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COMPARISON OF SUBMAXIMAL CYCLING AND TREADMILL EXERCISE AT SIMILAR WORK RATES

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RESEARCH AND TECHNOLOGY DIRECTORATE

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13. ABSTRACT (Maximum 200 words)
The increased use of both the treadmill and cycle ergometer for exercise testing during respirator wear has escalated the need to compare the physiological response relationships between modes. This study compared circulatory, respiratory, and metabolic responses of submaximal cycling and treadmill exercise of similar work rates in 8 males and 6 females to determine whether the two exercise modes elicited different responses. Gender differences for each exercise mode were also assessed. Subjects cycled or walked for 5 min at each of five incremental external work rates of 60, 90, 120, 150, and 180 W. Measurements of HR, V_T, F_b, $\dot{V}_E$, $\dot{V}o_2$, and $\dot{V}co_2$ were obtained for each minute of exercise. Varying differences were observed in the respiratory and metabolic responses within gender groups to exercise between cycling and treadmill exercise of equal work rates with cycling eliciting greater responses at intensities of ≥120 W. For cycling and treadmill exercise, females had significantly higher HR and F_b than males at intensities ≥90 W, but metabolic responses were similar between gender groups. These results suggest that both exercise modes are useful for protocols evaluating the physiological effects of mask wear during low levels of physical exertion. However, treadmill exercise seems better suited for testing at higher submaximal work rates.

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PREFACE

The work described in this report was authorized under Project No. 10162622A553, CB Defense/General Investigation. This work was started in November 1991 and completed in June 1992.

In conducting the research described within this report, the investigators adhered to Army Regulation 70-25, Research and Development -- Use of Volunteers as Subjects of Research, dated 25 January 1991, as promulgated by the Office of the Surgeon General, Department of the Army. Approval for the use of human volunteers was granted by the U.S. Army Edgewood Research, Development and Engineering Center (ERDEC)* Human Use Committee, Protocol Log No. 9105S.

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COMPARISON OF SUBMAXIMAL CYCLING AND TREADMILL EXERCISE AT SIMILAR WORK RATES

1. INTRODUCTION

The main work stress alternatives for evaluating the circulatory, respiratory, and metabolic effects of respirator wear during exercise are the treadmill and cycle ergometer. The increased use of both exercise modalities in our laboratory has escalated the need to compare the relationships between them. Differences in the circulatory, respiratory, and metabolic responses to these modes of exercise may be important considerations for exercise evaluation with or without respirator wear. Therefore, this study compared the circulatory, respiratory, and metabolic responses during progressive submaximal exercise at similar work rates of treadmill exercise and cycle ergometry. This investigation also compared the exercise responses of male and female volunteers for each mode of ergometry.

2. MATERIALS AND METHODS

Fourteen apparently healthy individuals (8 males and 6 females) participated in this study under written informed consent. All volunteers underwent a thorough medical evaluation before being allowed to participate in this project. Physical characteristics for the male subjects were as follows (means ± S.D.): Age = 22±3 years; weight = 76.1±11.0 Kg; and height = 179.4±5.9 cm. Female volunteers averaged 23±2 years of age, weighed 57.5±2.3 Kg, and were 164.3±4.7 cm in height. Subjects randomly performed two exercise iterations, one involving cycling and one entailing treadmill walking, on nonconsecutive days. The exercise protocols were designed to equalize external work rates between modes.

Cycling exercise was performed in an upright position using a Monark 867 cycle ergometer. Pedal rate was maintained at 60 RPM and controlled by a metronome. Following four minutes of unloaded cycling, subjects pedaled continuously at five incremental work rates of 60, 90, 120, 150, and 180 W for five minutes each. Exercise was terminated prematurely by the subject owing to fatigue or breathlessness, or by the examiner if the subject's heart rate exceeded their age predicted (the difference of 220 minus the subject's age) maximal heart rate for more than two minutes.

Treadmill exercise was performed on a Quinton Q65 motor driven treadmill. Again, exercise was continuous and involved equal 30 W incremental increases in work rate every five minutes, from an initial 60 W work rate, after a four minute warm-up of level walking. Treadmill grade and speed were adjusted according to each subject's body weight to obtain the proper work rates. However, treadmill speed did not increase enough to cause any subjects to jog or run during testing.

