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ABSTRACT

A study compared physiologic responses of healthy paraplegic males to those of healthy, able-bodied males during maximal arm ergometry. Fifteen able-bodied, healthy adult males and 13 healthy adult male paraplegics followed an exercise program involving heart rate, increased exercise loads, and oxygen uptake. Results from an analysis of the data reflect the need for using paraplegics as subjects when conducting research designed to elucidate specific exercise prescription regimens for paraplegics. The American College of Sports Medicine guidelines for exercise prescriptions are probably not valid for this population during arm work because the assumption cannot be made that the heart rate and oxygen uptake relationships of paraplegics and able-bodied subjects are similar. Further research comparing physiological responses to submaximal arm ergometry in similar groups is warranted. (JD)

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PHYSIOLOGIC RESPONSES OF ABLE-BODIED AND PARAPLEGIC MALES TO MAXIMAL ARM ERGOMETRY

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ABSTRACT

PHYSIOLOGIC RESPONSES OF ABLE-BODIED AND PARAPLEGIC MALES TO MAXIMAL ARM ERGOMETRY

This study compared cardio-respiratory responses of 15 sedentary able-bodied males and 13 healthy paraplegics during maximal arm ergometry. The initial exercise load was set at 150 $kgm \cdot min^{-1}$ and sequentially increased by 150 $kgm \cdot min^{-1}$ every two minutes until volitional fatigue or until the subject could no longer maintain a metronome-paced 70 rpm cranking rate. Heart rate (HR) was recorded during the last ten seconds of each minute from the ECG and $\dot{V}O_2$, $\dot{V}_E$ and RER were obtained using a Beckman Metabolic Measurement Cart. An independent t-test yielded significantly ($p < .05$) higher values for $\dot{V}O_2$ max, O_2 pulse max, $\dot{V}CO_2$ max, and $\dot{V}_E$ max in the able-bodied subjects. There were no significant differences between the groups for RER and $\dot{V}_E/\dot{V}O_2$. Since there were no significant differences in HR max, but large differences in $\dot{V}O_2$ max, paraplegics apparently tend to work at a higher percentage of $\dot{V}O_2$ max than normals when working at similar heart rates. These findings reflect the need for using paraplegic subjects when conducting research designed to elucidate specific exercise prescription standards for paraplegics.

Key Words: Paraplegia, Arm ergometry, Oxygen uptake.

A study conducted by the National Academy of Sciences reported that World War II veterans who had either one or both legs amputated had 150 percent higher death rate from cardiovascular disease than other wounded veterans who retained their mobility.[1] Zwiren and Bar-or have shown that adult sedentary paraplegics bound to wheelchairs for years are less fit than the general sedentary population.[2] Laporte and others recently compared high density lipoprotein (HDL) values of able-bodied sedentary males to male marathon runners, joggers, and paraplegics.[3] The paraplegics had significantly lower HDL levels than the other groups and the authors proposed that if risk estimates for various HDL concentrations were applied to the values, the paraplegics would be at 90 percent greater risk for heart attack than the controls and at 350 percent greater risk than the runners.[4] Low fitness levels in addition to an increased risk for cardiovascular disease reflect the need for aerobic training programs for paraplegics. Arm training has been shown to be a satisfactory mode of aerobic activity which can significantly improve cardiovascular function in paraplegics.[5,6] Previous investigators have made recommendations about arm training regimens for paraplegics based on data obtained while studying cardio-respiratory responses of healthy subjects during arm ergometry, or by simply applying exercise prescription standards published by the American College of Sports Medicine for healthy subjects during running, cycling, etc...[7] Exercise prescription guidelines developed using healthy subjects may not be directly applicable to paraplegics during arm ergometry. The purpose of this study was to compare physiologic responses of healthy and paraplegic males during maximal arm ergometry in order to determine whether further research is warranted concerning exercise prescription guidelines for paraplegics.

