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NATURAL EXERCISE PATTERNS IN CHILDREN USING THE TALK TEST AS THE MEASURE OF INTENSITY

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NATURAL EXERCISE PATTERNS IN CHILDREN USING THE TALK TEST AS THE MEASURE OF INTENSITY

By Brandon VanGalen

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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Physiologic exercise response tests are completed to determine the intensity of exercise and exercise capacity of a participant. These tests of physiological response and exercise intensity are easy to measure when in a clinical setting because of the readily available equipment. In a clinical setting it would be difficult to know intensity of exercise without monitoring equipment. Consequently, subjective measures for exercise intensity have been introduced to lessen the burden of using expensive equipment. Subjective tests allow for simple questions (i.e. “Are you able to speak comfortably?”) to be asked about intensity and the relative physiologic responses correlated with the answer. This simplicity of subjective measures sparked the interest in the Talk Test (TT). The purpose of this study was to identify if the TT is an appropriate measure of intensity with natural exercise patterns in children. This study looks specifically at the TT as a measurement of exercise intensity in children ages 9 to 12. Ten children were recruited to perform the study. Subjects completed three visits consisting of familiarization and the TT, a maximal oxygen consumption test, and an interval based exercise bout with the TT. Chi-square analysis found a significant relationship in the interval based exercise between predicted ability to speak comfortably and observed ability to speak comfortably. This study identified that the TT was an appropriate measure of intensity with natural exercise patterns in children.

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INTRODUCTION

The Talk Test (TT) as a technique for exercise prescription has been shown to work in a multitude of different populations. These populations range from athletes to cardiac patients (Brawner et al., (2006), Cannon et al. (2004), Gillespie, McCormick, Mermier, & Gibson (2015), Rodriguez-Marroyo, Villa, Garcia-Lopez, & Foster (2013), Voekler et al. (2002), Zanettini et al. (2012)). However, little research has been performed on the TT in children. Giddings (2018) performed the first research on the TT in children and demonstrated that the TT was an appropriate measure of assessing exercise intensity in children; however, the Giddings protocol was based on incremental exercise. From previous research on exercise habits in children, there is evidence that children perform intense exercise for only short periods of time (Armstrong et al., (1991), Benham-Deal, (2005)). Therefore, incremental exercise patterns in children may not be an ideal measure of their natural exercise patterns. Instead, interval based exercise may be a better approximation of how children experience exercise.

Foster et al. (2008) performed interval based exercise using the TT and found that subjects were able to predict when they were either above or below ventilatory threshold (VT). Although evidence from this study demonstrated that the TT in interval based exercise works as a predictor of exercise intensity in adults, this has yet to be demonstrated in children.

Dehart-Beverley, Foster, Porcari, Fater, & Mikat (2000) demonstrated that the TT can identify when an individual is at/below or above VT. The last positive stage, or last time an individual "can speak comfortably", represents a stage where they are at/below VT. Conversely, individuals are above VT when they are in the negative stage, or when they cannot "speak comfortably".

Establishment of research to manipulate exercise around VT in interval based exercise in children has yet to be completed. Therefore, the objective of this study was to identify if the TT is an appropriate measure of exercise intensity during natural exercise patterns in children. We hypothesized that the TT would be an appropriate measure of intensity during natural exercise patterns in children.

METHODS

Subjects

This study was approved by the Institutional Review Board of the University of Wisconsin-LaCrosse. All subjects were provided a written informed consent for their parents to sign. Subjects were also given a written assent form to sign on their own. The subjects completed the Physical Activity Readiness Questionnaire (PAR-Q) and an Exercise History Questionnaire in order to determine whether or not there were contradictions or limitations to performing exercise. This study included 10 subjects between the ages of 9 to 12 years old. Subject characteristics are provided in Table 1.

Protocol

The subjects came to the exercise laboratory on three separate occasions. The first visit consisted of familiarization to the treadmill and other equipment. Familiarization included time spent on practicing breathing into respiratory gas exchange equipment as well as becoming familiar with treadmill walking. After subjects felt comfortable with the equipment they performed a maximal exercise test using the TT. The second visit consisted of a maximal exercise test on the treadmill with measurement of respiratory gas exchange. The speed and grade at VT were defined during this test. The third visit required the subjects to complete an interval based exercise protocol while using the TT. There were approximately 48 hours between each of the three tests. Heart rate (HR) was assessed during all three tests via radio telemetry (Polar USA, Lake Success, New York).

The Rating of Perceived Exertion (RPE) scale (Nye & Todd, 2013) was used to assess the perceived exertion during the exercise tests. All three exercise tests were completed on a motorized treadmill. A modified Balke protocol was used for the graded exercise testing.

The Talk Test

The TT was performed on the first visit using 2 minute stages. The TT began with a 2-minute warm-up at one and a half miles per hour followed by the first stage at a speed of three miles per hour with a 0% grade. During the last 30 seconds of each stage HR & RPE were measured and subjects read a passage of approximately 100 words (Schroeder, Foster, Porcari, & Mikat, 2017). The passage was selected based on the subjects reading level. After subjects read the passage, they were asked if they "can speak comfortably". A response of "yes" was documented as (+), "yes, but" was a (+/-), and "no" resulted in a (-). The test continued until the subject was fatigued.

The Maximal Test

The maximal exercise test was performed at least 48 hours after the TT and included a measurement of the subject's maximal oxygen uptake (VO_2), VT, and Respiratory Compensation Threshold (RCT). To complete this test, the subjects exercised began with a 2-minute warm-up at one and a half miles per hour (mph) followed by the first stage at a speed of three mph with a 0% grade. Speed remained the same while grade increased by 2% after every 2 minutes until maximal effort was achieved. Heart rate and RPE were recorded during the last 10 seconds of each stage. Gas exchange was measured using open-circuit spirometry (Moxus Metabolic Cart System, AEI Technologies, Pittsburgh, Pennsylvania), calibrated using a 3.0 L syringe and known gas concentrations.

VT was identified via the "V"-slope method, as well as Ventilatory Equivalents Method (Beaver, Wasserman, & Whipp, 1986). Speed and grade at which VT was achieved, was compared to the last positive (LP) and equivocal (EQ) stages of the TT.

The Talk Test in Interval Based Exercise

The interval based TT began with a 2-minute warm-up at one and half mph and 0% grade. Following the warm-up, the TT began using 2 minute stages. Subjects began at a speed and grade that required about 30% of their VT. The determining factor for speed and grade following this phase was based on controlling their ability to speak (Foster et al., 2008). The grade was manipulated to periodically bring subjects at or above VT. Speed and grade were then lowered to a level that represents about 30% of the subjects VT. At the end of each 2-minute stage, the subject performed the TT. If subjects had difficulty sustaining this interval based exercise for the desired 30 minutes, the speed and grade during the recovery period were adjusted. Meanwhile, a researcher predicted whether the subject was above or below VT based on the defined speed and grade at VT from the GXT.

Statistical Analysis

Data were analyzed using analysis of variance (ANOVA). Post-hoc comparisons were justified through ANOVA and were then assessed through the Tukey post-hoc test to compare the VO_2, HR, and RPE at the VT as well as the LP, EQ, and negative (NEG) stages of the TT. A p-value of <0.05 was considered statistically significant. For the interval based TT data, a chi square was used to test for statistical significance for

predicted and observed answers during the test. A p-value of <0.05 was considered statistically significant.

RESULTS

Analysis was performed on N=10 (5 boys, 5 girls) children who completed the TT, VO_2 max test, and interval based TT. Descriptive characteristics of the subjects are summarized in Table 1.

Table 1. Descriptive characteristics of the children (N=10).

