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Official Research Journal of
the American Society of
Exercise Physiologists

ISSN 1097-9751

JEPonline

Response to Constant and Interval Exercise Protocols in the Elderly

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ABSTRACT

McKean MR, Stockwell TB, Burkett BJ. Response to Constant and Interval Exercise Protocols in the Elderly. **JEPonline** 2012;15(2):30-39. Exercise physiologists have previously avoided using interval exercise training with the elderly due to concerns over increased heart rates (HRs) and respiratory stress that are generally constant during a steady-state cardiovascular exercise session. The purpose of this research was to examine the physiological responses in the elderly using two protocols, constant and interval intensity cycle exercises. The subjects completed two randomised 20-min exercise protocols on an electronically braked cycle ergometer, one at a constant 50% of VO_2 max, and the second alternated intensity from 70% to 30% VO_2 max in 1-min cycles. Physiological measures of VO_2 , HR, RER, and RPE were taken. The subjects reported similar RPE values for both protocols. The elderly subjects generated a 16% higher VO_2 during interval training, when compared to a constant intensity exercise. The HR varied $12.1 \text{ beats} \cdot \text{min}^{-1}$ during the constant protocol compared to $22.6 \text{ beats} \cdot \text{min}^{-1}$ for the interval protocol. When coupled with the self-reported increased enjoyment, the interval protocol may be more beneficial for the elderly when used in a conditioning program.

Key Words: Aged, Exercise Test, Oxygen consumption, EPOC

INTRODUCTION

Traditionally, exercise protocols of intensity and duration have been determined for a broad and general population and then extrapolated or modified for other populations, such as the at-risk aged population. Regular physical activity is known to reduce the risk factors of chronic disease and disability and the aging process is known to correlate with a reduction in physical activity, which further reinforces the need for exercise protocols for the elderly that are not only efficient but also beneficial. Reductions in VO_2 max in non-endurance trained individuals are thought to be associated with the decrease in lean muscle mass that occurs with ageing (5).

Fitness professionals and coaches have generally avoided using interval training due to concerns regarding the increase in heart rate (HR) and respiratory stress of which both are constant during steady-state cardiovascular training. However, with recent research supporting the use of interval training for increased cardiovascular effect (6,20), patients with COPD (2,19) and fat oxidation (16), exercise physiologists may need to reconsider its use in at-risk populations. The aging population is one such group of people who are looking for ways to maintain good health and who are interested in participating in a range of conditioning activities to promote their health (13).

It is well known that the mode of exercise influences physiological responses, with differences found between a single continuous exercise protocol and three different intermittent exercise protocols (10). Intermittent training protocols at both 50% and at 70% of VO_2 Peak showed significantly lower HR, minute ventilation (V_E), and VO_2 when compared to a similar amount of work done within constant load protocols. This thinking suggests that intermittent training is more efficient than constant load training. However, HR, V_E , and VO_2 were taken at the mid-point of each stage of exercise, meaning that the total expired gas, HR, and energy expenditure for the duration of the exercise were not examined. A similar finding was made when comparing constant walking and high-intensity interval walking with the latter resulting in greater increases in VO_2 Peak (11).

As high-intensity interval walking helps to protect older persons against some of the age-related reductions in muscle strength and VO_2 Peak, it may also be valuable for the exercise prescription to encourage a high-intensity component during walking in the elderly. For the sedentary aged population, the problems of joint degeneration and the associated high ground force impact from walking may inhibit this mode of physical activity. Consequently, the low impact and simple nature of cycle ergometers are often preferred by people with orthopedic disabilities of the lower extremities, which are more prevalent in elderly people than younger populations.

The purpose of this study was to examine the physiological responses in the elderly using cycle ergometers across two different protocols, constant and interval. It is anticipated that the findings will help exercise physiologists understand exercise training in the elderly (1).

METHODS

Subjects

Sixteen subjects (10 males aged 69.2 ± 3.7 yrs, height 173.7 ± 7.1 cm, weight 85.2 ± 16.7 kg, and BMI 28.0 ± 3.9 with a predicted VO_2 max of 36.6 ± 4.9 $\text{mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$, and 6 females aged 66.2 ± 3.2 yrs, height 163.4 ± 6.4 cm, weight 69.3 ± 7.9 kg, and BMI 26.2 (4.4) with a predicted VO_2 max of 32.8 ± 5.1 $\text{mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ volunteered to participate in this study. The participants were informed of the research risks and all signed the University Human Ethics approved consent forms before the data were collected.

