ACCURACY OF RATINGS OF PERCEIVED EXERTION (RPE) DURING TREADMILL WALKING AT 50% AND 70% OF $\dot{V}O_2R$

THESIS

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CHAPTER 1

INTRODUCTION TO THE STUDY

Accurately and consistently monitoring exercise intensity has received much attention in the literature (American College of Sports Medicine [ACSM], 2000); (Borg, 1982); (Pollock, Jackson, & Foster, 1986, p. 161-176); (Pollock & Wilmore, J.H., 1990, p. 91-160). According to ACSM, the most accurate method for monitoring exercise intensity is the %$\dot{V}O_2R$ method (Pollock et al., 1998). $\dot{V}O_2R$ represents the difference between maximum VO_2 and resting VO_2, so that regular exercise performed at 50-85% of $\dot{V}O_2R$ has been reported to elicit optimal physiological adaptations (i.e., an increase in $\dot{V}O_2max$, lactate threshold, and aerobic fitness). Establishing recommended intensities using this method, however, requires either elaborate equipment or sophisticated mathematical formulas (e.g., the ACSM metabolic equations). In light of this, alternative methods for monitoring exercise intensity have been developed.

Research has shown heart rate (HR) to be a valid method for setting and monitoring exercise intensity (Pollock, Jackson, & Foster, 1986, p. 161-176);

(Pollock & Wilmore, J.H., 1990, p. 91-160). In fact, a linear relationship between VO_2 and HR exists, such that 50 to 85% of heart rate reserve (HRR) is equivalent to 50 to 85% of $\dot{V}O_2R$ (Pollock et al., 1998); (Swain, Leutholtz, King, Haas, & Branch, 1998), with HRR representing the difference between maximum HR and resting HR. Based on this model, achieving 50% of HRR, for example, elicits the same training adaptations as achieving 50% of $\dot{V}O_2R$. Although HRR is the most commonly employed method for regulating exercise intensity (Pollock et al., 1998), achieving a target HR range requires instrumentation or training in HR palpation (Gardner, Danks & Scharfsiein, 1979); (Oldridge, Haskell, & Single, 1981); (White, 1977). The degree of accuracy in estimating percent values for $\dot{V}O_2R$ using HRR varies with age, fitness level, and mode of exercise (Pollock et al., 1971); (Shepherd, 1975); (Sidney, Shepherd, & Harrison, 1977); (Swain & Leutholtz, 1997); (Thomas, Ziogas, Smith, Zhang, and Londeree, 1995); (Wenger & Bell, 1986). Furthermore, for some, HR palpation is difficult. In fact, studies have shown the accuracy of self-monitored pulse rates to be variable (McArdle, Zwiren, & Magel, 1969). In light of these limitations, other methods for monitoring exercise intensity should be considered.

Borg (1973) has suggested that ratings of perceived exertion (RPE) may be a more accurate way to measure exercise intensity during a graded exercise test (GXT) because individuals can learn how to use perceptual responses within recommended training intensities to improve the cardiovascular system. An important consideration is to identify the corresponding VO2 value to HR and RPE at specific intensities during exercise. This is known as an *estimation* procedure that identifies a specific RPE value to be prescribed according to a particular percentage of the individual's VO2max. This RPE can then be *reproduced* during exercise to regulate intensity and provide optimal results. Pollock et al., (1998) recommends using RPE as an adjunct to target heart rate (THR) to monitor the intensity of the physical activity. Once the individual can identify the appropriate intensity based on RPE compared to the recommended heart rate range, HR monitoring can be eliminated. Consequently, target RPE may be used as an alternative to HR monitoring.

The RPE method allows the subjects to easily monitor their exercise intensity and does not require any additional physiological monitoring or interruption of physical activity (Dunbar et al., 1992). The RPE scale has become a valid tool for setting and monitoring exercise intensity and is commonly used in a variety of settings such as clinical rehabilitation and fitness centers (Dishman, Patton, Smith, Weinberg, & Jackson, 1987). The Borg RPE scale quantifies an individual's subjective feelings of exertion on a 15-point scale, ranging from 6 – 20 (Borg, 1973). RPE has been shown to correlate well with blood lactate, HR, pulmonary ventilation (VE), and $\dot{V}O_2R$ responses to exercise (Borg, 1982); (Pollock & Wilmore, 1990). Based on these relationships, the ACSM recommends that a healthy adult exercise at an RPE of 12 – 16 on the 6 – 20 category RPE scale (Pollock et al., 1998). Exercising within a RPE range of 12 – 16 corresponds with 50 - 85% of $\dot{V}O_2R$ and individuals that train within this RPE range can expect improvements in cardiovascular fitness, as established by the ACSM (Pollock et al., 1998).

Borg and Linderholm (1970) recommend RPE should not vary according to gender when men and women of similar age are compared while exercising on a treadmill or cycle ergometer. The reproducibility of RPE among gender has been compared during various modes of exercise (i.e. treadmill and cycle) while using either absolute (VO2 L/min, HR b/min) and/or relative units (%VO2max, %HRR) as the reference criteria (Borg & Linderholm, 1970); (Noble, Maresh, & Ritchey., 1981). However, there is limited evidence regarding gender differences that consistently support or refute the accuracy of RPE replicability among males and females (Demello, Cureton, Boineau, & Singh, 1987); (Eston & Williams, 1988); (Kravitz, Robergs, Hayward, Wagner, & Powers, 1997); (Ueda & Kurokawa, 1995). Current research (Borg, 1982); (Dishman, Patton, Smith, Weinberg, & Jackson, 1987); (Dunbar et al., 1992) addressing the accuracy of reproducing a prescribed RPE from an estimation trial is limited to male subjects.

The purpose of this study is to compare perceived exertion responses (RPE) to steady-state treadmill walking at 50% of $\dot{V}O_2R$ and 70% $\dot{V}O_2R$ for males and females. In addition, this study will determine the accuracy in replicating exercise intensity using the Borg RPE scale while exercising on a treadmill.

CHAPTER 2

METHODS

Subjects

Subjects were recruited from physical education as well as fitness and wellness classes *(N=17 males, N=23 females)* at a south-central university in the United States. Written consent was obtained from all subjects after a detailed description of all testing procedures was provided. A comprehensive health appraisal questionnaire was completed and signed by all subjects as defined by the American College of Sports Medicine (American College of Sports Medicine [ACSM], 2000). Procedures to conduct this investigation were submitted to and approved by the university's Institutional Review Board.

Instruments

A calibrated physician's scale (Detecto Scale Co., Jericho, NY) served to measure heights and weights of all subjects, and Lange calipers (Cambridge, MD) were used to measure skinfold thickness. Body composition was assessed using a 3-site skinfold procedure (Pollock, Schmidt, & Jackson, 1980) (males:

chest, abdomen, thigh; females: tricep, suprailiac, thigh). An experienced test administrator, previously trained according to ACSM standards, performed the body composition assessment (ACSM, 2000). Maximal exercise tests were performed on a Trackmaster treadmill (FullVision, Newton, KS). During each exercise test, heart rate (HR) was measured by a Polar Vantage XL telemetric HR monitor (Stanford,CT). Expired air was analyzed throughout the tests with a PARVO Medics metabolic analyzer (Salt Lake City, UT). Minute ventilation (V_E), oxygen consumption (VO_2), carbon dioxide production (VCO_2), and respiratory exchange ratio (RER) were determined from 60-s averages. Calibration was performed before each test day using a certified gas mixture (O_2 = 16% and CO_2 = 4%, Scott Medical Products, Plumsteadville, PA).

Testing Procedures

All subjects visited the laboratory on three separate occasions within a two week period. Each subject participated in two estimation and two production trials, with a minimum of 48-hrs between trials yet no more than two weeks apart. Height, weight, and skinfold measurements were measured and recorded (in exercise clothes, without shoes). Prior to testing, subjects were instructed to: (a) drink plenty of fluids over the 24-hr period preceding the test; (b) avoid food, alcohol, nicotine, and caffeine for at least four hours before testing; (c) avoid strenuous physical activity the day of the test; and (d) attain six to eight hours of sleep the night before the test (ACSM, 2000). A 24-hr history questionnaire was completed by each subject and reviewed by the test administrator during each visit to confirm adherence to the pre-test instructions prior to testing.

During the first lab visit, each subject sat quietly for five minutes in which heart rate (HR) and oxygen uptake (VO_2) were recorded to replicate a typical state of rest (Swaine & Leutholtz, 1997). Resting VO_2 was recorded for at least five minutes, or until a steady-state condition was achieved. Stable VO_2 and VCO_2 values ($\pm$10%) and steady HR ($\pm$5 b/min) during the last three minutes of each stage was the criteria for determining steady-state intensity (Walker, Murray, Jackson, Morrow, & Michaud, 1999). This information was used to determine the subjects' VO_2 reserve ($\dot{V}O_2R$).