Variable	Girls (n=5)	Boys (n=5)	Total (N=10)
Age (years)	9.6±0.55	10.6±0.89	10.1±0.88
Height (cm)	136.6±4.17	150.6±10.31	143.6±10.44
Weight (kg)	32.4±3.92	43.8±8.02	38.1±8.44
VO_2max ($L*min^{-1}$)	1.3±0.23	1.9±0.39	1.6±0.43
VO_2max ($mL*kg^{-1}*min^{-1}$)	41.3±7.20	43.5±1.53	42.4±5.05
VO_2 at VT ($L* min^{-1}$)	0.84±0.259	1.3±0.10	1.1±0.29
HRmax ($b*min^{-1}$)	192.6±11.93	180.2±8.23	186.4±11.66
HR at VT ($b*min^{-1}$)	127.8±29.81	146.4±6.03	137.1±22.52
RERmax	1.0±0.45	1.0±0.37	1.0±0.04

Values represented by mean ± standard deviation.

Table 2 compares HR, VO_2, and RPE measures that were collected during VT, LP, EQ, NEG, and Max. It was found that VO_2 during the NEG stage was significantly greater than the VO_2 measured at both the LP and EQ stage. There were no other significant differences in VO_2 between the stages. HR measured during the NEG stage was significantly greater than HR measured during the other three stages. There was no other significant difference in comparison of HR during the TT. Comparisons between RPE measurements between stages found that RPE during the NEG stage was significantly greater than RPE measured during the other three stages. There was also a significant difference between RPE measured at VT and RPE measured during the LP

stage. There were no significant differences found between LP and EQ stages for VO_2, HR, or RPE. Figures 1-3 display the relationships of VO_2, HR, and RPE during the stages of the TT.

Table 2. Outcome variables at VT, LP, EQ, and NEG stages during the TT.

Variable	VT	LP	EQ	NEG	Max
VO_2 ($L*min^{-1}$)	1.05±0.292	0.81±0.282	0.93±0.276	1.28±0.298*	1.6±0.43
HR ($b*min^{-1}$)	137.1±22.52	128.6±21.06	133.6±23.82	166.9±24.69*	186.4±11.66
RPE	5.2±2.02	3.4±1.18*	4.3±1.21	7.7±1.33*	9.1±1.21

Values represented by mean ± standard deviation.

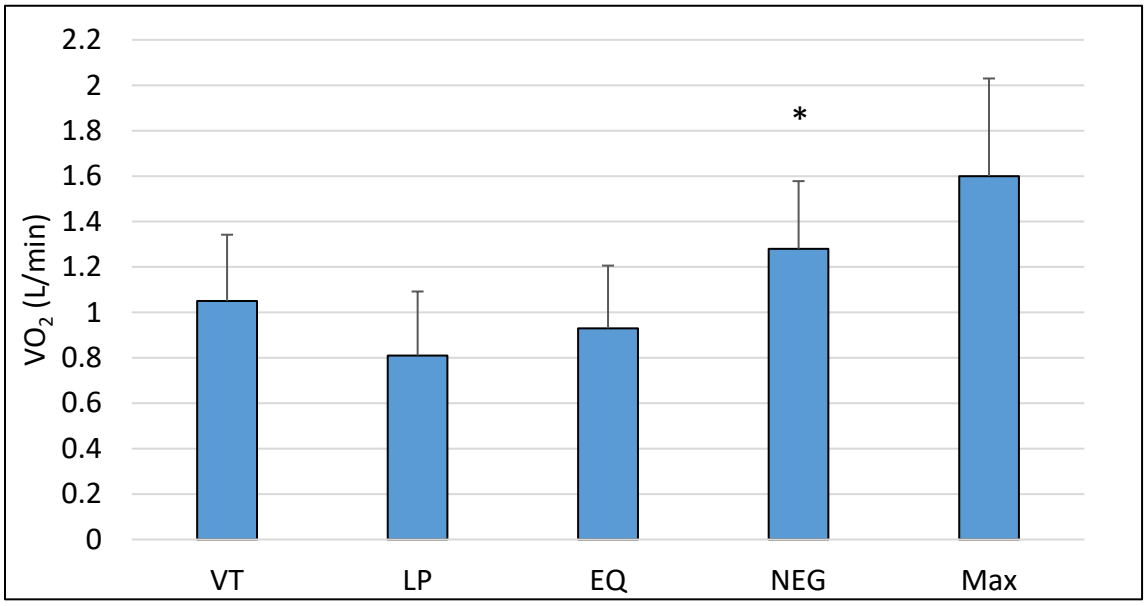

Figure 1. Oxygen consumption compared between VT, LP, EQ, NEG, and Max stages of TT.

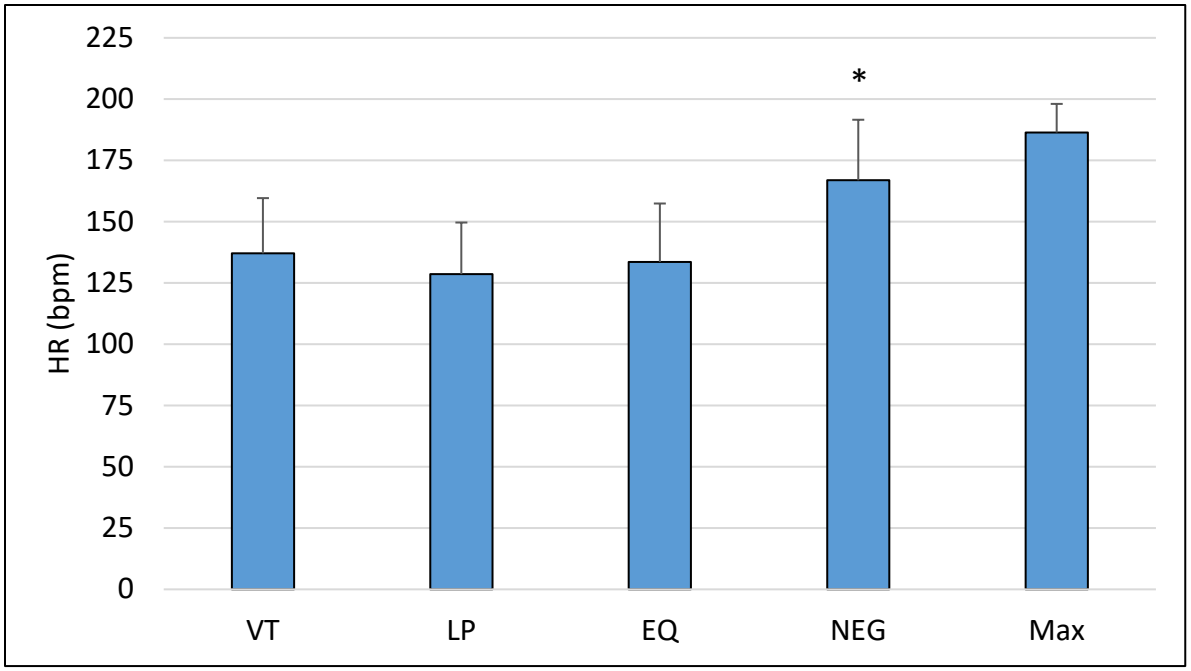

Figure 2. Heart Rate compared between VT, LP, EQ, NEG, and Max stages of the TT.

