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THE TALK TEST AS A MEASUREMENT OF EXERCISE INTENSITY IN CHILDREN

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Peter Giddings

College of Science and Health
Clinical Exercise Physiology

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THE TALK TEST AS A MEASURMENT OF EXERCISE INTENSITY IN CHILDREN

By Peter Giddings

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.

Carl Foster, Ph. D.
Thesis Committee Chairperson

3/26/18
Date

John Porcari, Ph. D.
Thesis Committee Member

3/26/18
Date

Debra Sazama, Ed. D.
Thesis Committee Member

3/26/18
Date

Thesis accepted

Meredith Thomsen, Ph.D.
Graduate Studies Director

5-7-18
Date

ABSTRACT

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The Talk Test (TT), used to prescribe exercise intensity based on subjective measurements, has been widely studied, but never in children. This study evaluated the relationship between the TT and physiological changes, to determine if the TT is an appropriate measurement of exercise intensity in children. Thirteen healthy children were recruited for this study. The first exercise test was the TT, in which subjects read a passage containing over 100 words, and responded whether they could speak comfortably. The second test measured the maximal exercise capacity while also measuring gas exchange, which was used to identify each subject's ventilatory threshold (VT). Results from the last positive (LP), equivocal (EQ), and negative (NEG) stages of the TT were compared to the subject's VT. There were significant differences ($p<0.05$) between VO_2 at VT and at the LP stage, in HR at VT and HR at the EQ and NEG stages, and a significant difference between RPE at VT and the LP and NEG stages. We concluded that subjects should exercise at a point where it is difficult for them to speak, below their VT. Thus, the TT is a valid tool to subjectively measure exercise intensity in children.

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INTRODUCTION

An ongoing argument regarding exercise prescription centers on the type of measurement of exercise intensity is more effective, absolute measurement or a subjective measurement. Absolute exercise intensity refers to the absolute heart rate (HR) or oxygen consumption (VO_2), often abbreviated as the maximal metabolic equivalent (MET's) of a task. Once the maximal MET's of an individual are measured, percentages can be determined for the optimal training zone for that individual. However, maximal exercise tests can be expensive to perform and the equipment that is needed is not always available outside of a laboratory setting. Thus, they are rarely done, and why subjective measurements of exercise intensity have come to be preferred.

One type of subjective exercise intensity measurement is the Talk Test (TT). The TT is a subjective exercise test that asks the simple question, "can you speak comfortably?" while a subject is exercising. Goode, Mertens, Shaiman, and Mertens (1998) began with the idea of "hearing ones breathing" while exercising, and it was concluded that at the point where one could first "hear their breathing", individuals were exercising at intensities between 60-90% heart rate reserve (HRR). At this point of "hearing their breathing", individuals were also exercising at their approximate ventilatory threshold (VT). It was later concluded by Creemers, Foster, Porcari, Cress, and de Koning (2017) that breathing frequency increases due to the muscular demand of the increase in exercise intensity. However, breathing frequency decreases during speech.

This leads to retention of CO_2, and subsequent increase in the partial pressure of CO_2, as ventilation is suppressed during speech. This means that as exercise intensity increases towards VT, the increased ventilatory drive overrides the demands of speech, creating discomfort while speaking.

Earlier studies by Dehart-Beverley, Foster, Porcari, Fater, and Mikat (2000) studied the TT and compared the results to maximal exercise tests in healthy adults. It was discovered that during the last positive (LP) stage of the TT, individuals were slightly below their VT. Similarly, the equivocal (EQ) stage of the TT, when the individuals could talk but speech was "no longer fully comfortable", approximated the VT. If the individuals could not speak comfortably (NEG), they were typically exercising above their VT. In a similar study, it was also concluded that the NEG stage of the TT intensity approximated the respiratory compensation threshold (RCT) (Recalde et al., 2002). Lastly, Schroeder, Foster, Porcari, and Mikat, (2017) concluded that longer passages (>90 words) of the TT more accurately predicted VT and RCT than shorter passages (~30 words).

The TT has been validated to estimate exercise intensity (Foster et al., 2008), as well as being a tool for creating exercise prescriptions (Woltmann et al., 2015). The TT has been validated in multiple populations, such as healthy, trained adults (Norman, Kracl, Parker, & Richter, 2002), untrained adults (Foster et al., 2009), and athletes (Gillespie, McCormick, Mermier, & Gibson, 2015). The TT has also been validated in special populations, such as patients with cardiovascular disease. Voelker et al. (2002) demonstrated the validity of the TT in patients in cardiac rehabilitation programs, and found that the TT appropriately measures exercise intensity related to VT and RCT.

Specific cardiac populations (Brawner et al., 2006) and post-revascularization patients (Zanettini et al., 2013), also recorded accurate exercise intensities based on the TT. Lastly, the TT accurately measured exercise intensity in patients just prior to the development of exertional ischemia (Cannon et al., 2004).

While less common, exercise tests have been performed on children in the past. Cunningham, Van Waterschoot, Paterson, Lefcoe, and Sangal, (1977), along with Mahon and Marsh (1993) studied physiological responses in children during maximal exercise. While not all of the children's tests demonstrated a plateau in heart rate with increased intensity, maximal exercise was determined via other physiological and subjective responses. It was identified that the Rating of Perceived Exertion (RPE) scale was understood by children, and could work as a subjective measurement of exercise intensity. A modified scale not only included numbers based zero to ten, but also included colors, pictures, descriptions, and phrases to help the child understand their perceived workload (Nye & Todd, 2013). This scale, which combines the RPE and the OMNI perceived exertion scale, created specifically for children (Utter, 2002), has demonstrated that children can read and understand how hard they are exercising in a subjective way.

This study aims to determine whether the TT can define an exercise intensity that is appropriate for children. The hypothesis was that the TT will accurately predict a child's VT, which will occur at approximately the EQ stage of the TT, where speech is becoming challenged. The last positive stage of the TT, subsequently, was hypothesized to be below the VT, while the negative stage of the TT was hypothesized to be above the child's VT.

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. Additionally, all subjects completed the Physical Activity Readiness Questionnaire (PAR-Q) and an Exercise History Questionnaire to determine any contraindications or limitations to participate in exercise. Sixteen children were recruited for this study. Children were aged from eight to twelve years old, and were either the children of university staff, or children that were known by university staff.

Protocol

The subjects came to the exercise laboratory on two separate days. The first day was for characteristic information collection, orientation to the laboratory, a habituation period to orient the children to the treadmill, and to complete an exercise test using the TT. The second laboratory visit was to complete a maximal exercise test on the treadmill with measurement of respiratory gas exchange. There was at least 24 hours between the first and second visit to the lab. HR was assessed during both tests via radio telemetry (Polar Vantage XL, Polar USA, Lake Success, New York). The RPE scale (Nye & Todd, 2013) was utilized to assess the exertion of the child during the exercise tests. The exercise tests were completed on a motorized treadmill. The protocol followed the modified Balke protocol for graded exercise testing. This allowed the children to begin at a slower speed, and since speed stayed constant, exercise intensity increased via grade increases.

The Talk Test

To measure the TT, during the last 30 seconds of each stage the child read a short passage. The passage was selected by the child, based on the appropriate reading level, with each passage being longer than 100 words (Schroeder, Foster, Porcari, and Mikat, 2017). After each passage, the children were asked if they "can speak comfortably". Answers that indicated they could still speak comfortably were documented as (+), when they were not unequivocally comfortable speaking was documented as (+/-), and when they were unable to speak comfortably was documented as (-). Additionally, there were subjective measurement, by the researcher, on the ability of the child to speak comfortably, using the same documentation. These measurements, though, were blinded to the child until after the test. HR and RPE were obtained during the last 10 seconds of each stage.

The Maximal Test

The maximal exercise test was performed to collect data regarding the child's maximal oxygen uptake (VO_2), VT, and RCT. Completion of the maximal exercise test was based maximal RPE indicating that the child could no longer continue. Gas analysis was measured by open-circuit spirometry (Moxus Metabolic Cart System, AEI Technologies, Pittsburg, Pennsylvania), calibrated using 3.0 L syringe and known gas concentrations. VT was identified via the "V"-slope method, as well as the Ventilatory

Equivalents Method (Beaver, Wasserman, & Whipp, 1986). The results of the maximal exercise test were then compared to the TT.

Statistical Analysis

Data were analyzed using analysis of variance (ANOVA). Post-hoc comparisons when justified by ANOVA were performed using the Tukey post-hoc test to compare the VO_2, HR, and RPE at the VT with similar measurements at the LP, EQ, and NEG stages of the TT. Interclass correlations were used to compare the relationship between HR, VO_2, and RPE at VT verses the LP, EQ, and NET stages of the TT. A p-value of <0.05 was accepted as statistically significant. Data was presented as mean $\pm$ standard deviation (SD).

