The Reliability and Validity of the Pacer for 3rd and 4th Grade Males

Jennifer A. Hinely

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THE RELIABILITY AND VALIDITY OF THE PACER FOR 3RD AND 4TH GRADE MALES

Jennifer A. Hinely
The Reliability and Validity of the PACER for 3rd and 4th Grade Males

A Thesis

Presented to

the College of Graduate Studies of

Georgia Southern University

______________________________

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

In the Department of

Health & Kinesiology

by

Jennifer A. Hinely

May 2001
May 2001

To the Graduate School:

This thesis entitled, "The reliability and validity of the PACER for 3rd and 4th grade males," and written by Jennifer Hinely is presented to the College of Graduate Studies of Georgia Southern University. I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science in Kinesiology.

We have reviewed this thesis and recommend its acceptance:

A. Barry Joyner, Supervising Committee Chair

W. Kent Guion, Committee Member

James McMillan, Committee Member

Garth Spendiff, Committee Member

Charles J. Hardy, Department Chair

Accepted for the College of Graduate Studies

G. Lane Van Tassell
Dean, College of Graduate Studies
DEDICATION

To those who have truly inspired n
ACKNOWLEDGMENTS

Like everything that I have ever done, this thesis could not have been completed without the help and encouragement from so many people. First, I would like to express my sincere gratitude to my thesis committee. Dr. Joyner, a favorite among many students, seemed to always have more confidence than I thought possible and challenged me beyond my expectations. Even when I was ready to throw in the towel, he threw it back at me. Dr. Guion, who somehow seemed to get all the necessary questions answered even if it required translation! Dr. McMillan, who always managed to point out things weren't as bad as they seemed. And Garth Spendiff, who was not only an encouraging and enthusiastic instructor, but also a great friend. Thank you all so much for your time and persistence in this project.

Others that deserve credit include the staff, particularly Mrs. Susanne Floyd, and the students from Rincon Elementary School. Without their enthusiasm and help, this project would have never survived the many technical problems that were encountered. Also, I would like to express my deepest thank you to my grandmother, Ruth Ambrose. Although she didn't fully understand the technical aspects of the project or the demands of being a graduate student, she smiled and assisted during every testing session and was proud nonetheless. Her support will always push me toward greater achievements.
Thank you to my fellow graduate students who provided many sanity checks and comic relief in regards to the whole thesis project. Dr. Munkasy, who continuously offered much appreciated technical assistance. Dr. Williamson, who exemplified the role of mentor and friend throughout my graduate studies. My family, who have always supported me in any endeavor. And lastly, to my closest friends, who suffered through many venting sessions yet still remained supportive, patient, and optimistic.

This study would not have been possible without a grant from the Georgia Southern University Graduate Student Professional fund. The Department of Health and Kinesiology at Georgia Southern University also made supporting funds available.
ABSTRACT

THE RELIABILITY AND VALIDITY OF THE PACER FOR 3RD AND 4TH GRADE MALES

May 2001

JENNIFER A. HINELY
B.S. GEORGIA SOUTHERN UNIVERSITY
M.S. GEORGIA SOUTHERN UNIVERSITY

Directed by: Professor A. Barry Joyner

BACKGROUND: FITNESSGRAM recommends the use of the PACER, a 20-meter shuttle run, to assess the aerobic ability of children in physical education classes.

OBJECTIVES: To examine the reliability and validity of the PACER for 3rd and 4th grade males. In addition, the reliability and validity of the criterion-referenced standards will be examined.

METHODS: 22 students ran 3 trials of the FITNESSGRAM PACER while wearing the Cosmed K4b2 system.

RESULTS: From the 22 students, the intraclass correlation for the number of laps for trial 2 to trial 3 was 0.81. The reliability of the estimated VO₂ from trial 2 to trial 3 was 0.83. For validity, the correlation for the estimated VO₂ max to peakVO₂ from the Cosmed was 0.42 for trial 2. For trial 3, the correlation was 0.60. The correlation between laps and peakVO₂ was 0.57 for trial 2. For trial 3, the correlation was 0.69. The consistency of the classification for the criterion-referenced standards was 0.91 with a modified kappa of 0.85. The accuracy of the
classification for the criterion-referenced standards for trial 2 was 0.59. For trial 3, the proportion of agreement was 0.68. CONCLUSION: The criterion-referenced standards consistently classifies the participants, however, the validity of the classification is low. PeakVO₂ scores and the estimated VO₂ did not appear to be highly related. However, the PACER has a high test-rest reliability for males ages 8-10 years.
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INTRODUCTION

Nobel prize winner, A.V. Hill, first introduced the term "maximal oxygen intake" in 1924. The term is used to describe the upper limit of performance by establishing the relationship of the cardiovascular system and the respiratory system while performing work (Powers & Howley, 1997). Maximal oxygen intake or consumption (VO₂ maximum) is the most objective method to assess the physical fitness of an individual (Powers & Howley, 1997). It is most frequently assessed in a laboratory setting while performing work to exhaustion on a treadmill, and it is a variable of interest to researchers in the field of exercise physiology.

Testing the cardiovascular system and the respiratory system, particularly examining oxygen intake and carbon dioxide production, and examining their contribution to performance is referred to as "VO₂max testing." VO₂max testing protocols can be maximal or submaximal, on a bicycle or treadmill, and many variables, such as heart rate, blood pressure and complex assessments of maximal oxygen intake (VO₂) can be done. Direct measurement of VO₂ requires trained personnel, and is both time consuming and expensive; therefore, many attempts have been made to develop field tests that accurately provide estimates of an individual's aerobic capacity. Such tests include the Cooper 12 minute run or a 1 mile run test, however, they often require high levels of motivation to accurately assess VO₂ given that they require a maximal performance from the beginning.
A relatively new field test, the PACER, was first introduced by Leger and Lambert in 1982 and was further validated with children by Leger, Mercier, Gadoury, and Lambert in 1988. The PACER, a component of the FITNESSGRAM, is a 20-meter progressive shuttle run that requires a maximal effort at the end. It scores participants based upon the number of laps that can be completed, and that score is used to estimate VO₂\text{maximum} (Leger & Lambert, 1982). In the development of the 20-meter shuttle run, expired air was collected using meteorological balloons (the Douglas bag method) during the recovery period of the test and back extrapolation was used to assess VO₂\text{maximum}. This method requires the expired gases be collected in the Douglas bags and transported back to the laboratory for testing.