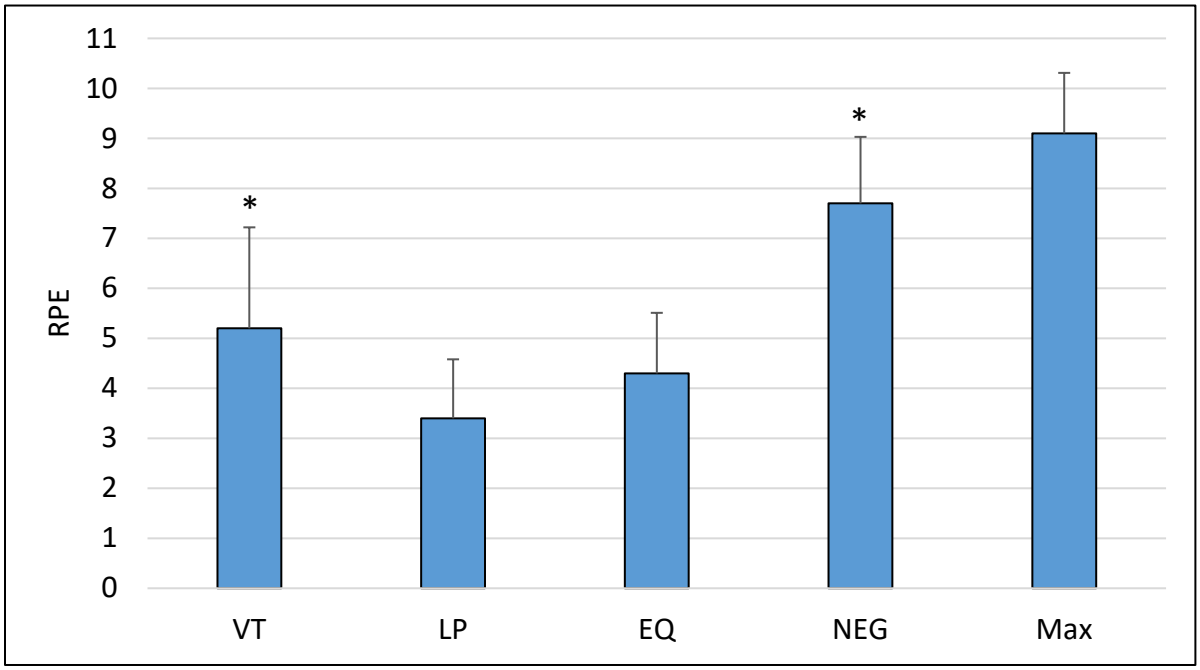

Figure 3. RPE compared between VT, LP, EQ, NEG, and Max stages of the TT.

Figures 4a-4c demonstrate the relationship between gas exchange at VT and gas exchange during the stages of the TT during the VO_2 max test. Similar to VO_2

comparisons, HR at VT was compared to HR at the stages of the TT in Figures 5a-5c. Additionally, in Figures 6a-6c RPE at VT was compared to RPE at the stages of the TT.

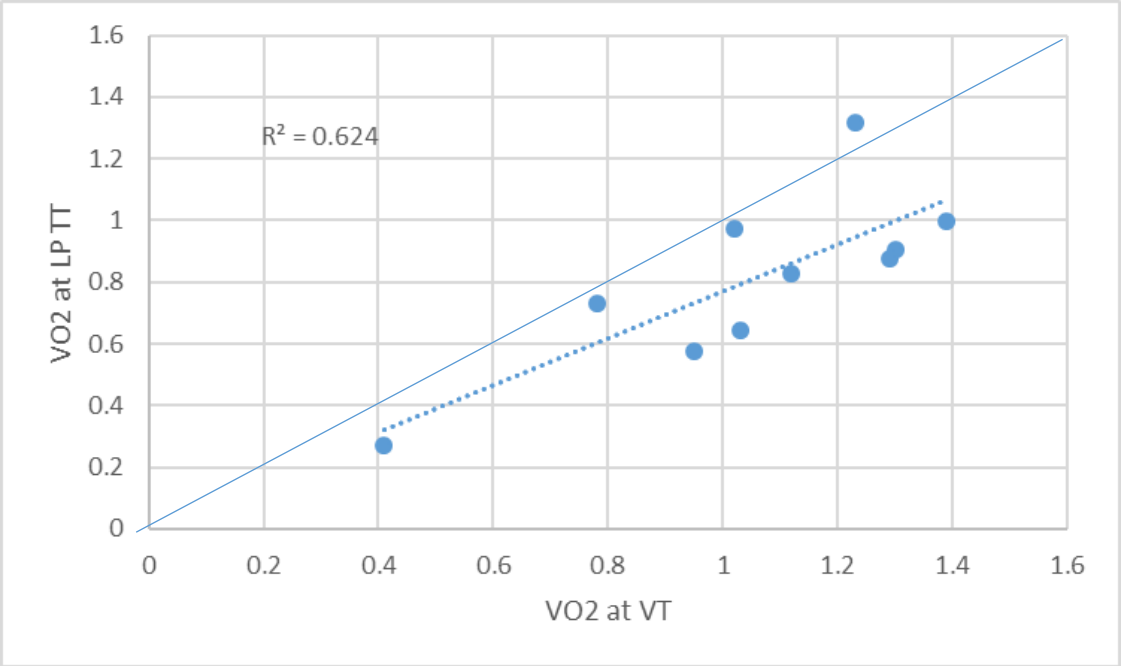

Figure 4a. Gas exchange versus TT oxygen consumption during LP stage.

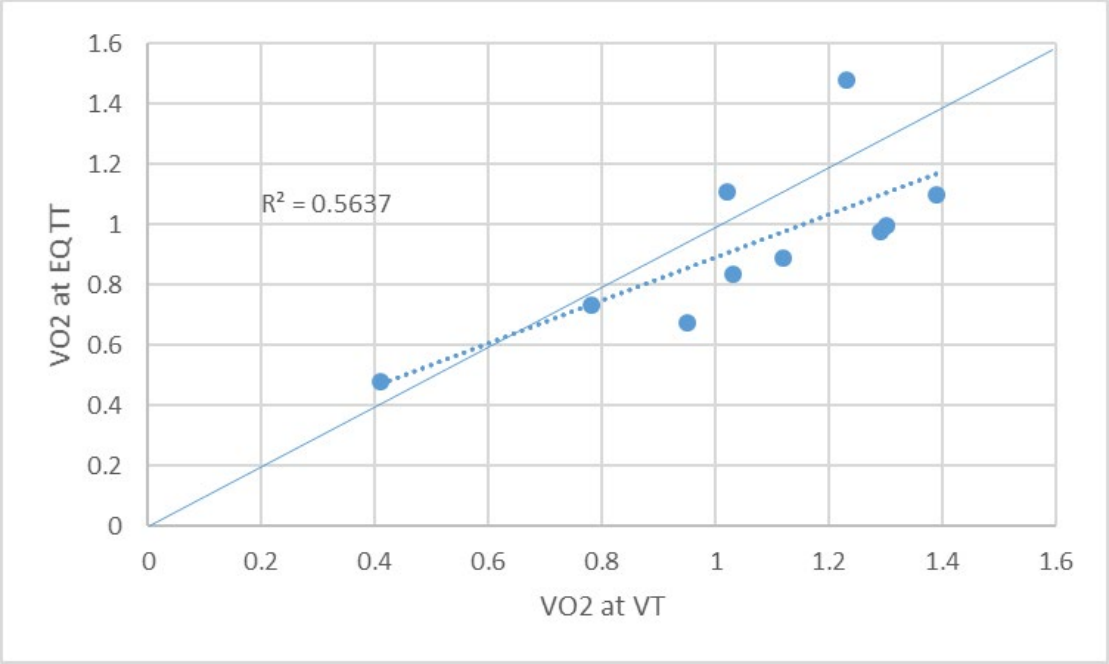

Figure 4b. Gas exchange versus TT oxygen consumption during EQ stage.