During each testing session, heart rate (HR) was monitored continuously using a Quinton Q3000 ECG monitor and recorded for each minute of exercise. Measurements of tidal volume (V_T) and respiratory frequency (F_b) were obtained with a turbine flowmeter (KL Engineering) mounted in-line with tubing from the expiratory port of the low-resistance half-mask (Hans Rudolph) worn by each subject to a mixing chamber. The output pulses from the flowmeter were counted on-line (Hewlett-Packard 9836 computer and 3852 data acquisition unit). Minute ventilation ($\dot{V}_E$) was calculated by the computer.

Respired gas concentrations of oxygen and carbon dioxide were measured from the mixing chamber with a mass spectrometer (Perkin-Elmer MGA 1100). Oxygen consumption ($\dot{V}O_2$) and carbon dioxide production ($\dot{V}CO_2$) were determined from mixing chamber concentrations and $\dot{V}_E$ values. The ventilatory equivalents for oxygen ($\dot{V}_E/\dot{V}O_2$) and carbon dioxide ($\dot{V}_E/\dot{V}CO_2$) were also calculated.

A three-way multivariate analysis of variance was used to assess the factors of exercise mode, work rate, and sex. Where appropriate, *post-hoc* analyses were performed with the Scheffe Test. Significance was accepted at the $p<0.05$ level.

3. RESULTS

3.1 Treadmill Exercise vs. Cycle Ergometry

As was the intent of this study, exercise work rates of cycling and treadmill walking did not differ between modes at all stages of progressive exercise. During cycling, none of the female test volunteers exercised beyond the 150 W work rate.

Heart rate responses for both the female and male subjects did not differ significantly between the two modes of exercise at any of the work rates. Stage-by-stage ventilatory responses to the two modes of exercise are illustrated in Figure 1 for both female and male subjects. Breathing frequency (F_b) did not differ between exercise modes for both subject groups. For the female subjects, V_T was also similar between exercise modes and $\dot{V}_E$ was significantly larger during cycling at the 150 W intensity. Male subjects exhibited significantly greater tidal volumes at both the 150 and 180 W stages of cycling, and significantly larger $\dot{V}_E$ at the three highest intensities (120 to 180 W) of cycling compared to treadmill walking.

No significant differences in $\dot{V}O_2$ were found between all levels of cycling and treadmill exercise for female subjects (Fig. 2). However, $\dot{V}CO_2$ was significantly larger during cycling compared to treadmill walking at the 90 and 120 W work rates. Both $\dot{V}_E/\dot{V}O_2$ and $\dot{V}_E/\dot{V}CO_2$ did not differ between exercise modos for female subjects.

