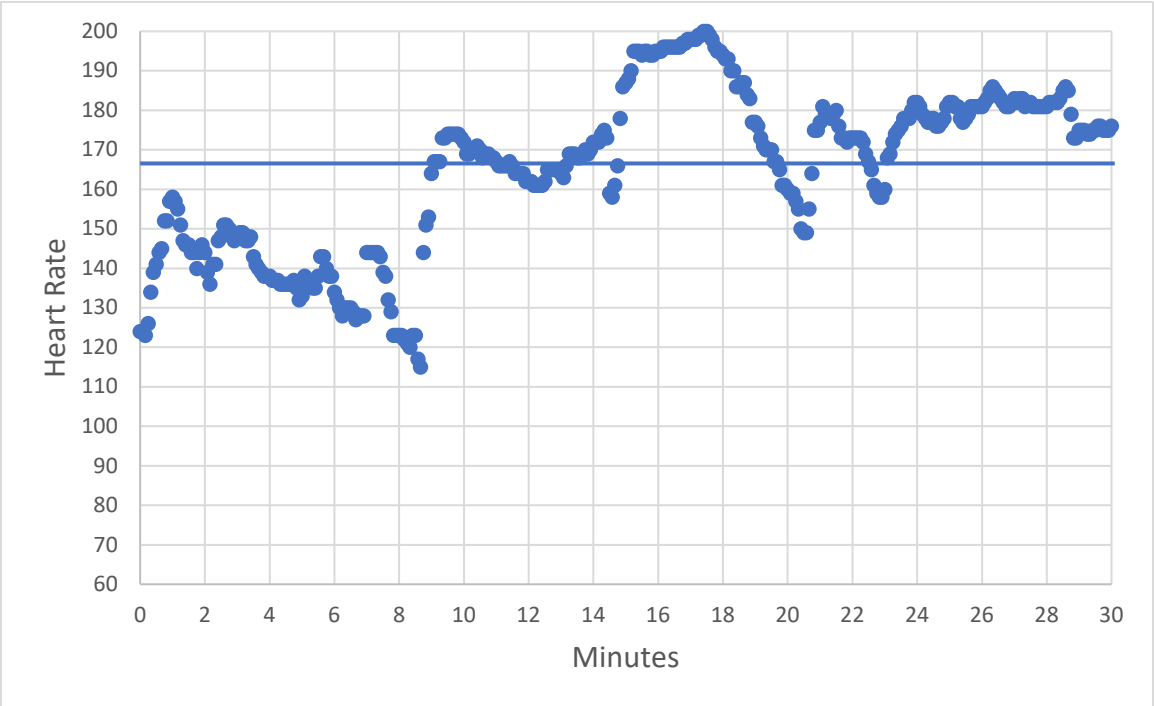


Figure 1f. Heart rate versus time during subject 06's free play session (male).

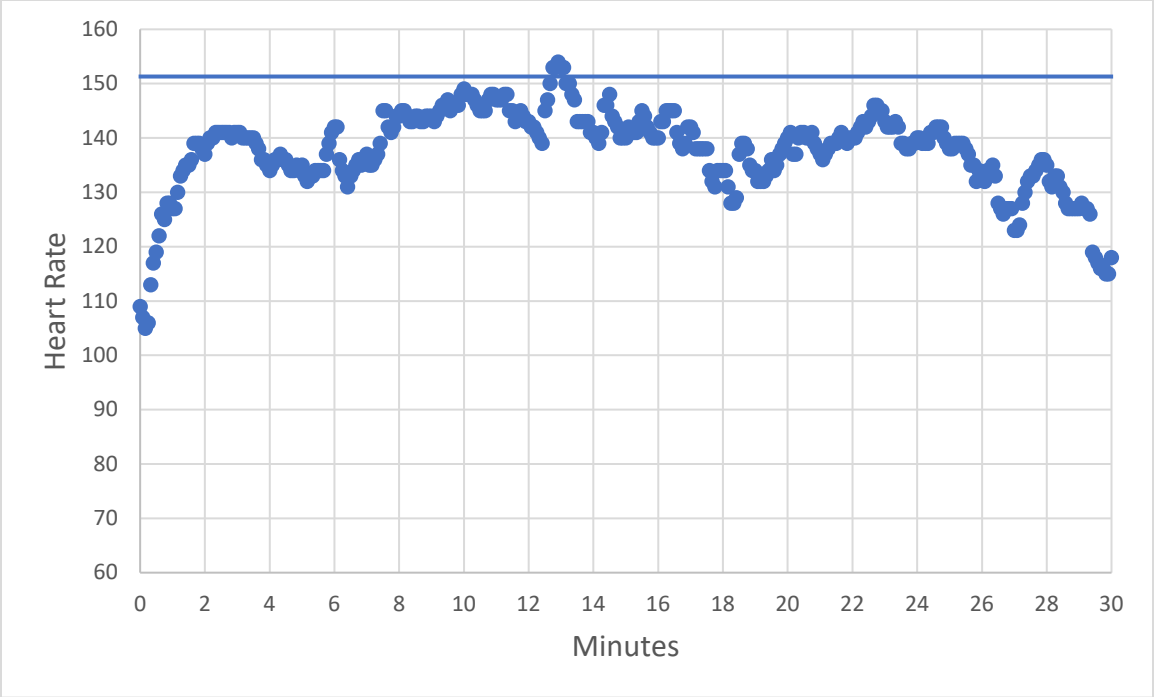


Figure 1g. Heart rate versus time during subject 07's free play session (female).

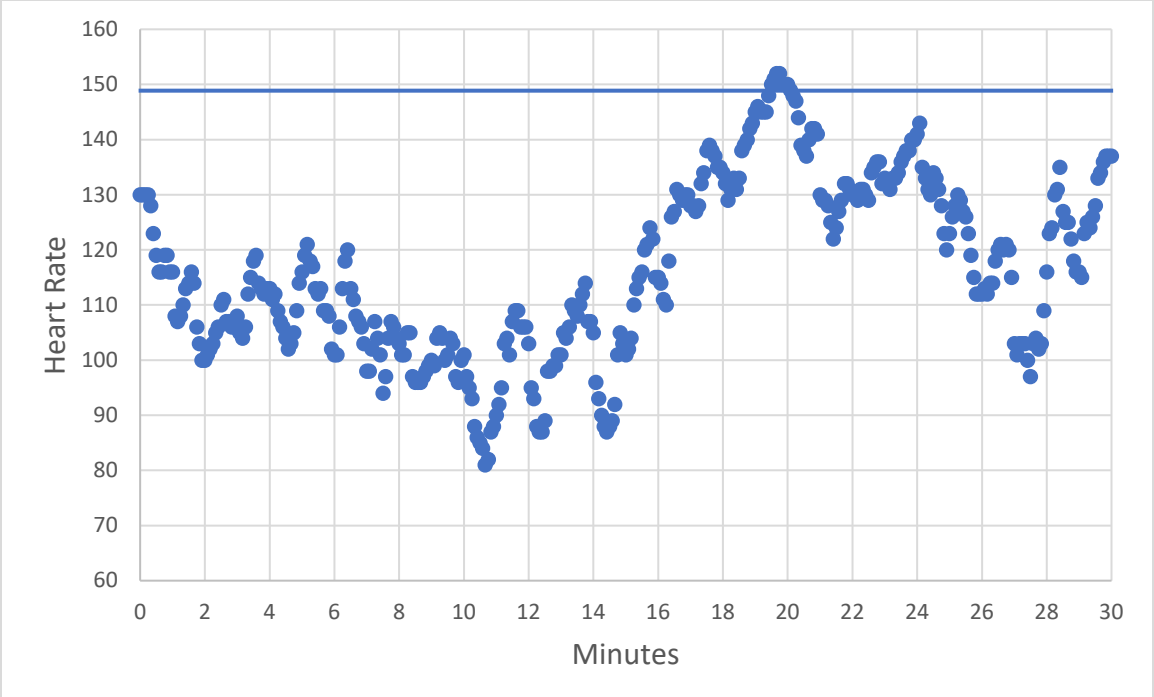


Figure 1h. Heart rate versus time during subject 08's free play session (female).

Individual responses of the TT throughout the free play session are provided in Figures 2a – 2h. A positive TT is represented by a "+", equivocal TT is represented by a "±", and negative TT is represented by a "-".

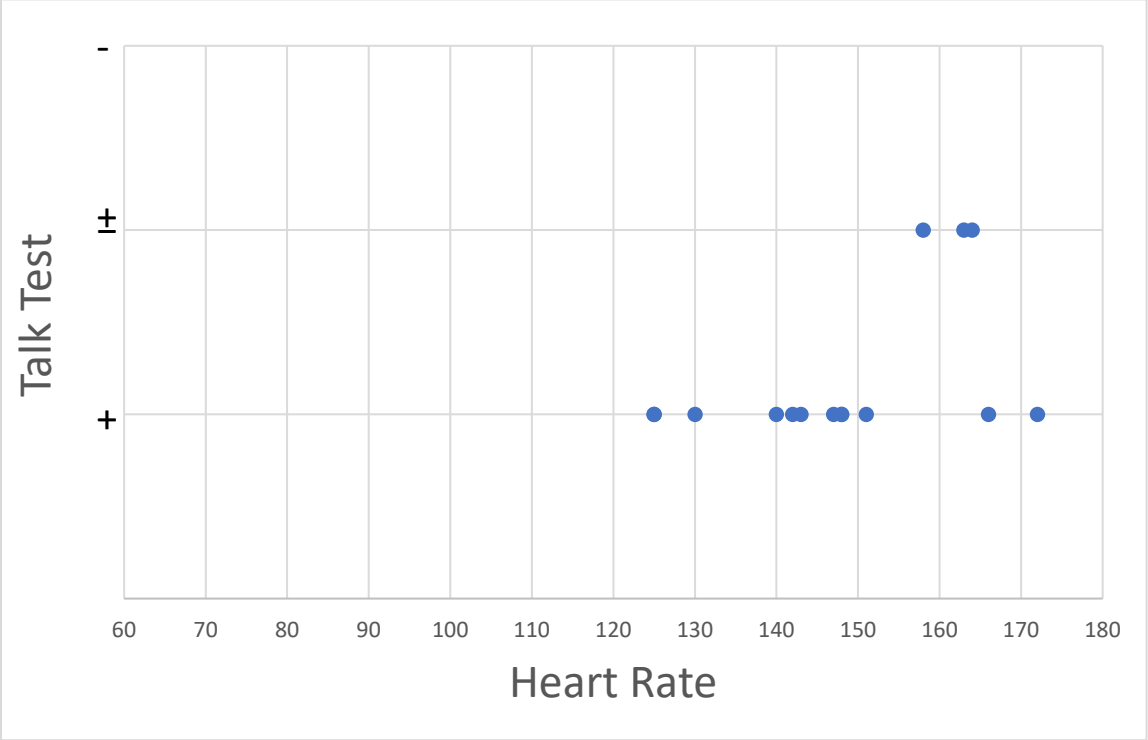


Figure 2a. Talk Test versus heart rate during subject 01's free play session (male).