RESULTS

At the time of data collection, the number of children was N=16. However, three children completed only the TT, so analysis was performed using N=13 (7 boys, 6 girls).

Descriptive statistics are presented in Table 1.

Table 1. Descriptive characteristic of the children.

Variable	Boys (n=7)	Girls (n=6)	Total (N=13)
Age (years)	9.4±1.27	9.7±1.51	9.5±1.33
Height (cm)	140.8±7.97	142.2±12.05	141.4±9.63
Weight (kg)	40.4±13.55	34.8±10.41	37.8±12.06
VO_2max ($L*min^{-1}$)	1.85±0.735	1.31±0.528	1.60±0.683
VO_2max ($mL*kg^{-1}*min^{-1}$)	45.9±11.61	36.3±9.59	41.5±11.42
VO_2 at VT ($L*min^{-1}$)	1.24±0.636	0.61±0.242	0.95±0.580
HRmax ($b*min^{-1}$)	183±12.7	169±15.3	177±15.0
HR at VT ($b*min^{-1}$)	147±16.4	122±9.6	136±19.0
RERmax	0.99±0.06	0.98±0.06	0.98±0.06

Data comparing HR, VO_2, and RPE at VT, the LP stage, the EQ stage, and the NEG stage are presented in Table 2. There was a significant difference between the VO_2 at the LP stage and the VO_2 measured at VT. There was no significant difference between the VO_2 at the EQ stage and the NEG stage verses VT. Additionally, there were significant differences between the HR at the EQ stage, the NEG stage and HR at VT. There was no significant difference between the HR at the LP of the TT. Lastly, there was a significant difference between the RPE at VT and the RPE at the LP stage and the

NEG stage of the TT. No significant difference was detected between the RPE at VT and the RPE at the EQ stage of the TT. These relationships are depicted in Figures 1-3. Bar measurements represent mean values, while error bars represent standard error.

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

Variable	VT	LP	EQ	NEG	Max
VO_2 ($L*min^{-1}$)	0.95±0.580	0.71±0.284*	1.04±0.427	1.17±0.504	1.60±0.683
HR ($b*min^{-1}$)	136.0±19.0	126.3±12.91	152.5±15.40*	160.5±16.28*	177±15.0
RPE	5.2±2.70	3.6±1.32*	6.2±1.30	7.2±1.09*	9.7±0.3

*Statistical difference compared to VT ($p<0.05$).

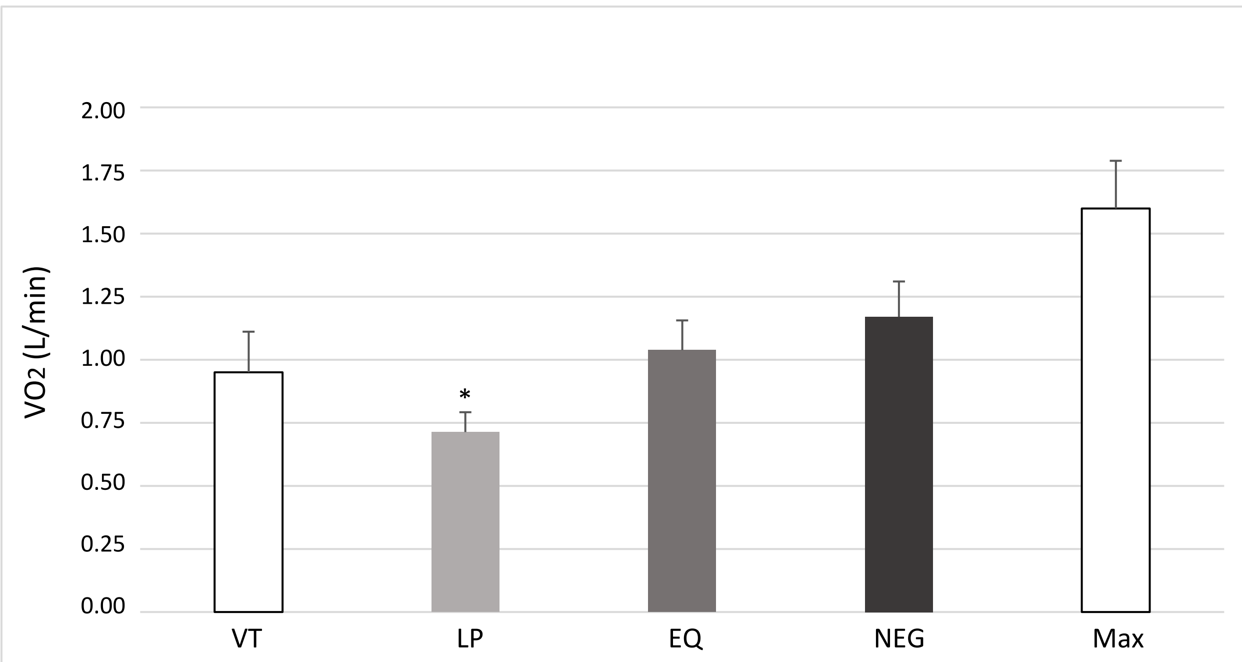

Figure 1. Oxygen consumption compared between VT and LP, EQ, and NEG stages of the TT.

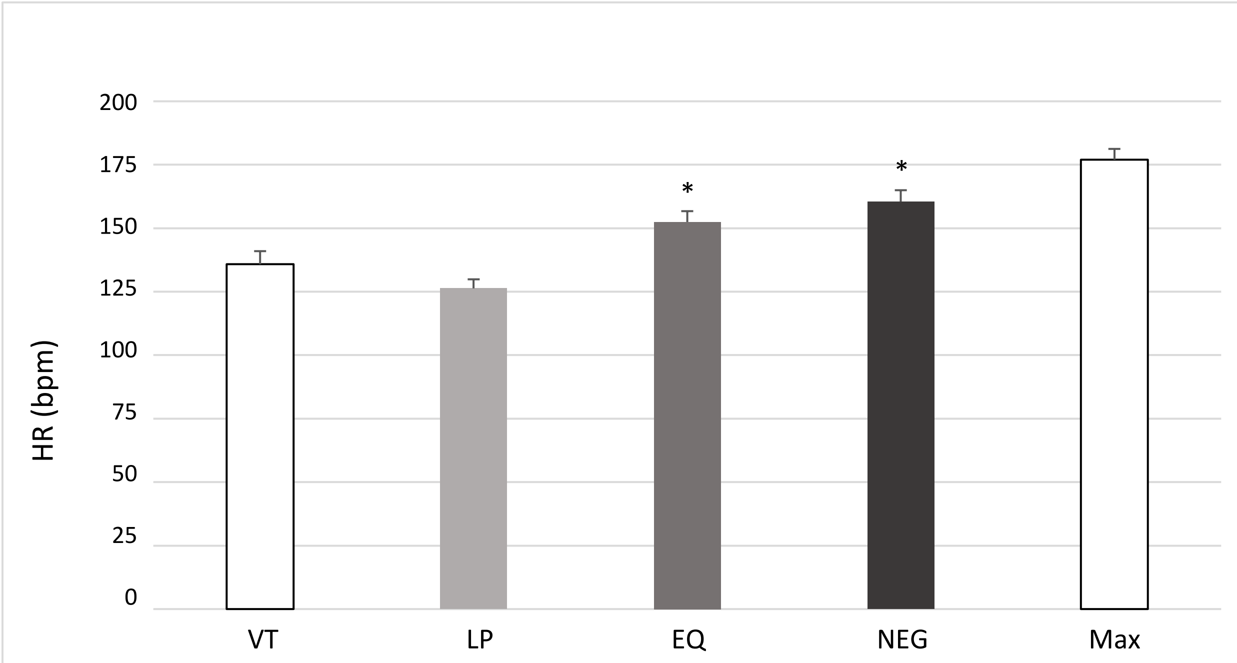

Figure 2. Heart rate compared between VT and LP, EQ, and NEG stages of the TT.