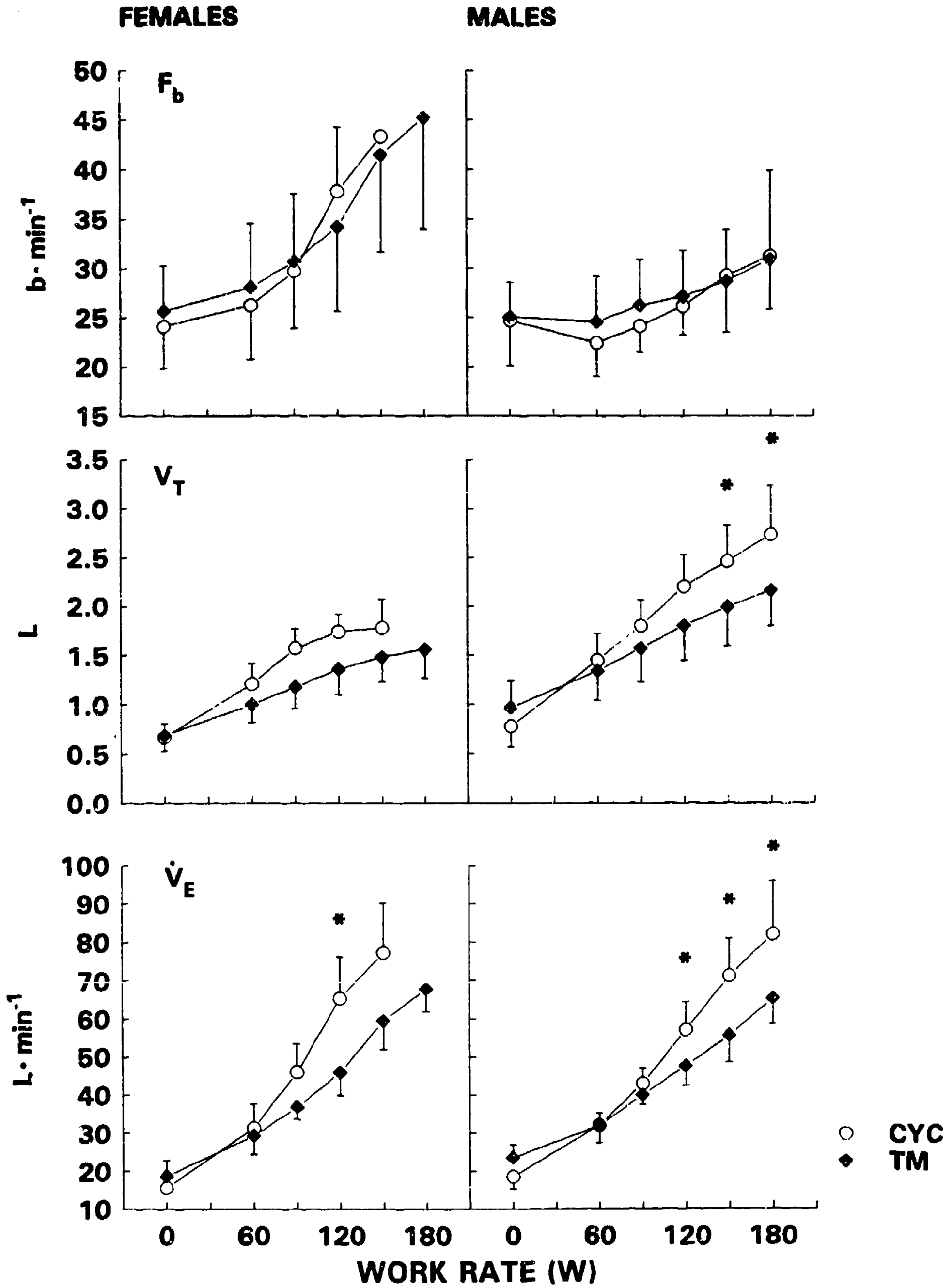

Figure 1. Comparison of ventilatory responses between modes for females and males. * $p<0.05$.