The K4b2 (Cosmed, Roma Italy), is a portable breath by breath gas exchange system that can be used to assess VO₂\text{maximum}. It is used to test the aerobic capacity of individuals in sporting activities where the sport cannot be simulated in a laboratory. It is an easier way to evaluate oxygen uptake when compared to the bulky, cumbersome Douglas bag method or the more permanent metabolic carts found in many labs. The PACER, a multistage activity, is an example of an activity that cannot effectively be simulated in a laboratory. Therefore, it would be beneficial to assess the reliability and validity of such a test with the K4b2 system.

The criterion-referenced standards for the PACER represent the level of risk for aerobic capacity (Morrow et al., 1994). When discussing the validity of criterion referenced standards, the validity is the ability of the test to accurately classify participants.
As for reliability, a test is reliable when it consistently classifies participants. According to the FITNESSGRAM technical reference manual (1994), PACER standards are derived from the regression equation of Leger et al. (1988) where VO$_2$max is predicted by using age and highest speed attained on the test. Although the PACER has been used for several years, the reliability and validity of the criterion referenced standards have not been fully examined for 3rd and 4th grade males.

An extended review of literature revealed no previous research where the K4b2 system was utilized to assess the reliability and validity of a field test protocol, nor is there literature on the criterion-referenced standards for the PACER set by FITNESSGRAM for this particular age group. Therefore, the purpose of the study is to examine the validity and reliability of the PACER and the criterion-referenced standards for 3rd and 4th grade males.

**METHODS**

**Participants**

Participants for this study were 30 male volunteers. Participants were from the 3rd and 4th grade. The Board of Education and the principal of the school approved the data collection. Written informed consent was obtained from the participant, as well as a legal parent or guardian. All participants gave consent and all procedures for the study were approved by the Georgia Southern University Institutional Review Board.
Procedures

Each participant performed the PACER, a progressive 20-meter shuttle run. The testing occurred in the gymnasium of the school during the student's designated physical activity time. According to the procedures in the FITNESSGRAM Technical Reference Manual (1994), the PACER consists of the participant running back and forth between two lines that were 20 meters apart. The participant crossed each end line. At the same time, a prerecorded sound signal was emitted from a tape recorder. The participant ran at a pace according to these signals, which began at an initial speed of 8.5 km/h and increased by 0.5 km/h each minute (initial sound signals are 9 seconds apart). The participant crossed each line prior to the next sound signal. At the sound of each signal, the participant changed direction and ran to the other line. The participants kept up with the sound signal as long as possible. Participants were uniformly encouraged by the researcher throughout the test following the script in Appendix C. Testing was terminated when the participant voluntarily stopped running. The last lap that they were able to successfully complete was recorded as their score. That score was then used to estimate the subject's maximal oxygen consumption (VO$_2$max) (Leger and Lambert, 1982).

While performing the PACER, the participant wore the Cosmed K4b2 portable gas exchange system. The device is a breath by breath analyzer that collects data on oxygen consumption and carbon dioxide output. The K4b2 system consists of a face mask, receiving unit, transmitting unit, wireless heart rate monitor, and a battery. The face mask contains a bi-directional digital turbine (28 mm) with a flow range of 0-20 L/sec.
(Cosmed K4b2 Users Manual, 1998). The ventilation range is from 0-300 L/min with an accuracy of +/- 2% (Cosmed K4b2 Users Manual, 1998). The accuracy of the O₂ analyzer is 0.02% and the accuracy of the CO₂ analyzer is 0.01% (Cosmed K4b2 Users Manual, 1998). Gas sampling occurs at a breath by breath rate with expired gas drying occurring by a Nafron tube (Permapure). The data collected from the K4b2 gas exchange system on each participant's peak oxygen consumption (peak VO₂) was used to compare to the participant's estimated VO₂max from the PACER.

Prior to testing, height and weight measurements were recorded for each participant. Calibration of the K4b2 portable system was done according to the manufacturer's protocol (Cosmed K4b2 Users Manual, 1998). A minimum of 45 minutes warm-up time was allowed before any gas calibration process. A reference gas calibration with a gas of known composition (5% CO₂ & 12% O₂) was done every two hours. A delay calibration was done weekly. Turbine calibration was done with a three liter syringe (Collins Co.) between participants.

The K4b2 system was fixed to the chest of each participant with a harness. The face mask was secured to the participant with a nylon mesh headnet and fastened with Velcro strips. A Polar heart rate monitor was secured to each participant. After securing the device, age, gender, height, and weight measurements was entered into the portable unit. Ambient humidity was determined with a hygrometer and entered into the portable unit prior to each test. The final calibration, room air calibration, was carried out by the K4b2 immediately prior to testing. All data collected by the K4b2 system was later
downloaded to a Windows-based computer for further analysis with the Cosmed K4b2 Data Management software (Version 6.2a). Using the edit menu, all tests were filtered by an average of 30 seconds and smoothed by 10 points.

The participant performed the PACER on three separate occasions in order to assess the validity and reliability of the scoring. Each testing session was separated by at least 48 hours. Previous research has shown that the PACER is more reliable if the participants have had an opportunity to have a practice trial of the test (Joyner et al., 1996). Therefore, trial 2 and trial 3 were used to assess reliability and validity.

In regards to the K4b2, the highest recorded VO₂ measure (VO₂peak) was used for comparison because it is difficult to motivate children to reach a true VO₂maximum (Rowland, 1993). During testing, the Cosmed K4b2 had to be returned to the company for service and repair. Because of this, errors were made in the gas calibration process. In order to adjust for this error, expired O₂ was reduced by 8% to establish linearity. The peakVO₂ measurement was taken after the data had been adjusted for the 8% and filtered using the software.