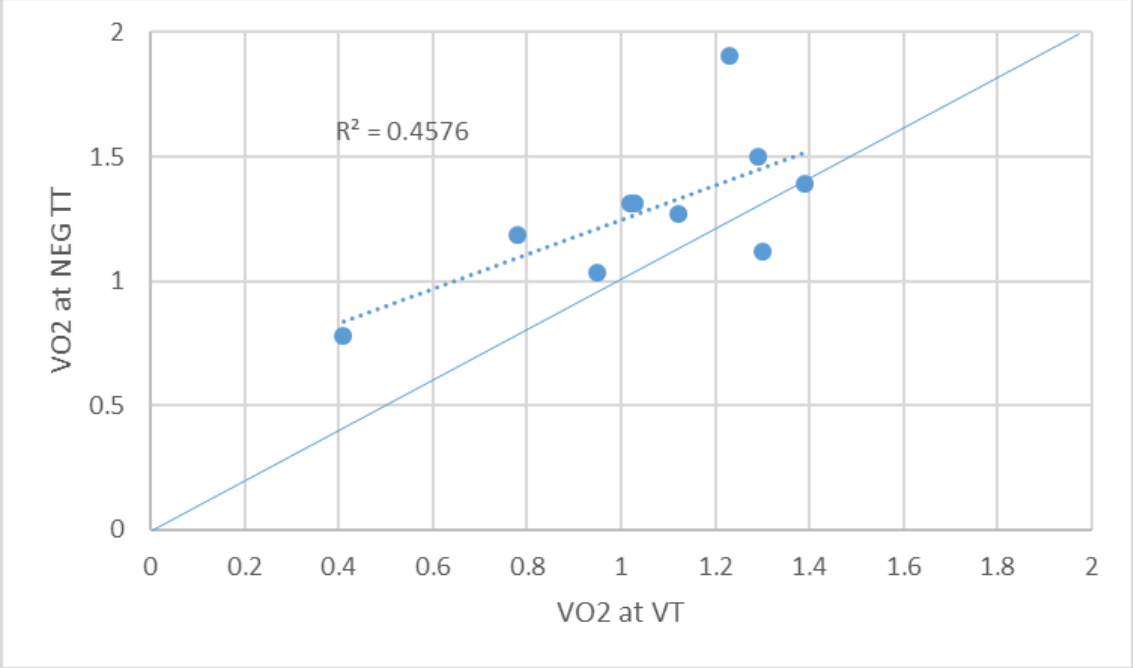

Figure 4c. Gas exchange versus TT oxygen consumption during NEG stage.

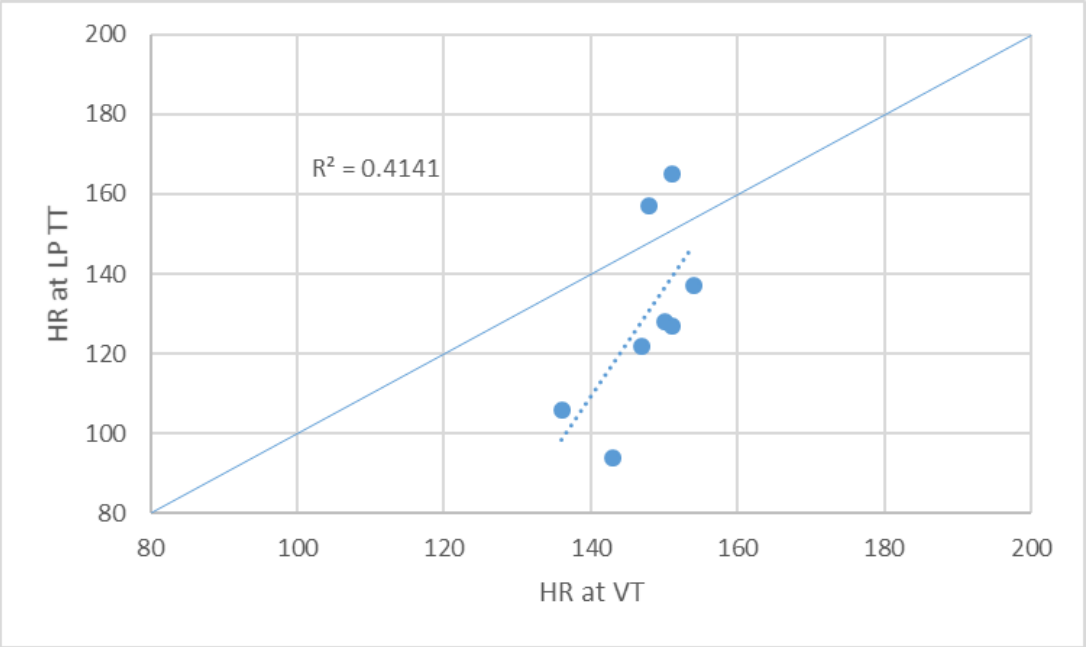

Figure 5a. Gas exchange versus TT heart rate during LP stage.

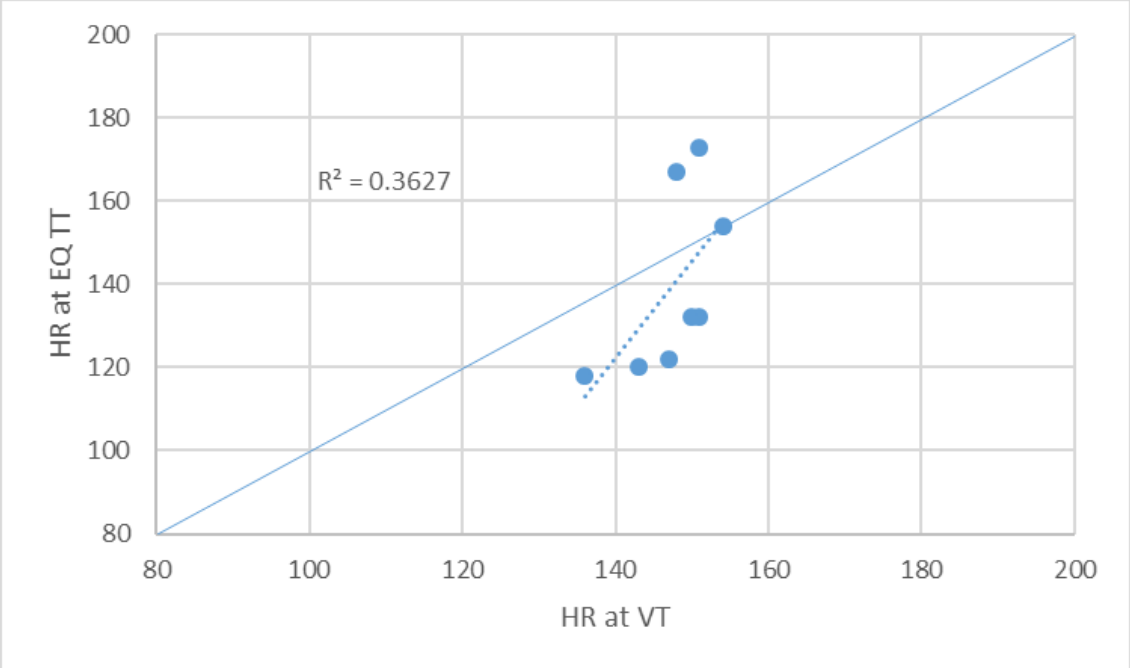

Figure 5b. Gas exchange versus TT heart rate during EQ stage.

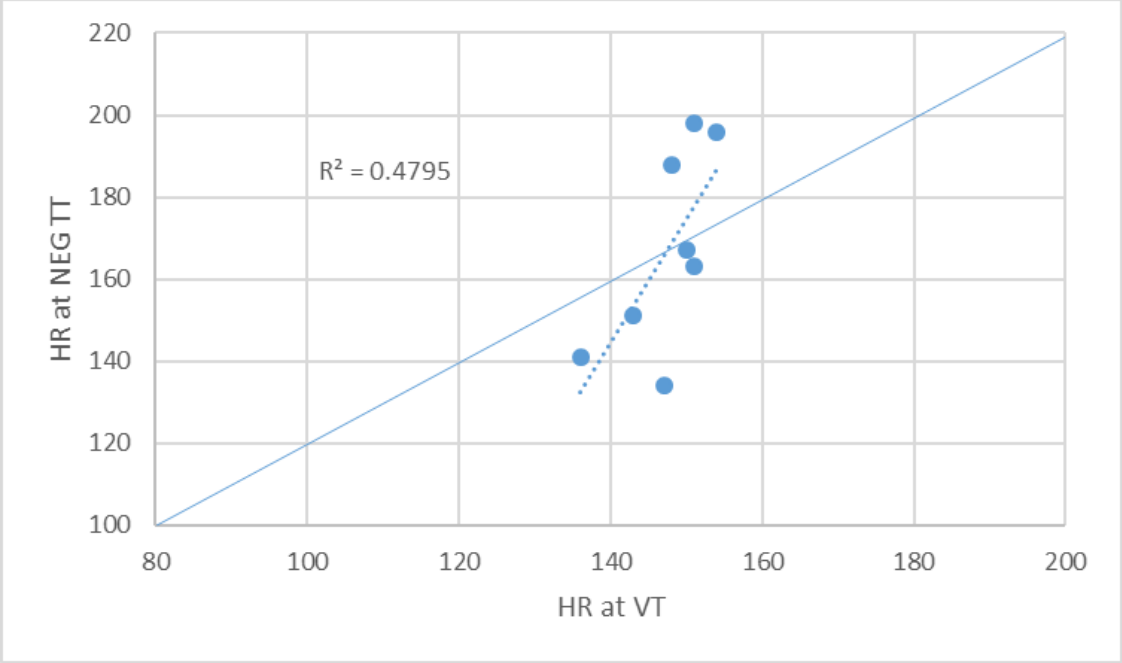

Figure 5c. Gas exchange versus TT heart rate during NEG stage.