To determine VO_2max, each subject performed a graded maximal exercise test according to the Bruce treadmill protocol (Bruce, 1971). Peak VO_2 was considered VO_2max if two of the three criteria were met: (a) leveling off of VO_2 despite an increase in workload; (b) achievement of age-predicted maximal heart rate (HR) (220-age); (c) an RER greater than 1.15; and (d) failure to maintain pace despite strong verbal encouragement. Measurements for VO_2, VCO_2, VE, and RER were determined from 60-s averages. Heart rate and RPE using the Borg scale (6-20) were recorded at the end of each minute. The data from this procedure was used to determine the subjects' $\dot{V}O_2R$ at 50% and 70%. Resting VO_2 was subtracted from VO_2max and then multiplied by 50% and 70%, respectively. Resting VO_2 was then added to this value to determine $\dot{V}O_2R$ at 50% and 70%. The participant was scheduled to return no sooner than 48-hours to complete the second visit.

The second visit included randomly administering estimation trials on the treadmill at 50% or 70% of $\dot{V}O_2R$ to determine an exercise RPE at the specified workload. This second session began with an explanation on how to utilize Borg's Rating of Perceived Exertion scale (6-20). Participants were instructed to read perceptual scaling instructions according to Borg (Noble et al., 1973). Any questions regarding instructions or procedures were addressed at this time. A RPE scale was posted and displayed throughout this and every testing session. The modified Balke protocol was used to set the treadmill speed (3.5 mph = males, 3.4 mph = females) and grade according to gender (Balke & Ware, 1959). In order to elicit 50% or 70% $\dot{V}O_2R$, treadmill speed was held constant and grade was increased once a steady-state condition was reached. To ensure accuracy of the subjects exercise VO_2, a steady-state was defined as a VO_2 within $\pm$2 ml/kg/min (Walker et al., 1999). Subjects were asked to rate their perception of effort each minute during the test while heart rate was recorded. During the last minute of each workload, VO_2, VCO_2, VE, and RER were collected from expired air which was then used to determine when subjects attained 50% of $\dot{V}O_2R$ or 70% of $\dot{V}O_2R$. After a five minute seated rest period, the same procedure was followed with the remaining workload.

The third visit included subjects performing a production trial at 50% or 70% of $\dot{V}O_2R$ in a counterbalanced sequence. Each subject was assigned a given RPE that corresponded to 50% of $\dot{V}O_2R$ on the treadmill as which was determined by their estimation trial at 50% of $\dot{V}O_2R$.

The RPE scale remained in full view. The trial began with a five minute warm-up on the treadmill which was held at a constant speed (3.5 mph = males, 3.4 mph = females) at 0% grade. Each subject then had three minutes to adjust only the grade in order to achieve the given RPE to represent 50% $\dot{V}O_2R$. The instrumentation panel (% grade) was concealed from the participants during testing. After the final minute of adjusting treadmill grade, the exercise was continued for an additional five minutes to collect HR as well as VO_2, VCO_2, VE, and RER from expired air after each minute.

Following the first production trial, a five minute seated rest period was performed and the same procedure was followed with the remaining workload. Again, the subject was assigned a given RPE that corresponded to 70% of $\dot{V}O_2R$ on the treadmill which was determined by their estimation trial at 70% of $\dot{V}O_2R$.

The subject was given a five minute warm-up on the treadmill during which speed was held constant (3.5 mph = for males, 3.4 mph = for females) at 0% grade. The subject then had three minutes to adjust the grade in order to achieve the given RPE to represent 70% $\dot{V}O_2R$. The instrumentation panel (% grade) was concealed from the participants during testing. After the final minute of adjusting treadmill grade, the exercise was continued for an additional five minutes to collect HR as well as VO_2, VCO_2, VE, and RER from expired air each minute.

Statistical Analysis

Linear regression was used to determine the correlation between the established and reproduced $\dot{V}O_2R$ values from the subjects reported RPE at 50% $\dot{V}O_2R$ and 70% $\dot{V}O_2R$. Standard Error of Estimation (SEE) was calculated $s(1-R^2)^{1/2}$. Reproduction error was calculated as $[\Sigma(y-y')^2 x n^{-1}]^{1/2}$, where y' is the established $\dot{V}O_2R$ and y is the reproduced $\dot{V}O_2R$. A Mixed-Model Repeated Measures ANOVA was used to determine if there were systematic errors in reproducing $\dot{V}O_2R$ values from RPE.

CHAPTER 3

RESULTS

A total of 40 subjects *(N=23 females, N=17 males)* were recruited to participate in this investigation. 8 subjects *(N=5 females, N=3 males)* discontinued participation due to personal reasons or were asked to withdraw from the investigation because of physical injuries sustained outside of the study. In addition, subject data (*N=1)* was excluded due to equipment malfunction during the reproduction phase. After data screening, the final sample included 31 subjects *(N=17 females, N=14 males).* Table 1 includes the subjects' descriptive characteristics. Males and females significantly differed on body weight $t(29) = -5.5$, $p<.05$, height $t(29) = -8.1$, $p<.05$, BMI $t(29) = -3.0$, $p<.05$, percent fat $t(29) = 6.8$, $p<.05$, and VO_2max $t(29) = -2.7$, $p<.05$.

Table 1. Characteristics of the subjects (Mean$\pm$ SD).

Variables	Female (N=17)	Male (N=14)	Total (N=31)
Age (yr)	22.94 $\pm$ 3.25	22.93 $\pm$ 2.45	22.94 $\pm$ 2.87
Height (in)*	63.37 $\pm$ 1.87	70.38 $\pm$ 2.90	66.50 $\pm$ 4.25
Weight (lbs)*	135.02 $\pm$ 19.61	199.16 $\pm$ 43.55	163.99 $\pm$ 45.60
BMI*	23.67 $\pm$ 3.08	28.19 $\pm$ 5.16	25.71 $\pm$ 4.67
% Body Fat*	22.37 $\pm$ 3.88	10.17 $\pm$ 6.03	16.86 $\pm$ 7.87
VO_2max (ml kg^{-1} min^{-1})*	39.47 $\pm$ 4.47	45.10 $\pm$ 6.88	42.01 $\pm$ 6.27
HRmax	187.12 $\pm$ 7.63	188.29 $\pm$ 8.19	187.65 $\pm$ 7.77

*P<.05 for differences between males and females

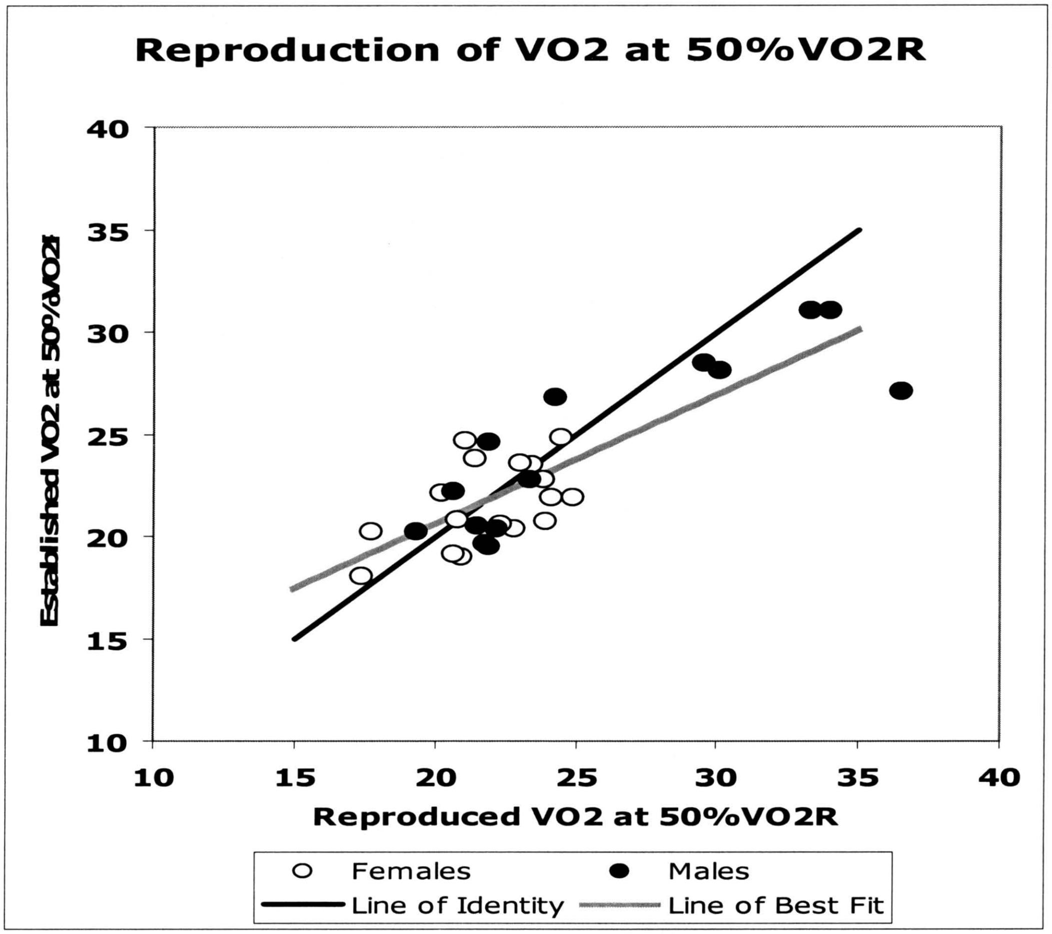
For predicting 50% $\dot{V}O_2R$ from RPE, there was a significant correlation of .83 between the estimation and prediction values, F(1,29) = 65.1, p<.05. This relationship is demonstrated in **Figure 1**. When split between the male and female sample, this relationship was stronger in the male subjects (r = .86, F (1,12) = 34.2, p<.05) than in the female subjects (r = .53, F (1,15) = 5.8, p>.05). The SEE was 2.0 ml/kg/min, and reproduction error was 2.6 ml/kg/min. The descriptive statistics for the estimation and prediction values are reported in Table 2. Repeated measure ANOVA revealed no mean difference in finding 50% $\dot{V}O_2R$ based on RPE, F(1,29) = 3.0, p>.05. There was no variation in this effect due to gender, F(1,29) = 1.2, p>.05.