**Data Analysis**

All statistical analysis was performed with SPSS (Version 10.0). In determining validity, a Pearson correlation was established between the peakVO₂ results from the K4b2 gas exchange system and the estimated VO₂max and also the lap results from the PACER. For reliability, data was analyzed using an intraclass correlation between trials
2 and 3. For reliability of the criterion-referenced standards, proportion of agreement and kappa will be used. For validity of the criterion-referenced standards, proportion of agreement will be used.

RESULTS

Of the 30 third and fourth grade male students that volunteered, 29 students were eligible to participate. One student moved before testing procedures began. Out of 29 volunteers, 22 completed the three trials. Seven students did not complete all three trials due to being absent on either of the last two testing days.

In reference to the first practice trial, the mean number of laps was 14.6 (+/- 4.3 laps) and ranged from 8 to 24 laps. Heart rate measurements were not taken during the first practice trial.

In the second trial, the mean number of laps was 18.27 (+/- 6.4 laps) and ranged from 7 to 31 laps. The mean heart rate for trial 2 was 198.6 bpm (+/- 11.8). Using each participant's lap score and their age, estimated VO$_2$max was calculated using the equation from Leger, Mercier, Gadoury, and Lambert (1988). The mean estimated VO$_2$max from trial 2 was 45.4 ml/kg/min (+/- 1.9 ml/kg/min) and ranged from 41.10 ml/kg/min to 49.70 ml/kg/min (see Table 3). The mean recorded peakVO$_2$ was 51.37 ml/kg/min (+/- 9.56 ml/kg/min) and ranged from 29.74 ml/kg/min to 65.66 ml/kg/min (see Table 2).

In the third trial, the mean number of laps was 20.86 (+/- 8.7 laps) and ranged from 9 to 43 laps. The mean heart rate was 203 bpm (+/- 9.4) for trial 3. The mean estimated VO$_2$max was 46.25 ml/kg/min (+/- 2.6 ml/kg/min) and ranged from 43.40
ml/kg/min to 54.20 ml/kg/min (see Table 3). The mean recorded peak VO₂ for trial 3 was 51.3 ml/kg/min (+/- 10.6 ml/kg/min) and ranged from 33.91 ml/kg/min to 74.78 ml/kg/min (see Table 2).

Subjectively, the participants all gave maximal effort as observed by the researcher and can be supported by their high heart rate measurements in both trials. Average test time was three to four minutes for both trials.

The intraclass correlation for the number of laps from trial 2 to trial 3 was 0.81. The lap scores for all three trials were significantly different than each other (p>.05). The reliability for estimated VO₂ max from trial 2 to trial 3 was 0.83.

The correlation in trial 2 between laps and estimated VO₂ was 0.54. For trial 3, the correlation was 0.84. For heart rate and peak VO₂, the correlation was 0.19 for trial 2. For trial 3, the correlation was 0.29. For heart rate and laps, the correlation for trial 2 was 0.25. For trial 3, the correlation was 0.17.

To examine validity, the estimated VO₂ score was correlated to the peak VO₂ score recorded by the Cosmed K4b2 system. For trial 2, interclass correlation between estimated VO₂ and peak VO₂ was 0.42. For trial 3, interclass correlation between estimated VO₂ and peak VO₂ was 0.60. The correlation between laps and peak VO₂ for trial 2 was 0.57. For trial 3, the correlation was 0.69 for laps and peak VO₂.

Criterion-referenced standards for the PACER do not exist for children under age 10. The number of laps needed to run to reach the minimum of the healthy fitness standards is 17 laps for 10-12 year old participants (Morrow et al., 1994). These
standards correspond to a VO$_2$ of 35 ml/kg/min as the healthy fitness standard for the 10-12 year old group (Morrow et al., 1994). Since the participant sample ranged in age from 8 to 10 years old, we applied the healthy fitness standard of 17 laps and 35 ml/kg/min to all participants' scores to establish if they passed or failed. Participant scores that were below 17 laps were a failing score, and a peak VO$_2$ below 35 ml/kg/min was considered below the healthy fitness standards also.

The proportion of agreement for reliability was 0.91 for the criterion-referenced standards, with kappa being 0.85. This means that 91% of the participants (20 out of 22) were consistently classified. Twelve participants passed both trials, eight participants failed both trials, and two were not consistently classified. Those two participants failed trial 2, however, they both passed trial 3 (see Table 6).

In regards to the validity of the criterion-referenced standards for trial 2, proportion of agreement was 0.59 meaning that 59% of the participants (13 out of 22) were accurately classified. Twelve participants passed both the laps score and the VO$_2$ score, one participant failed both the lap score and the VO$_2$ score, and nine participants failed the laps score, however, they had passing VO$_2$ scores (see Table 4).

For trial 3, proportion of agreement was 0.68 meaning that 68% of participants (15 out of 22) were accurately classified. Fourteen participants passed both the laps score and the VO$_2$ score, one participant failed both the lap score and the VO$_2$ score, and seven participants passed the lap score, however, failed to have a passing VO$_2$ score (see Table 5).
DISCUSSION

Research has shown the PACER to be a valid and reliable test for estimating aerobic capacity in children (van Mechelen, Hlobil and Kemper, 1986; Leger, Mercier, Gadoury, and Lambert, 1988; Liu, Plowman, and Looney, 1992). Results from this research are consistent with previous research in regards to lap scores. In the present study, the reliability of laps in trial 2 to laps in trial 3 was 0.81. This is consistent research on males by Leger, Mercier, Gadoury, and Lambert (0.89) (1988), Liu, Plowman, and Looney (0.91) (1992), and Joyner (0.89) (1997).

Previous research compared VO2 scores from the PACER to VO2max results from treadmill testing, bike testing, and/or other endurance field tests. The correlation in Leger, Mercier, Gadoury, and Lambert (1988) for comparing the estimated VO2 from the PACER to treadmill VO2max results was 0.71. In Liu, Plowman, and Looney (1992), the number of laps was correlated to peakVO2 recorded from treadmill tests and they found moderate correlation in males (r=0.65), in females (r=0.51), and the combined (r=0.69). In the present study, estimated VO2 from the PACER was compared to the peakVO2 obtained from the Cosmed K4b2. With a correlation of 0.42 during trial 2 and a correlation of 0.60 in trial 3, results from the PACER laps and the peakVO2 obtained from the Cosmed K4b2 did not appear to be highly related. The equation developed by Leger et al. (1988) involves the variable of lap speed that corresponds with a wide range of laps completed. For example, stage 3 involves laps 16-23 laps. Students of the same age that completed laps between 16 and 23 were all estimated as having the same VO2. This
would account for the small standard deviation in estimated $V_O^2$ for both trials. The peak $V_O^2$ recorded by the Cosmed K4b2 is more representative of $V_O^2$ ranges for children of this age group. There is a difference in students who ran 16 laps versus the student who ran 23 laps, but the estimated $V_O^2$ does not account for this variability.