METHODS

Subjects

Fifteen healthy, able-bodied males ($\bar{x}$ age 22.6) and 13 healthy male paraplegics ($\bar{x}$ age 28.2 years) with lesion levels ranging from T4 to T12, were recruited to serve as subjects (Tab. 1). All subjects received medical clearance for participation in the study and signed informed consent was obtained. The healthy, able-bodied subjects were untrained, and relatively sedentary, whereas the majority of the paraplegics were actively engaged in wheel-chair sports and as a group were relatively active.

Procedures

Each subject was weighed prior to the test. The paraplegics were weighed with a Hoyer lifter, and a Digitron 200 load cell. The healthy subjects were weighed with standard scales.

Previous research by Israel and others indicated that the sitting position was the most desirable as well as the most practical body position to assume during maximal and submaximal arm ergometry.[8] Each subject was seated such that the axis of movement of the gleno-humeral joint was horizontal to the axis of the arm ergometer rotary mechanism. Plywood sheets were used under the chairs to achieve this position if necessary. The arm ergometer was adjusted to allow full extension of the arms during rotation. A specialized set of "wheel chocks", in conjunction with brakes were used to stabilize the wheelchairs for the paraplegics. Healthy subjects were seated with legs crossed and bound at the ankles. Elastic safety belts were employed in an attempt to secure the subject's body to the chair and reduce the use of trunk muscles during exercise.

Each subject performed a maximal arm ergometry exercise test on a Schwinn Ergometric EX 2-0 bicycle ergometer that was modified for arm work.

The initial exercise load was set at 150 kgm · min^{-1} and was sequentially increased every two minutes by 150 kgm · min^{-1} until volitional fatigue, until the subject could no longer maintain a metronome-paced 70 rpm cranking rate, or until contraindications were observed. Previous research by Dotson and others showed 70 rpm to be the most efficient cranking rate for maximum arm ergometry testing.[9] All subjects reached volitional fatigue between 6 and 8 minutes.

Heart rate was determined from a CM5 lead arrangement during the final ten seconds of each minute from the EKG using a Burdick single channel electrocardiograph. Oxygen uptake ($\dot{V}O_2$), pulmonary ventilation ($\dot{V}_E$), carbon dioxide output ($\dot{V}CO_2$), and respiratory exchange ratio (RER) were obtained each minute using a Beckman metabolic measurement cart (MMC). The MMC was calibrated by a 2-point system of using ambient air, and a Scholander verified gas mixture of 16% oxygen and 4% carbon dioxide.[10] Other MMC calibrations were performed according to manufacturer specifications.[11] Ventilatory equivalent ($\dot{V}_E/\dot{V}O_2$) and oxygen pulse (O_2 pulse) were derived from the data collected.

Data Analysis

Independent t-tests were used to analyze maximal physiological data. F-tests were conducted to examine the equality of variances assumption for the t-tests. All comparisons were tested for significance at the $\alpha = .05$ level.

RESULTS

Table 1 contains a summary of descriptive data for the paraplegic subjects. Mean body weight for the paraplegic and able-bodied groups was 70.9 ± 13 kg and 72.4 ± 9.1 kg, respectively. Table 2 contains means ± SD, t-ratios and probability values for the dependent variables.

Although the paraplegics were approximately six years older than the able-bodied subjects this difference probably had no significant effect on the physiological responses obtained in this study. Maximum oxygen uptake ($\dot{V}O_2$), relative $\dot{V}O_2$ (expressed in $ml \cdot kg \cdot min^{-1}$), pulmonary ventilation ($\dot{V}_E$), oxygen pulse (O_2 pulse) and carbon dioxide output ($\dot{V}CO_2$) were significantly higher for the able-bodied subjects. There were no significant differences between the two groups for maximum heart rate ventilatory equivalent ($\dot{V}_E/\dot{V}O_2$) or RER.

