International Journal of EXERCISE SCIENCE

Original Research

Differences in Rate of Perceived Exertion and Workload Intensity in Males and Females during Submaximal Arm and Leg Ergometry

KONRAD J. DIAS‡1, AMANDA MUNGENAST†1, STEPHANIE SHERWOOD†1, PATRICK MCPHERSON†1, ALLISON VERVILLE†1, SHANNON EATON†1, and DUSTIN R. NADLER‡2

[1]Physical Therapy Program, Maryville University of St. Louis, St. Louis, MO, USA;
[2]Department of Psychology, Maryville University of St. Louis, St. Louis, MO, USA.

†Denotes graduate student author, ‡Denotes professional author

ABSTRACT

International Journal of Exercise Science 15(4): 1222-1235, 2022. Purpose: Arm ergometry (AE) is necessitated for individuals unable to perform leg ergometry (LE) exercise. This study explored gender differences in RPE and workload (WL) during AE and LE at submaximal target heart rates (THR). Methods: 35 healthy college-aged individuals were randomly allocated to begin exercise on either AE or LE. Participants exercised on both modes with increasing WL to achieve submaximal THRs of 110, 120, 130, 140 and 150 beats per minute (bpm). Factorial ANOVAs tested for differences in RPE and WL. Results: No significant differences were found in RPE between genders, as well as between arm and leg exercise ($p > 0.001$). For WL, a significant main effect was found for mode with LE greater than AE ($p < 0.001$), and gender, with males greater than females ($p < 0.001$). A significant interaction effect was also found for HR and mode, with a greater increase in WL during LE compared to AE in both genders ($p = 0.001$). Conclusions: Exercise specialists typically prescribe exercise based on a chosen THR. The results of this study provide meaningful data on mean RPE and WL responses that a given THR elicits for ergometry. The finding of no differences in RPE between AE and LE informs the clinician that at any given submaximal THR, similar RPE scores can be expected during AE and LE. Further research is warranted to investigate differences in wider populations.

KEY WORDS: Perceived exertion, arm exercise, leg exercise

INTRODUCTION

Exercise specialists utilize arm ergometry (AE) and leg ergometry (LE) for aerobic exercise testing and prescription. Although lower body exercise tends to be more common, not all individuals may be able to perform lower body aerobic exercise. Arm exercise is particularly beneficial for individuals incapable of leg work, including persons with spinal cord injuries and those who have sustained a lower extremity injury or surgery. Additionally, AE testing is ideal for individuals involved in occupations or sports involving a considerable degree of arm work where performance in their desired activities is considerably influenced by their upper extremity power. When working with these populations of patients, a clinician's awareness of differences in responses between arm and leg exercise is essential when incorporating arm exercise into any exercise program.

Prior research dedicated to understanding differences between AE and LE has primarily investigated differences based on peak maximal oxygen uptake (VO_2) (9, 12, 17, 22). These differences are challenging to interpret and use in clinical practice and in the community when peak VO_2 is not easily obtainable. Rather than using peak VO_2 in exercise prescription, heart rate, perceived level of exertion and workload are easier and more useful clinically to use in dosing exercise during exercise. Therefore, this investigation aimed to explore differences in the rating of perceived exertion (RPE) and workload (WL) measured at submaximal target heart rates (THR) during AE and LE exercise.

Borg's RPE is a widely used tool to assess an individual's subjective perception of effort during exercise (3). A 15-point scale (6-20) was developed by Borg to provide a simple approximation of HR, in which a 1-point increase in RPE correlates with an approximate 10-point increase in HR (1, 2). In looking at the association between HR and RPE, a large cohort study of 2,560 Caucasian men and women with a median age of 28 years found strong correlations between RPE and HR ($r = 0.74$, $p < 0.001$) and RPE and blood lactate ($r = 0.83$, $p < 0.001$) during incremental exercise tests on the treadmill and cycle ergometer (18). However, this relationship has not been consistent across all studies and has been thought to be influenced by the intensity of exercise, mode of exercise, gender, and the health of individuals (7). A meta-analysis revealed inconsistencies about the strength of the relationship between RPE and various physiological criterion measures with weighted mean validity coefficients of 0.62 for HR and 0.57 for blood lactate (7). These findings suggest that the validity of RPE may not be as high as previously thought, warranting the need for further research investigating differences in RPE responses between genders and between arm and leg modes of exercise in young healthy individuals.

The primary reason for differences between arm and leg exercise is the degree of muscle mass recruited during the activity. Leg ergometry exercise utilizes relatively larger muscles compared to arm ergometry exercise, which concomitantly alters physiological responses. Kang et al. explored differences in metabolic efficiency between arm and leg ergometry at the same relative intensities during AE and LE submaximal testing and found heart rate, power output, and work efficiency to be lower during arm ergometry at each relative intensity of 50, 60, and 70% of peak VO_2 (13). In general, based on results of a systematic review of 41 articles, Larsen et al. determined AE to elicit a maximal oxygen uptake of 70% of that achieved during LE exercise due to differences in muscle size between the arms and the legs (15).