In regards to the criterion-referenced standards, no research has been done regarding the healthy fitness standards for this age group. Joyner (1997) reported a reliability of 0.89 for males and modified kappa was 0.78 in 79 boys ages 10 and 11.

In the present study, the reliability of scoring participants consistently for both trial 2 and trial 3 was 0.91 with a kappa score of 0.85. Only two participants passed trial 3 but received a failing score on trial 2. Practice may have influenced the outcome for the two participants.

On the other hand, once the criteria of 35 ml/kg/min was applied to the pass or fail criteria, results were not as promising. The proportion of agreement for trial 2 was 0.59 where 9 of the 22 participants failed to run the 17 laps to receive a passing score, but had a peak $V_O^2$ of $>35$ ml/kg/min. For trial 3, the proportion of agreement was 0.68. Seven participants had peak $V_O^2$ of $>35$ ml/kg/min but were unable to run more than 17 laps. These results from trial 3 are similar to results found in previous research although different criteria were used. In Dinshel (1994), researchers used the one-mile run/walk for comparison and found that over 77% of 116 4th and 5th graders were accurately classified.
CONCLUSION

Based on the results of the present study, one can conclude that the criterion referenced standards consistently classify the participants (PA=.91 with kappa = 0.85), however, the validity of the classification is relatively low. One would assume the validity of the standards to be more accurate because direct measurement was compared to the lap score, however, the peakVO₂ measurements account for the variability among the students whereas the estimatedVO₂ does not. This would have influenced the validity of the classification. As for reliability, it appears that the PACER has high test-retest reliability with male participants ages 8-10 years old.
REFERENCES


**Table 1**  
Lap Scores

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<td>Trial 1</td>
<td>14.6 laps</td>
<td>+/- 4.3</td>
<td>8 laps - 24 laps</td>
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<tr>
<td>Trial 2</td>
<td>18.27 laps</td>
<td>+/- 6.4</td>
<td>7 laps - 31 laps</td>
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<tr>
<td>Trial 3</td>
<td>20.86 laps</td>
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Table 2
Peak VO2

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<tr>
<td>Trial 2</td>
<td>51.37 ml/kg/min</td>
<td>+/- 9.56</td>
<td>29.74 - 65.66</td>
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<tr>
<td>Trial 3</td>
<td>51.3 ml/kg/min</td>
<td>+/- 10.6</td>
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**Table 3**  
**Estimated VO2**

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<td>Trial 2</td>
<td>45.4 ml/kg/min</td>
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<tr>
<td>Trial 3</td>
<td>46.25 ml/kg/min</td>
<td>+/- 2.6</td>
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Table 4
Accuracy of classification (Trial 2)

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Accuracy of classification (Trial 3)

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Consistency of classification

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<th>Trial 2</th>
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<th>Fail (&lt;17 laps)</th>
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<tbody>
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<td>Trial 3</td>
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<td>Fail (&lt;17 laps)</td>
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APPENDICES
APPENDIX A: EXTENDED INTRODUCTION

STATEMENT OF PURPOSE

This study was to examine the reliability and validity of the PACER for 3rd and 4th grade males. Estimated VO₂ from the PACER was compared to the peak VO₂ from the Cosmed K4b2 system. The reliability and validity of the criterion-referenced standards were also examined for this sample of participants.

SIGNIFICANCE OF THE STUDY

In order to advance research in the area of pediatric exercise science, it is important that we continue to examine the physiological capacity of children in order to improve current testing protocols. The results from this study will further aid in the development of the PACER for children and help to establish criterion-referenced standards for this age group.

RESEARCH HYPOTHESIS

1. The PACER will be a reliable method for estimating the VO₂max of a 3rd and 4th grade male student.

2. The estimated VO₂max from the PACER will be highly (r > 0.70) correlated with peak VO₂ from the Cosmed K4b2 system.

3. The laps from the PACER will be highly (r > 0.70) correlated with peak VO₂ from the Cosmed K4b2 system.

4. The proportion of agreement for reliability and validity of the PACER's criterion-referenced standards will be at least 0.80.
LIMITATIONS
1. The sample of participants was not randomly selected.

DELIMITATIONS
1. The study was restricted to 3rd and 4th grade male students from an elementary school.
2. Participants were free from conditions that would limit their ability to perform aerobic activity.

ASSUMPTIONS
1. All participants gave their maximal effort.
2. The participants reported any complications related to the fitness testing.
3. The participants had varying levels of fitness.

DEFINITIONS
Criterion-referenced standards - a standard that explicitly defines a task to be achieved (Baumgartner & Jackson, 1999)

Field test - a test of physical performance performed outside the laboratory (Powers & Howley, 1997)

Intraclass correlation coefficient - a correlation coefficient that estimates test reliability (Baumgartner & Jackson, 1999)

Kappa coefficient - an indication of the reliability of a criterion-referenced test (Baumgartner & Jackson, 1999)
Peak VO₂ - the peak functional capacity of the oxygen delivery system without an observable plateau of oxygen uptake at high work intensities (Rowland, 1993)

Physical fitness - a broad term describing healthful levels of cardiovascular function, strength, and flexibility (Powers & Howley, 1997)

Proportion of agreement coefficient - an indication of the reliability of a criterion-referenced test (Baumgartner & Jackson, 1999)

Reliability - pertains to the consistency, or repeatability, of a measure (Thomas & Nelson, 1996)

Validity - degree to which a test or instrument measures what it purports to measure (Thomas & Nelson, 1996)
APPENDIX B: REVIEW OF LITERATURE

One of the components of physical health is an individual's cardiorespiratory endurance. As defined in ACSM's Guidelines for Exercise Testing and Prescription, cardiorespiratory endurance is "the ability to perform large muscle, dynamic, moderate-to-high intensity exercise for prolonged periods" (ACSM, 1995, p. 63). The Nobel prize winner, A.V. Hill, first described the relationship of the cardiorespiratory system and the respiratory system while performing work as "maximal oxygen intake" in 1924. This term is used to describe the upper limit of performance for these systems.

