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Research Article

Heart Rate and Perceptual Responses to Graded Leg and Arm Ergometry in Healthy College-Aged Saudis: Effects of Gender and Exercise Mode

Abstract

Objective: To assess gender differences in heart rate (HR) and perceptual responses during leg versus arm ergometry among healthy college-aged Saudis.

Methods: Forty healthy college-age Saudis (20 males) performed, in a random cross-over design, two maximal graded exercise leg (LE) and arm ergometry (AE). HR was continuously monitored/recorded during resting and throughout exercise period. Participants rated their perceived exertion (RPE), using Borg scale, at the end of each two-minute stage. Lactate from capillary blood was measured before and one minute after each test.

Results: Females had significantly ($p < 0.01$) higher resting HR and lower resting blood pressure than males. There were significant ($p < 0.05$) gender by exercise mode interactions in most of the parameters. Peak HR (bpm) was significantly ($p < 0.001$) higher during LE than AE in males (181 ± 12 vs 172 ± 21) and females (176 ± 9 vs 162 ± 16), without significant gender difference. Males had significantly ($p < 0.015$) higher values than females in absolute peak work load (WL) and exercise time and lower HR and RPE at absolute sub-maximal exercise. Peak arm/leg WL ratio was significantly ($p = 0.006$) higher among females ($54.6 \pm 12.7\%$) compared with males ($45.1 \pm 6.9\%$). Gender differences in HR and RPE at 50% of peak WL were significant at LE.

Conclusions: Significant hemodynamic, perceptual and performance differences existed between Saudi males and females in response to LE and AE. This has important implications to exercise testing, prescription and rehabilitation.

Introduction

Both leg and arm ergometers are commonly used as a mode of exercise testing. Leg ergometer which is widely used in clinical practice utilizes larger muscle group. However, arm ergometer though uses smaller muscle mass is an important testing modality especially in patients with reduced capacity to use their legs, as in those inflected with spinal cord injuries or peripheral artery diseases [1-4]. It is well recognized that physiological differences exist between upper and lower body sub-maximal and maximal exercise. In general, arm-cranking exercise elicits a maximal oxygen uptake (VO_2 max) corresponding to approximately 70% of the value reached during leg exercise [5]. However, at equal power output, arm exercise elicits greater cardiovascular, metabolic and perceptual responses compared to leg exercise [4,6,7].

The measurement of subjective feelings of exertion by means of 15 point category scale was first reported by Borg [8]. Since then, rating of perceived exertion (RPE) had been applied in numerous studies involving healthy adults and cardiac patients

[9,10]. The American College of Sports Medicine recommends basing exercise intensity on a power output or velocity, heart rate (HR) and /or RPE associated with target oxygen uptake [1]. In addition, there was a strong association between RPE and blood lactate, regardless of exercise mode or training status [11].

Gender-related RPE showed interesting and sometimes conflicting findings. Although heart rate responses were higher for females compared to males, no difference in RPE between groups of men and women of low and high athletic experience during different sub-maximal exercise intensities [12]. Moreover, Robertson et al. (2000) found no difference between genders when comparisons were made at relative oxygen uptake and heart rate reference criteria at exercise intensity between 70 and 90% of mode-specific maximal values [13]. In contrast, O'Connor, et al reported greater RPE in females compared to males during arm exercise at the same absolute power output [14]. In addition, when gender-specific RPE responses were studied during treadmill, cycle ergometer and ski machine, heart rate was higher in female than male participants for each of the three modes of exercise [15].

Previous local research indicates that only one study had been reported on the physiological responses of upper and lower body exercise testing and was involved adolescent males [16]. In addition, a graded leg ergometry testing in untrained Saudi males 20-50 year-old elicited lower maximal heart rate and maximal oxygen uptake than aged- predicted maximal values [17]. Saudi females were also shown to be much less active than males and have fewer opportunities for engaging in leisure sports compared with males [18-20]. The research hypothesis was that Saudi female's responses to arm and leg exercise may be significantly different to that of the males. All these considerations make it necessary to examine the gender-related perceptual, heart rate and performance differences in response to upper and lower body exercise testing in a group of Saudi young adults. Therefore, the present research was conducted to assess the gender differences in heart rate, perceptual and performance responses to leg versus arm ergometry among untrained yet healthy college-aged Saudi males and females.