Table 2. Estimation and Production Trials for Males and Females (Mean ± SD).

	Estimation		
Variables	Male	Female	Total
VO2 @ 50% VO_2R	24.45 ± 4.24	21.64 ± 2.03	22.91 ± 3.47
VO2 @ 70% VO_2R	33.18 ± 5.06	30.01 ± 2.26	31.44 ± 4.05
RPE @ 50% VO_2R	11.14 ± 2.18	10.77 ± 1.52	10.94 ± 1.83
RPE @ 70% VO_2R	14.07 ± 2.09	13.47 ± 1.55	13.74 ± 1.81
HR @ 50% VO_2R	137.29 ± 6.82	139.12 ± 13.88	138.29 ± 11.13
HR @ 70% VO_2R	161.0 ± 6.03	165.41 ± 8.79	163.42 ± 7.87
	Re-Production		
Variables	Male	Female	Total
VO2 @ 50% VO_2R	25.74 ± 5.74	21.94 ± 2.20	23.66 ± 4.53
VO2 @ 70% VO_2R	33.81 ± 6.42	27.90 ± 2.73	30.57 ± 5.55
RPE @ 50% VO_2R	11.14 ± 2.18	10.77 ± 1.52	10.94 ± 1.83
RPE @ 70% VO_2R	14.07 ± 2.09	13.47 ± 1.55	13.74 ± 1.81
HR @ 50% VO_2R	138.29 ± 11.87	141.12 ± 14.30	139.84 ± 13.12
HR @ 70% VO_2R	161.32 ± 11.72	161.41 ± 12.18	161.37 ± 11.78

Note: VO_2 = (ml kg^{-1} min^{-1})

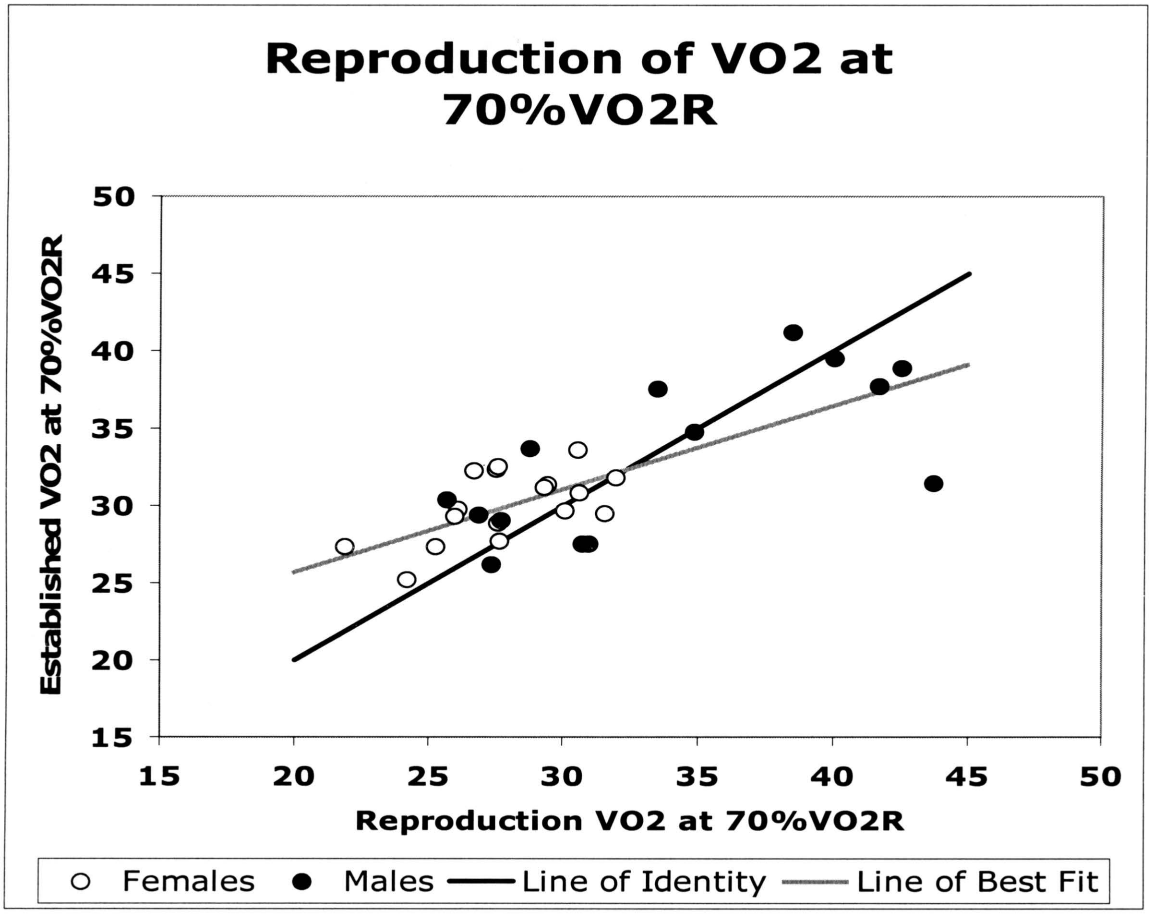
Figure 1.



For predicting 70% $\dot{V}O_2R$ from RPE, there was a significant correlation of .74 between the estimation and prediction values, $F(1,29) = 35.2$, $p<.05$. The SEE was 2.8 ml/kg/min and the reproduction error was 3.8 ml/kg/min. This relationship is demonstrated in **Figure 2**. When split between the male and female sample, this relationship was also stronger in the male subjects ($r = .70$, $F(1,12) = 11.5$, $p<.05$) than in the female subjects ($r = .60$, $F(1,15) = 8.6$, $p>.05$). Repeated measure ANOVA revealed no mean difference in finding 70% $\dot{V}O_2R$

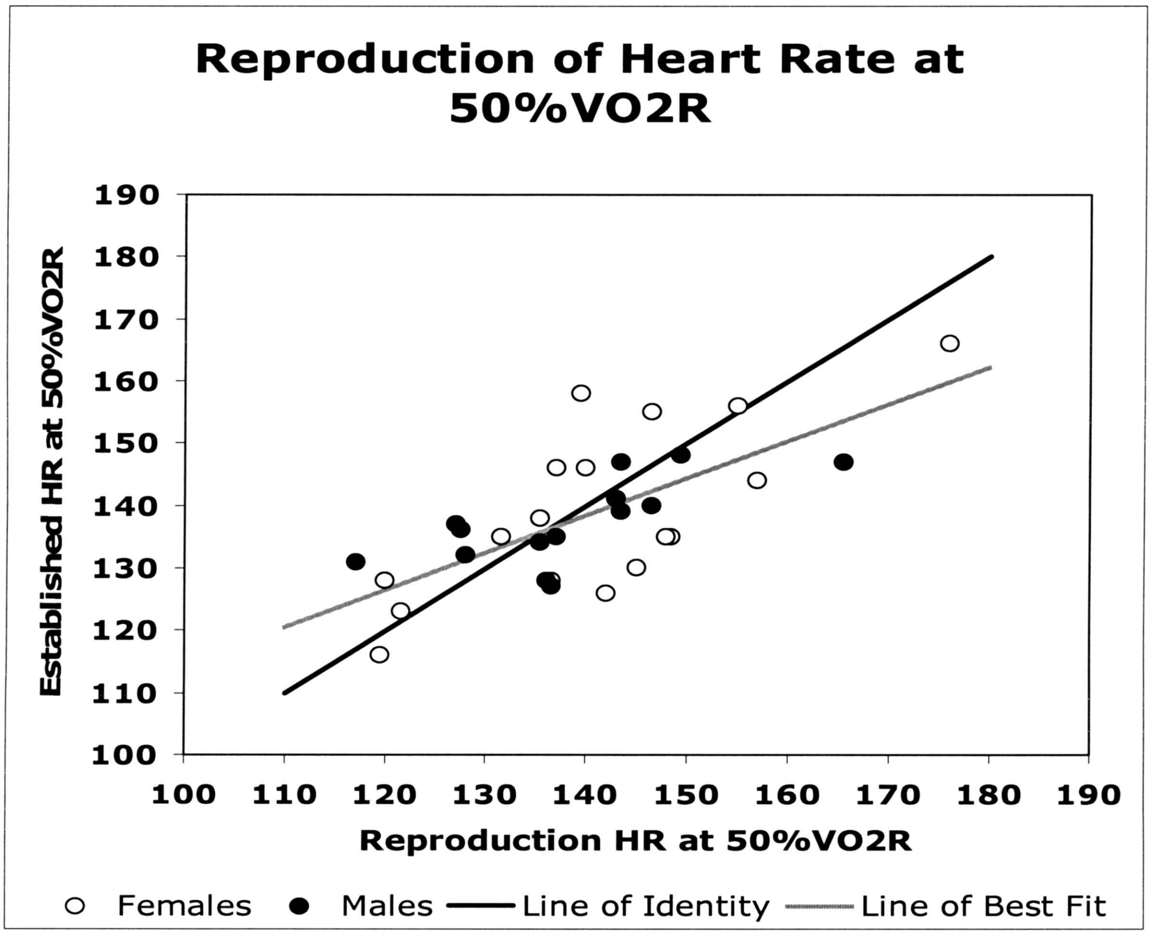
based on RPE, F(1,29) = 1.3, p>.05. There was no variation in this effect due to gender, F(1,29) = 2.1, p>.05.