Pivotal research was conducted in 1955 by Taylor, Buskirk, and Henschel at the Laboratory of Physiological Hygiene at the University of Minnesota to establish maximal oxygen intake as the most objective measure of cardiorespiratory performance. Their research was conducted during World War II, and their efforts were directed at compiling a test that would stress several components of an individual's performance capacity. Their research was attempting to eliminate criticism of work by previous physiologists that motivation to testing was a limiting factor in an individual's performance. They hypothesized that test conditions existed that would eliminate the contribution of motivation, as well as skill in the activity, as a limiting factor to performance capacity. The purpose of their research, specifically, was to describe maximal oxygen intake and present its limitations and usefulness in assessing physical performance (Taylor et al., 1955).
Subjects in their study were from both the Quartermaster Corps at Fort Lee and the University of Minnesota student body, and varied in age from 18 to 35 years. There was variance in the sample in regards to running ability as well as body composition. Methods employed included exercising at various speeds and grades on a motorized treadmill and expired air was collected in balanced spirometers. Their methods also compared the protocol of running at a constant grade and periodically increasing speed to running at a constant speed and periodically increasing the grade. The latter method proved more useful to testing wide varieties of performance capacity since most subjects cannot run at speeds necessary to elicit a maximal response.

In regards to the subjects that ran at constant speeds and increased grades, their first visit to the lab included familiarizing themselves with the testing equipment and performing the Harvard Fitness Test in order to correctly estimate the grade that would elicit a maximal response at subsequent visits. The second visit included a five minute warm-up at 3.5 miles per hour at a 10% grade. Subjects then ran for three minutes at seven miles per hour at the grade established by the Harvard Fitness Test. Gas collection occurred for one full minute at the 1 minute and 45 seconds mark in the test. The procedure was repeated the third visit with the grade being increased by 2.5%. Exhaled air was collected in the same manner and if the 2 samples, from testing session 2 to testing session 3, differed by less than 150 cc/min or 2.1 cc/kg/min, then researchers concluded that maximal oxygen intake had been reached (Taylor et al., 1955). If the difference was larger, the subjects returned for a fourth testing session and grade was
again increased by 2.5%. This procedure was repeated until two consecutive testing
sessions elicited the oxygen intake levels that met the stated criteria (Taylor et al., 1955).
Their data supported the idea that a plateau is reached by 1 minute and 30 seconds of
running at a speed and grade that would elicit a maximal oxygen intake (Taylor et al.,
1955). The coefficient of reliability was 0.95 in 69 of the test-retest situations (Taylor et
al., 1955). Their experiments showed that testing for maximal oxygen intake can be
efficiently used and testing protocols must be standardized in terms of work, time and
amount of warm-up time (Taylor et al., 1955).

In regards to VO$_2$ testing children, most research has centered around establishing
prediction equations for VO$_2$max with submaximal performance data. Also, many
investigators have researched the differences in using a treadmill or a cycle ergometer
protocol.

In Cunningham and Paterson (1984), sixty-two 10 year old boys were tested on
both a cycle ergometer and a treadmill over a span of 5 years. Using multiple regression
analysis, researchers predicted VO$_2$ at yearly intervals from the submaximal heart rates
from the cycle ergometer testing and anthropometric data. Mean absolute error of 6-8%
was shown for boys aged 12-15 years old, but 10% was found for the 10-12 years old
(Cunningham & Paterson, 1984). The authors point out that changes in body weight that
occur at puberty may have accounted for these differences.

VO$_2$ can be expressed in absolute (l/min) or relative terms (ml/kg/min). When
expressing in relative terms, VO$_2$ is normalized for differences in body weight and
comparisons can be made with different population groups. When discussing the
differences between boys and girls, and when expressing VO₂ in absolute terms (l/min),
the rate of increase in VO₂ is similar up until the age of 12 (Rowland, 1993). Changes
that occur during puberty nearly doubles the difference than before puberty.

In regards to children, VO₂ testing must be approached differently than when
testing adults. A plateau of VO₂ with increasing work is not frequently found in children
in order to define VO₂ max objectively (Cunningham et al., 1977). In fact, it has been
found to occur in as little as 20% of testing participants (Rowland, 1993). Therefore, a
plateau of VO₂ is not the most useful criteria for defining a maximal exercise test in
children. Target heart rate is commonly used as an indicator of exercise effort. Typically
target heart rate is defined as 220-age; however, this formula does not apply to children
because heart rate does not change during developmental years (Rowland, 1993). Data
from previous research suggests defining target heart rate for children as 200 bpm for
treadmill running protocols and 195 bpm for treadmill walking or cycle protocols
(Rowland, 1993). But one should keep in mind that this varies among individuals and the
standard deviation for most protocols is 5 to 7 beats per minute (Rowland, 1993). The
subject should also be monitored for signs of intense effort to indicate a maximal test.
Subjects have been found to reach a maximal effort with heart rates as low as 185 beats
per minute (Rowland, 1993).

To test for maximal effort, equipment such as a treadmill, a metabolic cart, and
experienced personnel are necessary. Obviously, laboratory testing for VO₂ max is not
always possible. Depending on the situation, it may be necessary to obtain information on someone's aerobic capacity when a laboratory setting is not available. A relatively new method of examining someone's aerobic capacity is with a portable breath by breath gas analyzer. One such instrument is the Cosmed K4b2 telemetry system.

**Cosmed Telemetry Device**

Presently, there are no published studies on the reliability and validity of the newest Cosmed K4b2 system. Therefore, research is limited to information on the older K2 model from Cosmed.