Gender related RPE data during arm and leg exercise reveals contradictory findings. Robertson et al. explored gender differences in RPE at maximal and submaximal exercise during treadmill, simulated ski machine, and leg ergometry exercise and found males to have a higher peak VO_2, but no gender difference in maximal and submaximal HR and RPE during exercise in any of the three modes (17). Scherr et al. found that women had a higher HR for every reported RPE during treadmill and bicycle ergometry exercise while Whaley et al. found men to have significantly higher RPEs at every given exercise intensity when compared to women during treadmill training (19, 21). Additionally, in an analysis of competitive swimmers, Koltyn et al. found females to paradoxically demonstrate lower RPEs but higher HRs than males following the completion of a 200-yard swim in their preferred stroke at 90% of the swimmer's current best time (14). These contradictory findings, suggest the need for further exploration of differences in RPE in a simulated approach that may be used by exercise specialists.

Therefore, the purpose of this study was to conduct a secondary analysis of collected data to investigate differences in RPE and WL at submaximal THR of 110, 120, 130, 140 and 150 beats per minute (bpm) in healthy, non-athletic, traditional college-aged individuals. The primary analysis of the data involved investigating differences in systolic and diastolic blood pressure between arm and leg exercise. For this current secondary analysis, we utilized subject data and generated four hypotheses related to our purpose. First, we hypothesized that there would be no significant difference in RPE between males and females in either exercise mode. Secondly, we hypothesized RPE to be significantly higher with arm ergometry compared to leg ergometry regardless of gender. With respect to WL, we hypothesized absolute WL at any given submaximal THR to be significantly higher in males than females as well as with LE compared to AE exercise.

METHODS

Participants

A power analysis conducted with G*POWER 3.1 (Universitat Kiel, Germany) determined that 40 participants were needed in the present study for a power of 0.92, with an effect size of 0.25 and an $\alpha = 0.05$. A convenience sample of 49 healthy, non-athletic, traditional college-aged students from a midwestern private university initially responded with interest to participate in this study. Participants were included in the study if they were healthy, within the ages of 18 and 25 years, and did not participate in routine exercise. Participants were deemed as being healthy based on their responses recorded on the *Get Active Questionnaire (GAQ)*. Participants that documented any medical condition on the *GAQ* were immediately excluded from the study. This study aimed to evaluate responses in non-athletic participants. In light of this, participants were excluded from the study if they reported exercise at least two times per week of moderate intensity or documented participation in a collegiate sport. Further, participants were not included if they were active smokers, pregnant, had a body mass index (BMI) greater than 30 kg/m^2, or had any known cardiopulmonary or musculoskeletal pathologies. Finally, participants were excluded from the study if they had elevated resting HR values greater than 100 bpm or resting blood pressure (BP) values greater than 130/80 mm Hg. All participants reviewed and signed an informed consent document approved by the Maryville University Institutional Review Board. This study followed all ethical guidelines involved in conducting, collecting and reporting data in exercise science as identified by Navalta and colleagues (16).

Protocol

This was a secondary analysis of a prospective, cross-sectional, observational study. Participants were required to complete arm and leg ergometry exercise. Data collection for each participant occurred on a single visit. This study involved collecting data on two outcome measures including RPE and WL measured at pre-assigned exercise THRs of 110, 120, 130, 140 and 150 bpm. Heart rates were recorded through a Polar H10 heart rate sensor. The Polar heart rate monitor measured HR with the Polar strap placed around the chest at the level of the xiphoid process.

Rating of Perceived Exertion: The 6 to 20 RPE scale developed by Borg was used to collect subjective ratings of perceived exertion. This scale is comprised of 15 grades that correlate with given verbal expressions of levels of exertion. The participant was given a visual of the numerical scale on a piece of paper that also provided verbal descriptors that correlated with specific numbers on the scale. The researchers verbalized descriptors to the participant at each submaximal THR. The participant confirmed the specific descriptor, and the researcher documented the number that correlated with the descriptor.

Workload: Workload was measured on the arm and leg ergometer. The SciFit Inclusive Fitness Pro Upper Body Ergometer was used for AE exercise and the Monark Ergomedic 828E was used for LE exercise. As the subjects exercised on the arm and leg ergometer, workload was progressively increased until each submaximal THR was achieved. At each THR, the researchers recorded the absolute workload in Watts achieved during exercise.

Participants were randomly assigned to begin with either AE or LE exercise. Simple random sampling without replacement was utilized to assign participants their first mode of exercise. Participants drew a single slip from an envelope containing 42 slips, half designated for AE and half designated for LE. This approach ensured equal distribution of participants beginning on either mode of exercise.

Prior to exercise, the participant was fitted with a Polar heart rate monitor which recorded HR measurements. If the individual presented with a resting HR over 100 bpm or BP greater than 130/80 mm Hg, the participant was asked to rest quietly for a 10-minute period. Following the 10-minute rest period, vital signs were reassessed. Participants that continued to present with HR vales greater than 100 bpm or BP readings greater than 130/80 mm Hg were disqualified from further participation in the study.