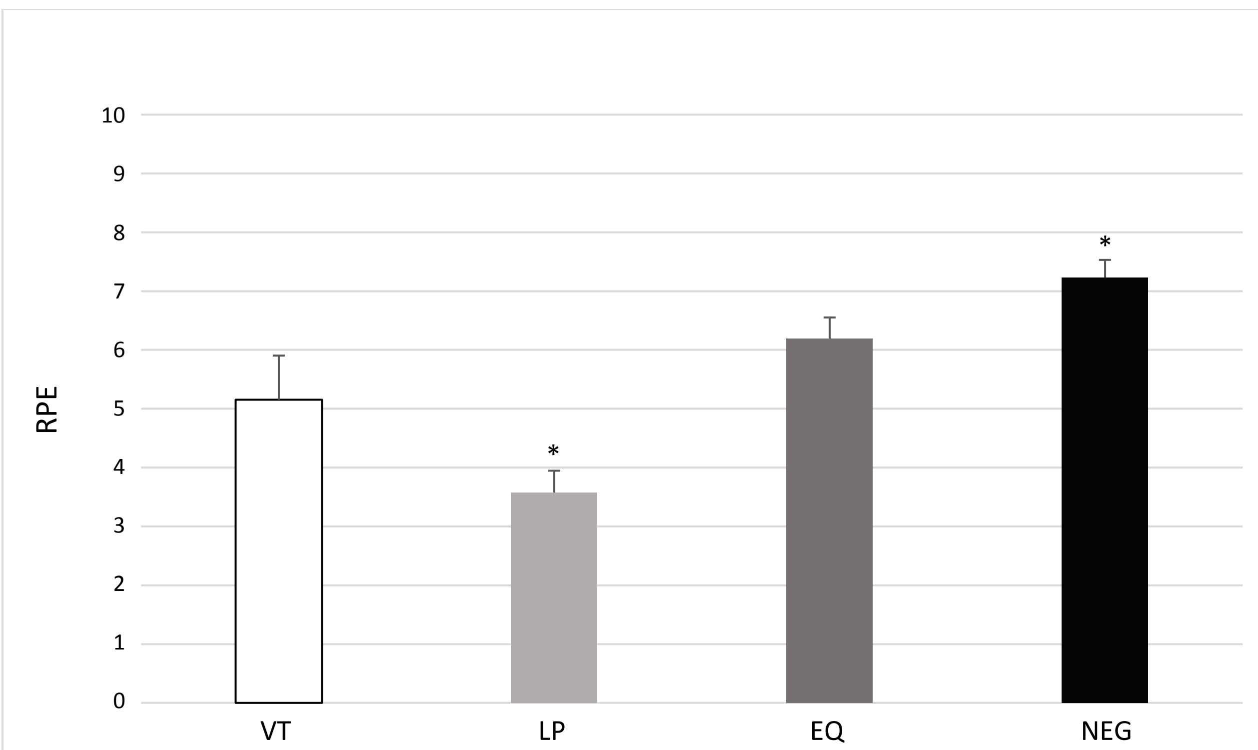

Figure 3. RPE compared between VT and LP, EQ, and NEG stages of the TT.

The individual relationship between the VO_2 at VT and the VO_2 at the LP (R=0.62), EQ (R=0.84), and NEG (R=0.83) stages of the TT are presented in Figure 4. The data was most evenly scattered around the EQ and NEG verses TT response.

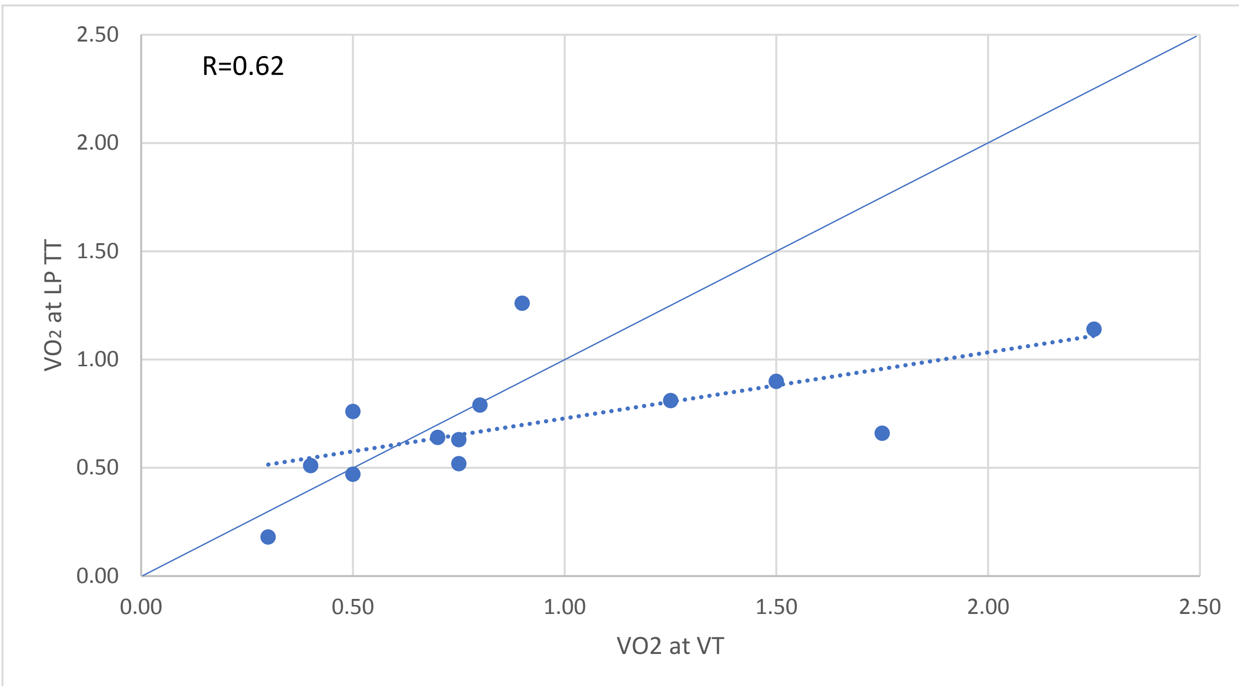

Figure 4a. Gas exchange verses TT oxygen consumption during LP stage.

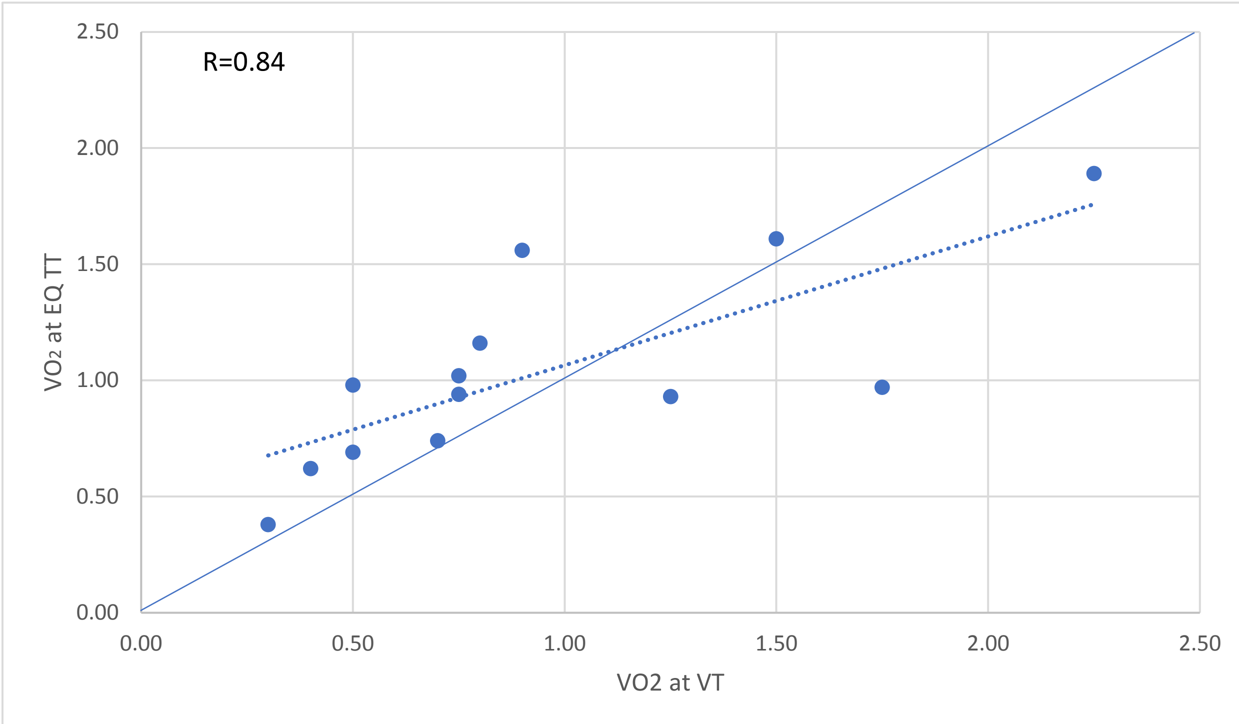

Figure 4b. Gas exchange verses TT oxygen consumption during EQ stage.