Procedures

All the subjects were currently participating in a minimum level of activity per week of 90 min. They were able to use a cycle ergometer unaided. Additionally, the subjects were not on any medications that might interfere with physical activity. The subjects were classified in the 'moderate' category through the risk stratification process (12). All subjects were tested on three separate mornings, having fasted overnight each time and refrained from strenuous exercise and activity on the preceding day to testing. The first session involved a pre-exercise screening questionnaire (12), a 20-min supine resting 12-lead electrocardiogram (ECG) and a submaximal fitness assessment. The 12-lead ECG placement was consistent with standard protocol (14). Subjects rested in the supine position for 20 min, after which a sample ECG was taken and assessed for any abnormalities.

The subjects engaged in a submaximal VO_2 test to predict their VO_2 max. The test was performed on an electronically braked cycle ergometer (Jaeger ER800, Bitz, Germany). The test commenced with the subjects cycling at $60 \text{ r} \cdot \text{min}^{-1}$ for 2 min at 20 W. The resistance was then increased to 50 W for 2 min and, then, an additional 25 W every subsequent 2 min until each subject's HR reached 75% of age-predicted maximal HR, using the formula $208 - [0.7 \times \text{age}]$ (17) or until each subject was unable to continue to pedal at $60 \text{ r} \cdot \text{min}^{-1}$. Maximum oxygen consumption was calculated by extrapolation using the Multi-stage Model (18). The values were then used to calculate the percent effort protocol for the constant and interval exercise sessions that were randomly held on the second and third morning exercise sessions. Heart rate was measured via the ECG throughout the testing sessions. Subsequent to each of the two exercise sessions, the participants completed another resting 12-lead ECG as part of the post exercise assessment process.

Expired gas samples were collected via a one-way re-breather mask (Hans-Rudolph 7930 breathing valve, Kansas City, MO) and analyzed using a calibrated TrueMax 2400 metabolic measurement system (Parvo Medics, Sandy, UT). The system was calibrated prior to the start of each session according to standard operating manual procedures. The data were sampled continuously but reported every 15 sec as averages for that period (5). The data were categorized into five different phases: (I) resting baseline; (II) warm-up; (III) exercise; (IV) cool-down; and (V) post-exercise resting. Baseline values were collected with participants seated on the cycle ergometer at rest. This was followed by the warm-up, which consisted of 2 min of $60 \text{ r} \cdot \text{min}^{-1}$ pedalling at 20 W. The exercise phase involved 20 min of pedalling at 50% of extrapolated VO_2 max for the constant session, or 20 min of alternating intensity equal to 70% VO_2 max for 1 min followed by 1 min of 30% VO_2 max in the interval session. The subjects were asked to indicate their RPE using the 6 to 20 Borg scale (3) after each min of exercise in the exercise phase. The cool-down involved 2 min at 20 W, and the post-exercise collection phase was 20 min of supine resting. All protocols for the two exercise sessions, pre- and post-exercise, were identical with the exception of the exercise phase of the session.

Statistical Analyses

The data were analyzed using a one-way analysis of variations (ANOVA), and reported as means with 95% confidence intervals, upper and lower bounds where applicable. Changes in effect statistics are presented in raw and percentage changes. One-way repeated ANOVA for all physiological responses showed there were no significant differences between gender, therefore the results are presented as $n = 16$. The threshold for statistical significance was set at $P < 0.01$.

RESULTS

Mean values for all responses between the two protocols for all subjects as shown in Table 1 were found to have no statistically significant differences. Total VO_2 for the 42-min period from exercise to

post-exercise was 28.07 Liters for constant and 29.40 Liters, respectively. The effect statistics showed that the interval protocol was greater for volume of O₂, volume of CO₂, and ventilatory equivalent values for all phases.

