ORIGINAL RESEARCH

Multiple Sclerosis: Treadmill Versus Cycle Ergometry Maximal Exercise Test Responses

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ABSTRACT

Background: Multiple sclerosis (MS) is an autoimmune disease that impacts the central nervous system. MS generally results in decreased mobility and work capacity. Our objective was to determine exercise testing responses on both a treadmill and cycle ergometer among individuals with MS who were able to ambulate freely.

Methods: Twenty-six individuals with MS participated in a cross-sectional study (44 ± 11 years; body mass index 26.8 ± 6.2 $kg \cdot m^{-2}$; expanded disability scale score 3.1 ± 0.9), with 24 individuals with complete test data for both treadmill and cycle ergometry tests. Peak aerobic capacity (VO_{2peak}) for both treadmill and cycle ergometry tests were measured with indirect calorimetry.

Results: Participants safely completed both treadmill and cycle ergometry tests, and treadmill testing yielded higher values (26.7 ± 6.4 $mL \cdot kg^{-1} \cdot min^{-1}$) compared with cycle ergometry (23.7 ± 5.7 $mL \cdot kg^{-1} \cdot min^{-1}$), with values ~12% greater for treadmill. When comparing tests to their respected predicted values within modality, treadmill tests were 8% lower and cycle ergometry tests were 10% lower than predicted.

Conclusions: While peak aerobic capacity was very low for this population, treadmill tests were still higher than cycle ergometry data, with this difference between modes being similar to that observed in healthy adult populations. Additional research is required to determine if these findings are impacted by participation in physical activity or regular exercise. *Journal of Clinical Exercise Physiology*. 2020;9(3):113–117.

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INTRODUCTION

Multiple sclerosis (MS) is a progressive, neurodegenerative disease of the central nervous system (1). Location and severity of these MS lesions can result in diverse symptoms throughout the patient population, often resulting in delayed diagnosis and worsening of the disease state prior to initiation of pharmaceutical or lifestyle-based interventions (2). Therapeutic interventions focusing on lifestyle modifications typically include physical activity and exercise, which have benefits on quality of life and cognitive outcomes among individuals with MS (3,4).

As a result of autonomic limitations, as well as decreased participation in physical activity, people with MS generally have diminished work capacity compared with healthy peers (5). This is highly related to mobility impairment in this population (6–9). The hallmark decrease in mobility experienced in MS results in exercise testing commonly performed using cycle ergometry, as opposed to using a treadmill, due to balance concerns; however, physical activity such as walking is strongly encouraged in current exercise guidelines and by healthcare providers (10). Furthermore, previous exercise intervention research in MS has included exercise testing using cycle ergometry, with subsequent exercise

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prescription incorporating treadmill walking (11,12), which affects the target workload.

In a population of healthy adults free of documented cardiovascular disease, aerobic capacity (VO_{2peak}) can vary by as much as 10% to 15% depending on the testing modality used, with treadmill tests generally eliciting a higher oxygen consumption than tests performed on a cycle ergometer (13,14). This is due in part to the larger muscle mass recruited while performing weight-bearing exercise on a treadmill, and also the potential for acute localized fatigue of the legs often experienced by untrained cyclists during maximal exercise testing on a cycler ergometer (15). Therefore, exercise prescriptions based on results of maximal exercise tests using either testing modality may not be directly translatable to other modes of exercise.

Direct comparisons between VO_{2peak} and other cardiopulmonary exercise test (CPET) responses to treadmill and cycle ergometry have yet to be made in a population with MS. An understanding of potential differences between testing responses to each modality is necessary to allow for the development of more effective exercise prescriptions to help combat the decline in physical function often seen in this cohort. The purpose of the current study was to characterize exercise testing responses on both a treadmill and cycle ergometer among individuals with MS who were able to freely ambulate. Further, comparisons of achieved VO_{2peak} with estimated metabolic demand of exercise test workloads (i.e., speed and grade for treadmill and Watts for cycle ergometry) were performed to assess whether previously established metabolic prediction equations for healthy adults were appropriate for individuals with MS (16). The authors hypothesized that VO_{2peak} obtained on the treadmill exercise test would be higher than that obtained via cycle ergometry.