Methods

Participants

Forty volunteers (20 females and 20 males) University-students from Riyadh, Saudi Arabia were recruited for this study through bulletin board announcement. The selection criteria included Saudi nationals, non-smokers, non-pregnant, non-athletes or not engaged in regular exercise program, free from any cardiovascular, pulmonary, metabolic or musculoskeletal problems and with age range from 18 to 24 years. Body weight and height was measured using Seca scale (Germany). Body mass index (BMI) was calculated by dividing weight in kg over squared height in meter.

Testing procedures

The study protocol and procedures were approved by the Boards of Research Center at the College of Applied Medical Sciences, King Saud University. The study protocol and procedures were in accordance with international ethical guidelines. In addition, each participant signed a consent form after reading the aim, procedures and possible risks and benefits of taking part in this study. Before tested, each participant was screened for major risk factors to rule out any contraindication to maximal exercise testing, using a modified Physical Activity Readiness Questionnaire (PAR-Q) form (1). Resting HR (using Exercentry, USA) and blood pressure (using a sphygmomanometer) were also measured while seated. Then, each participant performed, in a random cross-over design, two graded exercise tests (leg and arm ergometry) to maximal effort in separate sessions. The tests were conducted two hours after a meal in a comfortable laboratory environment while separated with at least one day.

Leg and arm ergometry testing

The leg exercise test was conducted using mechanical cycle ergometer (Monark- Sweden) in a comfortable laboratory environment (22 °C). After seat height adjustment, the participant started pedaling at 60 rpm starting at 30 watts for 2 minutes.

Thereafter, the power output increased 15 watts every 2 minutes until exhaustion. The arm exercise test was conducted using Monark Rehab Trainer 814E (Sweden) that was secured to a table. The seat was hydraulically adjusted to the participant's comfortable position, so that the acromion process was horizontal with the center of the axle connected to the hand grip. The arm ergometry test was a continuous progressive protocol started with zero watt for the first 2 minutes and the work load was increased the by 10 watts every 2 minutes until exhaustion or the subject was unable to maintain a cranking rate of 60 rpm.

HR and RPE measurements

HR was continuously monitored and recorded during resting and throughout the exercise period using heart rate measuring equipment (Exercentry, USA). RPE was assessed using Borg 15 point scale (6-20), which was mounted on a stand with clear and large letters in front of the participant.⁷ Participants were asked to rate their perceived exertions at the end of each two-minute stage. In addition, blood lactate was measured by Accutrend lactate analyzer (Roche, Germany) before and one minute after each exercise test, using capillary blood sample from finger brick.

Statistical Analysis

Data were analyzed using SPSS, version 20 (IBM). Descriptive statistics were presented as means, standard deviations. Differences in anthropometric and physiological measurements between males and females were tested using independent t-test. In addition, repeated measure 2-way ANOVA was performed to test the effect of exercise mode (arm versus leg ergometry) and gender (males versus females) on peak and submaximal physiological, perceptual and performance variables. In addition, the differences in HR and RPE responses at 50% of maximal work load values were tested using independent t-tests. Finally, multiple regression analyses, with stepwise procedures, were performed to predict maximal leg work load from gender and submaximal leg exercise variables (HR and RPE at minute 8 as well as predicting maximal leg work load from gender, maximal arm work load and submaximal arm exercise variables (HR and RPE at minute 8). Durbin-Watson coefficients to indicate independence of residuals were satisfactory (ranged from 1.236 to 1.333). The level of significance was set at a *p* value of 0.05 or less.

Results

Table 1 shows the anthropometric and resting physiological parameters of the participants. Females participants in the study were significantly younger ($p = 0.025$), shorter ($p < 0.001$) and weigh less ($p = 0.005$) than the males. There was no significant difference between males and females in BMI. However, the proportion of females with $BMI \geq 25 \text{ kg/m}^2$ was lower (25%) than that of males (45%). Females had significantly higher resting HR ($p = 0.009$) and lower resting blood pressure ($p < 0.001$) than males. No significant difference was exhibited between males and females in resting blood lactate.