Figure 2.



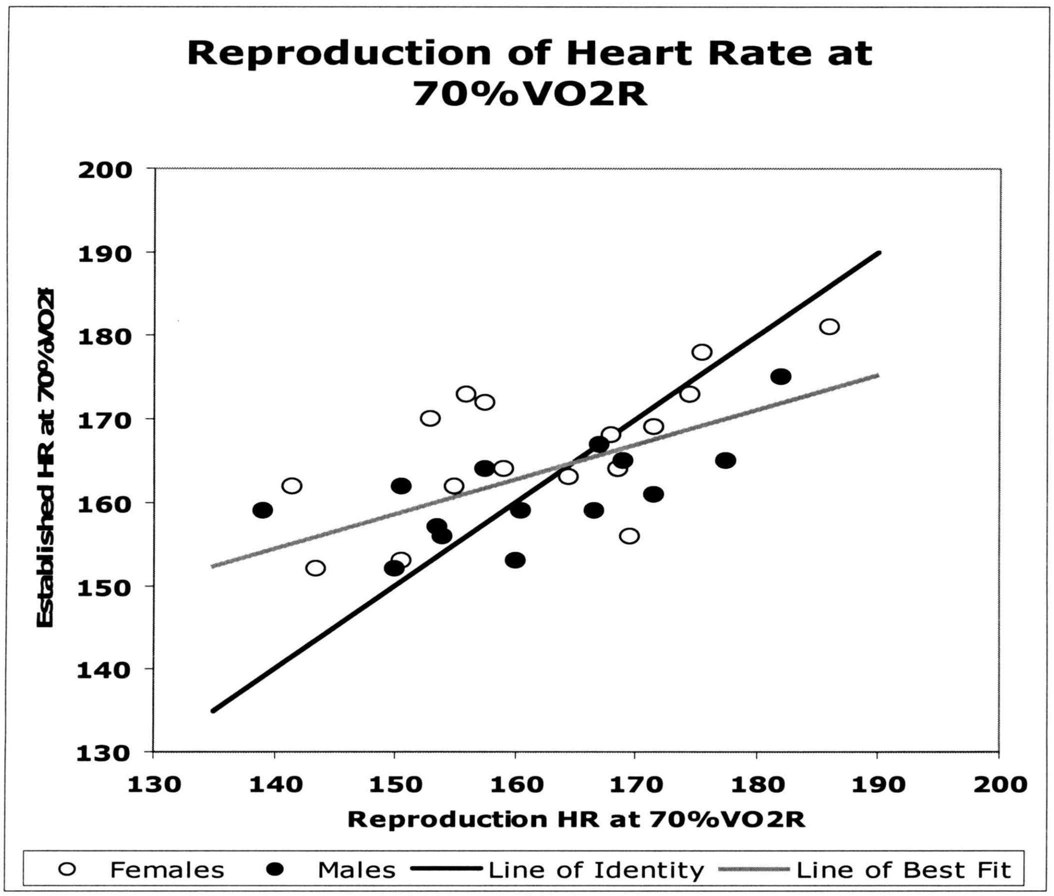
The descriptive statistics for heart rate (HR) values during estimation and prediction trials are also reported in Table 2. For predicting HR at 50% $\dot{V}O_2R$ from RPE, there was a significant correlation of .71 between the estimation HR and prediction HR values, F(1,29) = 28.8, p<.05. The SEE was 8.0 b/min and the reproduction error was 9.5 b/min. This relationship is demonstrated in **Figure 3**. When split between the male and female sample, this correlation was present in both the male subjects (r = .70, F (1,12) = 11.8, p<.05), and in the female subjects (r = .73, F (1,15) = 16.9, p<.05). Repeated measure ANOVA revealed no mean difference in finding HR at 50% $\dot{V}O_2R$ based on RPE, F(1,29) = 0.7, p>.05. There was no variation in this effect due to gender, F(1,29) = 0.08, p>.05.

Figure 3.



For predicting heart rate (HR) at 70% $\dot{V}O_2R$ from RPE, there was a significant correlation of .63 between the estimation HR and prediction HR values, F(1,29) = 19.1, p<.05. The SEE was 6.3 b/min and the reproduction error was 9.6 b/min. This relationship is demonstrated in **Figure 4**. When split between the male and female sample, this correlation was also present in both the male subjects ($r = .67$, $F(1,12) = 9.6$, $p<.05$), and in the female subjects ($r = .66$, $F(1,15) = 11.8$, $p<.05$). Repeated measure ANOVA revealed no mean difference in finding HR at 70% $\dot{V}O_2R$ based on RPE, $F(1,29) = 1.3$, $p>.05$. There was no variation in this effect due to gender, $F(1,29) = 1.8$, $p>.05$.

Figure 4.



CHAPTER 4

DISCUSSION

It has been established that prescribing an appropriate exercise intensity between 50% – 85% of maximum oxygen uptake reserve ($\dot{V}O_2R$) can help improve an individuals' level of cardiovascular fitness and overall health (Pollock, Jackson, & Foster, 1986, p. 161-176). The Borg scale is commonly used to monitor exercise intensity according to an individual's perception of effort (RPE) (Borg, 1982). ACSM recommends exercising at an RPE of 12-16, which corresponds to a $\dot{V}O_2R$ of 50 – 85% (Pollock et al., 1998). Rating of perceived exertion (RPE) is linearly related to VO2 and HR, regardless of age, gender or mode of exercise (Borg, 1982). However, previous studies suggest that the linear relationship between RPE and both VO2 and HR during treadmill exercise may not be consistent between genders. This study compared perceived exertion responses (RPE) during steady-state treadmill walking at 50% of $\dot{V}O_2R$ and 70% $\dot{V}O_2R$ among males and females. The accuracy of replicating these RPE responses according to gender was also examined.

Oxygen Uptake

During the RPE reproduction, comparisons of % $\dot{V}O_2R$ were made between males and females exercising on the treadmill at intensities of 50% and 70%. Males (r=.86) were more accurate at reproducing RPE compared to females (r=.53) at 50% $\dot{V}O_2R$, but there was a significant correlation between established VO2 and reproduced VO2 in both genders during this intensity. At 70% $\dot{V}O_2R$, males (r=.70) were also slightly more accurate at reproducing RPE than females (r=.60) but there was a significant correlation between established VO2 and reproduced VO2 in both genders during this intensity. For both males and females, these results support the accuracy of using an estimation session to define an appropriate RPE which could be used to regulate the intensity of exercise performed on a treadmill. The estimation-reproduction procedure is performed to increase accuracy in intensity during exercise. Pollock and Wilmore (1990) recommend using RPE as an adjunct to THR to monitor the intensity of the physical activity. However, once the individual is appropriately trained, the RPE method allows easy monitoring of exercise intensity and it does not require additional physiological monitoring or the interruption of physical activity

Furthermore, females were not quite as accurate as males in regulating exercise intensity based on RPE. The differences observed in the accuracy of the reproduction of RPE at specified intensities may lie within the perception mechanism. Ekblom and Goldbarg (1971) examined the relationship between the different physiological variables known to influence HR and RPE and propose the factors which influence perception of effort are local (e.g. feelings of strain in working muscles). This can influence RPE when small muscle groups are utilized during activity. RPE may be affected by not only metabolic function, but also by the stress placed on local musculature as resistance is increased (Noble et al., 1973). Ekblom and Goldbarg (1971) also suggest that an increased ventilation and respiratory rate are associated with producing and effecting central cues for the perception of exertion during physical activity. However, Ekblom and Goldbarg (1971) did not examine the effect of RPE on gender and was limited to male subjects.