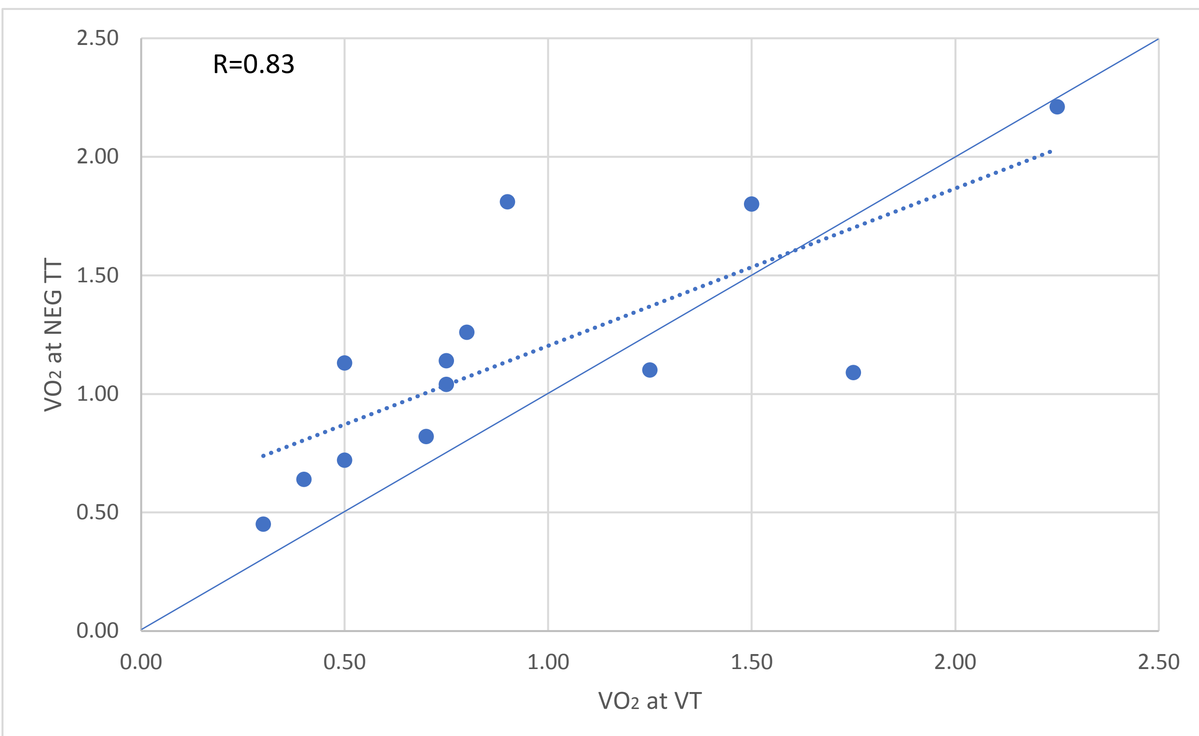

Figure 4c. Gas exchange verses TT oxygen consumption during NEG stage.

The relationship between the HR at VT and the HR at the LP (R=0.45), EQ (R=0.38), and NEG (R=0.23) stages of the TT are presented in Figure 5. The data was most closely scattered around the LP verses TT response, although the HR during the TT stages matched the HR at VT much less well than the VO_2 data.

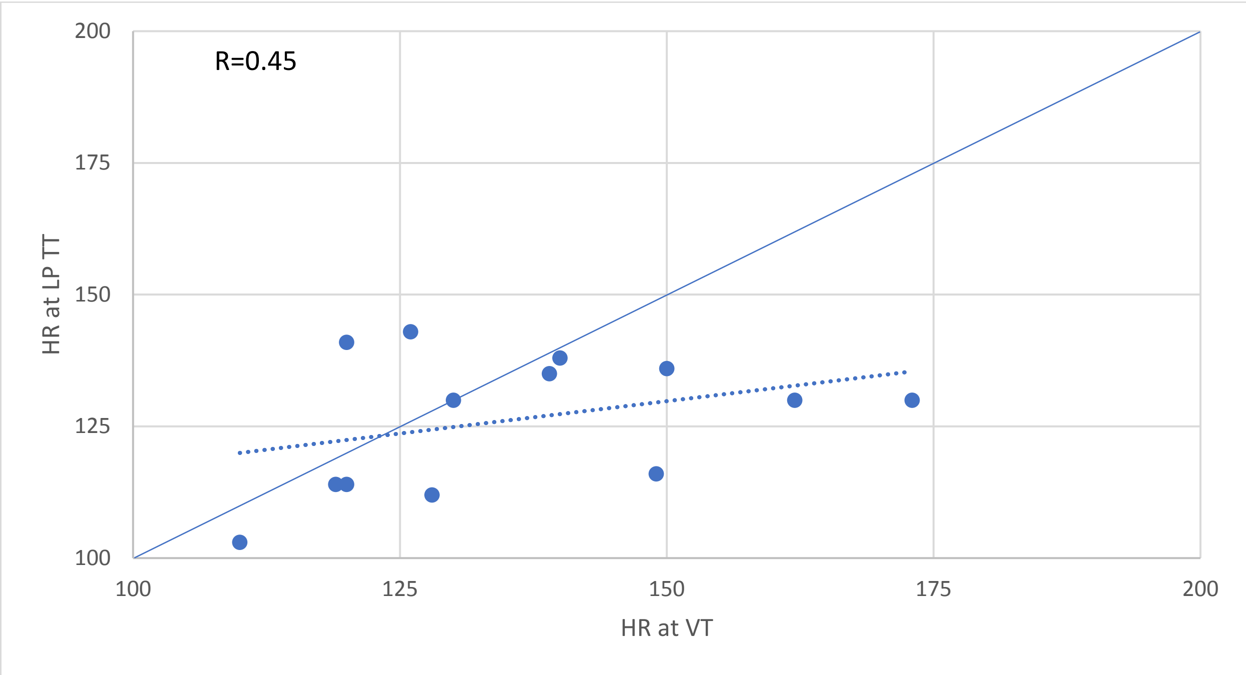

Figure 5a. Gas exchange verses TT heart rate during LP stage.

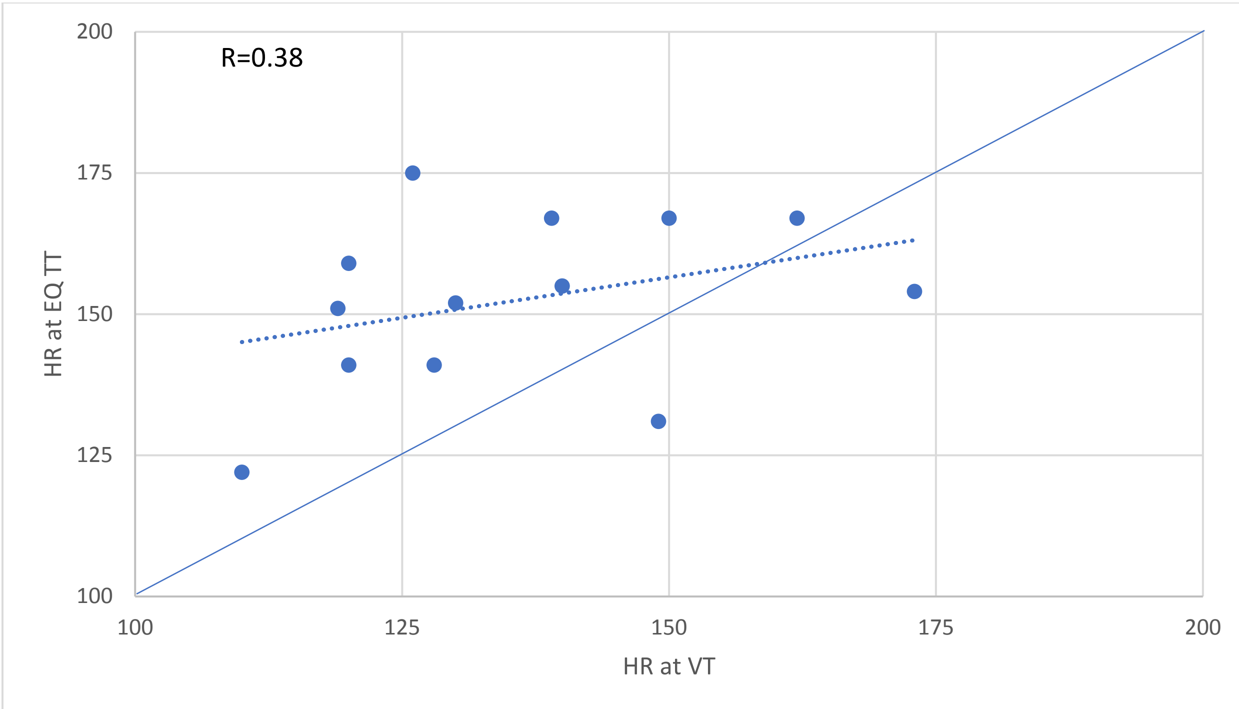

Figure 5b. Gas exchange verses TT heart rate during EQ stage.