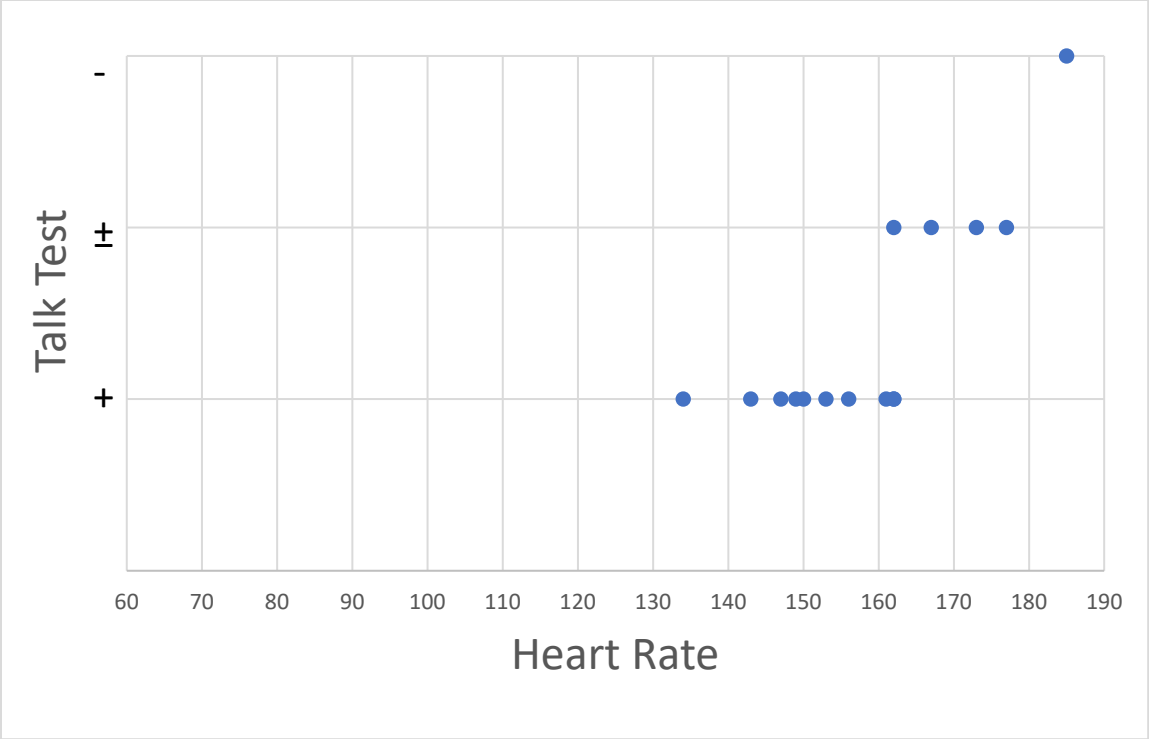


Figure 2b. Talk Test versus heart rate during subject 02's free play session (male).

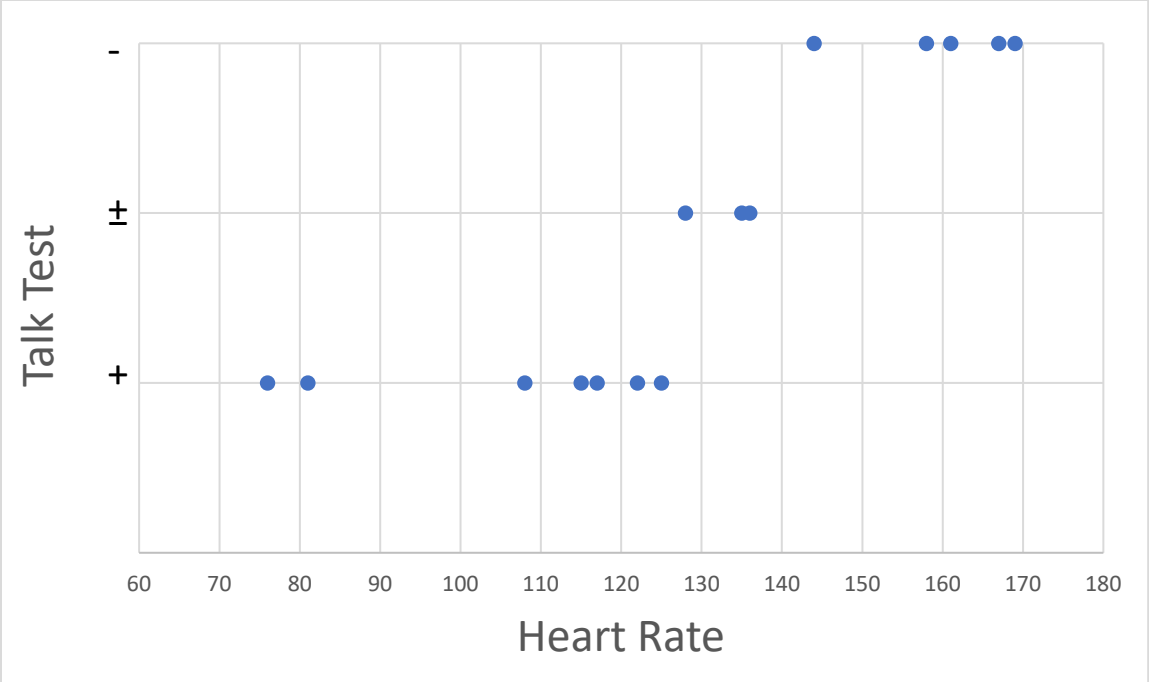


Figure 2c. Talk Test versus heart rate during subject 03's free play session (male).

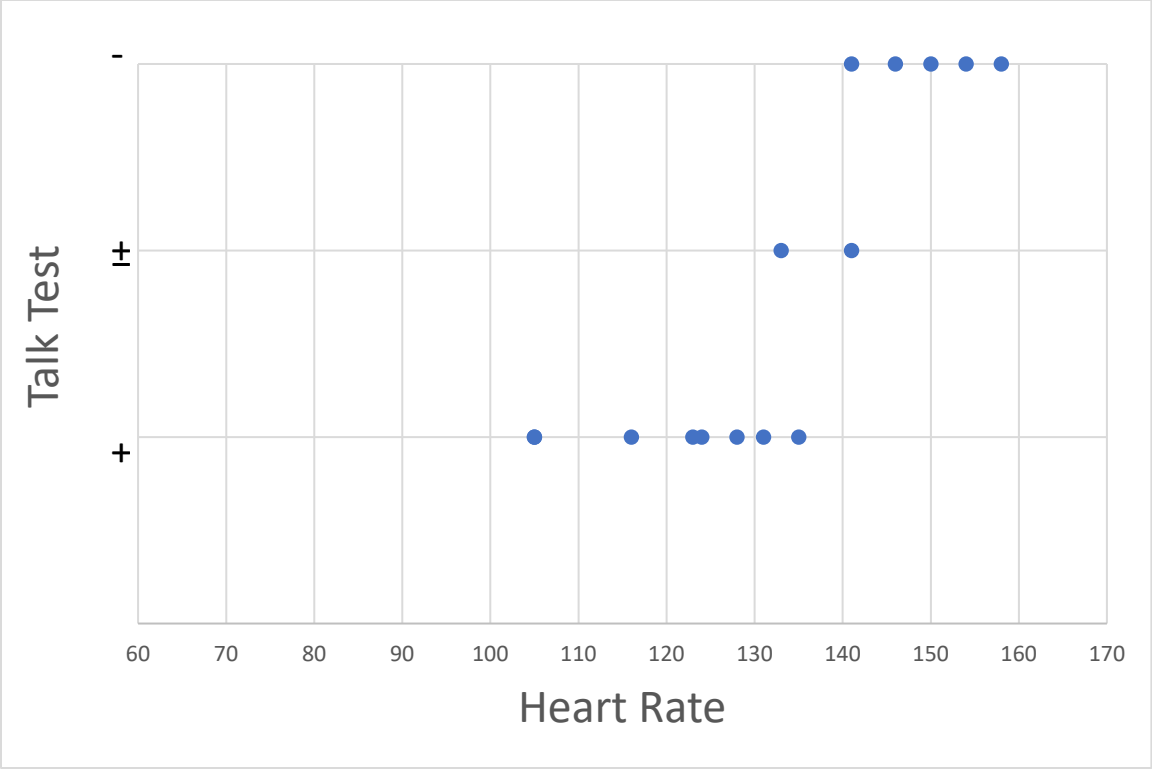
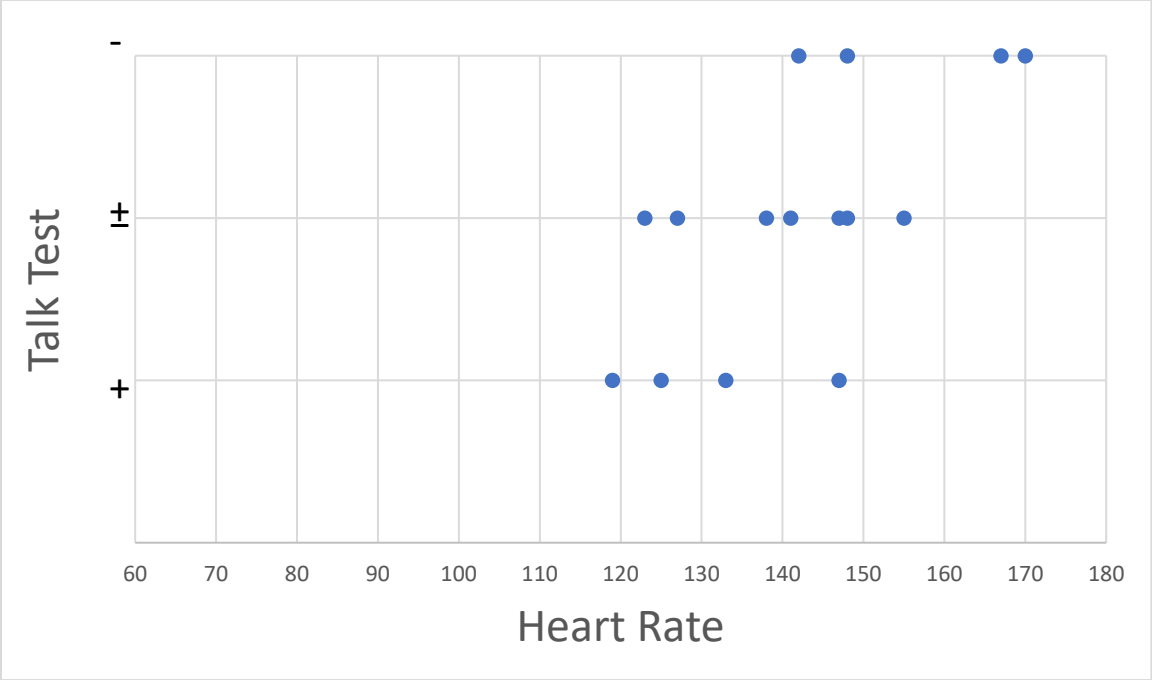