The exercise session began with a 4-minute active warmup involving exercise at 60 revolutions per minute (rpm) to achieve an intensity of 14 watts (W) for AE or 15 W for LE exercise. Following the active warmup period, the participant continued cycling at the same speed of 60 rpm while the intensity was increased by 5 W for AE or 15 W for LE every 15 seconds until the THRs of 110, 120, 130, 140, and 150 bpm were attained. Once the participant reached each THR, the intensity was held constant for a 15-second interval to ensure the participant remained within 5 beats above or below the THR. If the participant's HR remained outside 5 bpm of the THR, the intensity was adjusted to ensure the THR was maintained for a 15 second period. At each THR, the two outcome measurements of RPE and WL were recorded. After the RPE and WL were collected for the final THR of 150 bpm, the participant completed a 4-minute active cool down at 60 rpm at an intensity of 14 W for AE or 15 W for LE. A fixed 10-minute passive rest period was utilized between exercise on the arm ergometer or leg ergometer to ensure adequate rest and recovery before exercise on the second mode.

Statistical Analysis
Data was run using the statistical package Jamovi (Version 1. 2. 27). Descriptive statistics were performed for sample characteristics. In prior investigations, HR has typically been included as a dependent variable along with intensity of exercise as the independent variable (1, 5). In these investigations, differences in HR were measured at specific intensities during AE and LE exercise. In this study, an alternate methodology was used where HR was considered as an independent variable, with RPE and WL as dependent variables. As indicated in the protocol above, WL was adjusted during AE and LE exercise until a specific THR was attained. Workload in Watts and RPE responses were recorded at submaximal HRs. Therefore, by utilizing HR as the independent variable, this study is able to explore differences in RPE and WL at each of these submaximal heart rates. Factorial analysis of variance (ANOVA) tests were used to assess for differences in RPE and WL. In each of the ANOVAs, heart rate was considered as factor one. Depending on the condition being analyzed, factor 2 was defined as either exercise mode or gender. Each analysis tested for the main effect of each factor as well as the interaction between the two factors. A Bonferroni adjustment was utilized in the statistical analysis with significance set at $p \leq 0$ .001 to eliminate the possibility for a Type I error or false positive result. Rating of perceived exertion, although representing ordinal data, was utilized in the analysis as a continuous variable. Evidence by Gaito summarized that the original categorization of ordinal data if normal in distribution can be considered as a continuous variable and used in statistical processes including analysis of variance (8). All data was checked for normality and no significant deviations were found resulting in the use of parametric tests for analysis of the data.

RESULTS

Initially, 49 individuals responded to the study with their interest in participating in the study. Of these 49 participants, eight were excluded based on the exclusion criteria. Seven participants were excluded due to a BMI greater than 30 kg/m^2, and one was excluded based on a current diagnosis of asthma. Out of the remaining 41 participants, an additional six participants were excluded. Three participants were excluded for resting systolic BP greater than 130 mmHg and one was excluded for a resting HR greater than 100 bpm. Additionally, one individual was excluded due to improper cuff size fitting resulting in inaccurate blood pressure readings, and one was excluded due to inconsistent HR values recorded by the Polar heart rate monitor. The remaining 35 participants reflect the sample of this study (Figure 1).

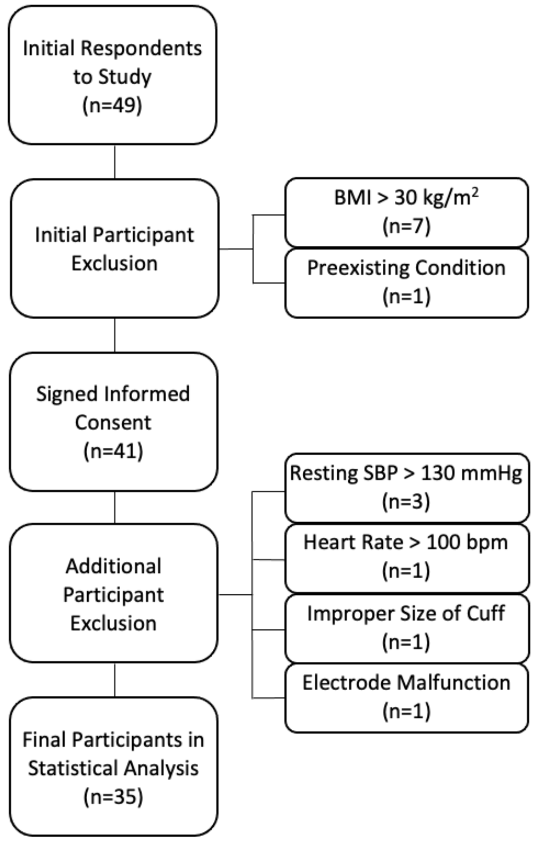

Figure 1. Participant Flow Diagram

Table 1. Subject Data for sample of 35 participants

Variable	Mean (SD)
Age (years)	22.20 (1.35)
Height (meters)	1.77 (0.09)
Weight (kilograms)	74.43 (10.14)
Resting HR (bpm)	77.94 (10.93)
Resting SBP (mm Hg)	110.00 (10.65)
Resting DBP (mm Hg)	61.69 (8.43)

The demographic data for the 35 participants is shown in Table 1. The participant pool consisted of 16 males and 19 females. These were non-athletic college-aged participants with a mean age of 22.2 ± 1.35 years. Participants recorded a healthy body weight with a mean weight of 74.43 ± 10.14 kilograms and a mean height of 1.77 ± 0.09 meters. All participants demonstrated hemodynamic stability with a mean resting HR of 77.94 ± 10.93 bpm, a resting systolic BP of 110.0 ± 10.65 mm Hg, and a resting diastolic BP of 61.69 ± 8.43 mm Hg. Additionally, the mean values with 95% confidence intervals for RPE and WL recorded at each submaximal THR are categorized by gender and mode of exercise in Table 2. Further, the main effects for factor 1 (heart rate) and factor 2 (gender or mode of exercise) and interaction effects for each of the two the dependent variables (RPE and WL) are summarized in Table 3.