Table 1. Constant and Interval protocol results for VO₂, VO₂/kg, VCO₂, V_E, V_E/VO₂, and V_E/VCO₂ presented as mean (95% CI) with differences (Interval-Constant) presented as absolute (raw units) and effect statistic percentage (95% CI).

	Constant (50%)	Interval (70%:30%)	Effect in Raw Units	Effect (%)
Volume of O₂ STPD (VO₂ - L·min⁻¹)				
Warm-Up (2 min)	0.424 (0.353,0.495)	0.486 (0.390,0.582)	0.06 (-0.01,0.13)	16.6 (-3.8,41.3)
Exercise (20 min)	1.076 (0.866,1.286)	1.128 (0.941,1.286)	0.05 (-0.04,0.14)	15.7 (-13.1,54.1)
Cool-Down (2 min)	0.804 (0.655,0.952)	0.750 (0.622,0.878)	-0.05 (-0.14,0.09)	5.1 (-26.1,49.4)
Post-Exercise (20 min)	0.247 (0.199,0.295)	0.267 (0.189,0.345)	0.02 (-0.03,0.07)	1.7 (-15.9,23.0)
Volume O₂ STPD (VO₂ - mL·kg⁻¹·min⁻¹)				
Warm-Up	5.4 (4.6,6.2)	6.2 (5.2,7.3)	0.83 (-0.03,1.70)	16.6 (-3.8,41.3)
Exercise	13.7 (11.1,16.3)	14.4 (12.4,16.3)	0.71 (-0.67,2.09)	15.7 (-13.1,54.1)
Cool-Down	10.2 (8.3,12.1)	0.7 (.06,0.9)	-0.64 (-1.90,0.63)	5.1 (-26.1,49.4)
Post-Exercise	3.1 (2.6,3.6)	3.3 (2.6,4.1)	0.23 (-0.41,0.86)	1.7 (-15.9,23.0)
Volume CO₂ STPD (VCO₂ - L·min⁻¹)				
Warm-Up	0.338 (0.277,0.399)	0.393 (.0312,0.473)	0.05 (-0.01,0.11)	17.7 (-3.5,43.7)
Exercise	1.024 (0.818,1.230)	1.105 (0.916,1.294)	0.08 (-0.01,0.17)	18.7 (-11.8,59.7)
Cool-Down	0.782 (0.627,0.936)	0.746 (0.616,0.876)	-0.04 (-0.13,0.05)	7.7 (-25.0,54.6)
Post-Exercise	0.299 (0.181,0.277)	0.247 (0.169,0.325)	0.02 (-0.03,0.07)	1.2 (-16.9,23.1)
Ventilatory Equivalent BTPS (V_E - L·min⁻¹)				
Warm-Up	12.359 (10.704,14.103)	14.013 (11.815,16.211)	1.65 (-0.29,3.60)	13.4 (-4.0,34.0)
Exercise	31.691 (25.955,37.427)	34.887 (29.670,40.104)	3.20 (-0.09,6.49)	17.0 (-7.3,47.6)
Cool-Down	25.834 (21.358,30.311)	25.659 (21.762,29.556)	-0.17 (-3.15,2.80)	6.5 (-18.8,39.8)
Post-Exercise	8.602 (7.276,9.927)	9.668 (7.014,12.323)	1.07 (-0.079, 2.92)	4.4 (-12.2,24.1)
Ventilatory Equivalent Ratio for O₂ (V_E/VO₂)				
Warm-Up	31.2 (28.3,34.1)	30.3 (28.0,32.6)	-0.89 (-2.55,0.76)	-2.5 (-7.0,2.2)
Exercise	32.0 (26.4,37.6)	31.5 (28.9,34.1)	-0.52 (-4.15,3.11)	0.6 (-6.1,7.8)
Cool-Down	36.2 (28.5,43.9)	35.4 (32.4,38.5)	-0.77 (-6.12,4.59)	1.1 (-7.2,10.1)
Post-Exercise	37.8 (33.1,42.5)	39.4 (34.5,44.2)	1.60 (-2.05,5.24)	4.3 (-2.4,11.6)
Ventilatory Equivalent Ratio for CO₂ (V_E/VCO₂)				
Warm-Up	39.1 (35.3,42.9)	37.5 (34.8,40.1)	-1.64 (-3.78,0.50)	-3.7 (-8.0,0.08)
Exercise	33.6 (28.0,39.3)	32.3 (30. 2,34.3)	-1.38 (-5.43,2.66)	-1.8 (-8.9,5.8)
Cool-Down	37.4 (28.8,46.0)	35.6 (32.8,38.4)	-1.85 (-8.31,4.61)	-1.1 (-10.1,8.9)
Post-Exercise	41.3 (35.4,47.1)	42.8 (37.6,48.0)	1.53 (-2.53,5.59)	4.5 (-2.8,12.3)