Figure 2d. Talk Test versus heart rate during subject 04's free play session (male).



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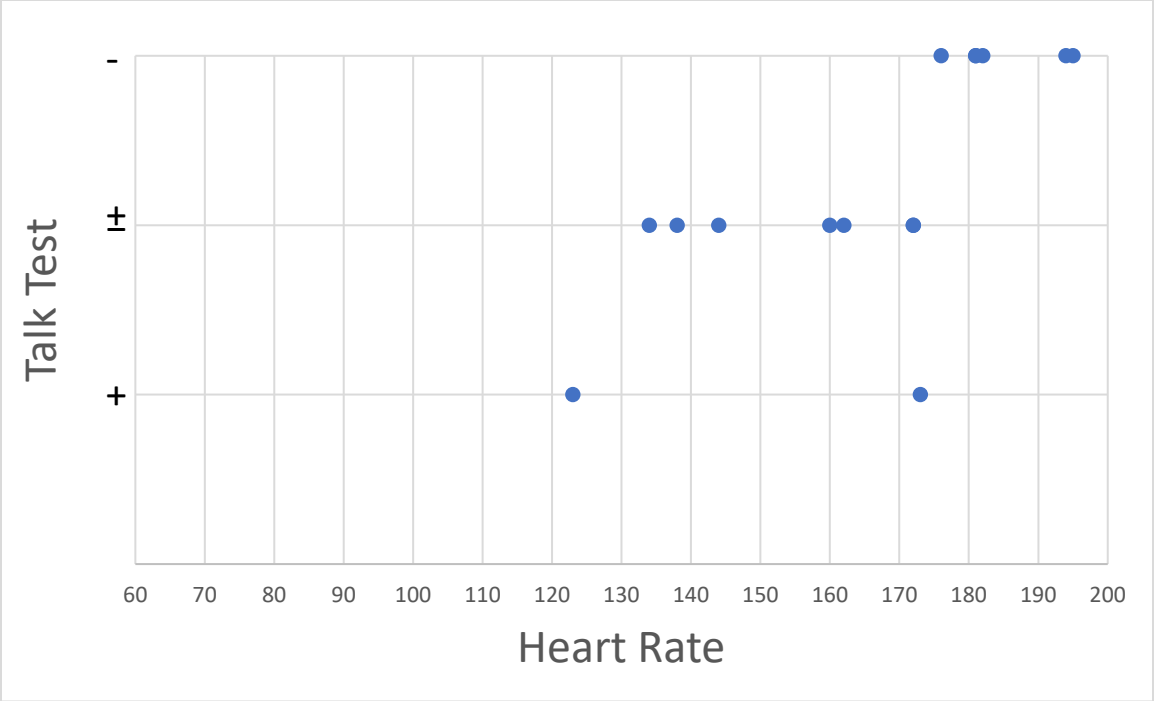

Figure 2f. Talk Test versus heart rate during subject 06's free play session (male).

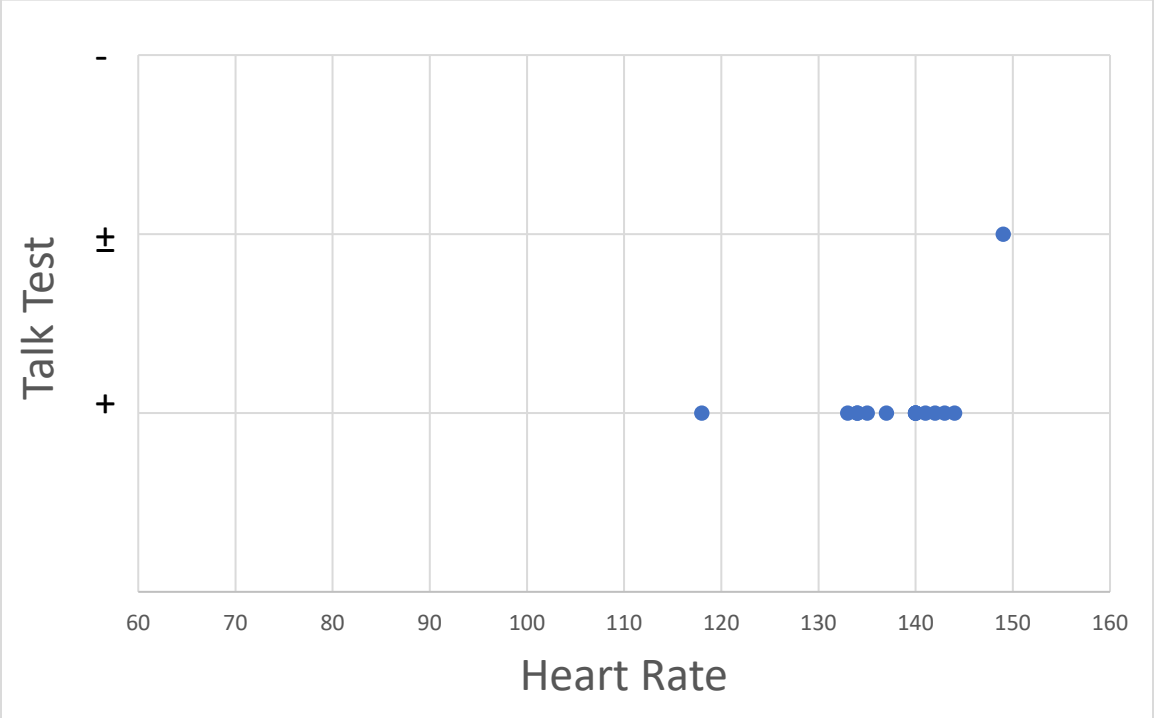

Figure 2g. Talk Test versus heart rate during subject 07's free play session (female).

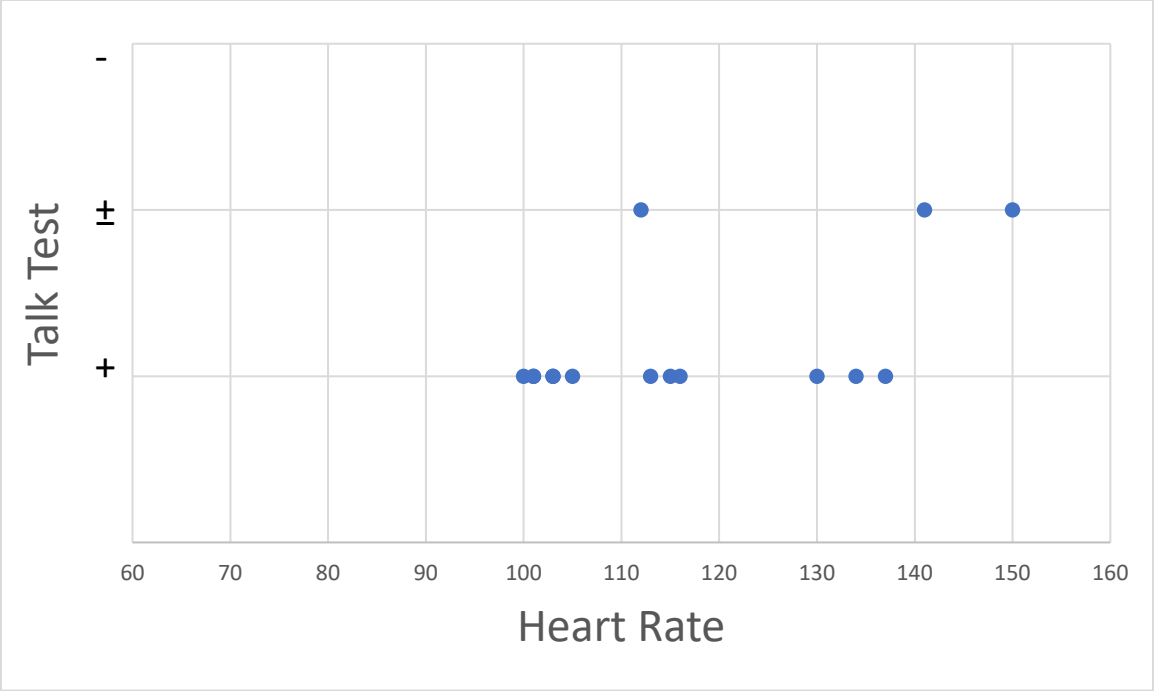

Figure 2h. Talk Test versus heart rate during subject 08's free play session (female).