METHODS

Study Design

Twenty-six individuals with MS were recruited from local support groups, through word of mouth, e-mail, and printed recruitment flyers. Prior to study enrollment, physician clearance was obtained to confirm the diagnosis of MS and approve exercise participation. Study participation involved 2 visits to the testing laboratory spaced ≥7 d apart, with cycle ergometry and treadmill tests randomized on these days. All subjects provided written informed consent, and all experimental procedures were approved by the Institutional Review Board at University of Illinois at Chicago, and conformed to the Helsinki Declaration.

Subjects

This study targeted subjects who had an Expanded Disability Status Scale (EDSS) rating in the 0 to 4 range—indicative of the early stage of disease progression—to ensure walking on a treadmill during the CPET would be safe. Length of time since diagnosis and disease-modifying medication regimen were recorded. Exclusion criteria consisted of known cardiovascular, pulmonary, or metabolic diseases, a change in disease-modifying medical therapy in the previous 6 months, a relapse within the past 30 d, and the use of any assistive device while walking.

Visit One

After height and weight were recorded, each participant completed a health history questionnaire. The EDSS was performed by the same trained member of the research team as a standardized neurological assessment of Kurtzke's Functional Systems (17). Participants then performed the first CPET, with the mode being randomized prior to arrival to avoid an order effect.

Visit Two

Participants returned ≥ 7 d after the first study visit and were matched for time of day, as was their first test, to minimize potential differences in fatigue level between visits. After assessing body weight using a calibrated digital scale (SECA, Hamburg, Germany), the second CPET mode was completed.

Treadmill Cardiopulmonary Exercise Test

VO_{2peak} was assessed using an individualized incremental exercise test protocol performed on a treadmill (Trackmaster, Newton, Kansas). Expiratory gases were analyzed using open-circuit spirometry (TrueOne, ParvoMedics, Sandy, Utah). The test began with a 2-min warm up at 4.8 to 6.4 kilometers per hour and 0% grade, after which the test consisted of a constant, subject-determined speed. The incline was raised by 2% every 2 min until volitional fatigue was reached. VO_{2peak} criteria were considered met when 2 of the 3 criteria were satisfied: (a) respiratory exchange ratio ≥ 1.10; (b) peak heart rate within 10 $b \cdot min^{-1}$ of age-predicted maximum; (c) peak rating of perceived exertion >17 on a scale from 6 to 20. VO_{2peak} was determined using 15-second averaging, and the highest single 15-second value was recorded as VO_{2peak}. This value was recorded during the last minute of exercise.

Cycle Ergometry Cardiopulmonary Exercise Test

VO_{2peak} was assessed using an incremental exercise test protocol performed on an electronically braked cycle ergometer (Lode BV, Groningen, The Netherlands). Expiratory gases were analyzed using the same system indicated above. The participants began with a 1-min warm up at 0 Watts, followed by an increase of 15 $Watts \cdot min^{-1}$ until the participants could no longer sustain a pedaling cadence of 60 $revolutions \cdot min^{-1}$. VO_{2peak} criteria were consistent with those indicated for treadmill testing. VO_{2peak} averaging and recording processes were consistent for both modes of exercise testing.

Statistical Analysis

All analyses were performed using SPSS 24 (IBM, Chicago, Illinois). Descriptive data include mean and standard deviation (SD) of all subjects who completed both tests, and cardiopulmonary and metabolic variables were analyzed using a one-way repeated measures analysis of variance to investigate potential modality effects (treadmill versus cycle ergometry). Comparisons between observed and estimated VO_{2peak} values were made using Bland-Altman plots. The alpha for all analyses was set at $P < 0.05$. Data are presented as mean ± SD.