FEMALES

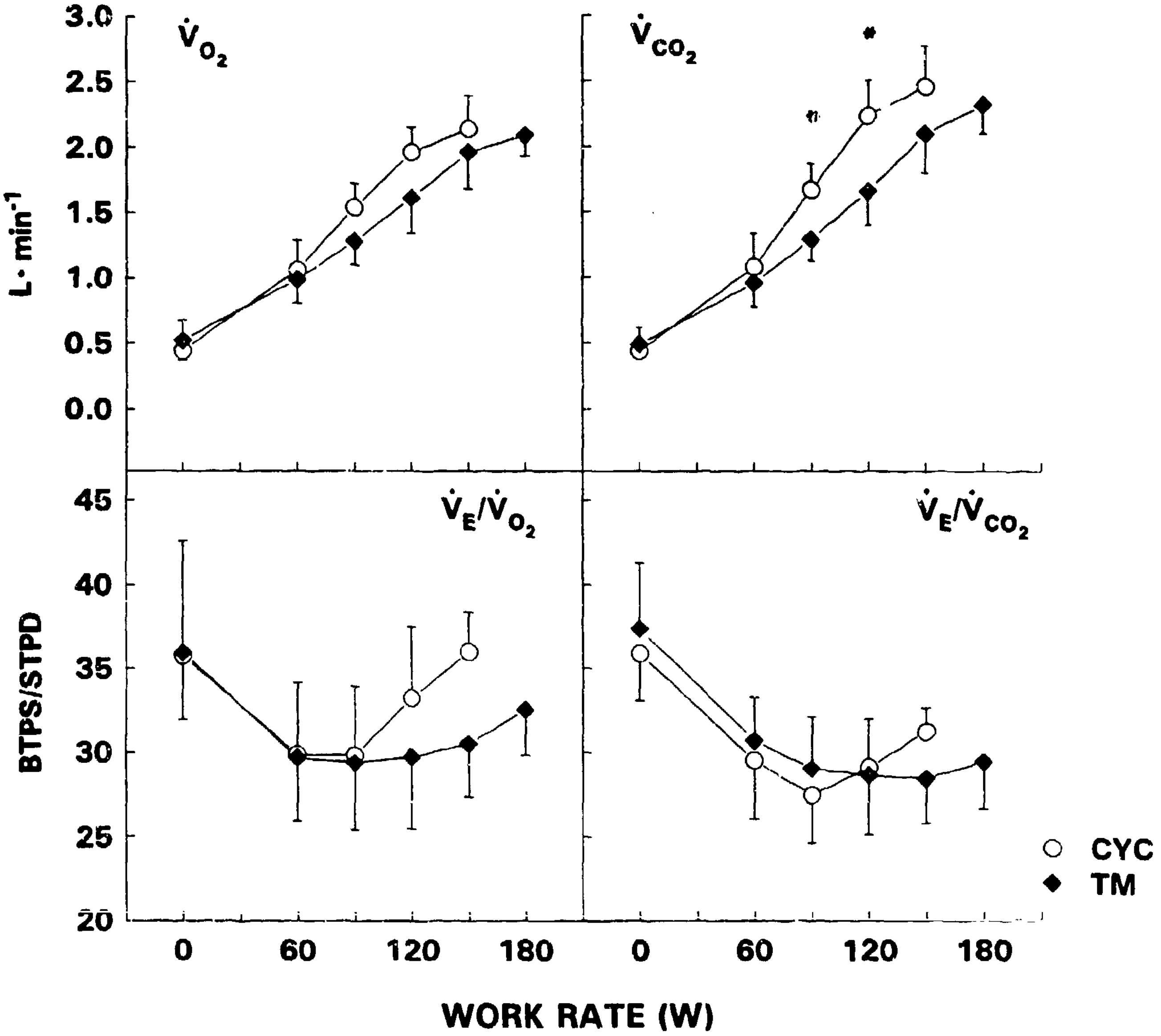

Figure 2. Metabolic responses of females during cycling and treadmill exercise at similar work rates. * $p<0.05$.

Oxygen consumption differed significantly between exercise modes for male volunteers at the 150 and 180 W exercise levels with cycling exercise eliciting the larger $\dot{V}O_2$ at both stages (Fig. 3). Carbon dioxide production was significantly greater during cycling compared to treadmill walking at the three highest work rates. However, as with the female volunteers, $\dot{V}_E/\dot{V}O_2$ and $\dot{V}_E/\dot{V}CO_2$ did not differ between exercise modes for the male subjects.

3.2 Male vs. Female Exercise Responses

Male and Female exercise responses during cycling are presented in Table 1. Females exhibited significantly higher heart rates than males during cycling at work rates equal to 90 and 120 W. Females also had a significantly higher F_b while cycling at 120 W. However, males and females had similar HR and F_b responses at all other work rates. In addition, V_T, $\dot{V}_E$, $\dot{V}O_2$, $\dot{V}CO_2$, $\dot{V}_E/\dot{V}O_2$, and $\dot{V}_E/\dot{V}CO_2$ responses during cycling did not differ between sexes at all work rates.

During treadmill exercise, females exhibited significantly higher heart rates than males at work rates of 120 and 150 W (Table 2). Higher F_b were observed for females at work rates of 150 and 180 W. Also, females had smaller V_T during treadmill exercise at 150 W and lower $\dot{V}O_2$ while exercising at 180 W. No significant differences between sexes were observed in $\dot{V}_E$, $\dot{V}CO_2$, $\dot{V}_E/\dot{V}O_2$, and $\dot{V}_E/\dot{V}CO_2$ during treadmill exercise.