Table 2. Mean Rate of Perceived Exertion and Workload at Submaximal Heart Rates

Target Heart Rate	Dependent Variable	Arm Exercise Males	Arm Exercise Females	Leg Exercise Males	Leg Exercise Females
110 bpm	Mean RPE [95% CI]	10.1 [9.4-10.9]	10.0 [9.2-10.8]	10.3 [9.6-11.4]	9.3 [8.5-10.1]
	Mean WL [95% CI] WL (Watts)	40.8 [25.4-56.1]	26.7 [17.7-35.7]	91.6 [76.2-106.9]	52.9 [43.9-61.9]
120 bpm	Mean RPE [95% CI]	12.3 [11-5-12.9]	12.3 [11.4-13.1]	12.0 [11.3-12.7]	10.9 [10.1-11.7]
	Mean WL [95% CI] WL (Watts)	59.7 [44.3-75.0]	37.3 [28.3-46.3]	119.1 [103.7-134.4]	72.6 [63.6-81.6]
130 bpm	Mean RPE [95% CI]	13.6 [12.8-14.3]	13.6 [12.8-14.4]	13.4 [12.7-14.1]	12.2 [11.4-13.0]
	Mean WL [95% CI] WL (Watts)	75.6 [60.3-91.0]	46.1 [37.1-55.0]	136.6 [121.2-151.9]	89.2 [80.2-98.2]
140 bpm	Mean RPE [95% CI]	14.9 [14.1-15.6]	15.2 [14.4-16.0]	14.3 [13.5-14.9]	13.4 [12.6-14.2]
	Mean WL [95% CI] WL (Watts)	87.5 [72.1-102.9]	55.0 [46.0-64.0]	155.9 [140.6-171.3]	103.4 [94.4-112.4]
150 bpm	Mean RPE [95% CI]	16.0 [15.3-16.8]	16.2 [15.4-17.0]	15.4 [14.7-16.2]	14.8 [14.0-15.7]
	Mean WL [95% CI] WL (Watts)	97.8 [82.5-113.1]	62.4 [53.4-71.4]	173.8 [158.4-189.1]	122.4 [113.4-131.4]

RPE = Rate of Perceived Exertion; WL = Workload; bpm = beats per minute; CI = Confidence Interval

Table 3. Effects of Heart Rate and Mode or Gender on Rate of Perceived Exertion and Workload

Differences in RPE and WL in Male and Female participants	Main Effect of Heart Rate.	Main Effect of Mode or Gender.	Interaction Effect
RPE between arm and leg exercise in Males	$p < 0.001$ [F = 188.5, df = 4]	$p = 0.52$ [F = 0.43, df = 2]	$p = 0.30$ [F = 1.2, df = 4]
RPE between arm and leg exercise in Females	$p < 0.001$ [F = 196.9, df = 4]	$p = 0.012$ [F = 7.1, df = 2]	$p = 0.21$ [F=1.5, df = 4]
RPE between males and females with Arm exercise	$p < 0.001$ [F = 205.9, df = 4]	$p = 0.86$ [F = 0.03, df = 2]	$p = 0.90$ [F = 0.3, df = 4]
RPE between males and females with Leg exercise	$p < 0.001$ [F = 171.3, df = 4]	$p = 0.04$ [F = 4.4, df = 2]	$p = 0.66$ [F = 0.6, df = 4]
WL between arm and leg exercise in Males	$p < 0.001$ [F = 160.9, df = 4]	$p < 0.001$ [F = 39.6, df = 2]	$p = 0.001$ [F = 4.91, df = 4]
WL between arm and leg exercise in Females	$p < 0.001$ [F = 129.9, df = 4]	$p < 0.001$ [F = 60.3, df = 2]	$p < 0.001$ [F = 12.70, df = 4]
WL between males and females with Arm exercise	$p < 0.001$ [F = 336.5, df = 4]	$p < 0.001$ [F = 29.6, df = 2]	$p < 0.001$ [F = 18.5, df = 4]
WL between males and females with Leg exercise	$p < 0.001$ [F = 128.6, df = 4]	$p < 0.001$ [F = 23.3, df = 2]	$p = 0.36$ [F = 1.1, df = 4]

RPE = Rate of Perceived Exertion; WL = Workload; df = Degrees of freedom.