RESULTS

In total, 25 individuals completed the treadmill test and 26 completed the cycle ergometry test. A total of 24 individuals completed both CPETs. Three subjects cited scheduling conflicts and therefore were unable to return for the second graded exercise test. Descriptive data for these 24 subjects are shown in Table 1. Eighteen of 24 (75%) subjects were female, which is expected in this population and representative of the sex-based prevalence difference in MS. Maximal exercise testing data for these subjects are shown in Table 2 and Figure 1. VO_{2peak} was higher for treadmill tests (12% higher) compared with cycle ergometry tests (Figure 1; $P < 0.05$). Additionally, respiratory exchange ratio was lower for the treadmill tests compared with those performed via cycle ergometry (Table 2; $P < 0.05$).

Comparisons of observed and predicted oxygen demand for the workloads achieved during these exercise tests demonstrated that predicted VO_{2peak} was higher than measured values for both treadmill and cycle ergometry CPETs (8% and 10%, respectively; $P < 0.05$). These data are shown in Figure 1.

Further, Bland-Altman plots illustrate wide limits of agreement, suggesting the accuracy in predicting individual VO_{2peak} values is compromised among individuals with MS. The Bland-Altman plots for treadmill and cycle ergometry are shown in Figures 2A and B, respectively. The bias, lower limit of agreement, and upper limit of agreement are represented for both tests.

TABLE 1. Descriptive data of 24 subjects who completed both maximal exercise tests. Subject characteristics indicate that this sample was minimally disabled (EDSS < 4.0), overweight, and normotensive. Data are presented as mean ± SD, unless otherwise noted.

Parameter	Value
Female (N, %)	18 (75)
Age (years)	44 ± 11
Time Since Diagnosis (years)	11.4 ± 10.2
EDSS	3.1 ± 0.9
Height (cm)	170.8 ± 9.8
Weight (kg)	78.3 ± 20.2
BMI ($kg \cdot m^{-2}$)	26.8 ± 6.2
Waist Circumference (cm)	82.4 ± 20.2
Resting SBP (mm Hg)	120 ± 11
Resting DBP (mm Hg)	73 ± 8
Resting HR ($b \cdot min^{-1}$)	68 ± 8

EDSS = Expanded Disability Status Scale; BMI = body mass index; SBP = systolic blood pressure; DBP = diastolic blood pressure; HR = heart rate

Table 2. Peak exercise test responses. Hemodynamic responses, rating of perceived exertion (RPE), and maximal ventilation (VE_{peak}) showed no differences between treadmill and cycle ergometry maximal exercise tests. Respiratory exchange ratio (RER) was significantly higher during cycle ergometry tests when compared with treadmill. Data are presented as mean ± SD.

	Treadmill	Cycle Ergometer
HR_{peak} ($b \cdot min^{-1}$)	158 ± 19	152 ± 15
SBP_{peak} (mm Hg)	168 ± 19	164 ± 25
DBP_{peak} (mm Hg)	74 ± 12	76 ± 11
RPE	18 ± 2	18 ± 2
VE_{peak} ($L \cdot min^{-1}$)	72 ± 22	75 ± 24
RER	1.08 ± 0.09*	1.18 ± 0.09

HR = heart rate; SBP = systolic blood pressure; DBP = diastolic blood pressure
*$P < 0.05$ = difference between modality

DISCUSSION

The current study evaluated cardiopulmonary and metabolic responses to maximal exercise using both treadmill and cycle ergometry in MS and is the first to directly compare maximal responses in this patient population. These fitness data agree with values previously reported in patients with MS who have minimal disability (18). The main finding was that VO_{2peak} was higher by approximately 12% for treadmill tests compared with cycle ergometry, which is consistent with previous studies in healthy adult populations. This result supports our hypothesis and is representative of greater muscle mass involvement during ambulatory exercise when compared with cycle ergometry, in addition to lack of training on a cycle ergometer compared with ambulation (15).