4. DISCUSSION

This study was designed to compare physiological parameters readily measured during exercise tests of respirator wear on either the treadmill or cycle ergometer. Varying differences were observed in the respiratory and metabolic responses within the male and female groups to exercise between treadmill exercise and cycle ergometry of equal work rates. For the males, V_T, $\dot{V}_E$, $\dot{V}O_2$, $\dot{V}CO_2$, were greater during high intensity cycling compared to treadmill exercise. Female subjects also exhibited significantly larger $\dot{V}_E$ and $\dot{V}CO_2$ during high levels of cycling. These results concur with other data reporting both no systematic differences between cycling and treadmill exercise modes (5,6,8) and slightly higher cardiopulmonary responses during submaximal cycling (3,4). Furthermore, these findings suggest that cycling, compared to treadmill exercise, causes greater ventilatory and metabolic responses during submaximal exercise of equivalent high power outputs.

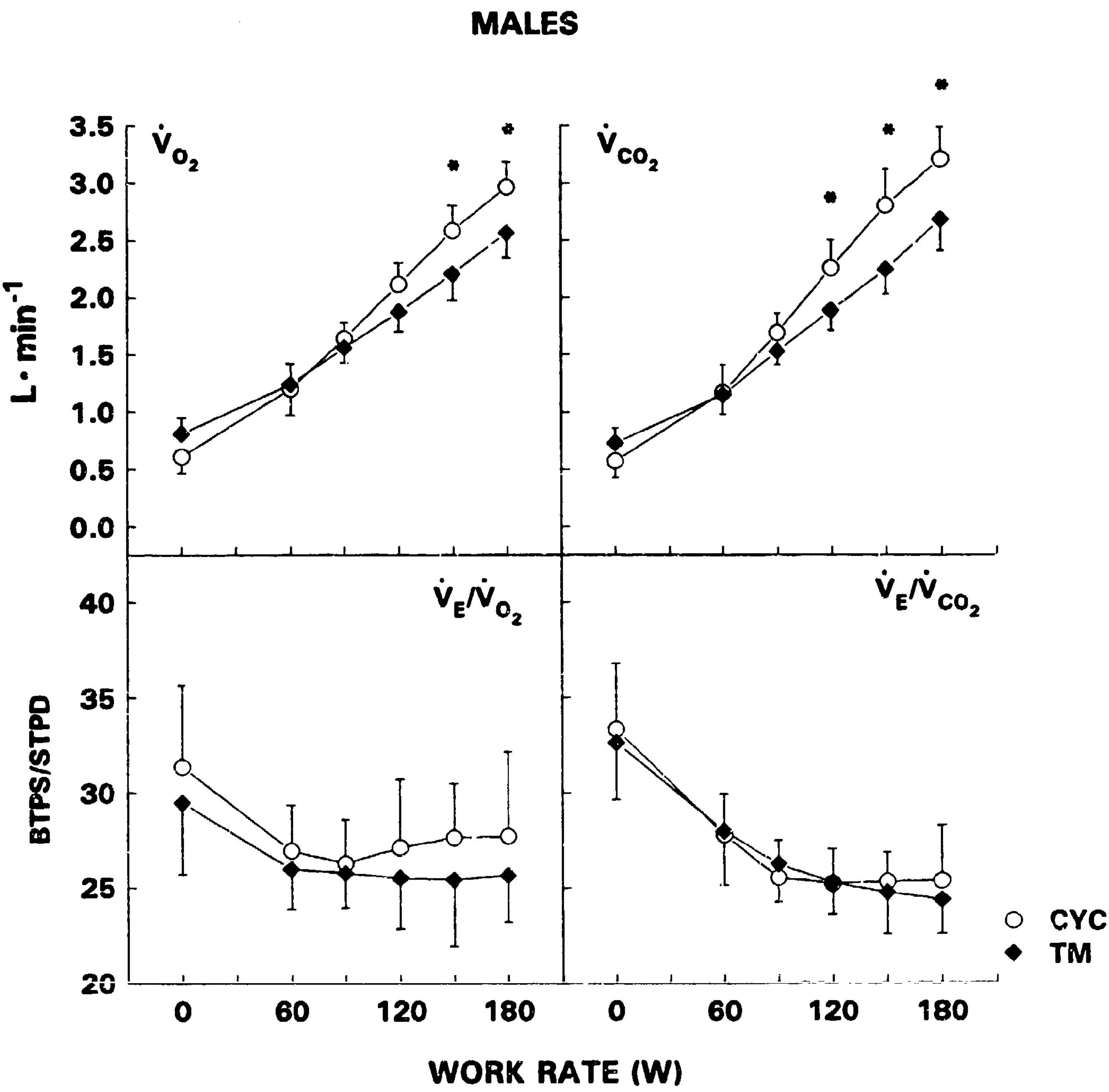

Figure 3. Metabolic responses of males during cycling and treadmill exercise at similar work rates.
* $p<0.05$.

TABLE 1. Male and Female Responses During Cycling.