Results for RPE: A significant main effect for HR was noted for RPE ($p < 0.001$). This represents a significant increase in RPE with increasing submaximal HR regardless of exercise mode or gender (Figures 2 and 3). Additionally, there were no significant differences in RPE between males and females during arm exercise ($p = 0.86$, $F = 0.03$) or during leg exercise ($p = 0.04$, $F = 4.4$). Further, no significant difference in RPE was noted during AE and LE in males ($p = 0.52$, $F = 0.43$). However, the difference in RPE between exercise modes in females approached significance ($p = 0.012$, $F = 7.1$), with RPE being higher in AE than LE (Figure 2: Female). Finally, no significant interaction effects for HR and gender were noted with AE ($p = 0.90$, $F = 0.3$) and LE ($p = 0.66$, $F = 0.6$), and no significant interaction effects were found between HR and mode in males ($p = 0.30$, $F = 1.2$) and females ($p = 0.21$, $F = 1.5$).

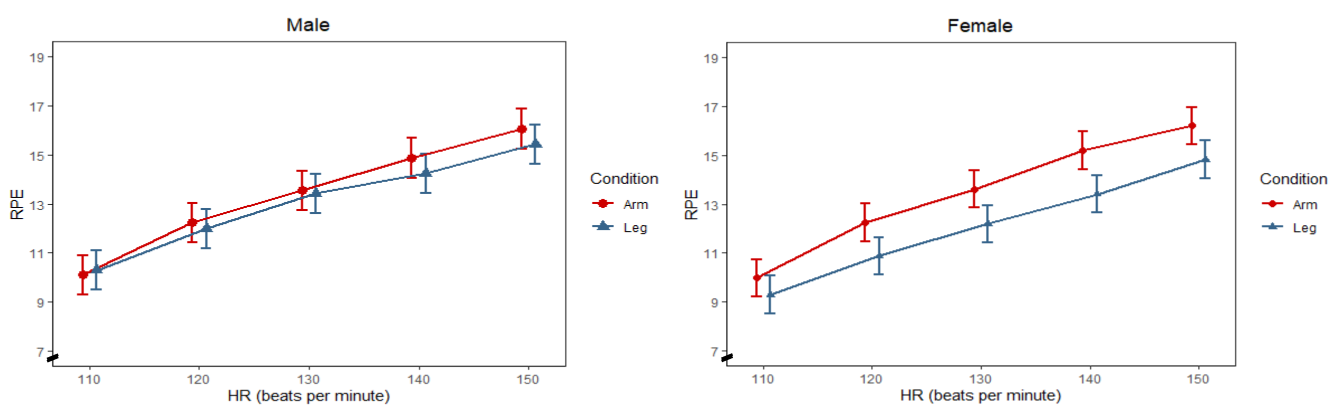

Figure 2. Differences in Rate of Perceived Exertion between Arm and Leg Exercise in Male and Female Participants

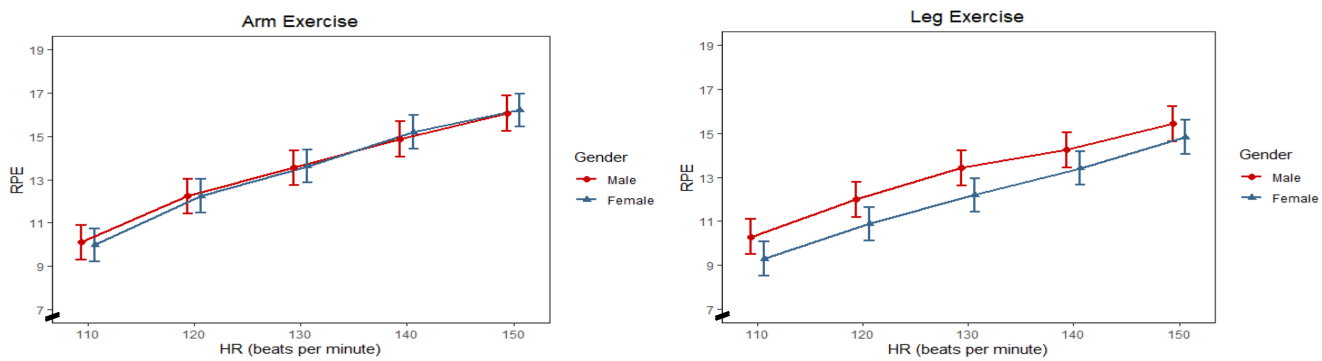

Figure 3. Differences in Rate of Perceived Exertion between Male and Female Participants during Arm and Leg Exercise

Results for WL: A significant main effect for HR was noted for WL ($p < 0 .001$). This represents a significant increase in WL with increasing submaximal HR regardless of exercise mode or gender (Figures 4 and 5). Additionally, WL was significantly higher with LE compared to AE in both males ($p < 0.001$, $F = 39.6$) and females ($p < 0.001$, $F = 60.3$) (Figure 4). There was also a significant interaction effect between HR and mode as seen in Figure 4, with WL increasing at a greater rate during LE as compared to AE in males ($p = 0.001$, $F = 4.91$) and in females ($p < 0.001$, $F = 12.70$). Regarding gender, males achieved a significantly higher WL than females during both AE ($p < 0.001$, $F = 29.6$) and LE ($p < 0.001$, $F = 23.3$) (Figure 5). Finally, a significant interaction effect between HR and gender was noted only with arm exercise, representing WL increasing to a greater extent with AE in males as compared to females ($p < 0.001$, F = 18.5) (Figure 5: Arm Exercise). No significant interaction was present between HR and gender during LE ($p = 0.36$, $F = 1.1$) (Figure 5: Leg Exercise).