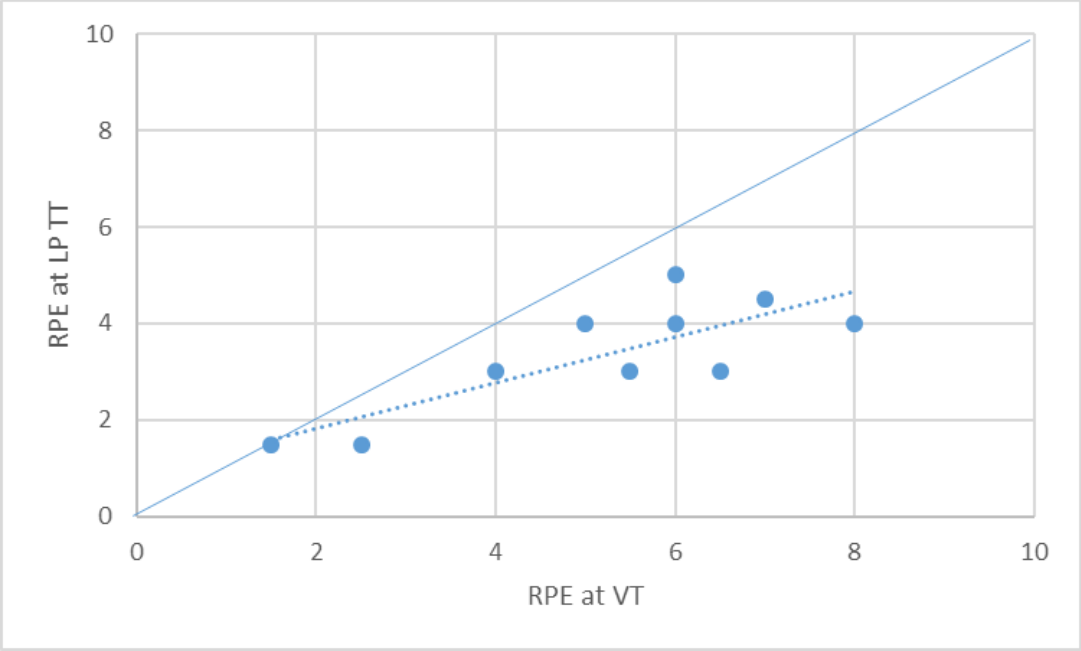

Figure 6a. Gas exchange versus TT RPE during LP stage.

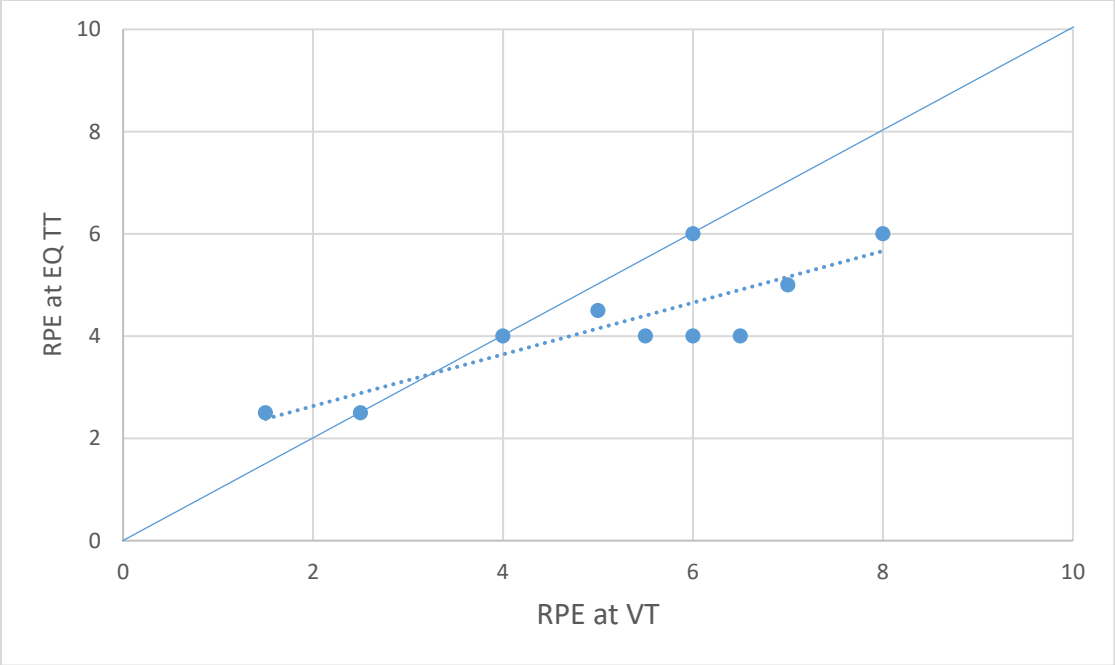

Figure 6b. Gas exchange versus TT RPE during EQ stage.

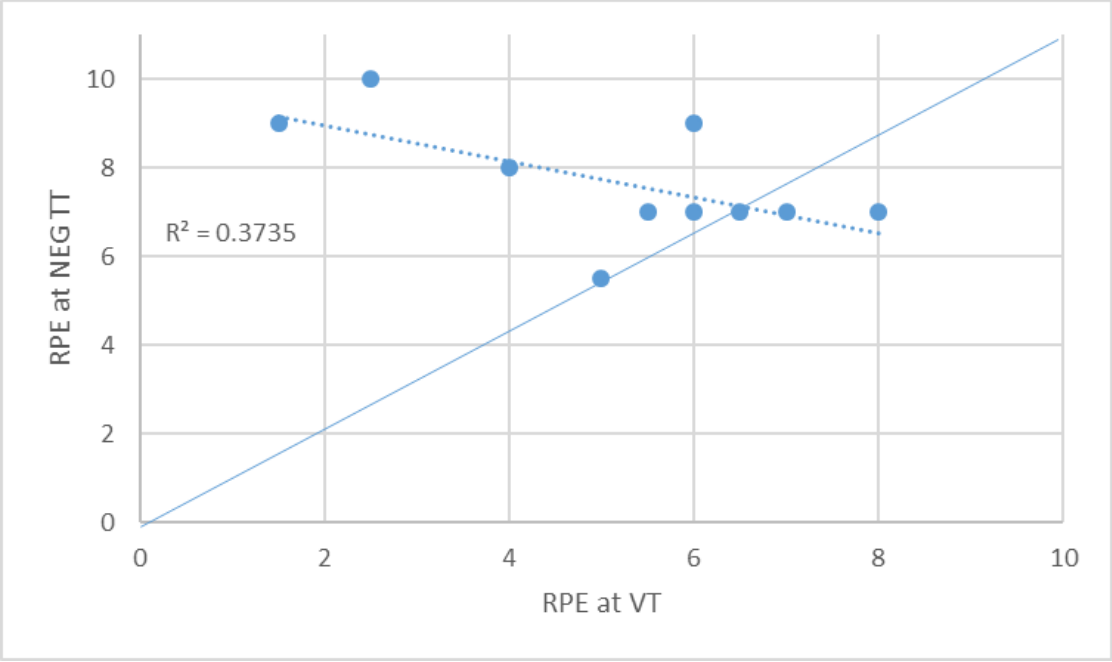

Figure 6c. Gas exchange versus TT RPE during NEG stage.