The results of the repeated measure ANOVA for the effects

of exercise mode and gender on physiological, perceptual and performance variables are shown in table 2. There were significant ($p < 0.05$) gender by exercise mode interactions in the majority of the examined parameters. Peak HR (bpm) was significantly ($p < 0.001$) higher during leg exercise than arm ergometry for both males (181 ± 12 versus 171 ± 21) and females (176 ± 9 versus 162 ± 16), without significant ($p = 0.083$) gender difference.

Males had significantly ($p < 0.015$) higher values than females in absolute peak work load (watts) and time (min) to exhaustion and lower HR and RPE at absolute sub-maximal but not at maximal exercise. The ratio of peak work load of arm relative to that of leg was significantly ($p = 0.006$) higher among females (53.8%) than that found in males (44.9%). Work load at minute eight of exercise test represented an absolute work rate of 30 and 75 watts for arm and leg testing, respectively. However, work

Table 1: Anthropometric and resting physiological characteristics of the participants.

Variable	Male N = 20	Female N = 20	p value *
Age (year)	21.6 ± 1.2	20.7 ± 1.2	0.025
Weight (kg)	74.6 ± 22.9	57.9 ± 11.0	0.005
Height (cm)	173.6 ± 6.1	158.3 ± 7.9	< 0.001
BMI (kg/m ²)	24.5 ± 6.3	23.1 ± 4.2	0.403
Resting heart rate (b/min)	76 ± 10	84 ± 10	0.009
Resting systolic blood pressure (mm/Hg)	123 ± 9	105 ± 8	< 0.001
Resting diastolic blood pressure (mm/Hg)	81 ± 7	71 ± 9	0.001
Resting blood lactate (mmol/l)	1.56 ± 0.56	1.70 ± 0.60	0.559

Data are means and standard deviations.

* Based on independent t-test.

Table 2: Results of repeated measure 2-way ANOVA for the effects of exercise mode (arm versus leg ergometry) and gender (male versus female) on physiological and performance variables.

Variable	Exercise mode	Male	Female	p value *		
				Exercise mode	Gender	Interaction
Peak heart rate (b/min)	Arm	172 ± 20	162 ± 16	< 0.001	0.083	0.599
	Leg	181 ± 12	176 ± 9			
Arm/leg heart rate max (%)		95.0	92.1			
Peak work load (watt)	Arm	64.5 ± 10.9	52.5 ± 12.1	< 0.001	< 0.001	< 0.001
	Leg	143.8 ± 17.3	97.5 ± 16.5			
Arm/leg work load max (%)		44.9	53.8			
Peak Work Load (watt/kg. body mass)	Arm	0.93 ± 0.3	0.93 ± 0.3	0.628	0.618	0.006
	Leg	2.1 ± 0.6	1.7 ± 0.3			
Peak blood lactate (mmol/l)	Arm	6.9 ± 1.7	7.2 ± 3.9	0.934	0.263	0.257
	Leg	8.0 ± 2.3	9.5 ± 2.6			
Arm/leg lactate max (%)		86.3	75.8			
Time to exhaustion (min)	Arm	14.9 ± 2.2	12.1 ± 2.4	0.029	< 0.001	0.001
	Leg	17.1 ± 2.1	11.6 ± 1.9			
Arm/leg exercise time (%)		87.1	104.3			
Heart rate at minute 8 (b/min) **	Arm	115 ± 18	127 ± 15	< 0.001	< 0.001	0.001
	Leg	128 ± 17	160 ± 14			
Heart rate at minute 8 as % of peak HR (%)	Arm	67.3 ± 7.7	78.4 ± 11.1	< 0.001	< 0.001	0.019
	Leg	70.7 ± 7.1	90.9 ± 8.1			
RPE at minute 8 **	Arm	13.4 ± 2.2	14.3 ± 2.5	0.714	0.001	0.047
	Leg	12.3 ± 2.4	15.1 ± 1.9			
RPE at minute 8 as % of peak RPE (%)	Arm	67.0 ± 10.8	71.5 ± 12.3	0.714	0.001	0.047
	Leg	61.3 ± 11.8	75.5 ± 9.6			
Work load at 50% of maximal work load (watts)	Arm	32.3 ± 5.5	26.3 ± 6.0	< 0.001	< 0.001	< 0.001
	Leg	71.8 ± 8.6	48.8 ± 8.3			

Data are means and standard deviations. RPE = Rate of perceived exertion.