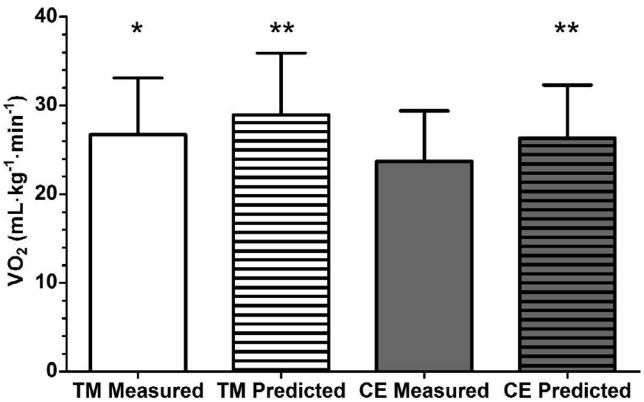

FIGURE 1. Peak aerobic capacity (VO_2) for treadmill (TM) and cycle ergometry (CE) testing, as well as predicted values. Treadmill testing yielded a 12% higher VO_{2peak} when compared with cycle ergometry (*$P < 0.05$). Additionally, predicted VO_{2peak} was elevated when compared with measured values (8% and 10% higher for TM and CE, respectively, **$P < 0.05$).

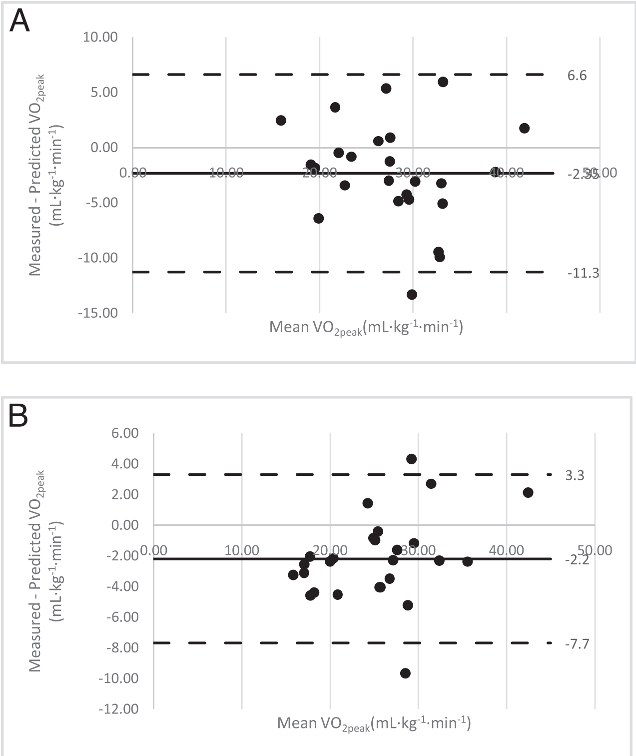

FIGURE 2. Bland-Altman plots for treadmill (A) and cycle ergometry (B) testing, demonstrating wide limits of agreement, suggesting prediction of oxygen use based on metabolic equations at maximal exercise in multiple sclerosis is inaccurate.

Interestingly, cycle ergometry yielded higher values for respiratory exchange ratio (RER). This is likely a result of the subjects' familiarity with each exercise modality, specifically that these subjects were not aerobically trained on a cycle ergometer. While they were generally not aerobically trained on a treadmill, their EDSS score of 0 to 4.0 indicates that they are minimally disabled and therefore familiarized with walking. Metabolically, cycle ergometry likely produces a greater amount of lactic acid due to a decreased reliance on fat oxidation. This may account for the increased RER, with even a lower VO_{2peak}, seen in cycle ergometry exercise, and is consistent with findings previously demonstrated in triathletes at various exercise intensities (19).

Additionally, comparisons were made between measured and predicted VO_{2peak} for each exercise modality by using common metabolic prediction equations based on work rates, which have been previously published (16). Direct measurement of oxygen consumption during exercise for each modality resulted in a lower value than predicted. This may be because the prediction equations were not initially intended to predict maximal VO_2, but rather for use during submaximal exercise, or higher-intensity submaximal exercise. The maximal work rates achieved and used in the oxygen consumption predictions, therefore, assumed the subject could have maintained that power production for the entire duration of the stage. Further, this is the first study to investigate the usage of these previously developed metabolic prediction equations in adults with MS. Because these equations were developed using a cohort of healthy adults, future research is required to develop MS-specific prediction equations to take into consideration unique movement patterns and well-documented associated metabolic demands of this population (20,21).