Individual responses of RPE after each TT throughout the free play session are provided in Figures 3a – 3h.

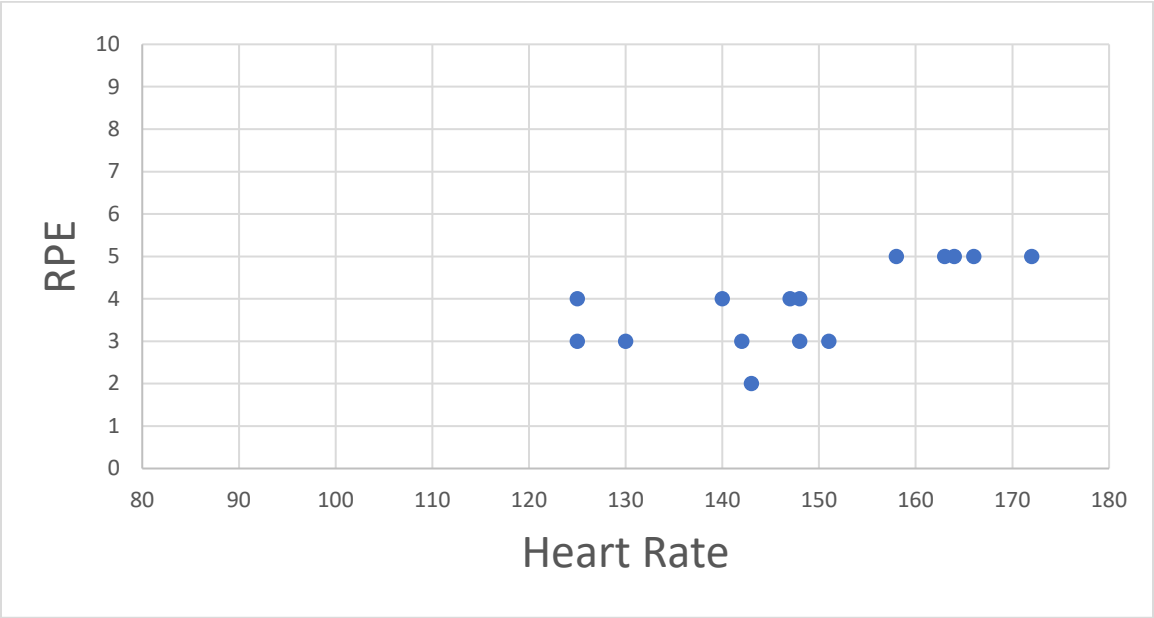

Figure 3a. Rating of perceived exertion versus heart rate during subject 01's free play session (male).

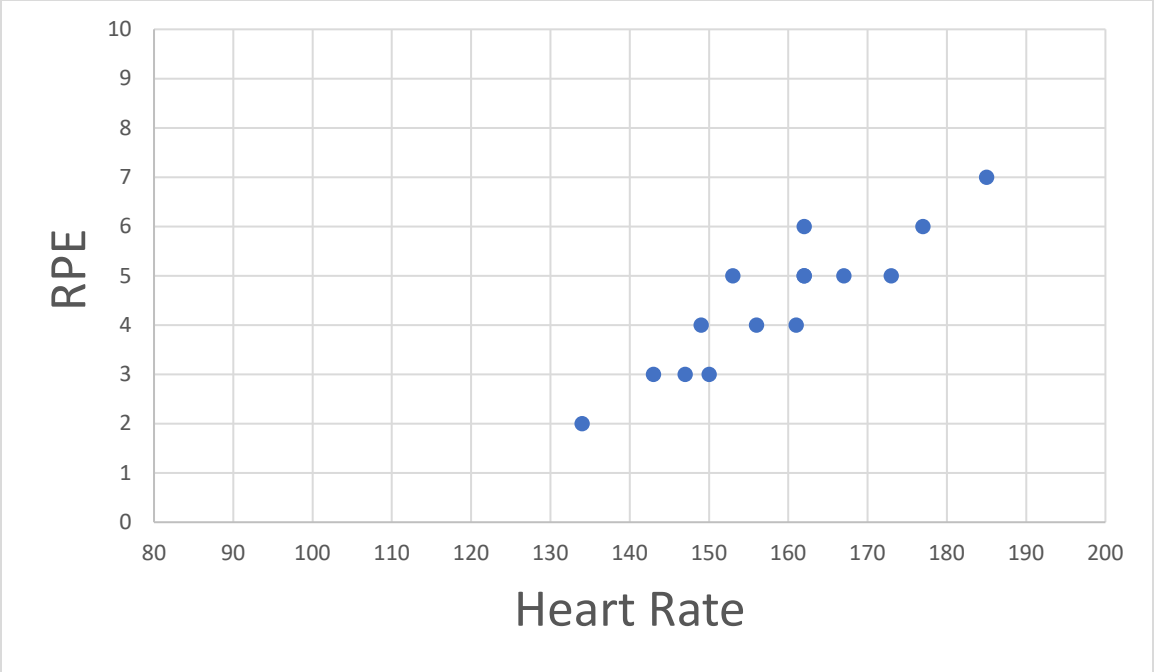

Figure 3b. Rating of perceived exertion versus heart rate during subject 02's free play session (male).

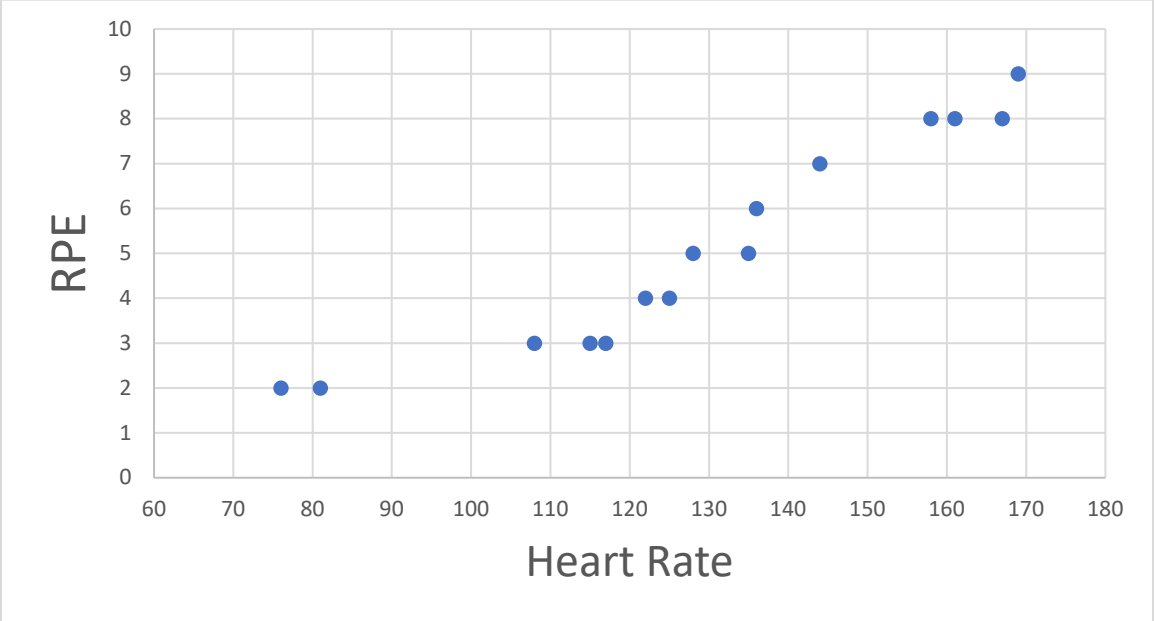

Figure 3c. Rating of perceived exertion versus heart rate during subject 03's free play session (male).

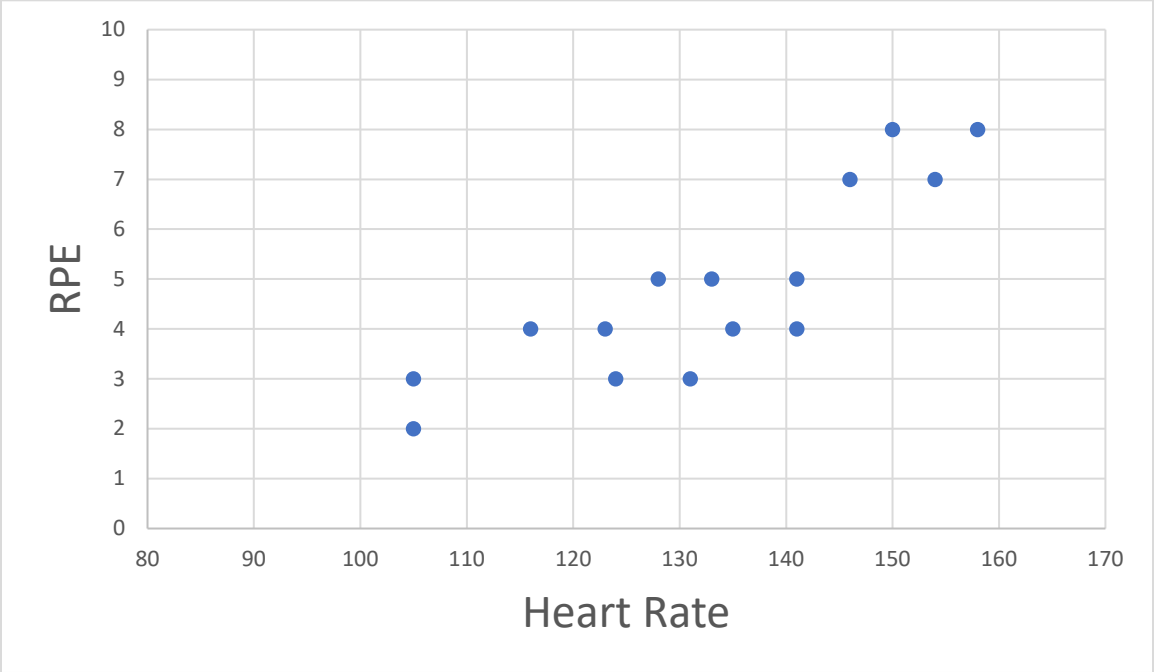

Figure 3d. Rating of perceived exertion versus heart rate during subject 04's free play session (male).