* Repeated measure two-way ANCOVA tests controlling for the effect of age. Interaction = gender by exercise mode.

** Work load at min 8: 30 watts at arm test and 75 at leg test for both males and females.

load at 50% of maximal work load is relative work load for both sexes.

Figures 1 and 2 exhibit HR and RPE responses to graded leg and arm exercise testing in each of Saudi males and females. Only exercise periods (min) where all subjects were able to have achieved are included in these figures. Tests of between subject effects for gender differences in HR at min 2 through 12 were significant ($p < 0.001$). However, tests of between subject effects of gender differences in RPE showed significance at only min 6 ($p = 0.026$), min 8 ($p = 0.001$) and min 10 ($p = 0.002$).

HR and RPE responses at 50% of maximal work load for Saudi males and females were presented in figures 3 and 4, respectively. Gender differences in HR ($p = 0.024$) and RPE ($p = 0.002$) responses were only significant at leg exercise tests. Also figure 5 exhibits the a three-way repeated-measure ANOVA for the heart rate responses at rest, at 50% of HR peak and at HR peak for male and female during both arm and leg ergometry. The interactions of exercise intensity by mode ($p = 0.011$) and exercise intensity by gender ($p < 0.001$) were all significant.

Table 3 presents the results of the multiple regression analysis. In model one, the significant predictors for the maximal leg work load are HR at submaximal leg (at minute eight of leg work) with the largest beta coefficient (-0.419) and gender followed by RPE at minute eight of leg work load. These predictors can explain 79% of the variance in maximal leg work (R-square = 0.790). In model two, gender and HR at minute eight of arm work can explain about 73% of the variance in maximal leg work load. In model three, adding maximal work load during arm exercise increased the total common variance to 76.3%.

Discussion

This investigation is the first to examine some physiological and perceptual responses to graded leg and arm exercise testing among young Saudi males and females. The main findings of the present study indicate that there were significant hemodynamic,

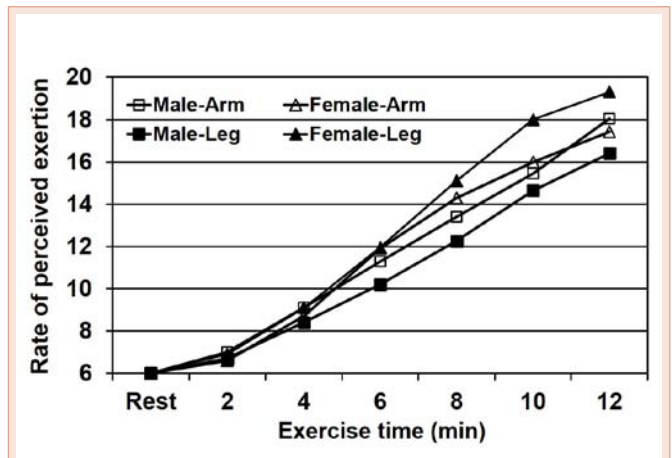


Figure 2: Rate of perceived exertion during graded arm and leg exercise testing in Saudi males and females. Only exercise periods (min) where all subjects were able to achieve are included. Tests of between subject effects for gender differences at min 2: $p = 0.731$, min 4: $p = 0.675$; min 6: $p = 0.026$; min 8: $p = 0.001$; min 10: $p = 0.002$ and min 12: $p = 0.110$.

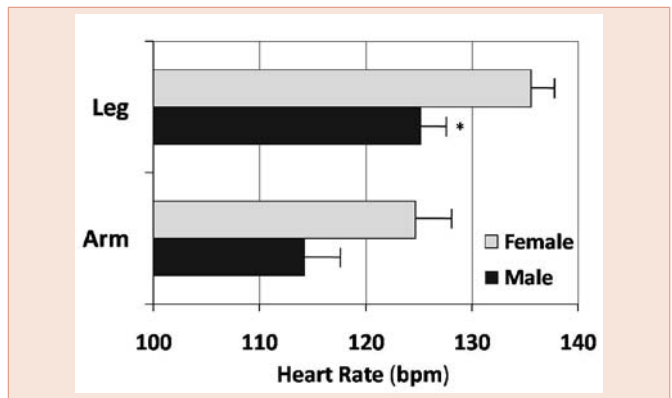


Figure 3: Heart rate at 50% of maximal work load for Saudi males and females in response to arm ($p = 0.064$) and leg ($p = 0.024$) exercise tests (* denotes a significant difference between males and females using independent t-test).