In 1993, Lucia et al. examined the validity and reliability of the Cosmed K2 instrument, particularly examining its ability to measure minute ventilation and fractional concentration of O₂ in the expired air at both submaximal and maximal intensities. The study involved 20 participants (14 males and 6 females) who reported no prior history of cardiorespiratory disease (Lucia et al., 1993). Each of the participants performed three separate testing sessions on three consecutive days. The testing involved both submaximal and maximal exercise tests on a Quinton Instruments Treadmill. On day one, expired air was collected by the Douglas bag method and on days two and three, the Cosmed K2 instrument was used to assess oxygen consumption (Lucia et al., 1993). The mean VO₂max measurements recorded by the Cosmed K2 system, at day two and day three, were not significantly different (p>0.05) than the measurements obtained by the Douglas bag method and correlations between all tests were high (Lucia et al., 1993).
In the calculation of \( \text{VO}_2 \text{max} \), the calculation using the data from the K2 equipment assumes that the volume of inspired air and the volume of expired air are equal (Peel & Utsey, 1993). In 1993, Peel and Utsey compared \( \text{VO}_2 \text{max} \) and respiratory rate measurements between the K2 system and a Gould 9000PC metabolic cart. Their subjects, five males and five females, only attended one exercise session. During the stages of the treadmill protocol, the device to collect the data on expired air was alternated. Measurements were taken every four minutes during the exercise stages which began at a treadmill speed of 3.0 mph and at levels 0%, 5%, 10%, and 15% grade (Peel and Utsey, 1993). The values obtained from the K2 telemetry system were consistently lower (averaging 2-3 ml/kg/min), and a possible factor for error would be the leaking of expired air (Peel and Utsey, 1993). Another potential factor for error would be that the two systems employed in this study, the K2 telemetry system and the Gould 9000PC metabolic cart, differ in their type of oxygen analyzer and their method for calibration.

**Field Tests**

Another means of assessing \( \text{VO}_2 \text{max} \) when a laboratory setting isn't available is through the use of field tests. Examples of field tests are the 3-minute step test, the Cooper 12-minute run, a 1.5-mile test for time, 10-yard dash, 50-yard dash, 300-yard run, and the 600-yard run. In Burke (1976), the validity of selected laboratory and field tests were investigated. There were high correlations between \( \text{VO}_2 \text{ max} \) and the 880-yd
run \( (r= -0.67) \), 1-mile run \( (r= -0.67) \), and the 2-mile run \( (r= -0.85) \) (Burke, 1976). However, the 12-min run was discovered to be the most valid measure of aerobic power \( (r=0.90) \) (Burke, 1976).

In regard to field testing and children, Kranenbuhl, Pangrazi, Burkett, Schneider, and Petersen (1977) examined the validity of the 600 yard run (549 meters), the 3/4 mile (1207 meters), and the 1 mile run (1609 meters) against subject’s VO₂ max. Their subjects were 44 third grade students, and they each performed a maximal treadmill test, in addition to the timed distance runs (Kranenbuhl et al., 1977). For the males, performance on each of the distance runs was significantly related to VO₂ max \((P<0.01)\), and the 1609 meters had the highest coefficient (Kranenbuhl et al., 1977). For the females, none of the timed distance runs was significantly related to the VO₂ max \((P<0.01)\); however, the 1609 meters had the closest significance (Kranenbuhl et al., 1977). It is therefore noted that significance increased with the distance in the timed run, and the 1609 meter is a valid test for VO₂ max in boys, but not girls (Kranenbuhl et al., 1977).

A relatively new field test, the PACER, is a multistage 20-meter shuttle run. It is a test that is useful for testing large groups of people, and is particularly enjoyable for children.

In 1982, Leger and Lambert looked at the reliability and validity of such a test. Their subjects were 32 females, ages 27.3 (+/- 9.2 years), and 59 males, ages 24.8 (+/- 5.5 years). Their mean VO₂ max was calculated at 39.3 ml/kg/min (+/- 8.3 ml/kg/min) for the females, and 51.6 ml/kg/min (+/- 7.8 ml/kg/min) for the males (Leger & Lambert,
The shuttle run that was performed began at a speed of 8.5 km/h and increased by 1 km/h every two minutes, which signifies an increase of 1 MET every two minutes (Leger and Lambert, 1982).

Measurement of VO$_2$max was assessed in three different ways: a directly measured VO$_2$max, a reextrapolated VO$_2$max, and the VO$_2$max that was generated from the last successful stage of the shuttle run (Leger and Lambert, 1982). The reextrapolation method is performed by establishing the O$_2$ recovery curve following a maximal multistage test such as the shuttle run (Leger and Lambert, 1982). Expired air (four 20 second samples taken consecutively) were measured at the end of the test, and VO$_2$max at time zero of recovery was obtained by reextrapolating the O$_2$ recovery curve (Leger and Lambert, 1982). The reextrapolation of VO$_2$max has been found to be a valid and accurate method for obtaining a measurement of VO$_2$max (Leger et al., 1980).

All subjects performed the shuttle run test and each had their VO$_2$max generated by the reextrapolation method; however, several sets of experiments were performed on varying amounts of subjects. In the first set, 25 subjects performed an inclined walking treadmill test (a modified Balke protocol) and the experimental 20-meter shuttle run on a rubber covered floor and also on a vinyl-asbestos covered floor. The reextrapolation method was used to generate VO$_2$max for each test performed. For the second set of experiments, 66 subjects ran the shuttle run once, and in the third set of experiments, 30 subjects performed the shuttle run and a maximal multistage running track test. For the set of 25 subjects, similar results were noted comparing their reextrapolated VO$_2$max
and the VO₂ max generated from the Balke treadmill protocol (r = 0.975 and SEE = 3.3 ml/kg/min) (Leger & Lambert, 1982). A regression equation was generated: y = 5.857x - 19.458 with a correlation coefficient of 0.84 and standard error of the estimate at 5.4 ml/kg/min (Leger & Lambert, 1982). Test-retest when performed a week apart also was comparable (r = 0.92, SEE = 2.6 ml/kg/min) with the second trial having significantly higher results by 0.75 ml/kg/min (Leger & Lambert, 1982). It was therefore concluded that the 20 meter shuttle run was a valid and reliable test for predicting VO₂ max. And for comparison of performance differences on running surfaces (i.e. different gymnasium floor coverings), it was noted that maximal speed scores were similar for the rubber floor and the vinyl-asbestos floor with a correlation of 0.93 and 0.92 (Leger and Lambert, 1982).