An example of the protocol versus observed results is displayed in Figure 7. Results were displayed at percentage of VO_2 at VT over time. The observed results came from one subject's results. The written protocol had subjects exercise around 30% of VO_2 at VT for the lower level, then randomly selected workloads above and below 100% of VO_2 at VT would factor into the predictions for being able to speak comfortably. With this individual, predictions followed with the expected observation in every stage of the interval test except for minutes 29 and 30. At those times the subject was predicted to be able to speak comfortably, but was not able to. The subject was at 86% and 91% of percentage of VO_2 at VT during those times.

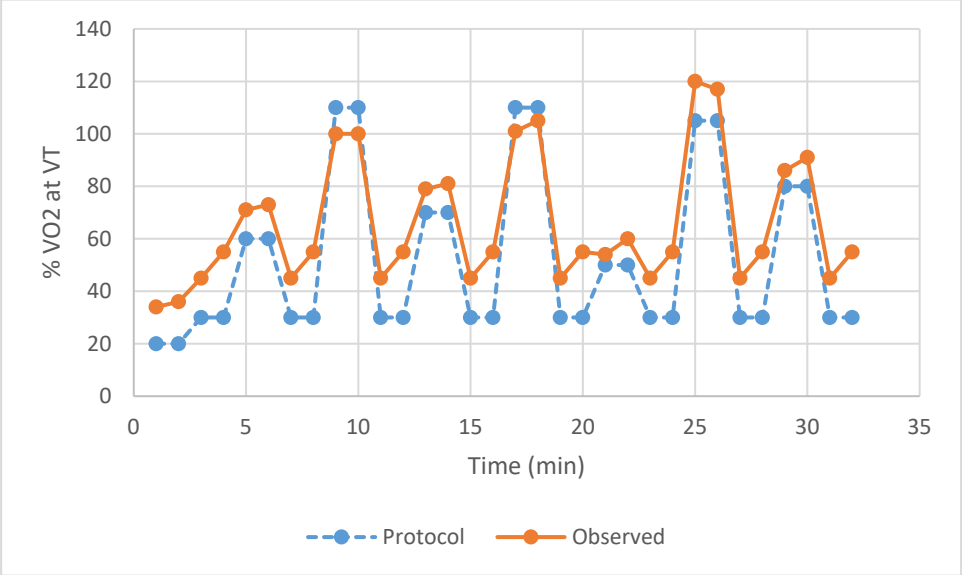

Figure 7. Observed vs expected results of VO_2 at VT during interval based exercise.

After establishing VT in the max test, comparisons were made with the interval test. During the interval based exercise, predictions were made regarding whether subjects were above or below VT based on exercise intensity. Predicted responses for individuals exercising at an intensity below VT compared to observed responses of being

able to speak comfortably were recorded. This showed that 82 of 111 (73.9%) cases were able to speak comfortably at an intensity below VT. When individuals were exercising above VT and were predicted to not be able to speak comfortably, 28 of 39 (71.8%) cases responded with not being able to speak comfortably. Predictions of individuals being able to speak comfortably and not being able to speak comfortably followed with the similar observation respectively in 110 of 150 (73.3%) cases. The majority (72.5%) of incorrect predictions were when the subject was not able to speak comfortably when they were predicted to be able to speak comfortably. The chi square analysis proved to have a significant relationship between observed ability to speak comfortably and predicted ability to speak comfortably.

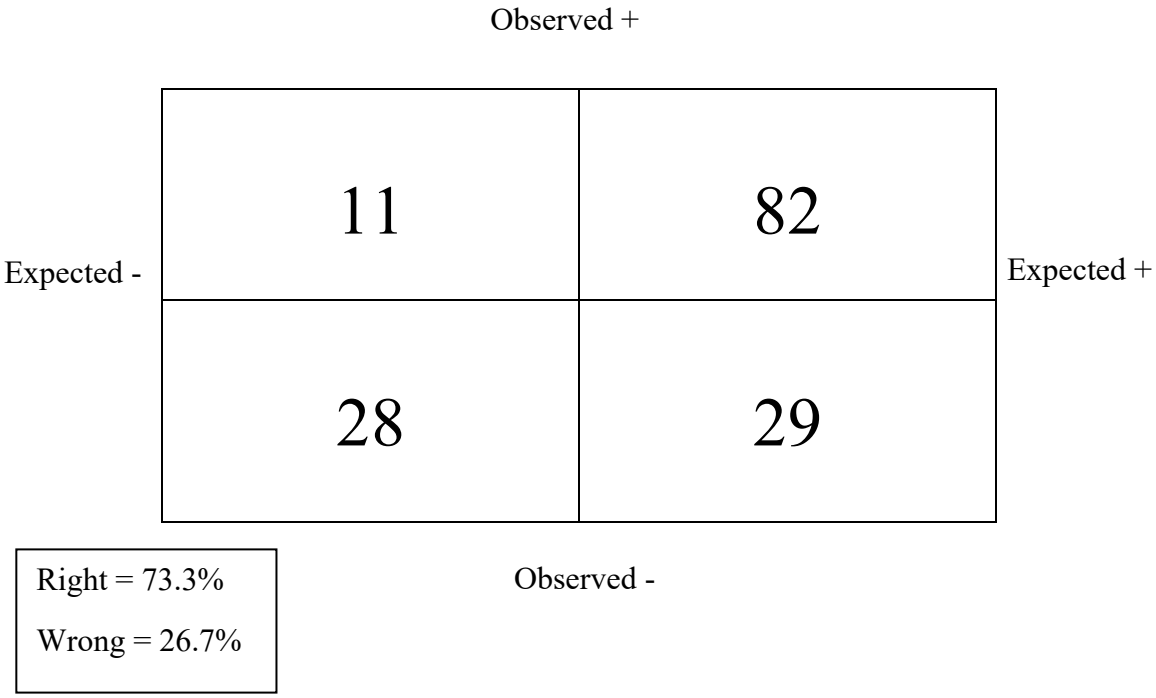

Figure 8. Expected versus observed results of the TT during interval based exercise.

DISCUSSION

The purpose of this study was to extend past Giddings (2018) findings and determine if the TT would be an appropriate measure of intensity during natural exercise patterns in children. Interval based exercise was completed by subjects to be able to compare to the Armstrong et al. (1991) findings that children were completing shorter intense exercise bouts, as well as Foster et al. (2008) results in adults. Results from the maximal exercise test contributed to finding VT using the "V" –slope method. After VO_2 at VT was compared to each stage of the TT, it was found that only the NEG stage had a significant difference from other stages. VO_2 at VT was not significant from other stages of the TT. The speed and grade at which VT occurred were then used during interval based exercise to predict subject's ability to speak comfortably. These results found that 73.3% of the predictions were right after correctly predicting when subjects could speak comfortably or could not speak comfortably.

The RPE results for subjects during the TT found that RPE at VT was significantly greater than RPE at the LP stage. Therefore, subjects were capable of acknowledging their ability to speak comfortably by rating RPE significantly higher at VT compared to when they could last speak comfortably. These results are similar to Giddings (2018) findings with children being able to identify their RPE at or around speed and grade of which VT occurred.

The results from the interval based exercise in children were consistent with the findings from Foster et al. (2008) in adults. Both studies proved that after establishing VO_2 at VT it could be predicted when subjects would be able to speak comfortably or not be able to speak comfortably. However, in contrast to the findings in adults, the majority of incorrect predictions with children were when they were predicted to be able to speak comfortably and were not able to speak comfortably. The speed at which the lower intensity of the interval based exercise for a few subjects was lowered in order to reach an ability to speak before adjusting to a higher intensity. Yet, in some cases that was not enough to assist in their ability to speak. Therefore, the methodology of 2 minute stages for subjects could have been lengthened to allow for a proper recovery in the lower intensity portion of this test. This difference between adults and children may arise from the adults improved ability to adapt to higher and lower workloads compared to children.