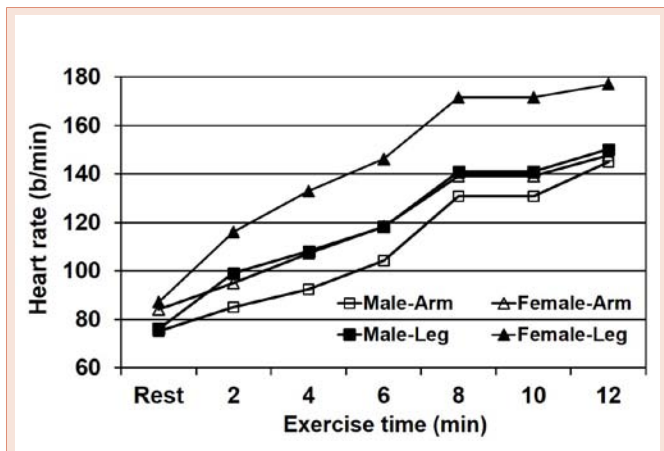


Figure 1: Heart rate response to graded arm and leg exercise testing in Saudi males and females. Only exercise periods (min) where all subjects were able to achieve are included. Tests of between subject effects for gender differences at min 2 through 12 were all significant at $p < 0.001$.

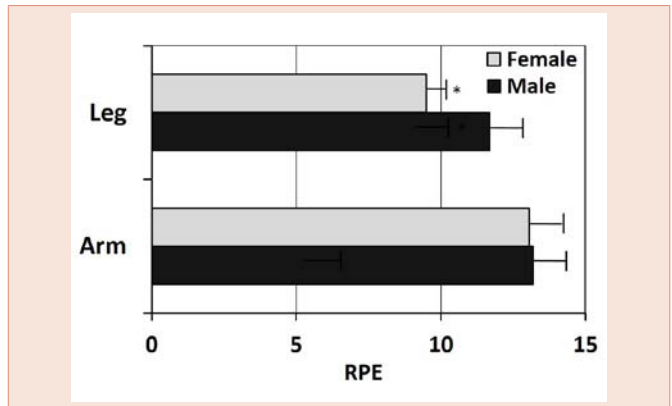


Figure 4: Rate of perceived exertion (RPE) at 50% of maximal work load for Saudi males and females in response to arm ($p = 0.822$) and leg ($p = 0.002$) exercise tests (* denotes a significant difference between males and females using independent t-test).



Figure 5: Three-way repeated-measure ANOVA (gender by exercise mode by exercise intensity- at rest, at 50% of peak exercise and at peak exercise) for heart rate responses during arm and leg ergometry. P-values for main effect of mode = <0.001, exercise intensity by mode = 0.011, mode by gender = 0.588, exercise intensity by gender = <0.001 and mode by gender by exercise intensity = 0.832.

perceptual and performance differences between Saudi males and females in responses to leg versus arm exercise testing. The present study did not find a significant difference in peak HR between males and females in either exercise mode. This finding is in agreement with that of a previous report on a large number of subjects ranging in age from 14 to 77 years, which did not find any significant differences in maximal HR between adult females and males [21]. However, females in the current study had significantly higher resting HR and lower resting blood pressure than males. The higher resting HR in women makes their HR reserve (maximal HR-resting HR) lesser than men. Furthermore, the average peak HR (bpm) for males in the present study (181) was very close to what has been previously reported (183) for young Saudi males aged 20-29 years who underwent maximal cycle test [17].

Peak HR in the current study was significantly greater during leg exercise than arm exercise in both males and females,

without significant gender difference. In addition, absolute work out put in the present study was significantly higher during leg exercise than during arm cranking. It has been reported that the main physiological and performance differences between maximal arm and leg work in healthy subjects were attributed to the amount of muscle mass involved with the effort [4,22]. In addition, maximal power output during leg exercise is thought to be limited by the capacity of the central system (cardiac output, stroke volume, heart rate, pulmonary ventilation or/and oxygen transport system) [5,23]. On the other hand, exercise with small muscle mass as in arm ergometry is limited by local muscle tissue capacity to utilize oxygen, as central function does not reach its maximal output during arm exercise [5,23].