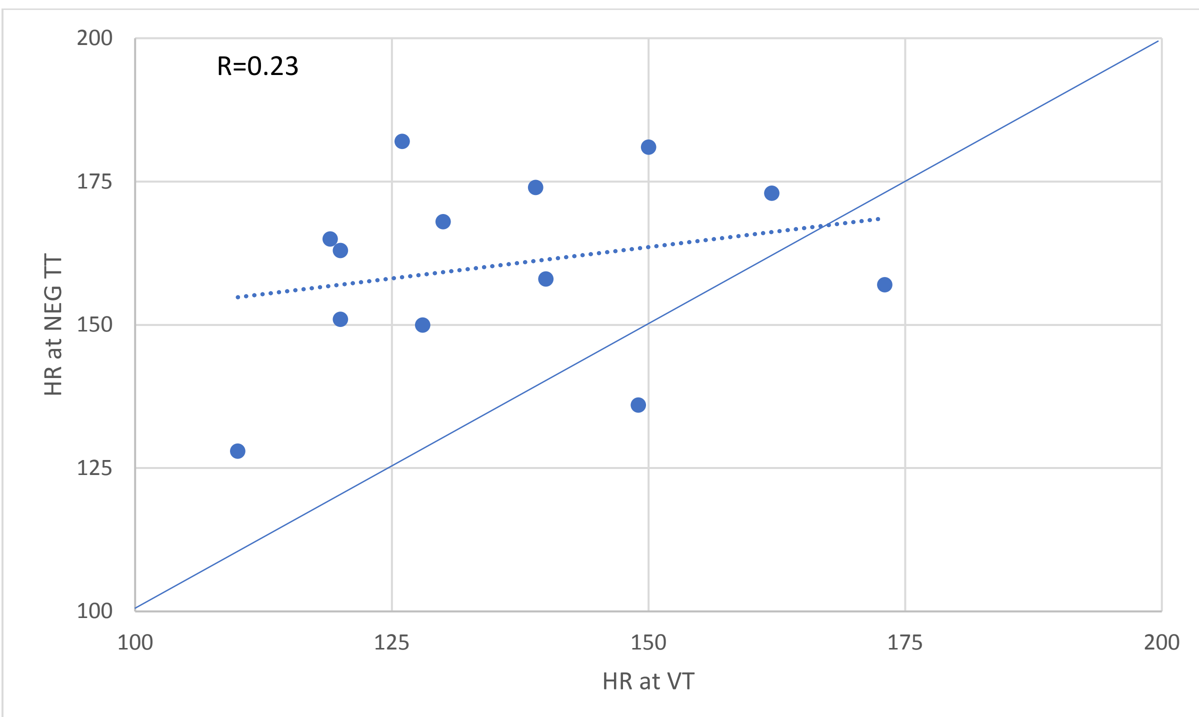

Figure 5c. Gas exchange verses TT heart rate during NEG stage.

The individual relationship between the RPE at VT and the RPE at the LP (R=0.42), EQ (R=0.65), and NEG (R=0.49) stages of the TT are presented in Figure 6. The data was most evenly scattered around the EQ verses RPE response.

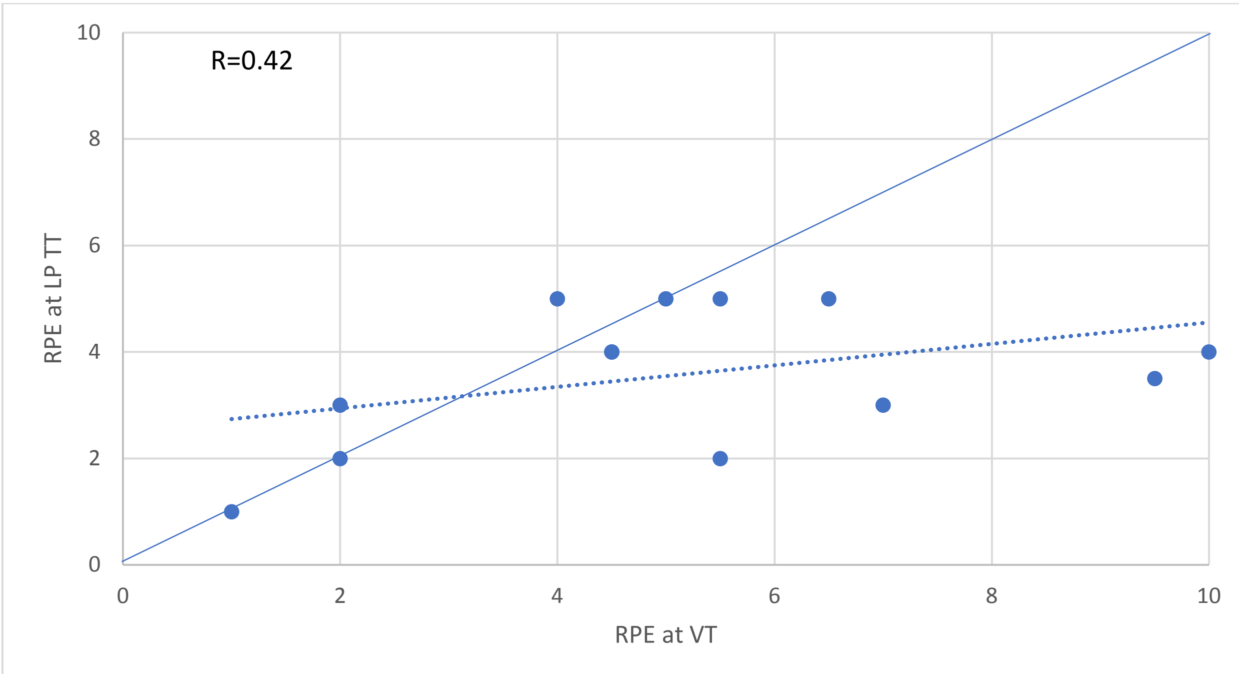

Figure 6a. Gas exchange verses TT RPE during LP stage.

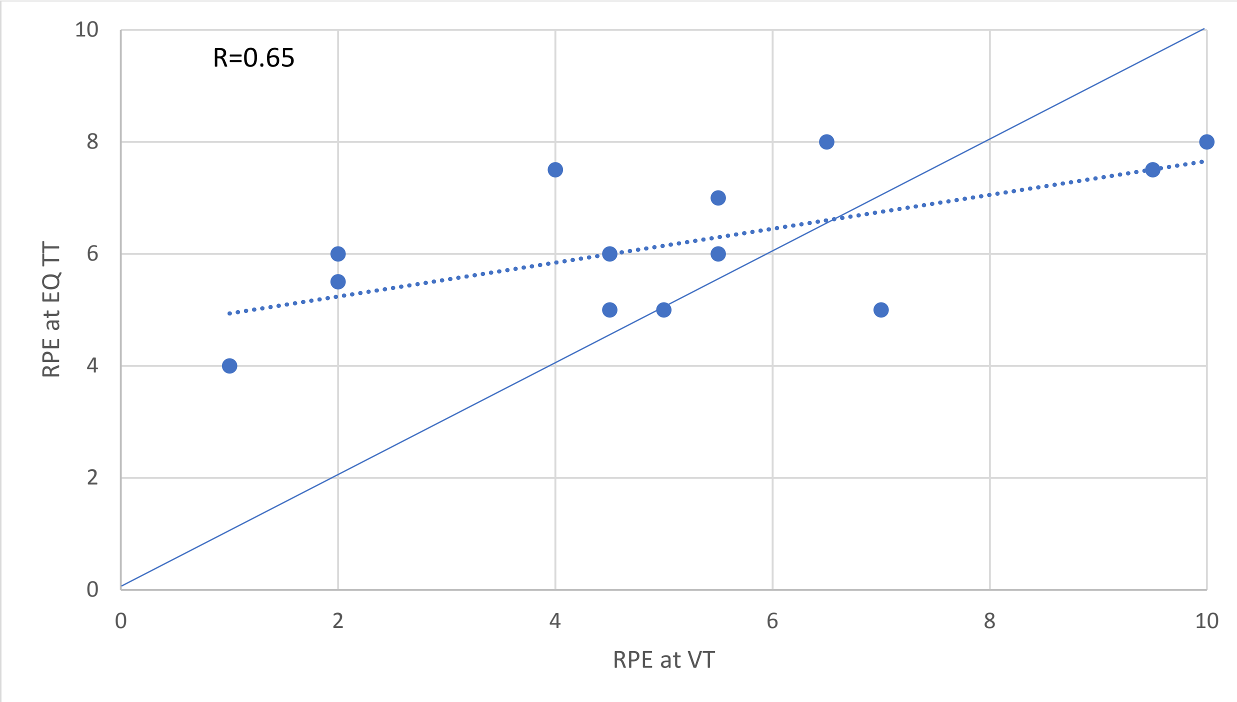

Figure 6b. Gas exchange verses TT RPE during EQ stage.