The stochastic pattern of exercise in the last test for subjects had randomized workloads occurring above and below VT. Even though this was a similar design as Foster et al. (2008), a different methodology could be established. This design for a future study could consist of a set of percentages of VO_2 around VT. For example, in the interval based exercise, subjects could have their lower intensity set, then increase randomly to 10%, 20%, and 30% above and below VT. Responses could then be compared between subjects at those percentages of VO_2 at VT.

Although this study was a step in the right direction for finding appropriate exercise intensity in children, a new environment could lead to a new study. One limitation that this study faced was having subjects complete the interval based exercise on a treadmill. Walking is one of the most common exercise modalities for the majority

of people, however, this is not how children usually “play”. In the future, it would be beneficial to have children “play” on playground equipment and compare responses of VO_2, HR, and RPE to that of the TT and maximal exercise test.

CONCLUSION

Exercise habits in children are characterized as short and intense bouts (Armstrong et al., (1991), Benham-Deal, (2005)). The interval based exercise designed in this study was meant to replicate those characteristics. Results from the interval based exercise in the children closely matched the results of Foster et al. (2008) in adults. The hypothesis was supported and the TT is an appropriate measure of intensity during natural exercise patterns in children. Further research in exercise habits in children is recommended in order to cover natural exercise patterns, as well as the natural environments in which exercise is performed.

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APPENDIX A

INFORMED CONSENT AND ASSENT

Title: The Talk Test as a Measurement of Exercise Intensity in Children

Why you have 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 when you desire.

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 results show that exercise intensity can be accurately and appropriately measured. Research has not yet been done on children, which has lead 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.

How many people will be in the study, and for how long?

The researchers are looking for between 12 and 20 children, aged eight to twelve, to be involved in this study. While the study may take up to eight months to complete, your participation will span only three hours on three separate occasions. There will be three meetings with the researches, each one lasting one hour.

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

Each participant will meet with 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, wearing the gas-analyzer mask (similar to a scuba mask), and reading the Rainbow Passage for practice. After orientating to equipment, each participant will take part in the Talk Test. This will consist of the child walking on the treadmill, which will increase in speed and grade as the test progresses. Each stage of the test will be three minutes long, with the last thirty seconds requiring the child to read a passage at their reading level. The child will then be asked if they can speak comfortably. The second meeting will involve an exercise test where the child will run until he or she feels like she 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 an interval session. The child will run until they feel like they can no longer run and will then be brought down to two minutes of rest and then back into intervals.

What are the potential risks associated with this study?

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

What are the benefits associated with this study?

There is unlikely any benefit to 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

- ***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 (Investigator or Designee) Date of Presentation

- ***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 (If 18 or older and able to give informed consent) Date of Signature

_____

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:

_____

_____

_____ _____

Signature of Presenter Date of Signature

_____

Printed Name of the Above Signature

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

READING PASSAGES

Reading a-z **Fluency Passage** **Level M**

Name _____ Soccer
Word Count: 105

Soccer is a great game for girls and boys. You play soccer with a soccer ball. You play soccer on a field. There is a net at each end of the field. There are eleven players on a team. 39

During the game, each team tries to get the ball into the other team's net. Each time the ball gets into the net, it is one point. The team with the most points wins. You can kick the ball in with your feet. You can hit the ball in with your head. You can hit the ball in with your knees. Girls and boys everywhere like to play soccer! 108

Number of Errors 1 2 3 4 5 6 Accuracy (%): _____

Reading Rate (Words Per Minute):

50 75 100 125 150 175 200

Reading a-z **Fluency Passage** **Level M**

Name _____

Tip the Pouncer
Word Count: 104

Tip, the cat, heard voices. Someone was coming home, 9
and Tip wanted to play. Anna came through the door. 19
Tip jumped up on Anna. "I will play with you, Tip," said 31
Anna. "But you cannot pounce on me." 38

Dan walked in, and Tip jumped up on him. "Stop it, Tip!" 50
said Dan. "Let's play something else." 56

Tip wanted to pounce. He pounced on a ball of string. He 68
pounced on a pair of socks on the floor. Tip loved to play. 81

But all that playing made Tip sleepy. "Come here, Tip," 91
said Dan and Anna. Tip curled up between them and 101
went to sleep. 104

Number of Errors 1 2 3 4 5 6 Accuracy (%):

Reading Rate (Words Per Minute):

50 75 100 125 150 175 200

Reading a-z **Fluency Passage** **Level M**

Name _____

Mars
Word Count: 100

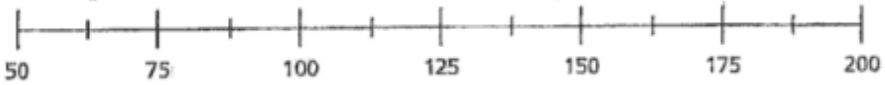
If you get a chance, look at Mars through a telescope. 11
Mars is the fourth planet from the Sun. It is smaller than 23
Earth and has two moons. 28

Mars is called the Red Planet because it is covered with 39
red rocks and dirt. There are even dust storms there! You 50
might also see an ice cap. People think that Mars used to 62
be like Earth. There are signs that there used to be rivers. 74
Now the rivers are dry. 79

People still do not know if there is or was life on Mars. 92
Would you like to make Mars your home? 100

Number of Errors 1 2 3 4 5 6 Accuracy (%): _____

Reading Rate (Words Per Minute):



APPENDIX D

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Introduction

When prescribing exercise, it is necessary to do so in the form of the FITT-VP principle. This principle is outlined by frequency, intensity, time, type, volume, and progression. Most of these outlined headings can be easily understood by a majority of populations. However, one that tends to give exercise participants difficulty is intensity. Intensity can be measured in a multitude of different forms such as percentage of maximal oxygen consumption, percentage of heart rate reserve (%HRR), percentage of maximum heart rate (%HRmax), ventilatory threshold (VT), and respiratory compensation threshold (RCT). All these methods require equipment in order to calculate. For certain populations those complex measurements of intensity do not work due to medications, money, or other physiological factors. In that case, it is necessary to use another measurement of intensity such as Rating of Perceived Exertion (Borg, 1998) or the Talk Test (TT)(Foster, 2008).

None of the schemes of exercise prescription would have been possible if it were not for Grayson (1937) and Karvonen et al. (1957). In 1937, Grayson stated that mountain climbers were to follow the "spoken rule" which meant they were to climb no faster than they could comfortably speak (Goode, 2008). This lead to Karvonen et al. (1957) questioning what the proper exercise intensity was in order to gain exercise benefits, which was found to be at least 50% of maximum heart rate reserve. The 50% of HRR was then met by continuing a pace at which a participant can "hear your breathing" (Goode et al., 1998). That pace also fell below 90% of maximum heart rate, leading to the conclusion that was an appropriate intensity for prescribing exercise. From then on it

became the objective to discover the wide variety of populations the TT could benefit for prescribing exercise intensity.

The Physiological Mechanisms of the Talk Test

The thought of normal ventilation, breathing frequency, and end-tidal carbon dioxide pressure probably never crossed the minds of those mountaineers in the Scottish Highlands in 1932. However, they were smart enough to be able to understand what physiological warning signs the body was sending them. Creemers, Foster, Porcari, Cress, & de Koning (2017) attempted to find what these physiological mechanisms of the TT were. What they discovered was consistent with previous research from Doust & Patrick (1981), as well as Meckel, Rotstein, & Inbar (2002) that a reduction of the volume of carbon dioxide during speech causes an increase in alveolar carbon dioxide pressure. This process then leads to an increased desire to breathe. Normal ventilation at rest is increased in comparison to when speech occurs. Speech suppresses breathing frequency, therefore decreasing ventilation (Creemers, Foster, Porcari, Cress & de Koning, 2017). When the mountaineers decided to slow the rate at which they were climbing because of the "spoken rule" they were decreasing their ventilatory drive and attempting to reach a state closer to normal ventilation that occurs at rest.