It appears that the differences in peak power output relative to exercise mode were found in older age patients. Carter and others had shown that among middle age and older COPD patients, peak work capacity was greater for men, and leg peak responses were greater than arm values for each gender, as arm value represented 62% of the measured leg value [24]. In the present study, the ratio of peak arm to leg power output was generally lower than the one reported in the literature and was significantly higher among females (54.6 ± 12.7%) than among males (45.1 ± 6.9%).

The present study revealed significant gender by exercise mode interactions in the majority of the examined parameters. Males in the present study had significantly higher values than females in absolute peak work load and time to exhaustion and lower HR and RPE at absolute sub-maximal exercise. Differences in maximal exercise responses were observed between men and women and that gender differences have been attributed to the greater cardiac output, stroke volume, ejection fraction, hemoglobin, and hematocrit values observed among men [22,25,26]. Furthermore, compared with women, men have greater body mass, lower fat % and higher maximal aerobic power [22]. That is why females respond inferiorly to absolute submaximal work load. Therefore, we adjusted the power output relative to body mass, which resulted in the disappearance of the peak work load differences between males and females.

Table 3: Results of multiple regression analyses for the prediction of maximal leg work load from submaximal exercise work variables.

Model	Dependent variable	Predictor variables	Standardized coefficient (Beta)	p-value	R	R ²
Model 1:	Maximal leg work load	Constant	263.9		0.889	0.790
		HR @ min 8-leg work	- 0.419	0.001		
		Gender	- 0.387	0.002		
		RPE @ min 8-leg work	- 0.213	0.029		
Model 2:	Maximal leg work load	Constant	236.5		0.855	0.731
		Gender	- 0.717	< 0.001		
		HR @ min 8-arm work	- 0.281	0.004		
Model 3:	Maximal leg work load	Constant	194.9		0.873	0.763
		Gender	- 0.634	< 0.001		
		HR @ min 8-arm work	- 0.241	0.010		
		Maximal arm work load	- 0.206	0.035		

Standard error of estimate (SEE): model 1 = 17.3 watts; model 2 = 115.2 watts; and model 3 = 14.5 watts. Male = 0 and female = 1.

Normalizing peak physiological parameters, such as anaerobic power, to body mass has been previously reported in young males and females when performing upper and lower body testing [27].

An absolute work intensity generally represents a greater percentage of peak aerobic power for female compared with males. Previous reports indicated that RPE estimates were greater for women than for men at absolute work load [14,15]. However, at relative work intensity most studies did not show significant gender differences in RPE [10,13]. O'Connor et al. reported that RPE during arm ergometry was greater for female than male participants when compared at the same absolute power output [14]. Green et al also found minimal RPE difference between men and women in response to leg cycling and treadmill running at relative peak power [28]. Similar gender physiologic and perceptual responses were reported during a one-hour treadmill run [29]. Such above mentioned findings agree with those results found in the present study.

In the present study, gender differences in HR and RPE responses at 50% of maximal work load were only significant at leg exercise. However, Robertson and colleagues found no difference between genders when comparisons were made at relative oxygen uptake and heart rate reference criteria at exercise intensity between 70 and 90% of mode-specific maximal values [13]. It was unlikely such a sex difference in leg exercise was due to variations in exercise efficiency between males and females, as gross efficiency (the ratio of work accomplished to total energy expended) at similar percent of ventilatory threshold was reported to be greater during leg cycling than during arm cranking in men and women, with no apparent sex difference [30].

Borg's RPE scale provides a simple and practical method for subjective assessment of overall exertion during exercise [1,8]. RPE method was advocated instead of HR method when monitoring exercise intensity, in order to avoid dangerous physiological responses that observed during exercise workout [8,31]. An important finding in the present study was that male and female participants terminated exercise at similar RPE scores. This may suggest that the maximal perceived termination threshold is similar, even though females performed less work as compared to males. A recent study has found that RPE at treadmill-determined ventilatory threshold was similar among a group of sedentary women, regardless of body mass index categories [32].