SEX	WR (W)	N	HR (beats·min⁻¹)	F_b (b·min⁻¹)	V_T (L)	$\dot{V}_E$ (L·min⁻¹)	$\dot{V}O_2$ (L·min⁻¹)	$\dot{V}CO_2$ (L·min⁻¹)	$\dot{V}_E/\dot{V}O_2$ (BTPS/STPD)	$\dot{V}_E/\dot{V}CO_2$ (BTPS/STPD)
MALE	0	32	81.5±8.8	24.7±4.6	0.78±0.21	18.5±3.3	0.61±0.14	0.57±0.14	31.4±4.3	33.3±3.4
	60	40	104.1±12.7	22.4±3.4	1.45±0.27	31.9±4.5	1.20±0.23	1.16±0.24	27.0±2.4	27.7±2.6
	90	40	125.1±17.3	24.2±2.6	1.80±0.26	43.0±4.1	1.64±0.14	1.69±0.17	26.3±2.3	25.5±1.2
	120	39	149.1±22.4	26.2±3.0	2.20±0.33	57.0±7.4	2.11±0.19	2.26±0.25	27.1±3.6	25.2±1.9
	150	34	164.3±20.9	29.3±4.6	2.46±0.36	71.2±9.6	2.58±0.22	2.81±0.32	27.6±2.9	25.3±1.6
	180	24	171.0±15.9	31.3±8.7	2.73±0.50	82.0±13.9	2.96±0.22	3.22±0.28	27.7±4.4	25.3±2.9
FEMALE	0	24	89.3±9.6	24.1±4.3	0.67±0.14	15.7±1.6	0.44±0.07	0.44±0.05	35.8±3.8	35.9±2.8
	60	30	127.7±14.6	26.2±5.5	1.21±0.21	31.3±6.4	1.06±0.23	1.08±0.26	29.9±4.3	29.5±3.5
	90	27	**159.5±14.2**	29.7±5.9	1.57±0.20	46.0±7.5	1.54±0.18	1.67±0.20	29.8±4.1	27.5±2.9
	120	20	**182.6±12.4**	**37.8±6.4**	1.74±0.18	65.3±10.8	1.96±0.19	2.24±0.27	33.3±4.2	29.1±2.8
	150	3	187.3±29.8	43.3±0.6	1.78±0.29	77.2±13.0	2.13±0.25	2.46±0.31	36.0±2.3	31.2±1.4
	180									

BOLD = Significantly different ($p<0.05$) from MALES at the same work rate.

TABLE 2. Male and Female Responses During Treadmill Exercise.