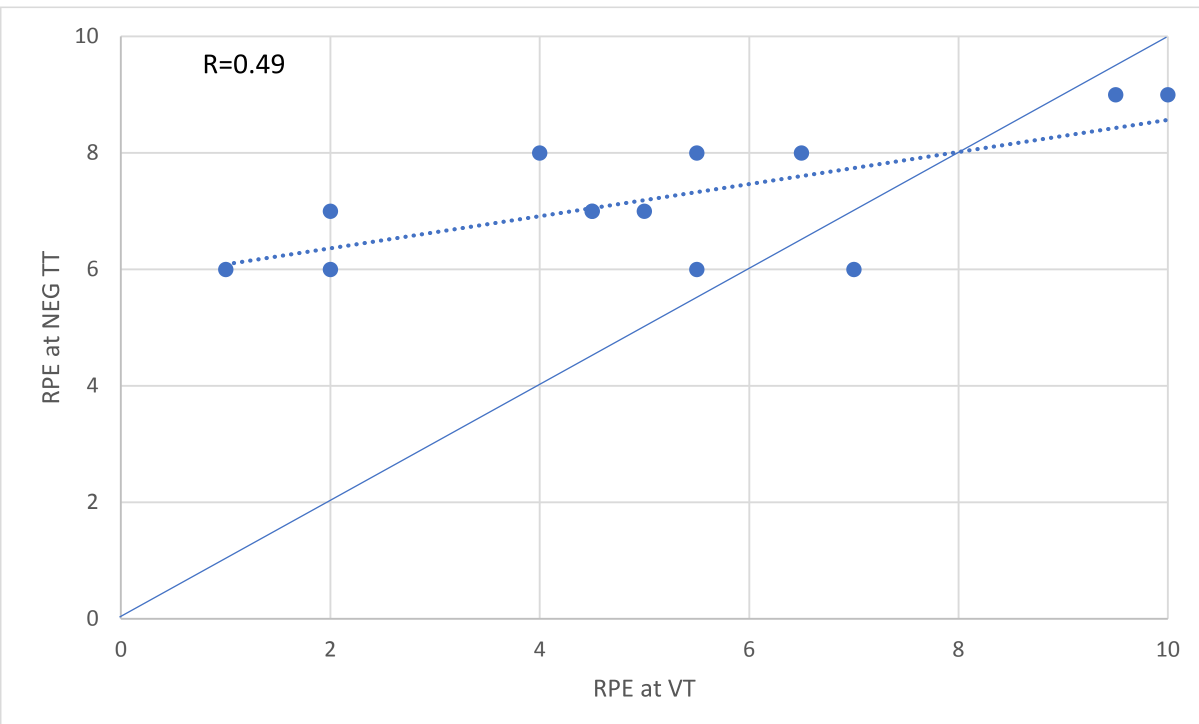

Figure 6c. Gas exchange verses TT RPE during NEG stage.

DISCUSSION

The purpose of this study was to determine whether the TT is an appropriate measurement of exercise intensity in children. This was tested via measurements of the VT during exercise, and then compared to the stages of the TT. The results indicate that at the stage when children are not equivocally comfortable speaking is equivalent to their VT. The stages just prior (LP) and past (NEG) the point of the TT EQ stage occur below and above the VT. These measurements are made by comparing the VO_2 at VT to the VO_2 at each stage of the TT.

These results coincide with previous studies that utilized the TT as a subjective measurement of exercise intensity. The results demonstrate that, similar to previous studies, when talking becomes too difficult, the NEG stage of the TT, children are beyond their VT. Additionally, exercising while still being able to speak comfortably means that the intensity is below their VT. Moreover, children accurately perceived their exercise intensity related to their VT. RPE below VT were significantly different, compared to above the child's VT. Based on a previous study (Dehart-Beverley, Foster, Porcari, Fater, and Mikat, 2000), if subjects are exercising at the EQ stage of the TT, they are exercising within the limits of the ACSM's recommendations.

In previous studies (Recalde et al., 2002), the RCT was measured at the NEG stage of the TT. This measurement was not consistently observed in our subjects. This could be in part to the differences in athletic ability between the children, the volume of physical activity each child performed, and the lack of a true maximal effort. While a maximal exercise test was terminated due to fatigue, RER showed that children rarely achieve the 1.10 measurement that is widely accepted to demonstrate maximal effort. Some children participated in sports outside of school, which was exemplified by their increased maximal oxygen consumption and increased RER. Lastly, some children lacked regular physical activity, thus had a low exercise capacity compared to their athletic peers.

Children's heart rate patterns differ with exercise, mostly based on the sporadic activity that children engage in. Benham-Deal (2005) observed that children's physical activity and exercise habits are not continuous, rather were characterized by frequent bursts of high-intensity exercise with rest periods in between. Thus, exercising children for longer times than normally experienced differs from natural or previously experienced activity pattern. Additionally, Armstrong & Bray (1991) echoed these results when studying British school children. They, too, experienced exercise in children to be more interval in character, rather than continuous. Short periods of intense physical activity seem to be more natural for children, rather than continuous exercise, or steady-state exercise. How this stochastic pattern of exercise matches TT responses, which are inherently better suited to steady state exercise, remains to be determined.

The findings of this study suggest that children should exercise at a point where it is beginning to be difficult for them to speak (LP, EQ stages). While still being able to speak, exercise would be performed below their VT, while not being able to speak would suggest beyond their VT. Using the TT is a tool that can be used to subjectively measure the intensity of exercise in children based on an individual's capacity.

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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 that 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, ages' 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. 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 involve 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 the Rainbow Passage, a short poem. The child then will 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, but has very little risk of injury or event. Small discomfort may be experienced towards the end of the test as exercise becomes more difficult. Precautions are made to make sure the child is safe, and the child 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 is 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 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 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:
____

____

____ __________________

Signature of Presenter Date of Presentation

____

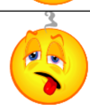
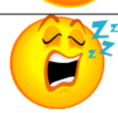
Printed Name of Presenter

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

READING PASSAGES

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

Soccer
Word Count: 105

Name ______________________________

Soccer is a great game for girls and boys. You play 11
soccer with a soccer ball. You play soccer on a field. 22
There is a net at each end of the field. There are eleven 35
players on a team. 39

During the game, each team tries to get the ball into 50
the other team's net. Each time the ball gets into the 61
net, it is one point. The team with the most points 72
wins. You can kick the ball in with your feet. You can 84
hit the ball in with your head. You can hit the ball in 97
with your knees. Girls and boys everywhere like to 106
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

	1	2	3	4	5	6
Number of Errors						

Accuracy (%): ________

Reading Rate (Words Per Minute):

50 — 75 — 100 — 125 — 150 — 175 — 200

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

One Big Storm

Name ______________________ Word Count: 106

In 1978, a big winter storm hit Boston, Massachusetts. 9
The winds blew over 35 miles an hour. Over two feet 20
of snow fell in one day. The plows could not keep up. 32

The snow fell so fast that cars were left in the middle of 45
the roads. People had to walk away from them. Many 55
people had to stay at work. They could not get home 66
because the roads had too much snow. 73

The heavy snows knocked down power lines. Many 81
people had no heat. It took over two weeks to get the 93
roads plowed and the power lines back up. It was one 104
big storm! 106

	1	2	3	4	5	6
Number of Errors						

Accuracy (%): ______

Reading Rate (Words Per Minute):

50 75 100 125 150 175 200

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

Mars

Name ____________________ 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):

50 75 100 125 150 175 200

APPENDIX D

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The purpose of this review of literature is to determine whether the Talk Test can be utilized to measure the exercise intensity in children. Subsequently, it will analyze the accuracy of the exercise intensity, to ensure appropriateness of exercise prescription.