How the Study of Speech is Involved within the Talk Test

Many exercisers have experienced the difficulty of producing speech while exercising. The initial reaction when speech becomes difficult is to slow down the pace at

which the athlete is working or decide to not talk. Truong, Nieuwenhuys, Beek, & Evers (2016) performed an analysis on how exactly exercise intensity is detected while running and talking. Speech was monitored while subjects were running in order to grasp the physical stress during activity. Prior to monitoring speech during physical activity was the study performed by Doust & Patrick (1981). Both studies proceeded to record speech during the tests in an effort to analyze the inspirations, expirations, and other possible variables involved in the speech process. Results from the studies established that ventilation is increased in exercise workloads without speech compared to ventilation when workloads involve speech. The reduced ventilation involved with speech production is caused by the reduction in respiratory frequency. Doust & Patrick (1981) also discussed what Otis and Clark (1968) found in the past that speech qualities tend to be louder, higher pitched, and more tremulous. This relates back to the everyday athlete who will begin to either slow their pace or talk less due to the need to breathe more during heavier exercise.

The Talk Test in Relation to Ventilatory Threshold

When the TT is performed on any given population, the usual measurement to compare results to is the VT. VT can represent lactate accumulation as well as the period in which anaerobic systems begin to take over. At this point exercise can no longer be sustained for an extended period of time. While performing the TT, subjects read a passage of 30 to 100 words. When asked “can you speak comfortably?” subjects respond with a “yes”, “yes, but”, or “no” (positive, equivocal, negative stages, respectively). Dehart-Beverley, Foster, Porcari, Fater, & Mikat (2000) found that when the subjects responded with “yes, but” (equivocal) they were very close to the intensity of VT. The

study also concluded that when subjects responded with “no” (negative), they were consistently above VT and close to the RCT. Both the last positive and the equivocal stage fell within the ACSM guidelines for exercise prescription at an average of 88% of peak heart rate (Dehart-Beverley et al., 2000). Recalde et al. (2002) replicated the results in athletes, also finding that the equivocal stage is at or near VT and the negative stage is near RCT.

Prescribing Exercise via the Talk Test

Over time the TT has proven to be consistent in terms of exercise prescription to meet ACSM Guidelines. The “hear your breathing” test was one of the first examples to do so (Goode 1998, 2008). From there more questions arose on how and when to use the TT. Porcari et al. (2018) tested sedentary college-aged individuals using both %HRR and the TT to determine training outcomes. The results of the study demonstrated that the TT fell within ACSM Guidelines for exercise prescription and could be used in place of %HRR. Using %HRR for exercise prescription requires an individual to perform a maximum exercise test. Instead of performing this test and individual could save time and money by using the TT methods for exercise training. When the individual is educated on how the TT is performed, they will be able to perform exercise at an intensity where they can “speak comfortably”. If they continue to the negative stage of the TT past the VT, be unable to maintain exercise performance for a long period of time. It is important to note that exercise benefits from the TT, such as power output and maximal oxygen consumption, stem from training just below the equivocal stage (Porcari, 2018). The equivocal stage represents an intensity where they respond with a “yes, but” to the question “can you speak comfortably?”. The last positive stage is considered the steady

state stage that is appropriate for trained individuals (Jeans et al., 2012). The last positive stage is the stage where the individuals respond with their last "yes" to "can you speak comfortably?". The ability of the TT to produce effective results while being an easily acquired skill to learn, shows that it has many benefits in the world of exercise training.

The Talk Test in Specific Populations

The subjective methods that the TT provides leads to possibilities for numerous populations. One of these populations includes cardiac patients. Voekler et al. (2002) discussed the difficulty with prescribing exercise intensity to cardiac patients because of the changes in medication from testing to exercise training. In this case using percentage of maximum heart rate or heart rate reserve, which are both example of prescribing exercise intensity, would not work because of the heart rate lowering effects of the medications. One of those medications is a ß-adrenergic blocking agent which was taken by 92% of the subjects in one study (Brawner et al., 2006). Therefore, the TT provides a substitute for objective methods of exercise intensity.

Difficulties in cardiac patients also arose when prescribing exercise for those who experience exertional ischemia. The purpose of Cannon et al. (2004) was to determine if the TT would be effective for determining exertional ischemia. Exertional ischemia becomes a key limitation to cardiac patients in their ability to perform exercise at high levels of intensity and the risk of exercise training. The reoccurring issue of finding a heart rate 10 beats per minute lower than the onset of exertional ischemia is found here as well. Especially if the patient completed their exercise testing prior to starting heart rate lowering medications the accuracy of a derived target HR may be suspect. The study that Cannon et al. (2004) performed discovered that the subjective method of the TT showed

that when patients were at the last positive stage of the TT, they had no electrocardiographic evidence of exertional ischemia. This presents a great opportunity to prescribe exercise intensity for exercise at home in cardiac patients when heart rate may not be monitored the proper way.

Now that it was established that the TT worked for prescribing exercise intensity in cardiac patients, there was a need to validate. The study performed by Zanettini et al. (2012) consisted of this validation in patients following myocardial revascularization surgery. Previous research had not looked into the topic of differences in operator-dependent TT results either. As a secondary finding within this study, they had found that there was no issue when the TT was led by different physiotherapists. This provides additional validation that the TT is not operator-dependent.

The Talk Test in Well-Trained Cyclists

Since it became known that the TT was a useful way to prescribe exercise intensity in cardiac patients and other adult populations, there was a desire to look into further populations. Well-trained cyclists were studied performing the TT by Rodriguez-Marroyo, Villa, Garcia-Lopez, & Foster (2013). The study found that the TT is capable of setting an exercise intensity at VT and RCT. Their results confirmed the earlier results of Recalde et al. (2002) on well-trained but less elite cyclists. Since the testing with well-trained cyclists proved to be successful, researchers continued to reach for yet another population. The next population was highly trained competitive male cyclists. Gillespie, McCormick, Mermier, & Gibson (2015) discussed the unreliable use of monitoring intensity through heart rate measures when cardiovascular drift is present. Similar to the study involving well-trained cyclists, the results of this study showed that when the

cyclists were able to speak comfortably they were below VT. When the cyclists were in the equivocal stage of the Talk Test when the early signs of difficulty of speech appear, they were near VT.

Exercise Testing in Children

The TT has been shown to be a useful method of exercise prescription through previous research from special populations from cardiac patients, to athletic populations. However, previous research had not been done on the TT in children until Giddings (2018). Research on exercise in children began in a study done by Armstrong et al. (1991), consisting of continuous heart rate monitoring. The subjects in the study were around 10 years old, in the age range of 8 to 11 years old, which Mahon & Marsh (1993) used to perform maximal oxygen consumption and VT testing on. In Armstrong et al. (1991), the results showed that children do not perform intense exercise for longer than 5 minutes at a time. Based on those findings, along with results from the TT in children, Giddings (2018) suggested that future research look at the TT as a basis for interval exercise prescription.

Talk Test in Interval Based Exercise

When children exercise they seem to do so for a shorten period of time at an intense pace. A possible sprint here or there to run to the slide or jungle gym. There is a need to discover more on how children respond to the TT. Based on Giddings (2018) future research possibilities of the TT are more natural exercise patterns. Therefore, interval based exercise is a great possibility for research. In Foster et al. (2008), the TT was performed in interval based exercise in well-trained subjects. After identifying the

workload where VT was defined, intensity was adjusted above and below VT. They were then able to predict whether or not subjects would be at or above VT based on the workload being performed. The most common errors from this study were from participants being able to "speak comfortably" when they were expected to not be able to "speak comfortably". This form of testing will be the next step in comparing whether or not interval based exercise in children follows the same responses as adults.

Conclusion

The TT can be used as a simple form of exercise prescription that can span from populations including athletes, sedentary individuals, cardiac patients, and now children. When other forms of intensity measurement are out of reach due to cost or equipment availability, the TT can be a great substitute. "Can you speak comfortably?" or "hear your breathing" are two phrases to follow in order to stay at or below VT. When taking notice of the difficulty to either speak or breathe an individual can manage exercise intensity that stays within ACSM guidelines while acquiring numerous cardiorespiratory fitness benefits.

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