Figure 1 presents the VO₂ comparisons between the two protocols averaged in 15-sec intervals. Heart rates during the interval protocol changed by approximately 10 beats·min⁻¹ between the effort at 70% and the recovery at 30% VO₂ max with a gradual increase over the 20-min exercise phase, which is similar to that of the constant protocol that showed an increase of ~10 beats·min⁻¹ over the course of the 20-min period.

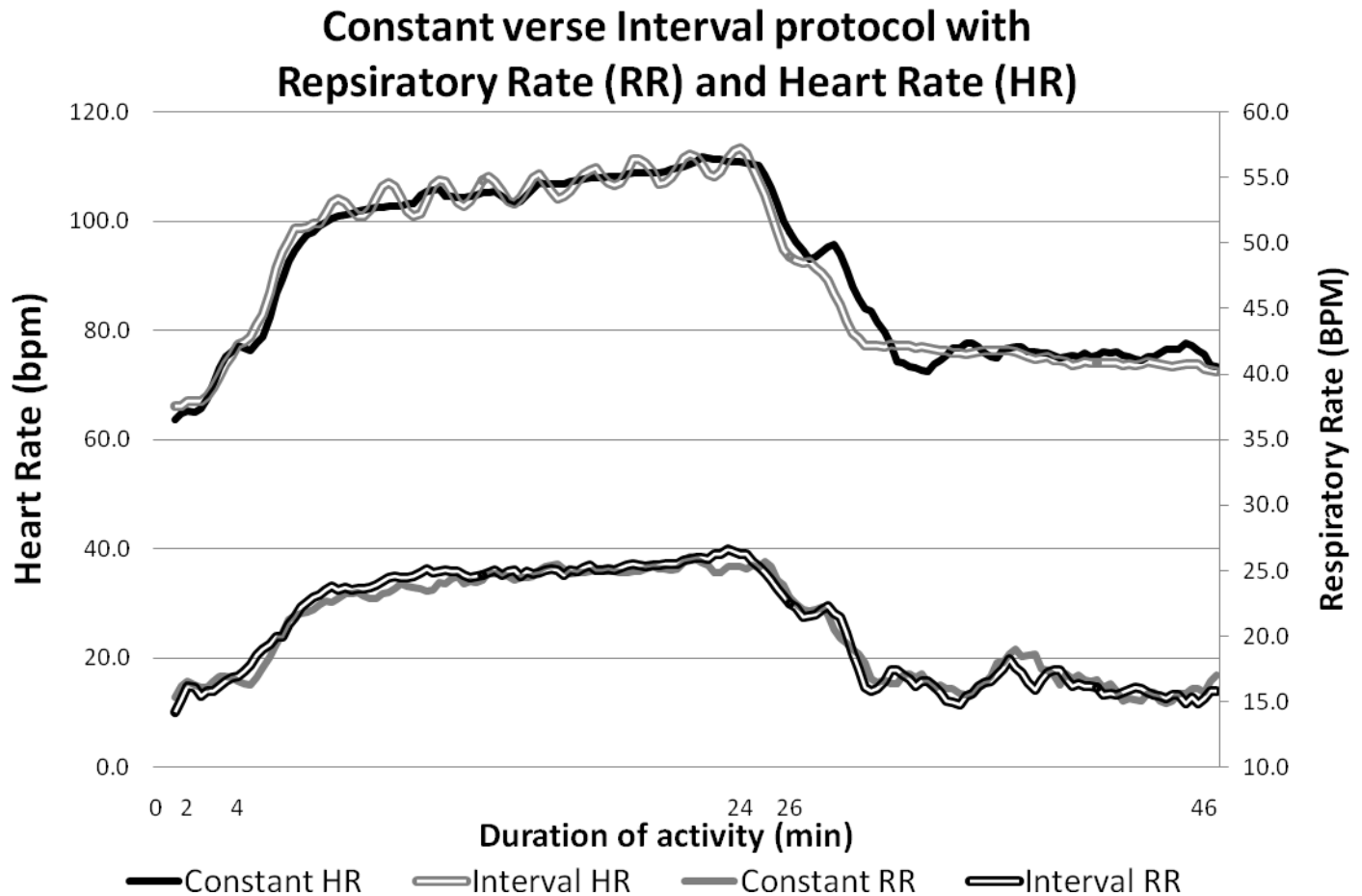


Figure 1. Graph showing comparative heart rates and respiratory rates for the constant and interval bouts of exercise

Mean HR presented in Table 2 showed no significant differences between the two protocols with relative differences in HR less than 1.2% in both the exercise and the post-exercise phases. Respiratory exchange ratios (RER) and respiratory rates (RR) did not vary significantly between phases except for the 2-min cool-down phase RER, which showed a statistically significant difference ($P = 0.05$).

Average RPEs for both exercise phases of the two protocols were almost identical with the constant session mean RPE of 11.4 and the interval session mean RPE of 11.3. This average is consistent with an RPE just above the 'light' level of exertion in both protocols.

Correlations reported as moderate ($R = 0.4$ to 0.7), strong ($R = 0.7$ to 0.9), and excellent ($R > 0.9$). Height and weight showed strong correlations with post-exercise VO_2 for constant, but not the interval protocol. Similarly, cool-down and post-exercise O_2 usage showed moderate correlations with constant and not interval. Post-exercise RER showed moderate correlations with both VO_2 max and O_2 usage during the exercise phase in interval, but not in constant. The pattern and strength of correlations were similar for most other measures.

Table 2. Constant and interval protocol results for RER, RR, $F_{E}O_2$, $F_{E}CO_2$, HR, presented as mean (95% CI) with differences (Interval-Constant) presented as absolute (raw units) and effect statistic percentage (95% CI).