Studies have consistently reported that arm ergometry induced higher RPE scores than leg exercise for the same absolute power output [33,34]. Also, among men who had undergone knee surgery, RPE and blood lactate concentration were lower during lower limb exercise than during arm cranking [35]. Our findings agreed with the previous reports. It has been reported that the greater physiological response as a result of increased arm exercise can be attributed to the hemodynamic differences between arm and leg work [4,36]. When compared with leg cycling at a given submaximal power output, arm exercise

produces increased systolic and diastolic blood pressure [36], heart rate [5] and total peripheral resistance [4].

Looking at the present study findings shown in figures 3 and 4, it is clear that RPE and HR responses to intensity at 50% of peak work output did not agree with each other. Also, as shown in figure 5, there were significant interaction effects between exercise intensity and mode as well as between exercise intensity and gender. HR values were much higher during leg exercise, whereas RPE were much higher during arm exercise. This may suggest that the sensory input to the perceptual structure of the participants does not facilitate a more accentuated calculation of effort intensity during arm exercise. Findings from a study conducted on young Americans showed that their ability to regulate exercise intensity using RPE was more accurate during arm than during leg testing at 50% of peak work output [7]. Nobel reported that RPE during treadmill exercise, in which large muscle group are utilized, followed HR response at low intensities but increased exponentially at higher exercise intensity because of signal from local factors [10].

Robertson has examined the physiological processes that have been linked to central signals of perceived exertion and concluded that minute ventilation and relative oxygen uptake were the strongest physiological precursors to central input influencing RPE; however, HR did not appear to associate with central factors [37]. Unfortunately, no gas exchange variables were assessed in the present study. Although endurance training has been shown to alter RPE for a given level of oxygen consumption [38], fitness levels did not moderate the relationship of overall RPE and oxygen uptake during graded treadmill exercise test [39]. Participants in the present study were all untrained, so training did not appear as an influencing factor of their exercise responses.

Using multiple regression analyses, we have presented three models for predicting maximal leg work output with high multiple regression coefficients ($R = 0.86-0.89$). The first model tried to predict maximal work load during leg cycling from sex, HR and RPE during submaximal leg exercise. This appears useful when trying to use data from submaximal exercise testing to predict maximal work load, thus avoiding subjecting patients to undue maximal exercise testing. The second and third models, presented two regression equations for the prediction of maximal leg work output from other variables during arm ergometry testing. This may be useful when patients are unable to perform leg exercise testing for various reasons. Both equation have a good predictive power as seen from the fairly high R-square and low standard error of estimates. Elsewhere, Schrieks et al predicted the peak oxygen uptake of arm cranking from treadmill peak oxygen uptake, gender and body weight and reported a high regression coefficient of 0.832 with standard error of estimate of 0.471 L/min [40]. Overall RPE was reported to be almost as highly correlated with $\dot{V}O_2$ as heart rate did during graded treadmill test to exhaustion (r was approximately 0.955-0.980) [39]. While one may argue that these prediction equations came from graded exercise testing and not from steady state exercise is testing, however, previous research has shown that perceptual

responses to a graded exercise testing can be utilized to correctly prescribe exercise intensity during steady state exercise [41].

Finally, although the present study is the first to present HR and RPE data on young Saudi adults, it has some limitations. The current study did not assess maximum exertion using more objective criteria such as maximal oxygen uptake. However, judging from peak exercise lactate and peak HR relative to the predicated maximal HR during leg ergometry (> 90%), we believe that our subjects did reach their peak exercise effort. Also, physical activity levels were not objectively assessed among the participant. A recent study showed that regular exercisers may underestimate exertion [42]. However, our participants did not report that they were engaging in any regular physical activity.

Conclusions

The current study revealed significant hemodynamic, perceptual and performance differences between young Saudi males and females in response to arm versus leg ergometry. These findings have important implications to graded exercise testing and physical activity prescription. Our data can be useful as reference (normal) values for healthy young Saudis and can also assist the clinicians when testing or prescribing exercise rehabilitation to cardiac and pulmonary patients. The use of RPE carries important applications in heart patients particularly who must be sub-maximally stressed tested as well as in cardiac rehabilitation, where RPE is effective in controlling exercise intensity.

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