According to Mihevic and Morgan (1980), RPE is influenced according to respiratory and local muscle exertion but the differences are not varied among gender. The accuracy of using RPE during exercise among gender has been examined by comparing criteria according to HR, VO2, or RPE in relative or absolute units. When comparing males to females, an absolute exercise intensity will generally represent a greater percentage of VO2max for females. Previous investigations (Demello, Cureton, Boineau, Singh, 1987); (Kravitz, Robergs, Hayward, Wagner, & Powers, 1997) suggest RPE estimations are higher for females when comparisons are made using absolute criteria. This may in part, be explained by gender differences in maximal aerobic power. There are a variety of physiological differences among males and females, such as an increase in lean body mass, larger blood volume and higher VO2max in males. However, Robertson et al., (2000) found when making comparisons using relative criteria, RPE does not differ at higher exercise intensities, according to gender.

Robertson et al., (2000) reported male RPE was significantly greater for men at specified sub-maximal VO2 intensities but RPE differences disappeared when comparisons were made at higher intensities (70%, 80%, and 90%). The VO2max values of the subjects were significantly lower for women, which the authors note may have contributed to the inaccuracies of the percent VO2 exercise values that were prescribed. Discrepancies between studies are speculative, but differences could not have resulted from gender-specific variations in the subjects' level of fitness. Although there were differences in VO2max, the level of fitness among males and females in the present study appear to be representative of individuals that are classified in good to excellent aerobic categories, according to ACSM (2000).

Heart Rate

The minimum threshold for improving aerobic capacity is 50% of oxygen uptake reserve ($\dot{V}O_2R$) or HRreserve (HRR) and the maximum limit is 85% of $\dot{V}O_2R$ and HRR (ACSM, 2000). Swain and Leutholtz (1997) found exercise intensities established at a specific % of $\dot{V}O_2R$ are equivalent to intensities at a specific % of HRR, suggesting that the use of %$\dot{V}O_2R$ rather than %VO2max is appropriate to prescribe intensity when calculating a target VO2 from the HRR method. The current results support this finding. For predicting HR at 50%$\dot{V}O_2R$ from RPE, there was a significant correlation of between the estimation HR and prediction HR total values (males, r=.70 and females, r=.73). For predicting HR at

70% $\dot{V}O_2R$ from RPE, there was also a significant correlation between the estimation HR and prediction HR values. HR @ 50% and 70% $\dot{V}O_2R$ did not greatly differ between genders on the treadmill. Robertson et al., (2000) reported there were no differences in HR between males and females when comparisons were made using both absolute (b/min) and relative (%HRmax) reference criteria. Robertson et al. (2000) also found that these results were consistent for treadmill, simulated ski, and cycle during exercise. The results of the present study indicate that HR is an accurate metabolic response to treadmill exercise for males and females and was consistent to the recorded VO2 data. It would then be expected that RPE is associated to the individuals' metabolic rate and would not differ between male and female subjects when comparisons were made using HR as the reference criteria.

Conclusion

The ACSM recommends using both HR and the rating of perceived exertion (RPE) to monitor exercise intensity (ACSM, 2000). The perceptual regulation of exercise intensity is a physiologically valid method if HR, VO2, rate-pressure product or ECG criteria are similar when comparing results between a graded exercise test and an exercise session so that RPE may be used in addition to HR or independently (ACSM, 2000). The differences in RPE between males and females have been examined in previous research, although the results are limited. Results of this study demonstrate there is a significant correlation between established and reproduced values of VO2 and heart rate based on RPE at 50% and 70% $\dot{V}O_2R$. This relationship differs only slightly by gender and is not significant.

These results may have important implications when using RPE to prescribe and regulate exercise intensity. Because RPE responses are rated higher among females, HR should be used to gauge exercise intensity and adjustments in exercise prescriptions based on RPE should be made to ensure adequate training levels and safety. A possible future investigation may be to examine the accuracy of an individuals' preferred intensity of exertion (RPE) during exercise. This may likely be used to promote adherence to an exercise prescription and physiological responses can indicate if the preferred intensity meets current exercise guidelines (ACSM, 2000).

APPENDIX A

REVIEW OF LITERATURE

ACCURACY OF RATINGS OF PERCEIVED EXERTION (RPE) DURING TREADMILL WALKING AT 50% AND 70% OF $\dot{V}O_2R$

$\dot{V}O_2R$ represents the difference between maximal oxygen uptake ($\dot{V}O_2max$) and resting $\dot{V}O_2$, and is commonly used to prescribe exercise intensity (American College of Sports Medicine [ACSM], 2000). Training adaptations (i.e., an increase in $\dot{V}O_2max$, lactate threshold, and metabolic fitness) occur in a healthy adult when aerobic activity is performed at 50 to 85% of $\dot{V}O_2R$ for 20 to 60 minutes 3 to 5 days per week (Pollock et al., 1998). Though $\%\dot{V}O_2R$ is the most accurate method of achieving optimal exercise intensity, it is impractical in most health and fitness settings as it requires expensive laboratory assessments and equipment. Fortunately, more realistic methods for estimating exercise intensity have been established.

Heart rate (HR) has been shown to be a valid method for setting and monitoring exercise intensity (Gardner, Danks, & Scharfsiein, 1979). A linear relationship between VO_2 and HR exists, such that 50 to 85% of heart rate reserve (HRR) is equivalent to 50%-85% of $\dot{V}O_2R$ (Pollock et al., 1998); (Swain, Leutholtz, King, Haas & Branch, 1998). Based on this model, achieving 50% of HRR, for example, is the can be expected to illicit the same training adaptations as achieving 50% of $\dot{V}O_2R$. Although the HRR method is the most commonly employed formula for regulating exercise intensity (Pollock et al., 1998), its degree of accuracy in estimating $\%\dot{V}O_2R$ varies with age, fitness level, and mode of exercise (Pollock et al., 1971); (Shepherd, 1975); (Sidney, Shepherd, & Harrison, 1977); (Swain & Leutholtz, 1997); (Thomas, Ziogas, Smith, Zhang & Londeree, 1995); (Wenger & Bell, 1986). In addition, achieving a target HR range requires instrumentation or training in HR palpation (Gardner, Danks, & Scharfsiein, 1979); (Oldridge, Haskell, & Single, 1981); (White, 1977). However, HR palpation may be difficult for some and studies have shown the accuracy of self-monitored pulse rates to be variable (McArdle, Zwiren, & Magel, 1969). Other methods for monitoring exercise intensity should be considered as either an adjunct or an alternative to HR monitoring.

Ratings of perceived exertion (RPE) have been shown to be a valid tool for setting and monitoring exercise intensity (Borg, 1982). RPE positively correlates with blood lactate, HR, pulmonary ventilation (VE), and $\dot{V}O_2R$ responses to exercise (Borg, 1982); (Pollock & Wilmore, 1990). Based on these relationships, the ACSM recommends that a healthy adult exercise at an RPE of 12 – 16 on the 6 – 20 category RPE scale (Pollock et al., 1998). Exercising within this RPE range can be expected to elicit the same training adaptations as exercising within $\%\dot{V}O_2R$ recommendations of 50% – 85% (Pollock et al., 1998).

The results of previous research examining the effects of gender differences when using RPE during exercise (Borg & Linderholm, 1970); (Henriksson, Knuttgen, & Bonde-Peterson, 1972); (Noble et al., 1981); (Robertson et al., 2000) have shown to be incongruent. For example, differences in RPE exist when absolute criteria, such as oxygen consumption (VO2) or HR (b/min) are used to compare RPE between males and females. Females tend to rate RPE higher than males at the same workload (Demello, Cureton, Boineau, & Singh, 1987); (Kravitz, Robergs, Hayward, Wagner, & Powers, 1997). In contrast, when using relative criteria such as % maximum oxygen consumption (%VO2max) and % heart rate maximum (%HR max) to compare perception of effort, only minimal differences in RPE are present between genders.

When investigating a gender effect, specific physiological differences exist that can impact the outcome of study results and should be evaluated. For example, males have an increased amount of upper body strength resulting in more muscle mass. Differences also exist in the amount of hemoglobin and hormone levels, as well as differences in heart and lung size (Drinkwater, Horvath, & Wells, 1975). This discrepancy between genders can result in a lower cardiac output among females, which is also influenced by lower blood volume (Drinkwater et al., 1975). Generalizations about RPE production at different intensities across gender are not well understood and are poorly documented because most research has been conducted with male subjects only. Although the use of RPE is promising in ensuring that individuals exercise at a sufficient intensity, its accuracy in regulating exercise intensity across genders warrants review and further discussion.

The purpose of this review is to discuss use RPE in monitoring exercise intensity between men and women. This review will begin with a brief discussion on the development of the minimal intensity threshold and the HR methods commonly employed to monitor exercise intensity, including their accuracy. Then, the derivation of the RPE method, how it is used to measure intensity of exercise, and its accuracy in estimating exercise intensity will be reviewed. Finally, limitations revealed in the research on the effectiveness of the RPE method in monitoring exercise intensity will be delineated and recommendations for future research will be made.