	Constant (50%)	Interval (70%:30%)	Effect in Raw Units	Effect (%)
Respiratory Exchange Ratio				
Warm-Up (2 min)	0.80 (0.77,0.83)	0.81 (0.78,0.84)	0.01 (-0.02,0.04)	1.2 (-2.4,4.9)
Exercise (20 min)	0.95 (0.93,0.98)	0.98 (0.95,1.00)	0.02 (0.01,0.04)	2.5 (0.08,4.3)
Cool-Down (2 min)	0.98 (0.95,1.00)	1.00 (0.97,1.03)	0.02 (0.00,0.05)	2.2 (-0.04,4.8)
Post-Exercise (20 min)	0.93 (0.90,0.96)	0.92 (0.90,0.95)	0.00 (-0.02,0.02)	-0.2 (-2.5,2.2)
Respiratory rate (breaths·min⁻¹)				
Warm-Up	16.6 (14.3,18.9)	17.2 (15.1,19.3)	0.57 (-0.31,1.46)	3.7 (-1.4,9.1)
Exercise	24.1 (21.6,26.5)	24.6 (22.5,26.7)	0.51 (-0.32,1.34)	2.6 (-0.7,6.0)
Cool-Down	23.7 (21.0,26.3)	23.3 (20.9,25.6)	-0.43 (-2.15,1.28)	-1.5 (-9.1,6.6)
Post-Exercise	16.9 (14.1,19.3)	16.5 (13.8,19.2)	-0.41 (-2.13,1.31)	-3.4 (-15.1,9.9)
Fractional Expired O₂ (%)				
Warm-Up	17.1 (16.8,17.4)	17.0 (16.81,17.3)	-0.10 (-0.25,0.05)	-0.6 (-1.4,0.3)
Exercise	17.0 (16.6,17.4)	17.0 (16.8,17.3)	0.05 (-0.11,0.22)	0.3 (-0.6,1.3)
Cool-Down	17.4 (17.0,17.7)	17.5 (17.2,17.7)	0.08 (-0.12,0.27)	0.5 (-0.6,1.5)
Post-Exercise	17.6 (17.4,17.9)	17.8 (17.5,18.0)	0.13 (-0.04,0.29)	0.7 (-0.2,1.6)
Fractional Expired CO₂ (%)				
Warm-Up	3.2 (3.0,3.5)	3.3 (3.1,3.5)	0.11 (-0.01,0.23)	3.8 (-0.7,8.5)
Exercise	3.8 (3.5,4.1)	3.8 (3.6,4.0)	0.02 (-0.15,0.20)	1.9 (-5.1,9.3)
Cool-Down	3.5 (3.1,3.9)	3.5 (3.2,3.7)	-0.03 (-0.22,0.17)	1.2 (-7.9,11.2)
Post-Exercise	3.1 (2.8,3.4)	3.0 (2.8,3.2)	-0.14 (-0.30,0.03)	-3.7 (-9.7,2.8)
Heart Rate (beatsmin⁻¹)				
Warm-Up	75.7 (69.0,82.5)	76.3 (70.4,82.3)	0.60 (-4.15,5.35)	1.1 (-4.2,6.5)
Exercise	104.7 (100.3,109.1)	105.4 (100.0,110.8)	0.71 (-1.58,3.01)	0.5 (-1.8,2.9)
Cool-Down	100.1 (95.7,104.6)	97.1 (90.4,103.7)	-3.07 (-7.05,0.91)	-3.6 (-7.8,0.9)
Post-Exercise	78.2 (69.2,87.1)	75.4 (68.2,82.6)	-2.77 (-7.06,1.52)	-3.2 (-8.1,2.0)