Another study of the validity of the 20-meter shuttle run was conducted by Ramsbottom, Brewer, and Williams (1988). They compared the subject's extrapolated VO₂ max from the shuttle run to an uphill treadmill test of VO₂ max, and they also made comparisons to a 5 km trial time. Expired air was collected in samples of one minute increments at the end of each three minute period of the treadmill test (Ramsbottom et al., 1988). Correlations were found between VO₂ max and the final shuttle level attained (r = 0.92; P < 0.01) with an estimated standard deviation of the regression line of 3.5 ml/kg/min (Ramsbottom et al., 1988). However, these results are limited by the fact that their subjects were young adults who were involved in physical training and who were already previously able to complete a 5 km run (Ramsbottom et al., 1988). Both the 5
km run and the 20-meter shuttle run both provided estimates of VO$_2$ max but the shuttle run has obvious advantages for testing many different age groups as well as groups of different activity levels (Ramsbottom et al., 1988).

In 1989, Leger and Gadoury assessed the validity of the 20-meter shuttle run with one minute increments for the adult population. It was found that the original 20-meter shuttle run protocol (Leger and Lambert, 1982) of 8.5 km/h with an increase of 1 km/h every two minutes hindered motivation as well as increased the time needed for administration. By examining the validity of one minute stages, test administrators would be able to keep subjects motivated to complete the test and actually reach their target physiological capacity. Subjects were 77 men and women between the ages of 20 to 47 years of age (Leger and Gadoury, 1989). Each subject performed the shuttle run with the one minute stages, and VO$_2$ max was generated with the reextrapolation method. VO$_2$ max from the shuttle run was compared to treadmill reextrapolated VO$_2$ max, and results were highly correlated with $r$ ranging from 0.89 and 0.92 (Leger & Gadoury, 1989).

**Children and the shuttle run**

For the comparison to submax testing, Boreham, Paliczka, and Nichols (1990) compared the PWC170 to the 20-MST. Their aim was to examine the validity of these two tests of aerobic performance for schoolchildren in comparison with VO$_2$ max measurements. Subjects were randomly selected and included 24 boys with a mean age of 15.6 (+/- 0.6 years), and 24 girls with a mean age of 15.4 (+/-0.7 years) (Boreham et
al., 1990). Each subject performed three tests of aerobic capacity: VO$_2$\text{max} using a treadmill, a physical work capacity test of 170 bpm (PWC170), and the 20-meter shuttle run (Boreham et al., 1990). Scores for VO$_2$\text{max} for boys were 53.3 ml/kg/min (+/- 5.9 ml/kg/min), results for the PWC170 were 2.84 w/kg (+/- 0.47 w/kg), and 81.7 laps (+/- 15.9 laps for the 20-MST (Boreham et al., 1990). For the girls, VO$_2$\text{max} was 42.6 ml/kg/min (+/- 5.8 ml/kg/min), results for the PWC170 were 1.86 w/kg (+/- 0.39 w/kg), and 50.4 laps (+/- 12.5 laps) for the 20-MST (Boreham et al., 1990). A correlation of $r = 0.84$ was reported for PWC170 and VO$_2$\text{max}, and a correlation of $r = 0.87$ was reported for 20-MST and VO$_2$\text{max} (Boreham et al., 1990). Thus, it can be concluded that both the PWC170 and the 20-MST both provide valid measurements of the VO$_2$\text{max} of schoolchildren (Boreham et al., 1990).

In reference to the shuttle run and VO$_2$\text{max} testing, Leger, Mercier, Gadoury, and Lambert (1988) used 188 boys and girls aged 8-19 as subjects in one set of experiments, and they also used 53 men and 24 women as subjects for a second set of experiments. They each performed the shuttle run and their VO$_2$\text{max} was determined by reextrapolation (Leger et al., 1988). It was discovered that the 20-meter shuttle run was reliable for children ($r= 0.89$) and adult subjects ($r= 0.95$) (Leger et al., 1988). Test versus retest had no significant difference (P > 0.05) (Leger et al., 1988).

In reference to Van Mechelen, Hlobil, and Kemper (1986), researchers examined the relationship between a 20-meter shuttle run, a 6 minute endurance run, and VO$_2$\text{max} measurements. Subjects for their study included 82 children (equal amounts of boys and
girls) and they ranged in age from 12-14 years (Van Mechelen et al., 1986). The mean \( \text{VO}_2 \text{max} \) of the boys was recorded at 53.2 ml/kg/min, and 44.1 ml/kg/min was recorded as the mean \( \text{VO}_2 \text{max} \) of the girls (Van Mechelen et al., 1986). When comparing their results from \( \text{VO}_2 \text{max} \) testing to the results from the 20 meter shuttle run, a correlation coefficient was recorded as being 0.68 for the boys, and 0.69 was recorded for the girls (Van Mechelen et al., 1986). When examining the two genders collectively, results were 0.76 (Van Mechelen et al., 1986). In looking at the 6 minute endurance run, scores for the boys were 0.51 and for the girls, 0.45 (Van Mechelen et al., 1986). It was therefore concluded that the 20-meter shuttle run was a "suitable tool" in the evaluation of \( \text{VO}_2 \text{max} \), and based on these results would be the preferred test over the 6 minute endurance run (Van Mechelen et al., 1986).

Another study examining the reliability and validity of the 20-meter shuttle run was conducted in 1992 by Liu, Plowman, and Looney. Subjects for their study included 20 American students between the ages of 12 and 15 years old. They discovered that the number of laps completed in the 20-meter shuttle run was correlated significantly with subject's \( \text{VO}_2 \text{ max} \) results. The correlation for males was 0.65 (n = 22), for females, \( r = 0.51 \) (n = 26) and for males and females, \( r = 0.69 \) (Liu et al., 1992). In reference to reliability testing, the intraclass coefficient was 0.93 (Liu et al., 1992).