DISCUSSION

Mean, relative arm $\dot{V}O_2$ max for the healthy able-bodied subjects was 26.4 $ml \cdot kg \cdot min^{-1}$, while mean relative $\dot{V}O_2$ max for the paraplegics was only 19.8 $ml \cdot kg \cdot min^{-1}$. This study compared a relatively active group of paraplegics to a sedentary sample of healthy able-bodied subjects. Astrand, as well as Israel and Hardison, have demonstrated that $\dot{V}O_2$ max during arm exercise is roughly 70% of $\dot{V}O_2$ max obtained by leg work.[12,13] By increasing the able-bodied $\dot{V}O_2$ max by 30%, a value of approximately 37 $ml \cdot kg \cdot min^{-1}$ would be predicted for leg work. A $\dot{V}O_2$ max of 37 $ml \cdot kg \cdot min^{-1}$ would be classified in a low fitness category for this age group.

In contrast, the highest $\dot{V}O_2$ max obtained by a paraplegic in this study was only 24 $ml \cdot kg \cdot min^{-1}$, and this subject was extremely active for a paraplegic. He wheels <u>3</u> miles per day, at least <u>6</u> days per week, in addition to participating in wheelchair sports. Even the best conditioned paraplegic's $\dot{V}O_2$ max wasn't comparable to the average sedentary able-bodied subject's arm $\dot{V}O_2$ max in this study.

These data suggest that cardio-respiratory responses of normals and paraplegics are very much different during maximal arm ergometry. Because there was no significant difference in maximum heart rate, but large differences in $\dot{V}O_2$ max (both absolute and relative), paraplegics apparently have a different heart rate - $\dot{V}O_2$ relationship during arm work than the able-bodied. Difficulty in isolating leg and trunk muscles in normals, during arm ergometry may explain some of the large difference in $\dot{V}O_2$ max, since $\dot{V}O_2$ is dependent upon the amount of active muscle mass involved during exercise.[12]

CONCLUSION

Results from this study reflect the need for using paraplegics as subjects when conducting research designed to elucidate specific exercise prescription regimens for paraplegics. The American College of Sports Medicine guidelines for exercise prescription are probably not valid for this population during arm work because the assumption cannot be made that the heart rate and $\dot{V}O_2$ relationships of paraplegics and able-bodied subjects (used to develop the guidelines) are similar.[7] Further research comparing physiological responses to submaximal arm ergometry in similar groups is warranted.

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Table 1
Summary of Descriptive Data for Paraplegics

Subject	Age (yr)	Weight (kg)	Lesion Level	Cause	Duration of Disability (yr)
1	30	81.18	T8-9	Tumor	12
2	42	54.42	T12	Car Accident	9
3	22	86.62	T8-9	Fall	2
4	32	57.59	T5	Gun Shot	8
5	27	84.35	T7	Car Accident	6
6	25	76.96	T12	Car Accident	10
7	29	56.46	T7-9	Car Accident	8
8	31	80.18	T5	Tree Fell On	15
9	22	52.43	T4	Gun Shot	9
10	28	68.71	T6	Car Accident	3
11	29	76.83	T12	Car Accident	10
12	30	68.84	T6	Car Accident	7
13	26	72.94	T7	Car Accident	6

Table 2
Means, Standard Deviations, t-Ratios and P Values
For Maximal Arm Ergometry Data

Variable	Units	Means ± SD Paraplegics (N=13)	 Able-Bodied (N=15)	t-Ratio	P
HR max	(bpm)	181.2 ± 15.7	171.3 ± 12.5	1.85	.074
$\dot{V}_E$ max	(L/min)	61.6 ± 20.1	79.7 ± 10.7	2.39	.024
$\dot{V}O_2$ max	(L/min)	1.41 ± 0.4	2.04 ± 0.2	7.69	.001
$\dot{V}O_2$ max	(ml/kg/min)	19.8 ± 3.2	26.4 ± 3.4	5.34	.001
$\dot{V}CO_2$ max	(L/min)	1.8 ± 0.5	2.4 ± 0.3	3.34	.002
$\dot{V}_E/\dot{V}O_2$ max	(L/L)	43.9 ± 8.2	41.3 ± 8.4	0.81	.423
O_2 pulse max	(ml/beat)	7.7 ± 1.8	11.3 ± 1.9	4.95	.001
RER		1.29 ± 0.1	1.23 ± 0.1	1.58	.120