DISCUSSION

The purpose of this study was to determine the physiological responses in the elderly using cycle ergometers across two different protocols, constant and interval. Oxygen consumption during the exercise phase of the interval protocol was 16% higher, when compared to the constant exercise protocol. This difference was not statistically significant. Further differences were noted during the cool-down (5%) and the post-exercise phases (2%). This specific at-risk population has not been investigated in published research for these two protocols and yet, although not significant the increase in the physiological measures support the previously reported advantages of interval training for increased cardiovascular effect in a younger adult population (6,20). Gender was found not to influence the physiological responses, which is also similar to previous research (4).

Table 3 - Correlations reported only for measures where $r > .400^{}$**

	VO₂kg	V_EVO₂	VCO₂	V_E	RER	RR	F_EO₂	F_ECO₂	HR
VO₂	.950**	-.529**	.993**	.977**	.490**	.528**	-.630**	.751**	.573**
VO₂kg		-.503**	.943**	.944**	.473**	.622**	-.594**	.708**	.646**
V_EVO₂			-.488**	-.439**			.825**	-.767**	
VCO₂				.987**	.553**	.530**	-.581**	.736**	.587**
V_E					.557**	.587**	-.506**	.670**	.592**
RER								.554**	.483**
RR									.502**
F_EO₂								-.933**	
F_ECO₂									.511**

**Correlation is significant at the 0.01 level (2-tailed)

VCO₂

For VCO₂ there were also differences in favor of interval protocol with an increase during the exercise phase of 18.7 %, during the cool-down phase of 7.7%, and the post-exercise phase of 1.2%. Whilst there are no significant differences between these figures the effect statistic suggests that interval protocol elicits greater energy expenditure during the exercise phase using more O₂ and producing more VCO₂. Thus interval training for the elderly may accumulate a greater response or training effect if performed over a period of time instead of a single bout as done in this study. However, the confidence interval for the both exercise and cool-down phases show these results varied with upper and lower limits more than 100% from the mean suggesting the range of response may still be quite varied and individual dependent.

EPOC

Considering EPOC (cool-down + post-exercise period 22 min) as a percentage of total (exercise + cool-down + post-exercise period 42 min) oxygen consumption during the two exercise sessions, the outputs were similar at 23.33% and 23.27% for the constant and interval sessions respectively. When reporting EPOC as a percentage of exercise phase only VO₂ results were also similar with values of 30.4% during constant exercise and 30.3% during interval exercise. Considering the O₂ usage rate per liter, similar values across all phases were found again with no significant differences. Similar values of EPOC were reported in young males when comparing constant and interval protocols which supports the results found in the current research (9).