Prescription of Exercise Intensity

The ACSM states that any low-intensity exercise performed below current recommendations may not sufficiently improve an individual's VO2max (ACSM, 2000). Prescribing an appropriate exercise intensity is important because health-benefits accrue from participating in cardiovascular exercise only at moderate to vigorous intensities for longer durations (ACSM, 2000). The health-benefits gained by participating in cardiovascular exercise are significantly increased when exercising at higher intensities and/or greater frequency/durations, although this is generally not recommended for the general population. High intensity exercise can increase the risk of musculoskeletal injury, cause cardiovascular symptoms or events to occur, and also may deter individuals psychologically from continuing exercise (Pollock & Wilmore, 1990). The current ACSM guidelines recommend adults should exercise at a moderate intensity for a long duration to reduce the risk of a cardiac occurrence.

The goal of a metabolic assessment is to measure the individual's maximal oxygen uptake (VO2max) and to prescribe an appropriate exercise intensity accordingly. Methods commonly used to prescribe exercise intensity include metabolic assessment (VO2 or METs), heart rate (HR) (beats/min) and the rating of perceived exertion (RPE) (Pollock & Wilmore, 1990). A direct measurement of VO2max is determined by assessing an individuals' maximum aerobic capacity during a graded exercise test (GXT). This is usually performed in a laboratory setting equipped with specific instruments. Other methods can be performed indirectly to provide an estimated VO2max. Over time, aerobic training can increase an individuals' VO2max. A comparison of VO2max responses with pretest and posttest measurements may be used to assess the effect of a cardiorespiratory exercise program. A re-evaluation may be periodically performed every three to six months to update the exercise prescription as the individual's level of fitness increases (Pollock & Wilmore, 1990).

Since heart rate (HR) is directly proportional to exercise intensity and is linearly related to %VO2max, it is one of the most widely used methods for measuring cardiovascular exercise (ACSM, 2000). If VO2max cannot be directly measured, exercise intensity can be prescribed using only HR responses to a GXT. A target heart rate (THR) range may be prescribed using a % of HR maximum (HRmax) and exercise intensity can be monitored based on HR. The HRmax method can establish a THR training zone by 1) utilizing the maximal HR recorded during a GXT or 2) subtracting the individual's age from 220 which is then prescribed as a percent of HR maximum (70-85 % of HRmax). The age-determined HRmax is frequently used to calculate THR, although there is a reported error in accuracy ($\pm$ 15 beat/min) (Londeree & Ames, 1976). This range of error may result in prescribing ineffective training intensities for individuals.

The Karvonen (Karvonen, Kentala, & Mustala, 1957) or HRreserve (HRR) method is also generally used since it does not require expensive instrumentation. The HRR method is a percentage of the difference between maximal and resting HR. HRR is the difference between HRmax and resting HR (HRmax – HRrest) and it has been more closely correlated with METs achieved on a GXT than the HRmax method. In order to ensure accuracy of the HRR method, resting HR should be counted for 30 seconds while the individual is seated upright and rested (Karvonen et al., 1957). However, if variability is found among resting HR measurements, an error of $\pm$10 beat/min will only affect the HRR value by 2-3 percent (Pollock & Wilmore, 1990).

VO2R is the difference between VO2max and resting VO2 (VO2max – VO2rest). The minimum threshold for improving aerobic capacity is 50 % of oxygen uptake reserve (VO2R) or HRreserve (HRR) and the maximum limit is 85 % of VO2R and HRR. Swain and Leutholtz (1997) found exercise intensities established at a specific % of VO2R are equivalent to intensities at a specific % of HRR, suggesting that the use of %VO2R rather than %VO2max is appropriate to prescribe intensity when calculating a target VO2 from the HRR method. The study examined 63 males and females (33 males, 30 females) ranging in age from 18 to 40 years old. The subjects performed incremental maximal tests on a cycle ergometer. There was a significant difference between %HRR and %VO2max ($P<0.001$) which supports the finding an inequality exists when using %VO2max to prescribe exercise intensity. There is a stronger relationship between %HRR and %VO2R and it is more accurate to use for prescribing exercise intensity because a person at rest will have a VO2 above zero. If %HRR and %VO2max are used, an error in prescribing exercise intensity will result since a range of heart rates will be directly compared to a range of VO2 starting at zero. Another significant difference was found between individual fitness level and %VO2max ($P<0.01$). Prescribing exercise based on a %VO2max is not accurate for individuals of varying fitness levels because it does not consider their relative efforts (Swain & Leutholtz, 1997). Resting VO2 will vary according to an individual's level of fitness. Consequently, it is recommended that exercise intensity should be prescribed according to a % of VO2R. The ACSM suggests (Pollock et al., 1998) that a sufficient intensity for developing and maintaining cardiovascular fitness in healthy adults is 50% to 85% of heart rate reserve (HRR) or 65% to 90% maximum heart rate (HRmax).

Pulse Monitoring

As mentioned earlier, exercise intensity can be monitored based on a THR range. Pulse monitoring can be performed by palpating several different points on the body, usually the radial or carotid arteries. The level of accuracy when palpating a pulse during exercise may depend on how well the individual can correctly locate the pulse and count the beats per minute (Pollock, Brodia & Kendrick, 1972). White (1977) states that using the carotid artery to monitor HR may reduce the immediate post-exercise HR and may not be an accurate monitor of exercise intensity, however, these results have not been supported in subsequent studies (Gardner, Danks & Scharfsiein, 1979); (Oldridge, Haskell &

Single, 1981). The pulse technique requires precision and may not be suitable for all individuals.

Chow and Wilmore (1984) compared the validity of the heart rate monitoring method to the RPE method. They found that when compared to an electrocardiogram, the accuracy of target heart rate did not greatly differ from the rating of perceived exertion (RPE) method by 55% vs. 49% respectively. Chow and Wilmore (1984) suggest RPE can be used in place of HR to accurately monitor exercise intensity. The ability for an individual to correctly monitor exercise intensity is needed to ensure improvements in health as well as adherence to the prescribed exercise program, particularly if the individual is a beginner or a cardiac patient undergoing rehabilitation (Dishman, 1982). Subjective tolerance to exercise should correlate with an ideal physiological response so that the individual may perceive the exercise session or rehabilitation process as fun or manageable.

Limitations of Using the Maximal Heart Rate Method for Exercise Prescription

When using the maximal heart rate (HRmax) method to prescribe exercise intensity, the results may lead to an inaccurate exercise prescription because the individual's true maximal HR is unknown. Additionally, the range of error may result in as much as $\pm$10 beat/min (Noble & Robertson, 1996); (Pollock & Wilmore, 1990). Londeree and Moeschberger (1982) found the age-predicted HRmax estimate (220-age) to under or overestimate by an average of 11 beats per minute. Age accounted for 70 to 75 % of the variance in HRmax and there was no reported difference in HRmax for gender or race (Londeree & Moeschberger, 1982).

Other problems associated with HR prescriptions include variability due to individual fitness level, age and testing mode. Prescribing an exercise intensity specific to mode may be preferred to ensure accuracy since Londeree and Moeschberger (1982) found that HRmax is lower on the cycle ergometer than the treadmill.

Swain et al., (Swain, Leutholtz, King, Haas, & Branch, 1998) noted %HRR is highly correlated with %VO2max during treadmill exercise however the regression analyses shows these two variables differ significantly from the line of identity. %HRR was more closely matched to %VO2R on the treadmill in the regression than was %HRR compared to %VO2max. Swaine et al., (1998) suggests the advantages to prescribing exercise using %VO2R will result in a more precise intensity to for a THR range. It will also allow an equivalent relative exercise intensity for individuals of different fitness levels and can translate %VO2R into net caloric expenditure more easily.

The ACSM recommends using both HR and the rating of perceived exertion (RPE) to monitor exercise intensity (ACSM, 2000). The perceptual regulation of exercise intensity is a physiologically valid method if HR, VO2, rate-pressure product or ECG criteria are similar when comparing results between a graded exercise test and an exercise session so that RPE may be used in addition to HR or independently (ACSM, 2000); (Pollock & Wilmore, 1990). RPE is linearly related to HR as power output increases during a variety of exercise modalities although previous research suggests that power output and MET level are higher for a given RPE or HR during a training session versus a GXT (Gutmann et al., 1981); (Pollock et al., 1971); (Van Den Burg & Ceci, 1986). This suggests RPE may be affected by not only metabolic function, but also by the stress placed on local musculature as resistance is increased (Noble et al., 1973). Current research is limited regarding the accuracy of perceptually regulating individual exercise intensity across different modes of activity.

RPE Production from an Estimation Assessment

An effective method used to reduce error in using RPE to regulate intensity is to administer estimation and production trials to determine an appropriate RPE while exercising on various modes of activity. In order to accurately correlate HR to RPE during exercise, it is recommended that a graded exercise test (GXT) be performed to identify the corresponding VO2 value at specific HR and RPE intensities (Borg, 1973). This is known as an *estimation* procedure, which identifies a specific RPE value that corresponds to a particular percentage of the individuals' VO2max. Ideally, this RPE should be *reproduced* during exercise in order to regulate intensity. Once the estimation-reproduction procedure is performed, Pollock and Wilmore (1990) recommend using RPE as an adjunct to THR to monitor the intensity of the physical activity. When the individual can identify the appropriate intensity with the recommended heart rate range, HR monitoring may be eliminated altogether and exercise intensity may be monitored exclusively by target RPE. Once appropriately trained, the RPE method allows the individual to easily monitor their exercise intensity and it does not require additional physiological monitoring or interruption of physical activity.