These findings are important to the development of exercise prescriptions for individuals with MS. Persons with MS experience a hallmark degeneration of walking mobility and balance, which are related to declining participation in physical activity (22). Aerobics favorably influences both fitness and physical activity participation (23) and is a key facet of disease management in this population. However, due to safety concerns, and gait and balance limitations, maximal exercise testing (which should be encouraged for accurate exercise prescription based on submaximal percentages of VO_{2peak}) has historically occurred on cycle ergometers. An important finding of the current study is that all of these minimally disabled participants successfully completed the treadmill exercise test with no safety concerns or issues. There were no disease relapses or exacerbations of MS symptoms reported by patients following maximal exercise testing.

Participants were all minimally disabled according to the EDSS (17) and were able to tolerate the incline and produce maximal efforts. This is important and reaffirms that treadmill exercise tests are appropriate, especially if the subsequent exercise prescriptions are to be completed via ambulatory exercise. Maximal tests performed via cycle ergometry (leading to walking-based exercise prescriptions) may result in insufficient exercise stimuli, thereby limiting the effectiveness and potential benefits typically experienced from aerobic training (24). Future research is needed to identify if MS patients with greater disability (i.e., EDSS > 4) have similar discrepancies between VO_{2peak} results obtained from treadmill and cycle ergometry.

Strengths of the current study include a testing schedule for both treadmill and cycle ergometry tests consistent within each patient, limiting the potential confounder of fatigue that MS patients might experience over the course of the day (25). Further, no complications arose following the tests, indicating that testing with proper prescreening is appropriate in this population. Additionally, our focus specifically on minimally disabled MS patients allows results to be generalized to those patients who are believed to still achieve improvements in fitness and, therefore, gain the myriad health benefits associated with increase in VO_{2peak} (26). Limitations of the current study include lack of data regarding participant exercise history, as trained cyclists tend to have a minimized difference between fitness measurements taken during treadmill and cycle ergometry (27).

CONCLUSION

Minimally disabled persons with MS exhibit a decrease in VO_{2peak} when assessed via cycle ergometry compared to treadmill. This 12% decrease in VO_{2peak} is similar to that observed in healthy adult populations and has implications for the development of exercise prescriptions. Additional research is required to determine if these findings are impacted by participation in physical activity or regular exercise.