Introduction

In 1957, research completed by Martti Karvonen concluded that exercise intensity measured via heart rate reserve was an appropriate measurement, based on each individual. This led way to an objective way to measure exercise intensity. From this research, maximal oxygen uptake tests were completed to determine an individual's exercise capacity. Problems arose, however, when the monetary cost of exercise testing increased, and estimations were too broad to predict a heart rate max or maximal exercise capacity. Thus, subjective measures of exercise intensity became popular. This then led to simple questions being asked; "How hard was your workout?" and "Can you speak comfortably?". This latter question became the premise for the Talk Test.

Physiology Behind the Talk Test

Subjectively exercise intensity using speech first began by "hearing your breathing". This began by analyzing one's ability to breath, and how hard one was breathing during exercise. This subjective analysis later led to the discovery that by hearing how hard you were breathing correlated relatively to 60-90% of the maximal oxygen uptake (Goode, Mertens, Shaiman, & Mertens, 1998). Goode et al. also concluded that this process approximated the ventilatory threshold. This allowed athletes to exercise in relation to their ventilatory threshold, simply by listening to their breathing patterns. All this research was built on an earlier study, relating the cost of ventilation during rest to the cost of ventilation during exercise (Doust & Patrick, 1981). Speech was found to require certain breathing patterns, and the intensity of exercise determined the response to exercise. The human body, which retains CO_2 during speech, increases the partial pressure of CO2. However, as exercise intensity increases, the body tries to expel the CO_2 to maintain homeostasis. This means that the body has to determine whether to maintain breathing frequency or to increase breathing frequency. Doust and Patrick (1981) observed that as exercise intensity increased, the body prohibited speech in attempt to maintain homeostasis. This correlates with a study that determined speech causes an increase of CO_2 partial pressure, which increases the ventilatory drive and compensation (Creemers, Foster, Porcari, Cress, & de Koning, 2017). Creemers et al. investigated how the body responded to retention of CO_2, and how the Talk Test would affect it during increasing exercise intensity. They observed that exercise above the ventilatory threshold caused the ventilatory drive increase, which in turn decreased the partial pressure of CO_2. This matched the results of Doust and Patrick (1981), that as the bodies increased need for oxygen to travel to the muscles also increased the expulsion CO_2 to maintain homeostasis.

Ventilatory and Lactate Threshold and the Relationship to the Talk Test

The Talk Test was created out of the disparity between absolute exercise intensity and relative exercise intensity. Karvonen created a way of measuring exercise intensity, on an individual basis, based on heart rate reserve. The idea, which involved everyone exercising at their specific target heart rate, which could then be translated to maximal oxygen uptake and metabolic equivalent of a task (VO_2 and MET's, respectively). The problem arises with the monetary cost of testing everyone to determine heart rate max, which was needed to calculate the target heart rate. Additionally, equipment needed to measure the heart rate was not readily available outside of a laboratory. This led to a more subjective approach; one where exercise can be measured outside of the laboratory, based simply on how you feel. Research had already been done involving "hearing your breathing" (Goode et al., 1998), but there needed to be an easier way. Thus, the Talk Test was born.

Ventilatory Threshold

In 2000, Dehart-Beverley, Foster, Porcari, Fater, and Mikat found that exercising while talking accurately predicts ventilatory threshold. By exercising in stages, the last positive stage where an individual can speak comfortably is slightly below the ventilatory threshold. The stage where the individual is first unsure if they can speak comfortably approximately the ventilatory threshold, and if the individual can no longer speak comfortably, they are above their ventilatory threshold. Speech was performed during the end of each stage, and individuals were asked "can you speak comfortably?" following each speech passage (101 words). The answers were recorded, and compared to their oxygen consumption. The results accurately predicted ventilatory threshold, meaning ventilatory threshold could be measured without laboratory equipment. Additionally, in a subsequent study, it was found that the negative stage of the Talk Test referred to the individual's respiratory compensation threshold (Recalde et al., 2002). This means that an individual who is exercising at an intensity that would translate to the negative stage of the Talk Test would be exercising at an intensity around the aerobic/anaerobic change.

This change is associated with the bodies inability to produce adenosine triphosphate (ATP) aerobically, and must now rely on anaerobic production of ATP to meet the need for energy. This is yet another subjective way of analyzing exercise intensity without the utilization of laboratory equipment. Research, conducted by Ballweg et al. (2013), confirmed the earlier discoveries, by testing the Talk Test against gas exchange. The Talk Test was found to be reproducible and valid, as gas exchange by the lungs was found to be accurate with the equivocal stage of the Talk Test and the ventilatory threshold. Additionally, the negative stage of the Talk Test was found to approximate the respiratory compensation threshold. Ventilatory threshold and respiratory compensation threshold were later found to be more accurately related to the stages of the Talk Test using longer passages (Schroeder, Foster, Porcari, & Mikat, 2017). Previous studies had used a passage containing relatively 30 words, using the Pledge of Allegiance. Longer passages more accurately measured ventilatory threshold and respiratory compensation threshold. While the majority of these studies were conducted among healthy adults, studies have also validated the relationship between the stages of the Talk Test and the ventilatory and respiratory compensation thresholds in high-level athletes (Rodriguez-Marroyo, Villa, Garcia-Lopez, & Foster, 2013) and untrained adults (Foster et al., 2009). The ability for the Talk Test to work among multiple populations proves its versatility across different individuals in different exercise states.

Lactate Threshold

The Talk Test has been shown to indicate metabolic responses, not strictly cardiovascular physiological responses. The lactate threshold has shown to dictate the Talk Test and the individual's ability to perform sustained exercise (Quinn & Coons, 2011). The body's physiological responses, either via cardiovascular or metabolic, have shown to influence the different intensities during each stage of the Talk Test. Thus, the lactate threshold corresponds to between the last positive stage of the Talk Test and the equivocal stage. The physiological responses were also found to be within the American College of Sports Medicine's (ACSM) recommendations for moderate to vigorous exercise. Not only was the subjective measurement accurate per the bodies' physiological responses of lactate threshold and ventilatory threshold, but also closely measured to appropriate maximal oxygen uptake percent and percent of heart rate max. The anaerobic threshold occurs when the body can no longer create ATP aerobically, and thus needs assistance from the anaerobic pathway to create the energy. During a maximal oxygen uptake test, this can be clearly seen by a spike in the pattern of ventilation. This occurs when the tidal volume can no longer increase, and the breathing frequency increases disproportionately. Thus, the respiratory rate increases as the body demands more energy, increasing ventilatory drive and oxygen uptake.

<u>The Talk Test and its Measurement of Intensity</u>

The Talk Test has been studied as a measure of exercise intensity. In course procedure with previous studies, Foster et al. (2008) surmised that exercise intensity can be measured via ventilatory threshold, respiratory compensation threshold, and relates strongly to the category-ratio perceived exertion scale (measurement of perceived exertion measure 0-10). An evaluation of intensity was utilized to increase maximal oxygen uptake in individuals who trained at or above their ventilatory threshold. With the ventilatory threshold relating to the equivocal stage of the Talk Test, individuals could exercise at this intensity and increase their maximal oxygen consumption. It was found, additionally, to work across multiple aerobic modalities (Reed & Pipe, 2014). The Talk Test as an evaluation of exercise intensity works on treadmills, as well as cycle ergometers. While the Talk Test is one form of evaluating exercise intensities subjectively, a similar concept; the counting Talk Test. This counting Talk Test can be applied by having the individual count as high as possible during one breath. As exercise intensity increases, there is a decrease in the ability for the individual to count to a number that was a as high as at rest. Thus, the increased intensity decreases the amount of numbers said during one breath. The counting Talk Test was validated, and shown accurately to predict ventilatory threshold and respiratory compensation thresholds, as well as relating to heart rate, maximal oxygen consumption, and metabolic equivalent (MET) levels during exercise (Norman, Kracl, Parker, & Richter, 2002). Norman, Hopkins, and Crapo (2008) discovered that the counting Talk Test can be utilized to as a tool to measure percent maximal heart rate, percent maximal oxygen uptake, and subjective rate of perceived exertion (RPE) in young, healthy adults. Some contradictions arouse when Gillespie, McCormick, Mermier, and Gibson (2015) found that the negative stage of the Talk Test was more accurate for ventilatory threshold and exercise intensity in highly trained, competitive male cyclists. Lyon et al. (2014) demonstrated that cardiac patients should exercise at one or two stages below the last positive stage of the Talk Test. Consequently, errors in these studies regarding the Talk Test could be due to a too short of passage spoken at the end of each stage. The longer the passage, the more accurate the Talk Test measurements were at predicting ventilatory and respiratory compensation thresholds. (Schroeder et al., 2017). In addition, some of the patients had diminished cardiac output, which affected ventilatory threshold and rate of perceived exertion (RPE).