The objective of an individual exercise prescription is to achieve the recommended HR and/or RPE. Although RPE is commonly used to measure exercise intensity, there is limited research regarding the validity of RPE for regulating exercise intensity across different modes of exercise (Noble, 1982). Dunbar et al., (1992) utilized an estimation-production technique to investigate the validity of regulating exercise intensity using RPE among young males on the treadmill and cycle. Results indicated the target RPE at 50% VO2max during the treadmill estimation trial (GXT) were valid to regulate exercise intensity on the cycle and treadmill, however was not as accurate at regulating exercise intensity at 70% VO2max on the treadmill. When group means were averaged across groups, less than a 2% difference existed for reproducing oxygen uptake from RPE. However, when these values were expressed intra-individually, the errors approximate 20-25% (Dishman, 1994). Errors encountered by using RPE to reproduce a prescribed exercise intensity may be accelerated by the changes in perceptual signal strength, making it difficult for the individual to perceive intensity.

Smutok et al., (1980) also found discrepancies in regulating exercise intensity using estimation-production trials. The authors collected HR and RPE data from 10 healthy male subjects as they performed a GXT. Two additional GXTs were conducted in which the subjects were asked to adjust the treadmill speed in an effort to reproduce the original RPE that was experienced during the first GXT. The correlation between speed and RPE was 0.83. However, at faster speeds, there were no significant differences between HR above 150 bpm and RPE above 12. At lower speeds and HR, RPE was associated with large production errors. Smutok et al., (1980) concluded that using a RPE to prescribe exercise may be misleading and requires further investigation. Noble (1982) states that HR and RPE have a high correlation when recommended to an individual after participating in a GXT but also suggests it may be a challenging task to require individuals to reproduce and control a specific RPE attained from a GXT and that continued research is necessary.

In addition, Ceci and Hassmen (1991) examined a group of 11 healthy male subjects and compared the results of two tests using different modes of exercise at specific RPE. In the first test, subjects performed treadmill running and adjusted the speed to produce the assigned RPE of 11, 13 and 15 during each stage, after which HR, blood lactate and velocity was collected and analyzed. The second test followed the same protocol except it was performed on an outdoor track. A significant difference was observed between the track and treadmill results for HR, blood lactate and velocity at the three RPE levels that were assigned. Ceci and Hassmen (1991) recommend prescribing an unfit individual to maintain a RPE at or below 13 in a field setting and a 15 on the treadmill, which is within the ACSM recommendation guidelines.

History on the Rating of Perceived Exertion

Borg constructed the initial RPE scale which quantified individual's subjective feelings of exertion by using a 21-grade category scale ranging from 0 to 20 (Pollock & Wilmore, 1990). Borg placed verbal anchors at every odd number on the scale to help the individual closely align perceived exertion with heart rate during exercise. The HR could then be predicted when the RPE value is multiplied by 10 (RPE x 10 = HR). The initial study (Borg, 1982) included 12 subjects which were instructed to pedal a bicycle ergometer for a duration of 6 min at each stage: 100, 300, 600, 900, and 1,200 kpm/min. Results showed that although heart rate increased linearly with power output, perceived exertion did not increase with power output. Additional investigations (Borg, 1973); (Borg & Linderholm, 1967) on the use of the 21-grade scale were conducted with individuals of various ages and results showed younger groups selected given ratings at higher hear rates. It was concluded that this scale was not linear with heart rate or power output so it was then altered to a 15-point category scale to increase the linearity between heart rate and workload. To assess the new scale, subjects performed a GXT on a cycle and a treadmill. Data was collected at all intensities and the results showed correlations between HR and RPE for work performed on a cycle ergometer and treadmill were .94 and .85 respectively (Borg, 1973).

As power output increases, lactate and ventilation rapidly accelerate and RPE is not linear so this scale is used to parallel the physiological response to perceptual response. Borg (1982) states that among the various scales that have been created, no particular scale is perfect for all situations, yet favors the use of the original 15-grade category scale for aerobic activities. To increase the validity of the scale, Borg (1982) recommends providing scaling instructions to the participant before performing the exercise test.

Perception Mechanism

Although a complex process, various studies have investigated how physiological factors contribute to an individual's perception of effort. Borg (1982) initially recognized a physiological influence on perceptual ratings and proposed that the components responsible are related to cardiovascular and muscular responses. In 1971, Ekblom and Goldbarg (1971) formally examined these factors which are known as central and local. Central factors are related to sensations from the cardiorespiratory system which include physiological processes such as HR, ventilation (VE), respiratory rate (RR) and oxygen uptake (VO2) and local factors are associated with feelings of strain in working muscles (Robertson, 1982). As an individual exercises, specific physiological factors are ultimately responsible for the perceptual rating of effort across varying levels of intensity.

Ekblom and Goldbarg (1971) examined the relationship between the different physiological variables known to influence HR and RPE. The study observed 19 male subjects, ages 21 through 32 years old. Eight subjects participated in an eight-week training program that included cross-country running 5 to 7 days/week and were tested before and after an 8-week period of physical training. In addition, six subjects performed work on the cycle ergometer, the treadmill and while swimming. Assessments of the perceptual response to various modes of exercise such as: arm versus leg exercise, cycling versus running, and swimming versus running were observed. Fourteen subjects also underwent the use of autonomic nervous system blocking agents to assess the effects on RPE after altering HR. Results from the training program show VO2max increased from 2.90 l/min to 3.35 l/min however, at a given sub-maximal percentage of VO2, RPE was the same. The comparison among various modes of exercise reveals a significant difference in RPE between arm versus leg work and cycling versus running. For a given %VO2max, RPE while performing arm work was significantly higher than during the legwork. RPE was higher when smaller muscle mass was utilized to perform the exercise as demonstrated during arm versus legwork. RPE values at a given sub-maximal VO2 while cycling were higher than running. The reported RPE increase while cycling versus running may be attributed to local muscular fatigue and higher levels of blood lactate production, which will enhance the perception of intensity. Swimming RPE remained unchanged when compared to running perception. RPE was not influenced by blocking agents, validating the use of RPE by individuals who are taking prescribed medications.

Ekblom and Goldbarg (1971) propose the factors which influence perception of effort are multiple and complex. They suggest local factors influence RPE when small muscle groups are utilized during activity. Ekblom and Goldbarg (1971) also suggested that an increased ventilation and respiratory rate are associated with producing and effecting central cues for the perception of exertion during physical activity.

Borg (1962) closely examined the relationship of heart rate with perceived exertion and found that RPE have a high association with HR. Perception may be regulated by physiological strains resulting from increases in metabolic rate, such as HR and VO2. Noble et al., (1973) conducted an investigation on the factors responsible for perception while walking versus running at velocities of 2.5, 3.5, 4.5 and 5.5 mph. The study included 20 males which were instructed to walk and run at four velocities (2.5, 3.4, 4.5, and 5.5 mph) which were presented randomly, for a duration of three minutes each. HR and RPE data were recorded during the last 30 seconds at each velocity. Results showed lower HR values while walking than for running at speeds less than 4 mph. At 4.92 mph, walking HR was higher. The results for RPE were considerably different, suggesting that HR is not linearly related to RPE. RPE in response to running was lower than walking RPE even though HR was equal. For example, RPE at a HR of 150bpm while running was 10.3 and while walking was 12.1. This supports Ekblom and Goldbarg's (1971) claim that HR is not a primary factor in rating perceptual intensity. They suggest other factors such as workload and VO2 may be more closely related to RPE.

Mihevic (1981) supports the notion that central factors begin to affect perceptual input approximately 30-180 seconds after the initiation of exercise and the corresponding time frame that is required for cardiovascular and ventilatory adaptation to occur. In addition, the prediction of heart rate from RPE as proposed by Borg, applies most reliability at higher exercise intensities (Mihevic, 1981). Overall the Borg scale is a valid quantative indicator of subjective effort and can provide a basis for exercise prescription, however, different psychological states such as anxiety or depression can also affect RPE ratings (Borg, 1982). Proper instructions on how to rate subjective perceptions increases the measurement error in the Borg scale.

Accuracy of RPE among Gender

Differences and similarities in gender and perception for a given exercise mode has been documented (Borg & Linderholm, 1970); (Demello, Cureton, Boineau, & Singh, 1987); (Noble, Maresh, & Ritchey, 1981); (Robertson et al., 2000); (Ueda & Kurokawa, 1995). Studies have made comparisons based on criteria expressed in absolute units (i.e., oxygen uptake (VO2 L/min), heart rate (HR b/min); (Demello et al., 1987) (Robertson et al., 2000) and also have used relative units (i.e., %VO2max, %HRmax) (Demello et al., 1987); (Robertson et al., 2000). However, there is limited research which collectively support or refute gender influence on RPE. Many investigations which examine RPE during exercise involve young, physically active males as subjects which limit the scope of research and ability to generalize across genders.

