Comprehensive Profile of Cardiopulmonary Exercise Testing in Ambulatory Persons with Multiple Sclerosis

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Introduction

The study and application of exercise in multiple sclerosis (MS) often requires cardiopulmonary exercise testing (CPET) to provide a comprehensive assessment of exercise tolerance and responses, including an evaluation of the pulmonary, cardiovascular, and skeletal muscle systems. Research on CPET in persons with MS has considerable limitations, including small sample sizes, often without controls; not reporting outcomes across disability status; and different modalities of exercise testing across studies. Although some key outcome variables of CPET have been studied in persons with MS, additional calculated variables have not been directly studied.

Purpose

The objective of this study was to provide a comprehensive examination of outcome variables from CPET among persons with MS and healthy controls.

Participants

This sample included 162 persons with MS and 80 controls. The characteristics of the participants are included in Table 1.

Measures

CPET variables included: oxygen uptake (VO_2), carbon dioxide production (VCO_2), ventilation (VE), respiratory exchange ratio (RER), work rate (WR), heart rate (HR), ventilatory anaerobic threshold (VO_2/VCO_2), VE/VCO_2 slope, VO_2/power slope, VO_2/HR slope, and oxygen uptake efficiency slope (OUES).

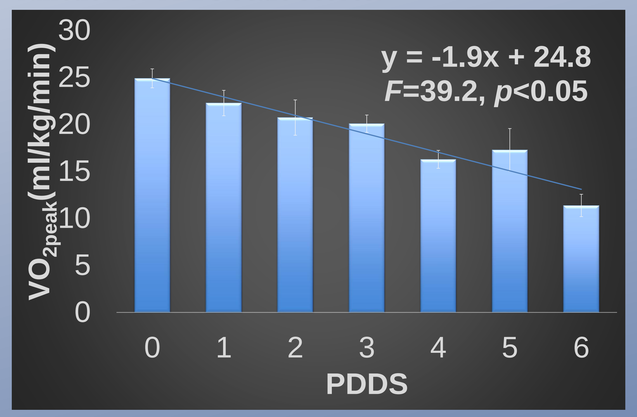
Method

The same university institutional review board approved all of the studies. After telephone screening for inclusion and provision of a signed informed consent, all participants completed CPET on an electronically braked, computer controlled cycle ergometer and an open-circuit spirometry system for analyzing expired gases. VO2, VCO2, VE, and RER were measured continuously by the open-circuit spirometry system and HR was measured using a HR monitor. VO_{2peak} (L/min; mL/kg/min), VE_{peak} (L/min), and RER_{peak} [VCO_2 (L/min)/VO_2 (L/min)] were defined as the highest recorded 20-s average during the final minutes of the test. WR_{peak} (W) and HR_{peak} (bpm) were recorded as peak power output and HR, respectively, during the incremental protocol. RPE was recorded every minute during the test and RPE_{peak} was recorded as the highest value.

Data Analysis

The data were analyzed using SPSS v.21.0. Only participants with a valid CPET were included in the analyses. The primary analytical model involved a between-subjects analysis of covariance (ANCOVA) on the main CPET variables, controlling for age (years), sex, and Body Mass Index (BMI) (kg/m²). We first examined differences in CPET variables between persons with MS and matched controls, and then examined differences in CPET variables among persons with MS based on categories of mild, moderate, and severe disability status controlling for disease duration (years) in addition to age, sex, and BMI. This analysis further involved post hoc Bonferroni corrections for examining specific differences in CPET variables between disability status groupings. Statistical significance was determined as $p<0.05$. We expressed the overall effect sizes from the ANCOVAs as partial eta squared and values of 0.01, 0.06, and 0.14 represented small, moderate, and large effects, respectively.

Figure 1. Mean aerobic capacity (VO_{2peak}) as a function of PDDS scale scores.



Results

Overall, persons with MS demonstrate alterations in outcomes from CPET compared with controls. This is demonstrated in Table 2. Further, these alterations are generally exacerbated with increasing disability. This is illustrated in Figure 1.

Conclusion

Our results provide novel information for the evaluation of CPET in MS for developing exercise prescriptions and documenting adaptations with exercise training based on the comprehensive variables obtained during CPET.

Table 1. Sociodemographic and clinical characteristics of persons with MS (n=162) and controls (n=80)

Variable	MS (n=162)	Controls (n=80)	*p* value
Age, years	44.5 (8.5)	44.1 (8.7)	0.4
Height, m	1.7 (0.8)	1.7 (0.8)	0.7
Weight, kg	79.9 (20.9)	76.9 (17.0)	0.04*
BMI, kg/m^2	27.9 (7.3)	26.6 (6.1)	0.02*
Female sex, %	87.0	91.3	0.001*
MS type, % RRMS	96.4		
MS duration, years	9.2 (7.1)		
PDDS [mdn (range)]	2.0 (0.0-6.0)		

Note. Values are mean (SD), unless otherwise stated.
RRMS = relapsing-remitting MS
PDDS=Patient Determined Disease Steps

Table 2. Comparisons of CPET variables between persons with MS (n=162) and controls (n=80)

Variable	MS (n=162)	Controls (n=80)	Mean difference (±SE)	*F* value	η_p^2
VO_{2peak}, L/min	1.6 (0.5)	2.1 (0.6)	0.5 (0.1)	57.2*	0.2
VO_{2peak}, mL/kg/min	21.4 (6.6)	27.5 (8.2)	6.1 (1.1)	52.4*	0.2
VAT: VO_2/VCO_2, mL/kg/min	13.6 (4.2)	16.6 (4.8)	3.0 (0.6)	27.7*	0.1
VAT: VO_2/VCO_2, %VO_{2peak}, mL/kg/min	64.5 (11.3)	63.4 (11.2)	-1.1 (1.5)	3.2	0.01
RER_{peak} (VCO_2/VO_2), L/min	1.2 (0.1)	1.2 (0.1)	0.1 (0.01)	13.7*	0.1
VE/VCO_2 slope	30.4 (6.6)	30.6 (5.3)	0.2 (1.0)	0.1	0.001
VO_2/power slope	8.4 (1.8)	8.9 (1.6)	0.5 (0.2)	6.2*	0.03
VO_2/HR slope	16.5 (4.6)	17.9 (6.4)	1.4 (1.0)	7.0*	0.03
OUES	1884.5 (496.7)	2156.1 (720.9)	271.6 (89.5)	21.4*	0.1
VE_{peak}, L/min	62.4 (20.2)	81.4 (24.9)	18.6 (3.2)	50.8*	0.2
HR_{peak}, bpm	155.0 (20.1)	170.0 (13.1)	15.0 (2.2)	39.3*	0.1
WR_{peak}, W	122.6 (37.2)	161.8 (49.2)	39.2 (6.2)	58.4*	0.2

Note. Values are mean (SD).