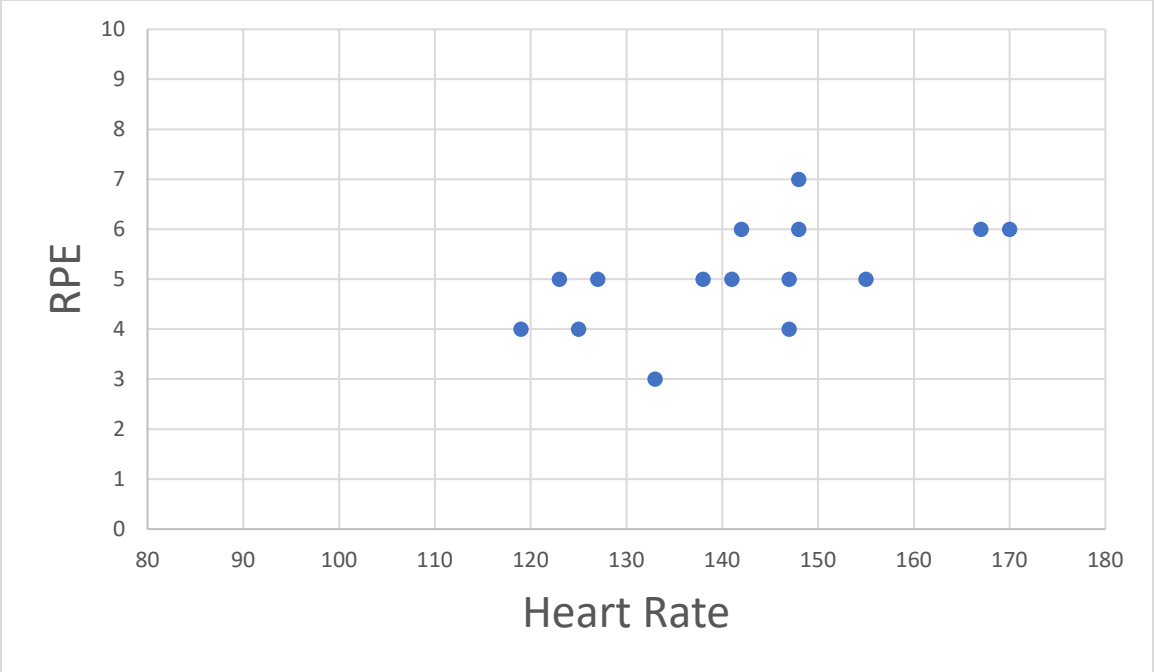

Figure 3e. Rating of perceived exertion versus heart rate during subject 05's free play session (male).

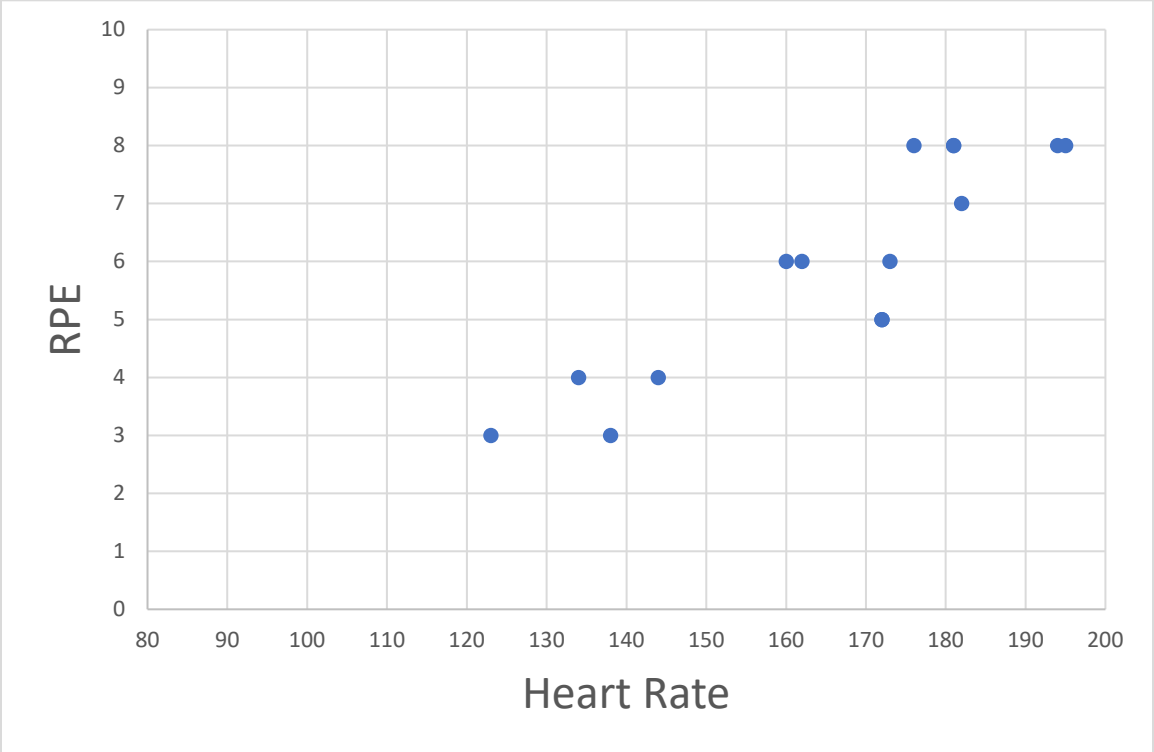

Figure 3f. Rating of perceived exertion versus heart rate during subject 06's free play session (male).

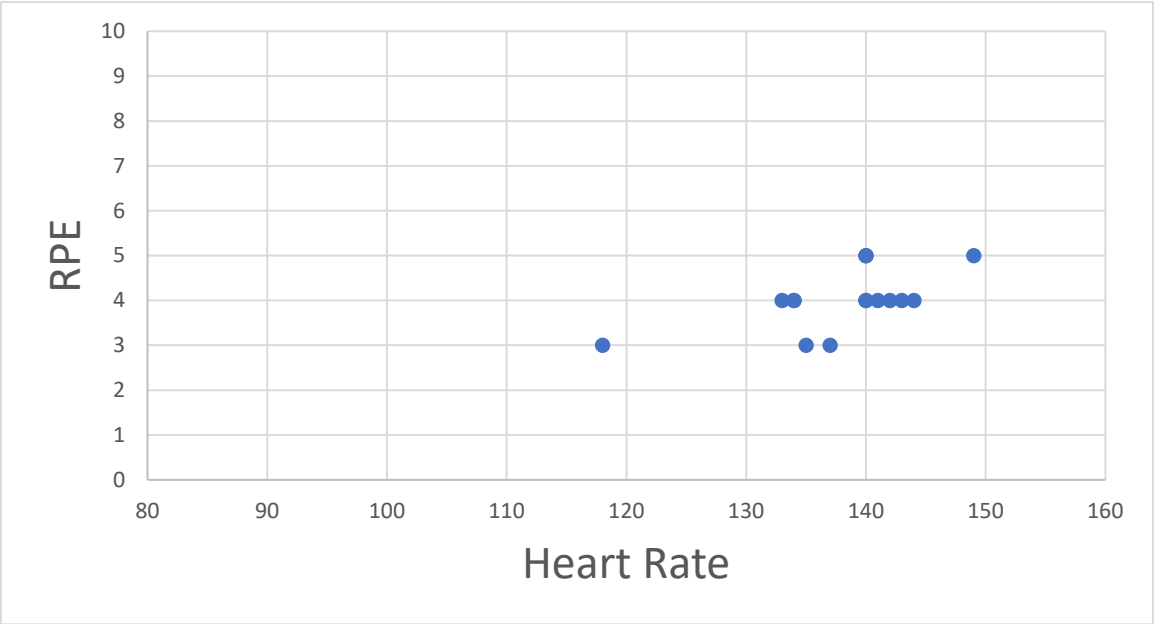

Figure 3g. Rating of perceived exertion versus heart rate during subject 07's free play session (female).