Prescribing Exercise via the Talk Test

Through various studies, the Talk Test has been a useful tool to prescribe exercise. As previously stated, intensity can be based on the Talk Test, which can then be employed to prescribe exercise. According to Woltmann et al. (2015), the Talk Test provided exercise intensity within the acceptable range set formed by the American College of Sports Medicine (ACSM). These recommendations, which include moderate exercise at 40-59% heart rate reserve or vigorous exercise at 60-89% heart rate reserve, can be found in the *ACSM's Guidelines for Exercise Testing and Prescription* (Riebe, 2017). Woltmann et al. discovered at the last positive stage of the Talk Test, steady-state exercise was possible relative to maintaining acceptable heart rate, rate of perceived exertion (RPE), and blood lactate levels. Additionally, it was concluded that exercise measured by the Talk Test meant exercise at 60-85% of the heart rate reserve during the last positive stage of the Talk Test. Lastly, the subjective rating of perceived exertion was found to be moderate, while blood lactate levels remained close to baseline. This study has been validated with the last positive stage equating to at or below the ventilatory threshold during steady-state exercise (Jeans, Foster, Pocari, Gibson, & Doberstein, 2011), as well as across multiple aerobic modalities (Persinger, Foster, Gibson, Fater, & Pocari, 2004). This means that individuals could utilize the Talk Test during training, while maintaining the same intensity that is measured during the last positive stage. Similarly, the counting Talk Test also proved to provide intensities that are moderate to vigorous, and can be employed in exercise prescription (Loose et al., 2012). Finally, Foster et al. (2009) demonstrated the ability for the Talk Test to be applied as a tool during submaximal exercise tests outside of the laboratory. This means that the Talk Test has the ability to be administered to multiple individuals, such as a way to measure maximal exercise, but also to a clinical population where exercise to maximal capacity may not be available.

Utilization of the Talk Test in Special Populations

Through validation studies involving the Talk Test, research shows that the Talk Test is a safe, subjective way to measure exercise intensity in multiple populations. The first study conducted on the Talk Test, comparing exercise stages and physiological responses (Dehart-Beverley et al., 2000), discovered that the Talk Test is appropriate and accurate in measurement of exercise intensity in active, adult students. Later, Norman et al. (2002) and Recalde et al. (2002) determined that the Talk Test was appropriate in healthy, active adults as well. In 2009, Foster et al. concluded that the Talk Test would accurately predict the ventilatory threshold, as well as accurately prescribe exercise intensity, in unhealthy, inactive adults. Similarly, the Talk Test was demonstrated to accurately prescribe exercise to high-level athletes competing around the world (Gillespie et al., 2015) (Woltmann et al., 2015). With research validating the Talk Test, the question was raised whether the Talk Test was safe to conduct on cardiac patients. In 2002, the Talk Test was first validated in cardiac patients performing exercises in a cardiac rehabilitation setting (Voelker et al., 2002). This study was conducted at a local cardiac rehabilitation center where patients were exercising at intensities below normal exercise intensities. This is due to the various damages that had occurred in each patient’s heart. Patients that completed the Talk Test demonstrated that when they were at their last positive or equivocal stage of the Talk Test, the patients were exercising at or below their ventilatory threshold. Later, research was conducted to test the intertester reliability within practitioners in cardiac rehabilitation (Petersen, Maribo, Hjortdal, & Laustsen, 2014). This study resulted in validation of intertester reliability, meaning that multiple practitioners were able to instruct and conduct the Talk Test to patients with similar results. Validation was confirmed by having cardiac rehabilitation patients exercise across multiple modalities, which demonstrated that the Talk Test is effective at estimating exercise intensity in many aerobic exercise machines (Nielsen et al., 2014).

Specific, Special Populations

To narrow down possible populations within those who participated in cardiac rehabilitation, Brawner et al. (2006) concluded that patients with coronary artery disease have the same results as those in cardiac rehabilitation. The Talk Test was confirmed to estimate appropriate exercise intensities in that population. Similarly, a study was conducted to determine whether the Talk Test would be valid with patients recovering from post-revascularization (Zanettini et al., 2013). It was concluded that the Talk Test accurately estimated ventilatory threshold, in addition to the last positive stage equating to the optimal training zone. As patients continue to exercise and decrease the risk of mortality, the Talk Test can continuously be utilized. Although no studies have been completed, it is not unreasonable to predict that these patients who exercise at their ventilatory threshold will increase their cardiovascular function, and employ the Talk Test as a measurement of their progress.

Ischemic Threshold

Lastly, relevant to exercise intensity in cardiac patients, research was conducted on the Talk Test as a measurement of the ischemic threshold. The ischemic threshold is the borderline between normal exercise reading on an electrocardiogram and the beginning of deviation on an electrocardiogram related to ischemia. Patients with a known history of exercise-induced ischemia are instructed to exercise ten beats per minute below their ischemic threshold. This is done to prevent angina and progressive ischemia. Research conducted in 2004 demonstrated that the Talk Test can, measure the exercise intensity for those exercising below their ischemic threshold (Cannon et al., 2004). This study concluded that patients who exercise at their last positive stage of the Talk Test are exercising at, or about 10 bpm below their ischemic threshold. This means that the Talk Test accurately measure exercise intensity that is safe for cardiac patients.

The Talk Test in Children

Ventilatory Threshold and Blood Lactate in Children

The Talk Test, to date, has not been applied as a subjective measurement of exercise intensity in children. Rather, graded exercise, as well as maximal exercise tests, have been employed to study the exercise behaviors of children. Multiple studies have shown that children can exercise to maximal capacity (Cunningham, Van Waterschoot, Paterson, Lefcoe, & Sangal, 1977). This study also reported that not all children reach the plateau phase of the maximal oxygen consumption test. This means that other indicators will be applied to measure whether a child reaches maximal oxygen uptake. Additional indicators of a maximal exercise test include rate of perceived exertion, respiratory exchange ratio, and predicted heart rate utilizing an estimation equation. However, research has shown that there is no difference in children that reach the plateau phase and those who do not (Mahon & Marsh, 1993). Interestingly, it was also discovered that blood lactate was lower when exercising at their ventilatory threshold when compared to adults exercising at the same intensity (Mahon, Duncan, Howe, & Del Corral, 1997). This means that children are able to exercise at or above their ventilatory thresholds for longer periods of time when compared to adults. This could affect the Talk Test, as it may take longer to reach the respiratory compensation threshold if children can exercise more efficiently at anaerobic power outputs when compared to aerobic power outputs.

RPE in Children

Research has been conducted using the rate of perceived exertion scale as a measure of exercise intensity in children (Mahon & Ray, 1995). It was concluded that children can exercise across multiple modalities while maintaining the same RPE intensity while comparing physiological responses. Mahon, Plank, and Hipp (2003) also researched the rate of perceived exertion scale in children while conducting submaximal tests, and found the scale to be accurate. Finally, it was concluded by Mahon, Gay, and Stolen (1998) that children are able to differentiate between a rate of perceived exertion scale based on cardiovascular and metabolic responses (such as ventilatory threshold, respiratory compensation threshold, and blood lactate) and a similar scale measuring workload fatigue on the muscles. This means that children understand when their bodies are fatigued, and can differentiate between the feeling of fatigue from ventilatory threshold and blood lactate, and muscular fatigue. To enhance understanding of the rate of perceived exertion scale, Nye and Todd (2013) created a scale that combined not only the traditional rate of perceived exertion scale, but also the OMNI scale, which was created to be employed in children. This new rate of perceived exertion scale utilizes numbers, colors, pictures, and descriptions to help enable the child to understand what level of intensity they are working. It was concluded by Nye and Todd that this scale enhanced understanding in children, and should be applied in this population.

Conclusion

Subjectively measuring an individual's exercise capacity has gained popularity as it is cheap and can be utilized outside of the laboratory. The Talk Test has been demonstrated to accurately, and appropriately measure exercise intensity in adults. This has been done by simply asking individuals if they can speak comfortably during exercise. Specific measurements to physiological responses can be employed as exercise intensities without the operation of a heart rate monitor or maximal exercise test. These responses refer to the ventilatory threshold and respiratory compensation threshold, which can be applied to gauge exercise intensity during a workout. By utilizing the Talk Test, individuals can exercise within a healthy, safe, and prescribed exercise intensity. While multiple populations have been receptive to the Talk Test, children are one population that has not been studied. Thus, my study aims to research the physiological response to the Talk Test in children.

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