REFERENCES

1. Goldenberg MM. Multiple sclerosis review. P T. 2012;37(3): 175–84.
2. Compston A, Coles A. Multiple sclerosis. Lancet. 2008;372(9648):1502–17.
3. Morrison JD, Mayer L. Physical activity and cognitive function in adults with multiple sclerosis: an integrative review. Disabil Rehabil. 2017;39(19):1909–20.
4. Petajan JH, Gappmaier E, White AT, Spencer MK, Mino L, Hicks RW. Impact of aerobic training on fitness and quality of life in multiple sclerosis. Ann Neurol. 1996;39(4):432–41.
5. Langeskov-Christensen M, Heine M, Kwakkel G, Dalgas U. Aerobic capacity in persons with multiple sclerosis: a systematic review and meta-analysis. Sports Med. 2015; 45(6):905–23.
6. Romberg A, Virtanen A, Aunola S, Karppi SL, Karanko H, Ruutiainen J. Exercise capacity, disability and leisure physical activity of subjects with multiple sclerosis. Mult Scler. 2004; 10(2):212–8.
7. Klassen L, Schachter C, Scudds R. An exploratory study of two measures of free-living physical activity for people with multiple sclerosis. Clin Rehabil. 2008;22(3):260–71.
8. Motl RW, Goldman M. Physical inactivity, neurological disability, and cardiorespiratory fitness in multiple sclerosis. Acta Neurol Scand. 2011;123(2):98–104.
9. Snook EM, Motl RW, Gliottoni RC. The effect of walking mobility on the measurement of physical activity using accelerometry in multiple sclerosis. Clin Rehabil. 2009; 23(3):248–58.
10. Motl RW, Pilutti LA, Sandroff BM. The importance of physical fitness in multiple sclerosis. J Novel Physiotherapies. 2013;3(2):1–7.
11. Sandroff BM, Hillman CH, Benedict RH, Motl RW. Acute effects of varying intensities of treadmill walking exercise on inhibitory control in persons with multiple sclerosis: a pilot investigation. Physiol Behav. 2016;154:20–7.
12. Sandroff BM, Wylie GR, Sutton BP, Johnson CL, DeLuca J, Motl RW. Treadmill walking exercise training and brain function in multiple sclerosis: preliminary evidence setting the stage for a network-based approach to rehabilitation. Mult Scler J Exp Transl Clin. 2018;4(1):1–5.
13. Mays RJ, Boer NF, Mealey LM, Kim KH, Goss FL. A comparison of practical assessment methods to determine treadmill, cycle, and elliptical ergometer VO_2 peak. J Strength Cond Res. 2010;24(5):1325–31.
14. McKay GA, Banister EW. A comparison of maximum oxygen uptake determination by bicycle ergometry at various pedaling frequencies and by treadmill running at various speeds. Eur J Appl Physiol Occup Physiol. 1976;35(3):191–200.
15. Beltz NM, Gibson AL, Janot JM, Kravitz L, Mermier CM, Dalleck LC. Graded exercise testing protocols for the determination of VO_2max: historical perspectives, progress, and future considerations. J Sports Med (Hindawi Publ Corp). 2016;2016:1–12.
16. American College of Sports Medicine. ACSM's guidelines for exercise testing and prescription. 10th ed. Baltimore: Wolters Kluwer; 2017.
17. Kurtzke JF. Rating neurologic impairment in multiple sclerosis: an expanded disability status scale (EDSS). Neurology. 1983;33(11):1444–52.
18. Klaren RE, Sandroff BM, Fernhall B, Motl RW. Comprehensive profile of cardiopulmonary exercise testing in ambulatory persons with multiple sclerosis. Sports Med. 2016;46(9): 1365–79.
19. Capostagno B, Bosch A. Higher fat oxidation in running than cycling at the same exercise intensities. Int J Sport Nutr Exerc Metab. 2010;20(1):44–55.
20. Olgiati R, Burgunder JM, Mumenthaler M. Increased energy cost of walking in multiple sclerosis: effect of spasticity, ataxia, and weakness. Arch Phys Med Rehabil. 1988;69(10): 846–9.
21. Sebastiao E, Bollaert RE, Hubbard EA, Motl RW. Gait variability and energy cost of oveground walking in persons with multiple sclerosis: a cross-sectional study. Am J Phys Med Rehabil. 2018;97(9):646–50.
22. Motl RW. Physical activity and irreversible disability in multiple sclerosis. Exerc Sport Sci Rev. 2010;38(4):186–91.
23. Karpathkin HI. Multiple sclerosis and exercise: a review of the evidence. Int J MS Care. 2005;7:36–41.
24. Mersy DJ. Health benefits of aerobic exercise. Postgrad Med. 1991;90(1):103–7, 10–2.
25. Freal JE, Kraft GH, Coryell JK. Symptomatic fatigue in multiple sclerosis. Arch Phys Med Rehabil. 1984;65(3): 135–8.
26. Confavreux C, Vukusic S. The clinical epidemiology of multiple sclerosis. Neuroimaging Clin N Am. 2008;18(4):589–622, ix–x.
27. Coyle EF, Coggan AR, Hopper MK, Walters TJ. Determinants of endurance in well-trained cyclists. J Appl Physiol. (1985) 1988;64(6):2622–30.