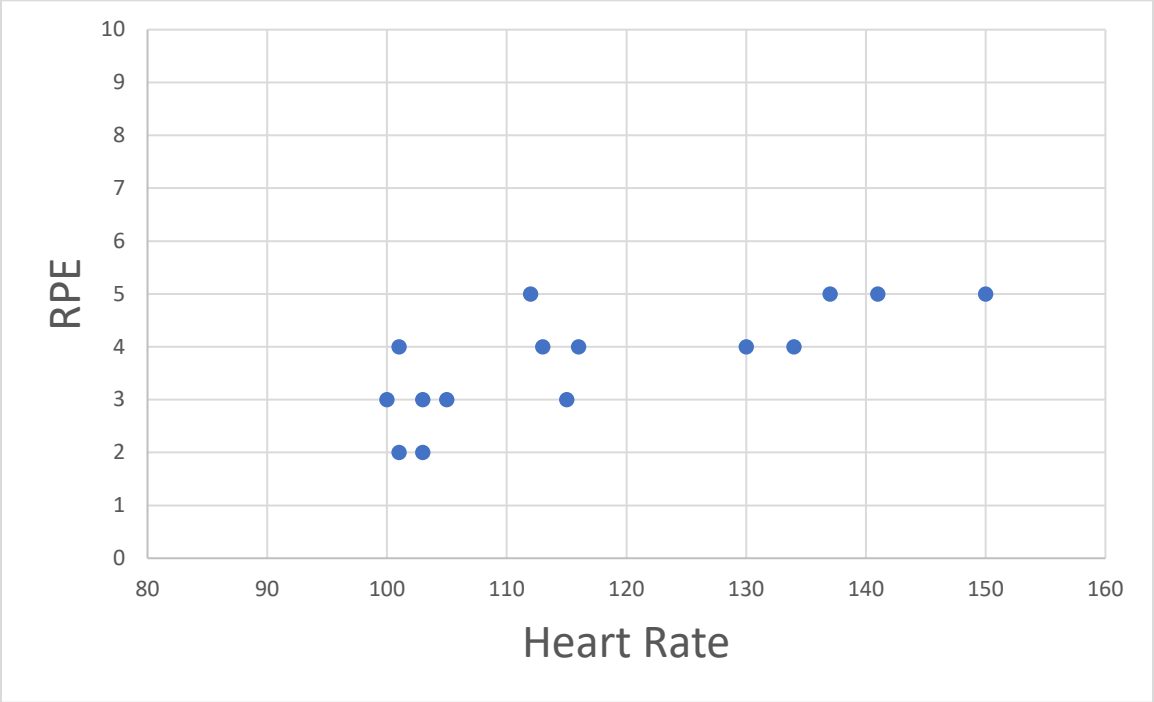

Figure 3h. Rating of perceived exertion versus heart rate during subject 08's free play session (female).

The field session produced the same patterns seen in the lab with increased HR and RPE. There was a linear increase between HR and RPE. There was also a linear increase between HR and TT responses. As HR increased, the ability to talk comfortably or talk at all decreased.

After establishing VT in the TT, comparisons were made with the field test. During the free play session of the field test, predictions were made regarding whether subjects were above or below VT based on their heart rate. Predicted responses for subjects with a heart rate below VT compared to observed responses of being able to

speak comfortably were recorded. A comparison of the predicted and observed TT responses are presented in Table 2. Most (81.6%) of the observed responses were within prediction. This showed that 71 of 90 (78.0%) cases were able to speak comfortably at an intensity below VT. When subjects were playing above VT and were predicted to not be able to speak comfortably, 27 of 30 (90.0%) cases responded with not being able to speak comfortably. Predictions of subjects being able to speak comfortably and not being able to speak comfortably showed a similar observation in 98 of 120 (81.7%) cases. Most of the predictive errors (86.4%) were in the direction of not being able to speak even though the subjects were predicted to be able to speak. The chi square analysis proved to have a significant relationship between observed ability to speak comfortably and predicted ability to speak comfortably.

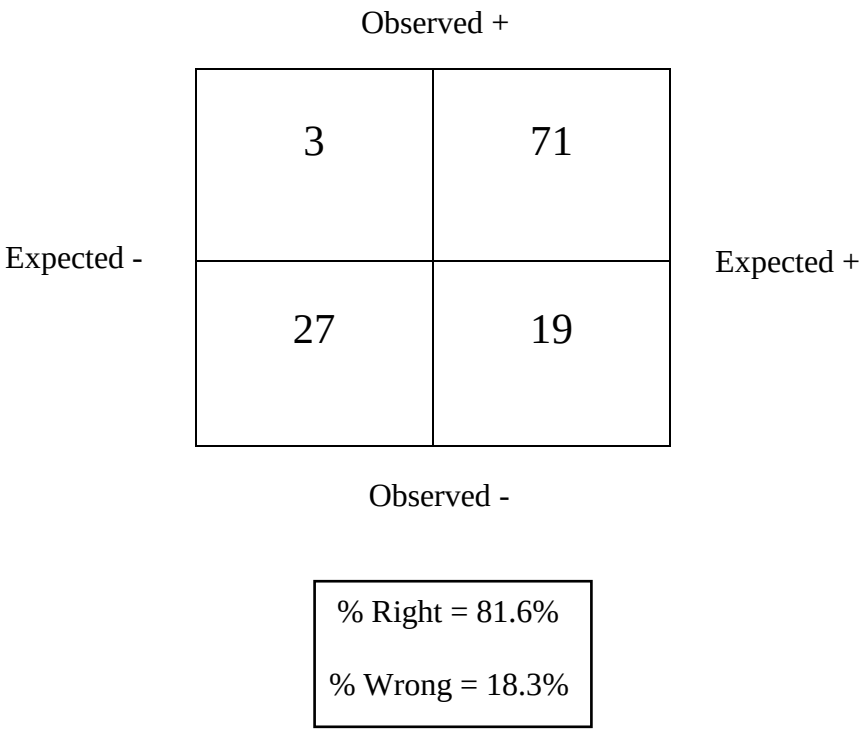

Figure 4. Expected vs. Observed TT Response

DISCUSSION

The purpose of this study was to determine whether the TT is an appropriate measurement of exercise intensity with natural movement patterns in children age eight to twelve. The TT in the lab was completed by subjects in order to compare TT responses in the field, as well as, determine the subject's VT. On average, the boys spent 11.2 minutes of their free play session above their VT compared to the girls' 1.2 minutes. In order for the subject's heart rate to get above their VT, they were working at an intensity where they could no longer speak comfortably. This gender difference was expected as girls are habitually less active than boys. This finding supports Ridgers et al., 2005, Stellino et al., 2010, and Sallis et al., 1996 where boys engage in more moderate and high intensity activity during recess and physical education classes than girls do.

There was a clear difference between boys and girls in the zones that facilitated the most activity. The basketball/football zone resulted in the most activity with boys. Both basketball and football had competitive aspects and allowed for physical contact. The boys were most active in zones with more structured games that allowed teamwork and physical contact, whereas the girls shied away from this type of activity. The girls participated in activities with less structure and with the choice to adjust the games, like volleyball and frisbee. These findings were consistent with Barnas et al., 2018.

The stochastic pattern of exercise in children is represented accurately in the subject's individual responses of HR over time. Naturally, children don't play at a

continuous level of intensity or perform steady state exercise and, perform more short bursts of high intense physical activity. Accordingly, children's HR patterns should fluctuate up and down with physical activity. This pattern was visible with all the subject's HR responses during the 30-minute free play session. This response was also seen in Armstrong & Bray (1991) study where the majority of physical activity patterns of school age children were more interval in nature rather than continuous.

This is the first study of its kind and subsequently, there are no similar studies to compare the field session results too. However, the HR, RPE, and TT responses observed during the field session do imitate HR, RPE, and TT responses observed in the lab. As the subject's HR increased, so did their RPE responses, while the ability to talk comfortably decreased. Similar to Giddings (2018), the results demonstrate that when talking becomes too difficult, children are beyond their VT and while still able to speak comfortably, the intensity was below their VT. The results from this study found that 81.6% of the TT predictions were right. The majority of the observations support the concept that HR at VT observed during children's natural movement patterns was a reasonable prediction of whether the child would be able or unable to speak comfortably. These results are similar to VanGalen (2019) who had children complete interval based exercise to predict subject's ability to speak comfortably using the TT. VanGalen (2019) found 73.3% of the predictions were right after correctly predicting when subjects could speak comfortably or could not speak comfortably.

This study is a step in the right direction for determining if the TT is an appropriate tool to subjectively measure the intensity of exercise in children's natural movement patterns. Although the field session in the gym was set up in specific zones,

and selected equipment, it was an adequate environment to encourage natural play movements and patterns. Future research should explore the natural movement patterns of children in a recess setting, physical education class, and on a playground. Future research should involve one or more of these settings and compare responses of HR, RPE, TT to that of the TT in the lab.

CONCLUSION

Exercise habits in children are described as short intense bouts of exercise with short rest periods in between (Armstrong & Bray, 1991). Heart rate, RPE, and TT responses were similar between the TT exercise test and field session. Results from the field session are supported by the interval based exercise results of VanGalen (2019) in children. The hypothesis was supported and, the TT is an appropriate subjective measurement of intensity for children to use with their natural exercise patterns. Further research is needed to support these findings.

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APPENDIX A

INFORMED CONSENT AND ASSENT

Title: Talk Test as a Measure of Exercise Intensity in Children

Why have you been asked to take part in this research?

You are being asked to participate in this study because of the age range you fall into. This research involves the use of children to further understand the effectiveness of the Talk Test. Joining this study is completely voluntary and you are free to leave at any time.

We have attempted to write this consent form as clearly as possible for your understanding. Feel free to ask as many questions as you wish about this consent form, the procedures, and any information that you do not understand. Study personnel will explain all the procedures that you will be asked to follow.

Research has been done, previously, on the Talk Test, and the results show that exercise intensity can be accurately and appropriately measured. Research has not yet been done on children and their typical real-world physical activity patterns, which has led us to conduct this study. The purpose of this study is to examine the Talk Test and its ability to accurately and appropriately measure exercise intensity in children during typical physical activity and play.

How many people will be in this study and how long will this study last?

The researchers are looking for 12 to 20 children aged eight to twelve years old to be involved in this study. While the study may take eight months to complete, your participation will take only one hour or less on three separate occasions.

What will happen if you agree to take part in this study?