Demello et al. (1987) investigated gender differences in RPE at lactate threshold among trained and untrained males and females during treadmill exercise. Results found no gender differences in RPE even though the lactate thresholds were reached at significantly different percentages of VO2max. RPE had a stronger association with lactate threshold than %VO2max. The study also found when comparing absolute VO2, females estimated RPE to be greater than males, however, when compared to relative VO2, RPE did not differ.

Robertson et al. (2000) suggests when comparing RPE at relative and absolute intensities, there are no gender differences in VO2 and HR at exercise intensities between 70% and 90%. This study investigated 9 men and 10 women which performed a perceptual anchoring and estimation trial on three different modes: treadmill, simulated ski machine and cycle ergometer to determine VO2max/peak. Oxygen uptake and heart rate were recorded and compared using relative criteria among genders and results show that VO2max/peak was higher for females during each exercise mode but HR and RPE did not differ according to gender. When comparing absolute VO2 between genders, RPE was significantly higher for females. This study supports the finding that gender differences in RPE are not evident when comparisons are made among relative criteria such as VO2 and HR. However, absolute and relative VO2max values for males were significantly higher than females. This difference in overall aerobic fitness levels may have contributed to the RPE differences for each mode.

The goal of a VO2 assessment is to prescribe an appropriate target heart rate that the individual can exercise at to elicit an increase in VO2. Monitoring and measuring HR during some modes of exercise may be difficult to perform. For example, Ueda and Kurokawa (1995) investigated the relationship between perceived exertion and physiological variables (HR) in swimming among a group of healthy male and female subjects. HR during swimming can be 10 to 20 b/min lower than in air and is influenced by water temperature. The study concluded RPE is an effective measurement of exercise intensity for men and women and can be easily used during activity.

Many investigations involve young, physically active males as subjects which may limit the scope of research. The simplistic use of RPE seems to be an effective and accessible tool to use for monitoring exercise intensity. However, there is a need for additional research involving women of various ages in order to investigate the accuracy of RPE while participating in different modes of aerobic activity. The differences between males and females using RPE has been ambiguous and limited, particularly when using absolute HR and VO2 as a reference criteria. Additional research using a variety of physiological and psychophysical measurements may provide a valid means of regulating exercise intensity.

APPENDIX B

INFORMED CONSENT

Statement of Informed Consent to Participate in Research Study

1. Testing Purpose:

   I have been selected to participate in a study investigating the accuracy of individual perceptual regulation of exercise intensity. The purpose of this study is to determine if rating individual exercise intensity is accurate while exercising on a treadmill. This study is conducted by Susan Feldpausch, a graduate student in the Health, Physical Education, and Recreation Department at Texas State University-San Marcos. This study is being conducted to fulfill her thesis requirement in the final semester of her master's program. I was selected as a possible participant in this study because of my enrollment in 1) a Physical Fitness and Wellness (PFW) or 2) a Physical Education course at Texas State University-San Marcos. I am one of 40 subjects chosen to participate in this research study.

2. Explanation of Procedures:
   1. If I decide I would like to participate, I will complete the following during my three (3) visits:
      a) a health and history questionnaire.
      b) height, weight, and body composition measurements.
      c) participate in a maximal test to assess my level of cardiovascular fitness.
      d) perform 2 additional cardiovascular assessments on the treadmill in the Human Performance Lab at Texas State University-San Marcos.
   2. I will wear a heart rate monitor and allow metabolic data to be collected for the duration of the assessments.

3. Description of Potential Risks

   I understand there should be minimal risks by participating in this study. However, as with every study, there is a potential. Every effort will be made to minimize these risks by participating in preliminary evaluations and assessments. If I decide to participate in this study, I will be advised not to overexert myself during the assessment phase to enhance the results of the study. I will have an adequate warm-up and will receive instruction prior to testing to reduce the risk of injury.

4. Benefits to be Expected

   Based upon my personal results, I will be able to determine my level of cardiovascular fitness which may indicate my risk level for developing a chronic disease.

5. Participant Responsibilities

   To ensure accurate data collection I will follow the requirements to participate:

(a) drink plenty of fluids over the 24-hr period preceding the test;
(b) avoid alcohol, nicotine, and caffeine for at least 4-hours before testing;
(c) avoid strenuous physical activity 48-hours prior to testing;
(d) get 6 to 8 hours of sleep the day before and
(e) avoid food for at least 4 hours before the test.

I understand I am responsible for disclosing my medical history as well as my current health status. I assume any and all risks of bodily injuries to myself. I should immediately report any unusual feelings that I may experience during testing.

6. Confidentiality

I understand all of the information gathered from this study is confidential and will be disclosed only if I provide written permission. However, I am in agreement that the information from these tests not identifiable to me can be used for research purposes. The data collected for this research will be kept for approximately one year in a confidential file located in the Human Performance Lab which may be accessed by only the primary investigator and the lab coordinator.

If I have any questions, I may contact Susan Feldpausch at (210)273-3721 or the chair of my thesis, Dr. Lisa Lloyd (512)245-8358.

I may request a copy of this form. My decision whether or not to participate in this study will not prejudice my future relations with Susan Feldpausch, or Texas State University-San Marcos. If I decide to drop out of the study, I am free to do so.

I have read this form, and I understand the test procedures, risks, and, benefits of the study I have agreed to participate in. Knowing these risks, and having had an opportunity to ask questions that have been answered to my satisfaction, I consent to participate in this study, and release Texas State University-San Marcos and the investigator of any liability if injury should occur. My signature indicates that I have read the information above and consent to participate in this study.

______________________________	______________
Signature of Participant	Date
______________________________	______________
Signature of Witness	Date
______________________________	______________
Signature of Investigator	Date

APPENDIX C

24-HOUR HISTORY

24-HOUR HISTORY

NAME:______________________________ DATE:________________

TIME:_______________________________

HOW MUCH SLEEP DID YOU GET LAST NIGHT? (Please circle one)
(HOURS) 1 2 3 4 5 6 7 8 9 +10

HOW LONG HAS IT BEEN SINCE YOUR LAST MEAL/SNACK? (Please circle one)
(HOURS) 1 2 3 4 5 6 7 8 9 +10

- IF YOU CIRCLED 1-3, PLEASE LIST THE FOOD/DRINK BELOW:

  ____

HOW LONG HAS IT BEEN SINCE YOU DRANK COFFEE/TEA/SODA/ALCOHOL?
(HOURS) 1 2 3 4 5 6 7 8 9 +10

- IF YOU CIRCLED 1-3, PLEASE LIST THE DRINK BELOW:

  ____

HOW LONG HAS IT BEEN SINCE YOU USED TOBACCO PRODUCTS?
(HOURS) 1 2 3 4 5 6 7 8 9 +10

HOW LONG HAS IT BEEN SINCE YOU PERFORMED INTENSE PHYSICAL ACTIVITY?
(HOURS) 1 2 3 4 5 6 7 8 9 +10

- IF YOU CIRCLED 1-3, PLEASE LIST THE ACTIVITY BELOW:

  ____

APPENDIX D

RPE SCALING INSTRUCTIONS

Instructions for use of the Borg Rating of Perceived Exertion Scale during Exercise:

We will use this Borg scale, which contains numbers 6 to 20 to translate your feelings of exertion while exercising. The range of numbers should represent a range of feelings from “No exertion at all” (number 6) to “Maximal exertion” (number 20). In order to help you select a number which corresponds to your subjective feelings, every other number has an attached verbal expression. For example, point 6 would be the equivalent of sitting down doing nothing, 9 would be walking gently, 13 a steady exercising pace and 19 and 20 would rate the hardest exercise you have ever done.

6
7 - Very, very light
8
9 - Very light
10
11 - Fairly light
12
13 - Moderately hard
14
15 - Hard
16
17 - Very hard
18
19 - Very, very hard
20 - Exhaustion

Your goal is to **rate your feelings which are caused by the work** and **not the work itself**. These feelings should be general, which is about the body as a whole. We will not ask you to specify the feeling but to select a number which most accurately corresponds to your perception of your total body feeling. Keep in mind that there are no right or wrong numbers. Use any number you think is appropriate. (Noble et al., 1972)

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VITA

Susan Feldpausch was born in San Antonio, Texas, January 5, 1980, to Donald and Myra Feldpausch. In 1998, she graduated from John Marshall High school and attended Southwest Texas State University (now Texas State University-San Marcos) where she developed interests in the field of exercise science. She became a member of the American College of Sports Medicine and was certified as a Health/Fitness Instructor. She was selected to intern at the Baylor-Tom Landry Fitness Center in Dallas, Texas, where she worked as a research assistant in the exercise physiology lab. It was during this experience that she developed a research proposal and investigated perceptual regulation and human performance. The results and valuable information obtained from an exploratory study was used to formulate research questions leading to her current research interests. She received the degree of Bachelor of Exercise and Sport Science from Southwest Texas State University in the Fall of 2002. In the Spring of 2003, she entered the graduate program at Texas State University-San Marcos. While pursuing her graduate studies, she accepted a position as a graduate teaching assistant for the Health, Physical Education, and Recreation Department. She will continue her professional development in the field of health and fitness.

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