Ventilation

Ventilatory equivalent (V_E) values in L·min⁻¹ also showed similarly higher values for interval protocol. Ventilation is associated with metabolic demand for VCO₂ and V_E/VCO₂ is used to assess the efficiency of V_E (8). The values in the current study show that both constant exercise 33.6 L·min⁻¹ and interval 32.3 L·min⁻¹ were slightly higher than previously reported (8), but decreased during exercise (constant 33.6, and interval 32.3) which has also been reported previously (15).

Respiration Ratios

Respiratory exchange ratios and respiratory rates also provided no significant differences between the two protocols. The baseline (0.80) and exercise phase RER (1.01 interval) values are within normal resting levels and 95%CI range was less than 0.04 above or below the mean. This is in

conflict with previous research, but it may be explained by the different populations used between the studies. The peak RER has been reported at 1.10 to 1.20 or higher (7) and normally indicates an end to a VO_2 max test. The RER values found in the current study match the percentages used and rated at moderate intensity. The similarity in RER between the two protocols also suggests similar use of energy sources between the two protocols and resultant similar oxygen consumption values. However, there were moderate correlations between post exercise phase RER and VO_2 submax ($R = 0.523$), and exercise phase O_2 usage ($R = 0.514$) in the interval protocol, yet no correlations between the same measures for the constant protocol. Respiration rates also showed similarities across all phases with no significant differences.

Heart Rates

Mean HRs differed by less than $1 \text{ beat} \cdot \text{min}^{-1}$ or 1.2%, during exercise and recovery phases which was matched by the RPE values of 11.4 and 11.3 rated on the Borg scale. In younger populations, heart rates have been reported as achieving higher values for an interval protocol (9). For the constant exercise protocol the mean HR slowly increased over the course of the 20-min exercise phase, while the interval protocol had rapidly changing peaks and troughs. The rate of change from start to finish was similar for both protocols with general trend lines being almost identical. The constant protocol produced a range of $35.6 \text{ beats} \cdot \text{min}^{-1}$ between highest and lowest during the exercise phase (4 to 24 min), whilst the interval produced a range of $40.6 \text{ beats} \cdot \text{min}^{-1}$. If we ignore the first 2 min of each exercise phase allowing for HRs to increase under the new work levels, the range reduces to $12.1 \text{ beats} \cdot \text{min}^{-1}$ for constant and $22.6 \text{ beats} \cdot \text{min}^{-1}$ for interval which is now noticeably different as you would expect between the two types of exercise protocols.

As this participant group has not been previously studied, and naturally this response not reported, we can still deduct several things from this. Firstly, the difference in range during the exercise phase was quite small and helps explain the similar values in the RPE for the exercise phase. This may be accounted for by the lower percentages of VO_2 max used for the aged group of participants which is below that used by previous research with younger male participants. Further, the total amount of work performed between the two protocols was also the same and along with similar values in VO_2 and HRs, explains the similar values in the reported RPE. The correlations between post exercise phase HRs and other measures produced the greatest amount of variability with four instances where a correlation occurred with one protocol and not the other. There appears to be no real pattern of these different correlations that can be explained through the literature and may require further study. Finally, participants were also questioned about the different protocols and most stated they enjoyed the interval training protocol more and suggested it kept them interested and was easier to work with.

CONCLUSIONS

Oxygen consumption during the exercise phase of the interval protocol was 16% higher, when compared to the constant exercise protocol. The HR variation during the exercise phase increased by $12.1 \text{ beats} \cdot \text{min}^{-1}$ for the constant protocol, and when compared to the $22.6 \text{ beats} \cdot \text{min}^{-1}$ increase during the interval protocol suggests interval exercise protocol may be effective methods of improving general fitness and condition of an elderly population.

Practical Implications

1. An interval exercise protocol elicits higher VO_2 when compared to a constant exercise protocol in the aged population, and should be considered for improved physical conditioning.

2. In populations similar to those used in this study, there are no significant differences between genders when comparing constant and interval protocols and all participants can be dealt with equally.
3. The self-reported feedback suggested the interval exercise protocol was more enjoyable when compared to the constant exercise protocol and may contribute to increased adherence of exercise routines.

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