Each participant will meet the researchers on three separate occasions, each one lasting about one hour. The first meeting will be to measure descriptive characteristics, become oriented to the lab, practice running on the treadmill, and practice wearing the gas-analyzer mask (similar to a scuba mask). After orientation of the equipment, each participant will take part in the Talk Test. This will consist of the child walking on the treadmill, which will increase grade as the test progresses with speed remaining constant at 3 mph. Each stage of the test will be two minutes long, with the last thirty seconds requiring the child to read the Pledge out loud three times. The child will then be asked if they can speak comfortably. The child will proceed until they can no longer speak comfortably. The second meeting will involve an exercise test where the child will run until they feel like they can go no further. The mask will be worn during this test to measure the gas exchange during exercise. The last meeting will consist of the Talk Test during the child's natural physical activity play pattern. Similar to the lab protocol, every two minutes

the child will be asked to recite the Pledge out loud three times. The child will then be asked if they can speak comfortably.

What are the potential risks associated with this study?

Risk or discomfort with participation is minimal. The exercise test is a maximal test so you will get tired but has very little risk of injury. Small discomfort may be experienced towards the end of the test as exercise becomes more vigorous, but the child has the option to stop the test at any time.

What are the benefits associated with this study?

There is unlikely any direct benefit to me from this study, other than a greater understanding of the child's exercise capacity. The information obtained from this study, though, will go on to improve knowledge within the field of exercise. What if I do not want my child/myself to participate in this study? This study is completely voluntary, and there are no consequences to doing so. Your child/you can withdraw at any time during the study.

Informed Assent Form

(Required for Age 11 through 17)

Child/Adolescent's Understanding:

Have all your questions regarding how the research study might affect you been answered?

Yes / No (Circle one)

If you want to be part of the study, please sign your name. If you do not want to be part of the study, then do not sign your name. You can say no to being in the study, and you will not be disliked or treated differently.

_____ _____

Child/Adolescent's Signature Date of Signature

_____

Printed Name of Subject

Parent's/Court-Appointed Guardian's Understanding:

Have all your questions about how the research study is going to affect your child and/or yourself been answered? Yes / No (Circle one)

I believe my child is fully informed and is willing to participate in this study.

_____ _____

Parent's/Court-Appointed Guardian's Signature Date of Signature

Please indicate below if we can videotape your child.

☐ My child will participate in the study and CAN be videotaped.

☐ My child will participate in the study but CAN NOT to be videotaped.

Investigator/Presenter:

I have discussed this study and the possible risks and benefits of the study with the child, and I believe he/she is fully informed and is willing to participate in this study.

_____ _____

Presenter's Signature Date of Presentation

(Investigator or Designee)

What does signing this consent form mean?

A signature indicates that:

You or your child has read the above.

You or your child has freely decided to take part in the research study described above.

The studies general purposes, details of involvement, and possible risks and discomforts have been explained to you and your child.

You and your child will receive a signed copy of this consent/authorization form.

_____ _____

Signature of Subject Date of Signature

(If 18 or older and be able to give informed consent)

_____

Printed Name of Subject

..... OR .....

_____ _____

Signature of Parent (If Subject is less than 18) Date of Signature

..... OR .....

Health Care Agent as Designated by Power of Attorney For Health Care (if participant is 18 or older)

..... OR .....

Court-Appointed Guardian (Circle appropriate title)

Reason subject was unable to give informed consent:

_____
_____

Printed Name of the Above Signature

_____ _____

Signature of Presenter Date of Presentation

_____

Printed Name of Presenter

APPENDIX B

RPE SCALE

Rating of Perceived Exertion Chart

(Cardiovascular Endurance)

#10 	**I am dead!!!**
#9 	**I am probably going to die!**
#8 	**I can grunt in response to your questions and can only keep this pace for a short time period.**
#7 	**I can still talk but I don't really want to and I am sweating like a pig!**
#6 	**I can still talk but I am slightly breathless and definitely sweating.**
#5 	**I'm just above comfortable, I am sweating more and can talk easily.**
#4 	**I'm sweating a little, but I feel good and I can carry on a conversation comfortably.**
#3 	**I am still comfortable, but I'm breathing a bit harder.**
#2 	**I'm comfortable and I can maintain this pace all day long.**
#1 	**I'm watching TV and eating bon bons.**

APPENDIX C

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Introduction

According to the Centers for Disease Control and Prevention (CDC, 2019), data from 2015-2016 show that nearly one in five school age children and young people (six to nineteen years old) in the United States is obese. The prevalence of childhood obesity has been increasing over the last two decades. The childhood obesity epidemic is linked to many different factors including physical inactivity. On average, children spend about seven and a half hours per day in front of a screen (e.g., TV, videogames, computer). Only six states (Illinois, Hawaii, Massachusetts, Mississippi, New York, and Vermont) require physical education in every grade, K-12 (U.S. Department of Human & Health Services, 2017). The American College of Sports Medicine (ACSM) recommends children and adolescents participate in aerobic exercise at a moderate intensity for 60 minutes daily (ACSM, 2018). It is also recommended children and adolescents participate in aerobic exercise at a vigorous intensity at least 3 days a week. With performance of moderate and vigorous aerobic activity, it is important to discern when an individual is performing at a vigorous intensity. In a clinical setting, it is possible to perform physiological exercise tests to establish an individual's exercise intensity and exercise capacity. In a non-clinical setting, it is difficult to determine an individual's exercise intensity and exercise capacity without laboratory metabolic equipment to measure these variables. Consequently, subjective methods to measure and determine exercise intensity have been created for the general public. One subjective method, the Talk Test (TT), uses the simple question "Are you able to speak comfortably?" to

evaluate one's exercise intensity. The TT has become one of the easiest, most universal methods to monitor and measure exercise intensity.

Establishment of the Talk Test

In 1937, John Grayson was climbing in the Scottish Highlands. He and the other climbers had a rule of thumb to "climb no faster than you can talk" (Goode, Mertens, Shaiman, and Mertens, 1998). In 1957, Karvonen, Kentala, and Mustala used heart rate (HR) to measure exercise intensity and were able to show there was a minimum exercise intensity needed before a training effect occurred. A HR greater than 50% from the range of rest to maximum would be needed to develop a training effect. Karvonen's method requires knowledge of an individual's maximum heart rate. Expensive equipment is needed to determine an individual's maximum heart rate. Consequently, measuring the general public's maximum heart rate is impractical and costly. With these two events in mind, Goode et al. (1998) was interested in developing a simple and convenient technique that the public could use to determine an appropriate exercise intensity without using laboratory equipment. A series of experiments were performed with young, college-aged males exercising at an intensity where they could "hear their breathing". Goode et al. (1998) reported that when a subject could "hear their breathing" while exercising they were at or near their ventilatory threshold (VT) and their HR was appropriate for a training effect to be present. Since this period, numerous studies have been conducted on the validity and reproducibility of the TT on several different populations (Foster et al., 2018).

Physiological Processes and the Talk Test

There is a physiological explanation of why the TT functions so effectively for determining exercise intensity. The mechanism behind the TT is the struggle between the need to suppress breathing frequency to allow speech and the need to increase breathing frequency due to an increased ventilatory drive above the VT (Brawner et al., 2006). Breathing frequency increases because carbon dioxide (CO_2), epinephrine, norepinephrine, and hydrogen increase past the anaerobic threshold (Goode, 2008). Ventilation and breathing frequency both increase at the VT and the respiratory compensation threshold (RCT). Respiratory compensation threshold is representative of the inability to speak comfortably due to exercise intensity (Recalde et al., 2002). Speech discomfort happens with this mismatch of normal breathing functions leading to CO_2 retention (Creemers, Foster, Porcari, Cress, & de Koning, 2017). This change in speech comfort justifies the practicality of the equivocal and last negative stages of the TT as surrogates for VT and RCT, respectively.

There is a significant decrease in oxygen consumption ($\mathrm{VO_2}$) during speech production (Meckel, Rotstein, & Inbar, 2002). The act of speaking during exercise decreases breathing frequency which suppresses ventilation. This can lead to a reduction in both $\mathrm{VO_2}$ and carbon dioxide output ($\mathrm{VCO_2}$). To stop this reduction in $\mathrm{VCO_2}$, arterial $\mathrm{CO_2}$ partial pressure must be increased ($\mathrm{P_aCO_2}$). However, with an increase in $\mathrm{P_aCO_2}$ usually causes a significant increase in effort to breathe and the feeling of breathlessness. This implies that the need to reduce total ventilation and breathing frequency to allow talking could lead to an increase in $\mathrm{P_aCO_2}$, which would increase the drive to breathe and

increase the discomfort in producing speech (Creemers et al., 2017). This physiological process has been studied as a credible mechanism behind the significance of the TT.

Relationship Between the Talk Test and Ventilatory and Lactate Thresholds

The TT is an uncomplicated, subjective method to identify exercise intensity in addition to ventilatory and lactate thresholds. The main protocol utilized in many of the studies involved three stages of the TT that corresponded with metabolic thresholds. The last positive stage of the TT or where the subject can speak comfortably is identified at intensities just below the VT. The equivocal stage or when the subject is uncertain if they can speak uncomfortably is recognized as an intensity very close to the VT. Lastly, the first negative stage of the TT or when the subject is unable to speak comfortably is observed at intensities above the VT (Dehart-Beverley, Foster, Porcari, Fater, & Mikat, 2000; Recalde et al., 2002).

Ventilatory Threshold

The TT has been validated as a simple marker of VT. The TT is highly related to VT because high levels of ventilatory control are required for normal speech (Dehart-Beverley et al., 2000). Dehart-Beverley et al. (2000) studied the relationship between the TT and VT in healthy, well-conditioned college aged students. The results from the study suggest when an individual was able to talk comfortably, they were just below or at the VT. When an individual was unable to speak comfortably, they were above the VT. The significance of this study suggests the TT can be used as a simple, less expensive alternative to VT. Similarly, Recalde et al. (2002) found the TT to be highly comparable to VT. The results demonstrated the last positive stage of the TT were consistent with exercise intensities below the VT. The equivocal stage of the TT was consistent with

exercise intensities very close to the VT, and the negative stage of the TT was consistent with the RCT.