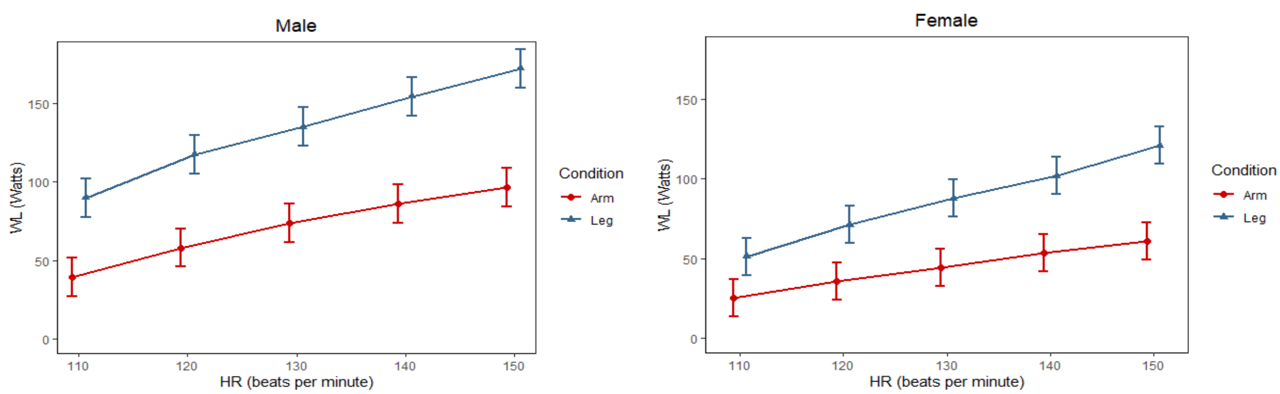

Figure 4. Differences in Workload between Arm and Leg Exercise in Male and Female Participants

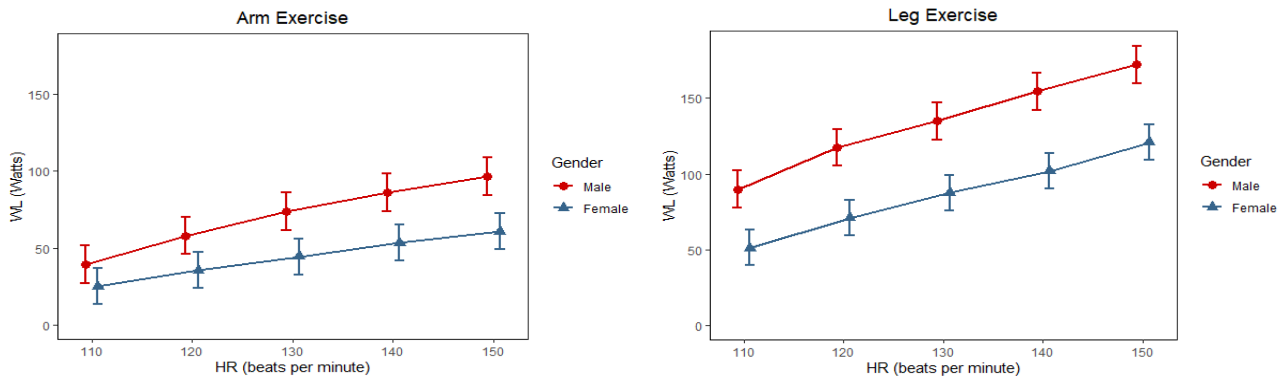

Figure 5. Differences in Workload between Male and Female Participants during Arm and Leg Exercise

DISCUSSION

This study investigated the differences in RPE and WL based on gender and mode of exercise at specific submaximal THRs in healthy, non-athletic, traditional college-aged individuals. This study featured a novel approach to understanding gender and exercise mode differences in RPE and WL measured at specific submaximal THR. In determining the clinical usefulness of this study, absolute and relative intensity of exercise must be considered during exercise on either mode of exercise. Differences in absolute intensity between arm and leg exercise can be directly determined by the external workload (WL) applied to the respective ergometer during exercise. On the other hand, differences in relative intensity of an activity can be defined by the work intensity relative to maximum capacity and can be determined in a variety of ways including submaximal oxygen uptake (VO_2) values, submaximal heart rate (HR) values, or an individual's rate of perceived exertion (RPE) (2). Prior research has looked at RPE based on VO_2 and WL, with HR as a secondary measurement collected throughout the testing procedures (9, 12, 17, 21). The utilization of oxygen consumption as a means of exercise intensity to demonstrate differences in AE and LE is challenging for exercise specialists to use and interpret. However, the use of submaximal HR as an independent variable to explore differences in RPE and WL is novel and is potentially useful to exercise specialists and other rehabilitation professionals.