SEX	WR (W)	N	HR (beats·min^{-1})	F_b (b·min^{-1})	V_T (L)	$\dot{V}_E$ (L·min^{-1})	$\dot{V}O_2$ (L·min^{-1})	$\dot{V}CO_2$ (L·min^{-1})	$\dot{V}_E/\dot{V}O_2$ (BTPS/STPD)	$\dot{V}_E/\dot{V}CO_2$ (BTPS/STPD)
MALE	0	32	90.1±14.7	25.0±3.5	0.97±0.27	23.6±3.2	0.81±0.14	0.73±0.13	29.5±3.8	32.6±3.0
	60	40	103.5±16.2	24.6±4.7	1.34±0.30	31.8±3.3	1.24±0.18	1.15±0.17	26.0±2.1	28.0±2.0
	90	40	120.1±19.3	26.3±4.7	1.57±0.34	39.9±2.6	1.56±0.13	1.52±0.12	25.8±1.8	26.2±1.2
	120	40	136.2±23.6	27.2±4.7	1.80±0.35	47.6±5.1	1.87±0.17	1.89±0.17	25.5±2.7	25.2±1.6
	150	38	151.9±26.0	28.7±5.2	1.99±0.40	55.6±7.0	2.20±0.23	2.25±0.22	25.4±3.5	24.7±2.2
	180	35	164.1±25.0	31.0±5.1	2.16±0.36	65.3±6.8	2.56±0.22	2.69±0.27	25.6±2.4	24.4±1.8
FEMALE	0	21	96.7±18.2	25.7±4.6	0.69±0.12	18.8±4.0	0.52±0.16	0.49±0.13	35.9±6.6	37.4±3.9
	60	30	126.0±15.1	28.1±6.4	1.01±0.18	29.3±4.9	0.99±0.18	0.96±0.18	29.7±3.8	30.7±2.6
	90	30	146.8±12.1	30.7±6.8	1.18±0.22	36.8±3.1	1.28±0.18	1.29±0.16	29.4±4.0	29.0±3.1
	120	29	**168.8±9.3**	34.2±8.4	1.36±0.26	45.9±6.0	1.61±0.27	1.66±0.26	29.7±4.3	28.6±3.5
	150	21	**185.6±10.6**	**41.5±9.8**	**1.48±0.25**	59.4±7.5	1.96±0.28	2.10±0.30	30.5±3.1	28.4±2.7
	180	10	195.0±6.5	**45.2±11.2**	1.56±0.29	67.8±5.9	**2.09±0.16**	2.32±0.22	32.5±2.7	29.4±2.8

BOLD = Significantly different ($p<0.05$) from MALES at the same work rate.

Comparisons of physiological responses to submaximal exercise between female and male subjects at identical work rates of cycling and treadmill walking showed that females had higher heart rates and breathing frequencies than males during exercise at intensities greater than 90 W. Overall, metabolic responses were similar for female and male subjects. Higher heart rates for women compared to men at identical submaximal exercise levels have been reported previously (1).

The implications of the results of this study as they relate to assessment of the effects of mask wear during exercise are relatively minor. Obviously, based on the number of data points (N in Table 1) available for analysis and the fact that none of the females cycled beyond the 150 W intensity, cycling at the higher work rates (greater than 120 W) was difficult for both males and females. It has been suggested that local metabolic and circulatory factors in the leg muscles may restrict performance on the cycle ergometer and that training could eliminate this detriment (7). Therefore, the treadmill appears to offer an advantage over cycling for the evaluation of exercise performance at work rates higher than 120 W if subjects are not familiar with cycling. However, because of the identical physiological responses during cycling and treadmill walking at the lower exercise intensities, cycle ergometry remains a viable alternative for implementing work stress.

Other considerations for determining the use of treadmill or cycle ergometry include the fact that most measurements of cardiorespiratory performance can be made on both modalities, but less artifactual measurement of electrocardiogram, blood pressure, and ventilation occurs during cycling. Also, external work rate and energy output can be predicted more accurately during cycling than during treadmill exercise (2).

5. CONCLUSIONS

The relatively minor differences in the physiological responses observed during cycling and treadmill walking at similar work rates supports the continued use of both exercise modalities for assessment of performance during respirator wear and exercise. However, careful scrutiny of the particular mask factor to be tested must be made prior to choosing which method should be used. The results of the current study suggest that both cycling and treadmill exercise would be useful for protocols requiring evaluation of the physiological effects of mask wear during low levels of physical exertion. On the other hand, treadmill exercise seems better suited for testing at higher submaximal work rates.

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