To further support the validity of the TT, Foster et al. (2008) studied the responses of the TT in four independent series of experiments designed to change the exercise intensity above or below the VT. In series one and two the exercise intervention associated changes in VT supported the validity of the TT. Series three experiment was based on changes in exercise intensity during one training bout. The results of series three suggest comfortable speech is inhibited at exercise intensities greater than VT, and recovered as soon as the intensity falls below the VT. The results from series four demonstrated the time before speech became uncomfortable above the VT is most likely longer than two minutes.

In contrast, Ballweg et al. (2013) conducted a study on the reliability of the TT as a surrogate of ventilatory and respiratory compensation threshold. Although the study found the threshold determination for both the TT and gas exchange techniques to be high for reproducibility, the data suggests the equivocal stage of the TT overestimates the gas exchange VT, and the negative stage of the TT overestimates the gas exchange RCT.

Lactate Threshold

In previous research, it has been shown that differences exist between lactate threshold (LT) and VT (Quinn & Coons, 2011). Quinn and Coons (2011) looked at whether the LT and VT have the same relationship with the TT. Fifteen young, fit subjects completed a treadmill LT test followed by a maximal oxygen consumption (VO_{2max}) test where VT was determined. The results of the study showed the VT values were lower than those associated with the three stages of the TT. The study confirmed

that the LT, not the VT, were more related to the values measured in the last positive TT and equivocal TT stages. Therefore, HR and VO_2 measured at the VT inadequately represent values measured at all three stages of the TT.

Exercise Prescription and the Talk Test

When prescribing exercise, determining the appropriate intensity can be problematic. The TT has been a consistent guide of exercise intensity. Dehart-Beverley and colleagues (2000) found when subjects could still talk comfortably during exercise, they were at approximately 75% of their VO_{2max} and 85% of their maximal HR. When subjects could not talk comfortably, they were at approximately 90% of their VO_{2max} and 92% of their maximal HR. Likewise, cardiac patients were able to maintain a conversation during exercise when they were exercising at about 64% of their VO_{2max} and 70% of their maximal HR (Brawner et al., 2006; Voelker et al., 2002). When the subject could speak comfortably when exercising, they were within the acceptable exercise intensity parameters set by the American College of Sports Medicine (ACSM, 2018). In agreement with the previous studies, are the findings from Quinn & Coons (2011). They determined that participants exercising at the last positive stage of the TT were within the ACSM intensity guidelines for $\%VO_{2max}$, $\%HR_{max}$, and Rating of Perceived Exertion (RPE). Participants were exercising at 82% of their maximal HR, 64% of their VO_{2max}, and at an RPE of 12.

In 2014, Lyon and colleagues used responses of an incremental TT and translated them to training intensities for steady-state exercise. The purpose of the study was to provide a suitable absolute training intensity for cardiac rehabilitation patients based on the amount of reduction in absolute workload intensity from an incremental exercise test

using the TT. The results show the stage preceding the last positive stage of the TT would be the appropriate level of intensity for clinical populations. In addition, Jeans, Foster, Porcari, Gibson, and Doberstein (2011) completed a similar study on translating incremental exercise test results into appropriate exercise training intensities based on TT responses in well-trained individuals. The findings from the study demonstrated exercise performed at the last positive stage of the TT during the incremental exercise generated responses during a 40-minute steady-state exercise session consistent with exercise intensity at or below the VT. This suggests it would be appropriate for well-trained athletes to perform steady-state training at an intensity below VT. Altogether, the TT can be utilized to monitor exercise to help stay within the ACSM exercise intensity guidelines.

Special Populations and the Talk Test

Cardiac Patients

Much of the published research on the TT has been performed on healthy adults and competitive athletes (Reed & Pipe, 2014). Less research has been conducted on the sedentary population and clinical populations, such as cardiac patients. Identifying the appropriate exercise intensity for cardiac patients using HR-derived and VO_2 measurements frequently overestimate or underestimate intensity, but the TT has been studied as a valid and reliable method to use in cardiac patients (ACSM, 2018). Zanettini et al. (2012) performed a study to validate the TT for exercise prescription in cardiac patients who had experienced a recent myocardial revascularization. The results from the study showed 88% of patients were in their optimal training zone or between their individual aerobic threshold and anaerobic threshold. None of the patients were

overtraining or beyond the anaerobic threshold. Another important finding was the good reliability of the patient's assessment of the three TT thresholds over repeated measures. Brawner et al. (2006) also studied exercise prescription using the TT in a group of patients with stable coronary artery disease (CAD). The findings indicated when exercise was guided by the TT the HR during exercise was in most cases within the recommended range of 50% - 85% of heart rate reserve (HRR). Brawner et al. (2006) demonstrated that the HR seen during exercise guided by the TT is similar to HR at VT. Eighty-nine percent of the patients reported they could not talk comfortably when they exercised above the VT. In addition, Voelker et al. (2002) found the TT to be a valid subjective measure of exercise intensity in patients with clinically stable cardiovascular disease. Patients were either at or below their VT when they were at the last positive or equivocal stage of the TT.

Since heart rate targets in patients with exertional ischemia can be difficult to determine, subjective methods like the TT can be useful to establish the appropriate exercise training intensity. Cannon et al. (2004) studied the relationship between the TT and exertional ischemia in patients with cardiovascular disease. The results from the study demonstrated that when patients were able to speak comfortably, they were unlikely to experience exertional ischemia. The TT could be implemented to minimize the risk of catastrophic events during exercise. The implications of the studies presented suggest the TT is a valid and reliable method to prescribe cardiac patients the appropriate exercise training intensity in a simple, effective, and safe manner.

Exercise Testing in Children

Ventilatory Threshold

In 2002, Mahon and Cheatham compiled a review on VT in children. On the reliability of VT on children, Weymans and Reybrouck (1989) reported a test-retest correlation for the $\dot{V}O_2$ at VT was $r = 0.87$ in 10 children aged 9 to 13 years of age. Likewise, Mahon and Marsh (1992) reported the reliability for the $\dot{V}O_2$ at VT was $r = 0.87$ in 27 children aged 8 to 12 years of age. Several exercise protocols and modalities have been used for exercise testing in children. Studies have used treadmill exercise involving running, walking, or a combination of both. Mahon and Cheatham (2002) stated the best protocol to use for children should involve equal increases in work rate throughout the whole test. Cycling protocols have also been used in children to successfully determine VT. In the review by Mahon and Cheatham (2002), they reported a study by Cooper et al. (1984) who found an incremental rate of 10 W·min was appropriate for measuring VT in children as young as six years old. In summary, VT can be measured successfully in children using a treadmill or cycle ergometer.

Blood Lactate Levels

Children experience lower blood lactate levels than adults during submaximal exercise at an intensity based on $\%\dot{V}O_{2max}$ (Mahon, Duncan, Howe, & Del Corral, 1997). This difference is related to muscle metabolism. Therefore, Mahon et al. (1997) looked at the blood lactate response in boys and men at an intensity associated to the subject's VT. The results indicated children have lower blood lactate levels during submaximal exercise compared to adults. The children were able to exercise longer above their VT

and still maintain a steady blood lactate level. This suggests VT is not representative of the maximal blood lactate in children.

Rating of Perceived Exertion for Children

Rating of Perceived Exertion has been used extensively in adults but has also been used in studies with children. Children as young as 9 to 10 years old can understand the RPE scale (Mahon et al., 1997). The category rating scales that were developed for adults have limitations for children (Utter, Robertson, Nieman, & Kang, 2002). Many children cannot or have difficulty with assigning numbers to words or phrases that describe exercise responses and recognizing words that are not in their vocabulary. In response to this, Robertson et al. (2001) developed the Children's OMNI Scale of Perceived Exertion. The Children's OMNI scale uses pictures and child-friendly language next to a numerical range of 0 to 10. Utter et al. (2002) used a modified version of the Children's OMNI scale called the Children's OMNI walk/run Scale that shows a child running at various stages up an incline. This scale was evaluated in Utter's study on children aged 6-13 years of age during a treadmill graded exercise test. The results validated the OMNI run/walk scale as a measure of exercise intensity. The results showed RPE was correlated with the physiological measures during both walking and running. Mahon, Plank, and Hipp (2003) looked at RPE and VT in 10-year-old children during two different graded exercise tests. The results showed RPE at VT was higher in the 10·W protocol compared to the 30·W protocol. On the other hand, RPE at a given submaximal power output was not affected by how the power output was increased, if the overall rate of increase was constant.

It has been shown that children rate a given intensity of exercise with a lower RPE than adults (Mahon et al., 1997). This contrasts with what Mahon, Gay, and Stolen (1998) found when examining RPE between children and adults during a graded exercise test on a cycle ergometer. Overall, children rated their leg and chest RPE at VT higher than adults RPE at the same VO_{2max}. To summarize, children can use words and pictures from the Children's OMNI Scale to interpret how they feel during exercise. These findings could be significant for physical education in schools and health promotion for today's youth.

The Talk Test and Children

The literature on the TT with children was non-existent until Peter Giddings in 2018 who studied if the TT can define an exercise intensity that is appropriate for children. Children between the ages 8-12 performed two treadmill exercise tests; one using the TT and one completing a maximal exercise test while measuring respiratory gas exchange. The results showed when children were at the equivocal stage of the TT, they were also at their VT. When the children were at the last positive and negative stages of the TT, they were below and above the VT, respectively. These results agree with previous studies who used adult subjects. Giddings (2018) also discovered children were accurately representing their RPE related to their VT (Giddings, 2018). This is a substantial start to understanding the relationship between children and the TT.

Conclusion

The TT has been studied as a reliable and valid self-reported subjective method to determine exercise intensity. With many objective methods to measure exercise intensity requiring expensive laboratory equipment, the TT has become a popular alternative due

to its easiness and economical factor. The TT has been studied considerably in a variety of populations like young adults, competitive athletes, sedentary individuals, and cardiac patients. Due to the childhood obesity epidemic, it would be beneficial for children and adolescents to determine and learn how to measure their exercise intensity by using the TT. A solid foundation has been started with studying the TT in children. More studies are required to validate the present results and verify reliability using the TT with children.

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