This investigation was driven by four main hypotheses. The first hypothesis was that males and females would demonstrate similar RPEs at predetermined submaximal THRs regardless of exercise mode. The rationale for this hypothesis was based on the premise that RPE has been shown to be highly correlated with HR (4, 10, 18). The results of this investigation confirm this hypothesis in indicating no significant difference in RPE with increasing submaximal HR between genders during either AE or LE exercise. These findings are consistent with previous research by Robertson et al. who found no significant differences in RPE between genders during exercise on three different modes including treadmill, skiing, and cycling that use leg or a combination of arm and leg musculature (18). Additionally, evidence by Green et al. confirmed no gender differences in RPE during two different forms of leg exercise including treadmill running and leg cycling (9).

The second hypothesis generated was that both male and female participants would report higher RPE scores during AE than LE at given submaximal HR values. Rationale for this hypothesis was based on differences in muscle mass and exercise efficiency between arms and legs (2, 11, 20). This hypothesis was not supported, as RPE did not differ significantly between arm and leg exercise in males or females. However, it is interesting to note that the statistical difference approached significance ($p = 0.012$) in female participants, with AE triggering higher RPE scores. Females have been shown to have a lower relative percentage of muscle mass in the upper body than the lower body, which could explain why females tended to report a slightly higher RPE for arm exercise than leg exercise at the same HR (11). Based on the findings of this small study, clinicians can appreciate the possibility of similar RPE scores between AE and LE at specific submaximal THR.

In regards to WL, the authors hypothesized that males would achieve greater WL than females across submaximal HRs in both exercise modes. This hypothesis was based on differences in muscle mass between males and females, with males having a greater overall muscle mass than females (11). Janssen et al. demonstrated that males have higher relative skeletal muscle mass in the legs and arms, thus capable of generating a higher WL (11). A greater muscle mass would allow male participants to perform more work at the same cardiovascular demand as determined by HR. The results of this study support this hypothesis with male participants demonstrating a higher WL at each submaximal HR in both AE and LE exercise. In fact, in both modes of exercise at any given THR, females achieved a mean WL of only 58-70% of the WL achieved by females. In a sample of individuals with airflow obstruction, Carter et al. found similar results with males completing significantly higher work than females during both AE and LE at peak exercise (6). Additionally, Rascon et al. found significantly higher power outputs in males than in females at moderate and high exercise intensities determined by blood lactate values (17).

The final hypothesis for this study postulated WL at a given submaximal HR to be higher with LE than AE regardless of gender. Prior research has demonstrated that the upper body has less muscle mass than the lower body, which permits a greater WL to be achieved at the same cardiovascular expense during LE exercise (19). The results of this study support this hypothesis and reveal significantly higher WL values with LE exercise compared to AE exercise at submaximal THR. Although most previous research has investigated differences in WL based on the peak oxygen uptake, this study provides valuable data on differences in WL achieved at given submaximal HR during arm and leg exercise.

Much of prior research has utilized peak VO_2 to depict differences in responses between arm and leg exercise (13, 15). Understanding these differences based on the peak VO_2 is challenging in clinical practice. Further, a variety of modes including treadmill running, skiing, elliptical training that may not be typically used in clinical practice have been used to identify differences between AE and LE. In this study, through a novel approach of using submaximal HR as the independent variable, we provide clinicians with noted differences in RPE and WL between arm and leg ergometry exercise. Clinicians often exercise patients at submaximal THR on the arm or leg ergometer and now have mean values that clinicians can use to compare WL and RPE responses that a chosen target HR or zone elicits for arm or leg ergometry exercise. Further, the findings of no difference in RPE between arm and leg exercise provides the clinician with the understanding that similar RPE scores can be expected at any given submaximal target heart rate on either mode. Similarly, the findings of no significant difference in RPE between males and females provides the clinician with the knowledge that similar RPE scores can be expected when exercising male or females on the arm or leg ergometer. Finally, when exercising at submaximal THR a clinician can expect a greater WL with LE compared to the AE exercise.

Several potential limitations must be considered while interpreting the results of this study. Firstly, the study comprised a small sample of participants. Secondly, due to the utilization of multiple statistical tests, a Bonferroni correction was applied in the analysis with a significant p value set to be less than 0.001. This mitigated the possibility of Type I error (false positive rate) but could potentially cause a Type II error. As an example, in this study, the difference in RPE between modes of exercise in females recorded as $p = 0.012$, did not meet the threshold to be considered statistically different. Thirdly, a sample of convenience utilized in this study, threatened the external validity of the results. Generalizability of the results to other cohorts is difficult because the researchers used a limited age range and a sample of healthy participants. Finally, mode-specific familiarity was not recorded for the participants. Varying levels of prior exposure to AE and LE could have influenced the physiological responses to submaximal testing in this study design.

Further research should look to corroborate the findings of this study using a larger sample size. Studies should also include a more comprehensive exercise history on intake. Additionally, future research should look to use different cohorts of participants to increase generalizability to a larger population. Participants of various ages, those with various diseases, or higher-level athletes could be used as alternate study populations.