McVeigh, Payne, and Scott (1995) also examined the reliability and validity of the 20-meter shuttle run; however, subjects for their study were 13 to 14 year old Edinburgh school children. Subjects for their study performed three shuttle run tests and three
treadmill tests for VO$_2$max. In addition to the aerobic tests, subject's skinfold measurements were taken which combines a feature that is different than previous studies. In reference to females, it was discovered that by adding the subject's tricep skinfold thickness, a more accurate regression equation could be generated (R$^2 = 0.85$, SEE = 2.4) (McVeigh et al., 1995). For males, the addition of subject's combined tricep and subscapular skinfold thickness leads to a more accurate equation (R$^2 = 0.68$, SEE = 3.23) (McVeigh et al., 1995).
REFERENCES


APPENDIX C: DATA COLLECTION GUIDELINES

Preliminary set up for testing:

- Floor swept and clear of debris
- Lines marked with tape and cones
- Tape recorder set up
- K4b2 system warm-up
- Gas calibration
- Height and weight measurements

Instructions for participant:

You will run across the area and pass the line by the time the beep sounds. At the sound of the beep, you may turn around and run back to the other end line. If you get to the line before the beep, you must wait for the beep before running in the other direction. If the next beep sounds and you haven’t reached the end line, turn around and run in the other direction to the other line. The beeps will get faster and faster. You will hear a triple beep sound when the beeps start to get closer together. You may quit running at any time that you choose; however, I encourage you to give your best effort.

Before starting the test:

- Ask if any questions
- Make sure shoes are tied
- Remind them to catch themselves if they start to feel off-balanced
- Remind them that a researcher will be near at the end

Encouragement script:

First 2-8 laps: “Good job!” “You are doing good!”
Laps 9-16: “Way to go (name)!” “Keep it up!”
Laps 16+: “You are doing great (name)!” “Keep it up!”

* Always clapping and following near participant
* Move in closer to participant near the end of the test
* Be prepared to catch him should he lose balance
APPENDIX D: IRB LETTER

To: Jennifer A. Hinely
    Health & Kinesiology

Cc: Dr. Barry Joyner, Faculty Advisor
    Health & Kinesiology

From: Mr. Neil Garretson, Coordinator
      Research Oversight Committees (IACUC/IBC/IRB)

Date: September 15, 2000

Subject: Status of Application for Approval to Utilize Human Subjects in Research

After an expedited review of your proposed research project titled “The Reliability and Validity of the PACER for 3rd and 4th Grade Children,” it appears that the research subjects are at minimal risk and appropriate safeguards are in place. I am, therefore, on behalf of the Institutional Review Board able to certify that adequate provisions have been planned to protect the rights of the human research subjects. This proposed research is approved through an expedited review procedure as authorized in the Federal Policy for the Protection of Human Subjects (45 CFR §46.110(4)), which states:

(4) Collection of data through noninvasive procedures (not involving general anesthesia or sedation) routinely employed in clinical practice, excluding procedures involving x-rays or microwaves. Where medical devices are employed, they must be cleared/approved for marketing.

However, this approval is conditional upon the following revisions and/or additions being completed prior the collection of any data:

1. You will need to obtain, and submit a copy of to the IRB Coordinator, a letter of permission/support from the principal of the school. This letter should clearly indicate that he/she has granted you permission to conduct this project, with students of this school.

2. Bulleted item number 8 of the informed consent document, please provide details on this “assessment of my physical condition prior to participation.” Who will be conducting this assessment? What will the assessment involve? What are the individual(s) qualifications to conduct this assessment?

3. Bulleted item number 8 of the informed consent document should be revised so that it accurately reflects the participants of this study (i.e., it is relevant to those individuals being asked to consent), and not an over-generalized ‘catch-all’ statement.
4. Bulleted item number 9 of the informed consent document should read as follows:

If you have any questions about this research project, please call me (the researcher) at (phone number). If you have any questions or concerns about your rights as a research participant in this study, they should be directed to the IRB Coordinator at the Office of Research Services and Sponsored Programs at (912)681-5465.

5. Lastly, please provide a published article or summary of the use of the PACER field test and the "K4b2 portable gas exchange system."

If you have any questions, comments, or concerns about these conditions of approval, please do not hesitate to contact the IRB Coordinator. Please send a copy of all revised and/or additional materials to the IRB Coordinator at the Office of Research Services and Sponsored Programs (PO Box 8005).

This IRB approval is in effect for one year from the date of this letter. If at the end of that time, there have been no changes to the exempted research protocol, you may request an extension of the approval period for an additional year. In the interim, please provide the IRB with any information concerning any significant adverse event, whether or not it is believed to be related to the study, within five working days of the event. In addition, if a change or modification of the approved methodology becomes necessary, you must notify the IRB Coordinator prior to initiating any such changes or modifications. At that time, an amended application for IRB approval may be submitted. Upon completion of your data collection, please notify the IRB Coordinator so that your file may be closed.

Oversight Coordinator

Research Oversight Committees
Georgia Southern University
PO Box 8005
Statesboro, GA 30460

P: 912-681-5465 F: 912-681-0719
http://www2.gasou.edu/research/Resources/ovrsight@gasou.edu
To: Jennifer A. Hinely
Health & Kinesiology

Cc: Dr. Barry Joyner, Faculty Advisor
Health & Kinesiology

From: Mr. Neil Garretson, Coordinator
Research Oversight Committees (IACUC/IBC/IRB)

Date: October 17, 2000

Subject: Status of Conditional IRB Approval to Utilize Human Subjects in Research

The Institutional Review Board (IRB) Committee has received your revised and/or additional application materials for the approved research titled, “The Reliability and Validity of the PACER for 3rd and 4th Grade Children.” You have satisfactorily met the conditions of your Institutional Review Board (IRB) approval, as detailed in the September 15, 2000 approval letter.

Please remember that this approval is in effect for one year (9/15/00 – 9/15/01) and if at the end of that time there have been no substantive changes to the approved methodology, you may request a one year extension of the approval period.

Good luck with your research efforts, and if you have any questions, comments, or concerns about the status of your approval, please do not hesitate to contact me.

Oversight Coordinator

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