In summary, this is a novel study that investigated differences in RPE and WL responses in healthy participants exercising at submaximal THRs during AE and LE. This study provides valuable data on mean scores for RPE and WL that can be used by exercise specialists and other rehabilitation professionals to dose exercise in healthy individuals during AE and LE. Additionally, the findings of no differences in RPE between arm and leg exercise informs the clinician that at any given submaximal THR, similar RPE scores can be expected during AE and LE exercise. Further, no significant differences in RPE between genders provides insight in the possibility of similar RPE scores between males and female participants during submaximal arm and leg exercise. Finally, greater workloads can be expected during leg exercise compared to arm exercise as well as in males compared to females. As the findings of this study are limited to young healthy individuals, additional research is warranted to investigate differences in wider populations.

REFERENCES

1. Borg G, Hassmén P, Lagerström M. Perceived exertion related to heart rate and blood lactate during arm and leg exercise. Eur J Appl Physiol 56(6): 679-685, 1987.

2. Borg G, Linderholm H. Perceived exertion and pulse rate during graded exercise in various age groups. Acta Med Scand 181(S472): 194-206, 1967.

3. Borg GAV. Perceived exertion as an indicator of somatic stress. Scand J Rehabil Med 2(2): 92-98, 1970.

4. Borg GAV. Psychophysical bases of perceived exertion. Med Sci Sports Exerc 14(5): 377-381, 1982.

5. Calbet JAL, González-Alonso J, Helge JW, et al. Central and peripheral hemodynamics in exercising humans: leg vs arm exercise. Scand J Med Sci Sports 25(Suppl. 4): 144-157, 2015.

6. Carter R, Holiday DB, Stocks J, Grothues C, Tiep B. Predicting oxygen uptake for men and women with moderate to severe chronic obstructive pulmonary disease. Arch Phys Med Rehabil 84(8): 1158-1164, 2003.

7. Chen MJ, Fan X, Moe ST. Criterion-related validity of the Borg ratings of perceived exertion scale in healthy individuals: a meta-analysis. J Sports Sci 20(11): 873-899, 2002.

8. Gaito J. Measurement scales and statistics: resurgence of an old misconception. Psychol Bull 87(3): 564-567, 1980.

9. Green JM, Crews TR, Bosak AM, Peveler WW. Overall and differentiated ratings of perceived exertion at the respiratory compensation threshold: Effects of gender and mode. Eur J Appl Physiol 89(5): 445-450, 2003.

10. Green JM, McLester JR, Crews TR, Wickwire PJ, Pritchett RC, Lomax RG. RPE association with lactate and heart rate during high-intensity interval cycling. Med Sci Sports Exerc 38(1): 167-172, 2006.

11. Janssen I, Heymsfield SB, Wang ZM, Ross R. Skeletal muscle mass and distribution in 468 men and women aged 18-88 yr. J Appl Physiol 89(1): 81-88, 2000.

12. Kang J, Chaloupka EC, Mastrangelo MA, Donnelly MS, Martz WP, Robertson RJ. Regulating exercise intensity using ratings of perceived exertion during arm and leg ergometry. Eur J Appl Physiol 78(3): 241-246, 1998.

13. Kang J, Robertson RJ, Goss FL, et al. Metabolic efficiency during arm and leg exercise at the same relative intensities. Med Sci Sports Exerc 29(3): 377-382, 1997.

14. Koltyn KF, O'Connor PJ, Morgan WP. Perception of effort in female and male competitive swimmers. Int J Sports Med 12(4): 427-429, 1991.

15. Larsen RT, Christensen J, Tang LH, et al. A systematic review and meta-analysis comparing cardiopulmonary exercise test values obtained from the arm cycle and leg cycle respectively in healthy adults. Int J Sports Phys Ther 11(7): 1006-1039, 2016.

16. Navalta JW, Stone WJ, Lyons TS. Ethical issues relating to scientific discovery in exercise science. Int J Exerc Sci 12(1): 1-8, 2019

17. Rascon J, Trujillo E, Morales-AcuÑa F, Gurovich AN. Differences between males and females in determining exercise intensity. Int J Exerc Sci 13(4): 1305-1316, 2020.

18. Robertson RJ, Moyna NM, Sward KL, Millich NB, Goss FL, Thompson PD. Gender comparison of RPE at absolute and relative physiological criteria. Med Sci Sports Exerc 32(12): 2120-2129, 2000.

19. Scherr J, Wolfarth B, Christle JW, Pressler A, Wagenpfeil S, Halle M. Associations between Borg's rating of perceived exertion and physiological measures of exercise intensity. Eur J Appl Physiol 113(1): 147-155, 2013.

20. Undebakke V, Berg J, Tjønna AE, Sandbakk O. Comparison of physiological and perceptual responses to upper-, lower-, and whole-body exercise in elite cross-country skiers. J Strength Cond Res 33(4): 1086-1094, 2019.

21. Whaley MH, Thomas Woodall M, Kaminsky LA, Emmett JD. Reliability of perceived exertion during graded exercise testing in apparently healthy adults. J Cardpulm Rehabil 17(1): 37-42, 1997.

22. Winborn MD, Meyers AW, Mulling C. The effects of gender and experience on perceived exertion. J Sport Exerc Psychol 10(1): 22-31, 1988.