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Comparison of energy consumption in different clinical forms multiple sclerosis with normal subjects (cohort study)

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ABSTRACT

Background: Multiple sclerosis (MS) is one of the most common joint disorders that influence walking performance.
Objectives: The objectives are to determine if energy consumption of three different clinical forms of MS differs from each other. Is there any difference between MS and normal subjects? Is there an association between the Physiological Cost Index (PCI) and the Expanded Disability States Scale (EDSS)?
Methods: MS subjects (EDSS > 4) were separated in three groups based on the Ashworth and Ataxia scales, including ataxic ($n=16$), spastic ($n=15$) and ataxic-spastic ($n=14$). In addition, 13 age-and-gender-matched healthy subjects were used as the control group. A Heart Rate (HR) Polar Electro Finland was used to record the heart rate during resting and walking. The energy consumption was measured based on PCI. ANOVA, MANOVA, Post-hoc Tukey analysis and Pearson correlations were used for statistical analysis ($P<0.05$).
Results: There was a significant difference between the walking speeds of normal (76.05 ± 5.70 m/min) with ataxic (36.78 ± 12.68 m/min), spastic (34.45 ± 16.32 m/min) and ataxic-spastic (27.21 ± 14.76 m/min) groups ($P<0.001$). There were no significant differences between the resting HR and walking HR of four groups, and no significant difference between the PCI of ataxic, spastic and normal groups ($P>0.1$). The correlation between PCI and EDSS was 0.65 ($P<0.001$).
Conclusion: The performance of the cardiovascular system in MS subjects was the same as normal subjects. Their energy consumption increased significantly due to a decrease in their walking speed. It seems that the weakness of muscles of the lower extremity and spasticity of knee extensors play a significant role in this regard.

1. Introduction

Multiple sclerosis (MS) is one of the most common neurological disorders that influence the ability of subjects to stand and walk (Martin et al., 2006; Soyuer et al., 2006; Karst et al., 2005; Jackson et al., 1995). It has been shown that the occurrence of this disorder varies between 5 and 30 per 100,000 individuals (Toro et al., 2007). Various types of treatment methods have been used to restore the abilities of the MS subjects to stand and walk, some of which include the use of various assistive devices and rehabilitation exercises. Based on the results of studies done by Cammeron and Wagner (2011) and Sosnoff and Remeluse (2012), the speed of walking decreases due to shorter stride length and decrease in cadence (Sosnoff et al., 2012; Remelius et al., 2012; Cameron and Wagner, 2011).

These subjects have high energy cost during walking. Olgiati et al. showed that the energy consumption of the subjects with MS disorders was two to three times greater than that of normal subjects; they showed that the leg fatigue associated with MS disorder might be due to high-energy consumption during walking. Moreover, they concluded that poor conditioning, altered cardiovascular control and muscle weakness may be important parameters in this regard (Oligati et al., 1998). In contrast, Tantucci et al. (1996) found that MS subjects with mild spasticity had the same energy consumption during walking as normal subjects. Another study done by Olgiati et al. (1986) showed that energy consumption during comfortable walking was significantly high in

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MS subjects compared to normal subjects. The results of regression analysis showed that their energy consumption depends on spasticity of the lower extremity, but the weakness of trunk musculature did not influence the energy consumption. There are various types of MS disorder including spastic, ataxic, and ataxic-spastic (Bickley and Szilagyi, 2012).

However, it is not clear whether their energy consumption differs from each other or not, or if there is any difference between energy consumption in MS and normal subjects while walking. Finally yet importantly, the effect of spasticity and functional disability on energy consumption was not well understood. Therefore, the aim of this research was to find answers to the aforementioned questions. The main hypothesis associated with this study was that the energy consumption of these subjects depends on the level of spasticity and the subjects' muscular weakness.

2. Methods

2.1. Trial design

A range of symptoms such as ataxia, spasticity and both ataxia and spasticity will be dominant in MS patients with an EDSS of more than 3.5. Therefore, the MS population is a heterogenous population that is split into fairly homogenous groups. As a result, stratified sampling was used in this study.

2.2. Sample size

The sample size was estimated by the sample size calculation formula for quantitative variables (Hafeznia, 1996). In this formula, $N=204$, $S=0.19$ (walking speed variable) (Franceschini et al., 2010), $t=1.96$ and $d=0.05$ (confidence interval=95%) were estimated, and $n=44$ was calculated. 45 patients participated in coherence to this study. The following equation was used for sample size calculation:

$$n = \frac{Nt^2S^2}{Nd^2 + t^2s^2}$$

The following table was used for sample size calculation in every stratum (Hafeznia, 1996) (Table 1).

A neurologist referred 204 patients with symptoms of ataxia ($n=70$), spastic ($n=68$) and ataxia-spastic ($n=66$), but the details of the research were unknown for the neurologist and the other investigators. Patients were recruited and began participating in this study from May 2013 to February 2014. For allocation of the patients, a computer-generated list of random numbers was used and the patients were randomly assigned to three groups. Among these, 18 patients (the larger number of patients being due to losses or exclusions after randomization) were selected randomly in each stratum while 54 patients participated in the study with complete consent and desire. 9 patients were excluded due to lack of cooperation. Forty-five patients (ataxia ($n=16$), spastic ($n=15$) and ataxia-spastic ($n=14$)) completed the protocol tests.

Table 1
Sample size calculation in every stratum.

Population	Groups (Strata)	Obtain a simple random sample	Sample
All MS patient recruited to MS clinic	3 group MS (ataxia, spastic and ataxia-spastic)	15 MS patients from each group	$15 \times 3 = 45$ selected patients
204 patients (70 ataxia patients, 68 spastic patients, 66 ataxia-spastic patients)			
Sample size (Ataxia group)	Sample size (Spastic group)	Sample size (Ataxia-spastic group)	
$(70 \times 100)/204 = 34\%$	$(68 \times 100)/204 = 34\%$	$(66 \times 100)/204 = 32\%$	
$45 \times 34\% = 16$ ataxia patients	$45 \times 34\% = 15$ spastic patients	$45 \times 32\% = 14$ Ataxia-spastic patients	

2.3. Subjects

Two groups of normal subjects ($n=13$) and those with multiple sclerosis disorder ($n=45$) were recruited in this study. MS subjects were divided into three groups base on spasticity, ataxia and ataxic-spastic syndromes. The study took place at the MS clinic of "XXXX". "XXXX" has the highest level of prevalence of MS diseases in "XXXX". The MS subjects were selected from those referred to "XXXX" for periodic evaluation based on the following inclusion criteria. Eligibility criteria for participants included a definite diagnosis of MS (relapsing-remitting and progressive type) with a duration of 5 years, being relapse-free during the past 30 days before testing, having an EDSS range of 4−6.5, having dominate symptoms of spasticity or ataxia, or both symptoms, and being between the ages of 25 and 52 years old. Criteria for rejection included the inability to give informed consent, pregnancy, lactation or pregnancy during the study, having cognitive disorders, severe disorders in visual function, serious psychological disorders, intense arthritis in the knees or hips, and skin diseases. Table 2 shows the characteristics of the subjects who participated in this study.

An ethical approval was obtained from "XXXX", ethical committee (No. 5850/9/35/16/C). Each subject was asked to sign a consent form before data collection. The neurological impairment of the MS subjects was diagnosed by a neurologist and was divided into three groups based on clinical tests. The Ashworth Scale and Brief Ataxia Rating Scale (BARS) were used to determine the rate of spasticity and ataxia rating, respectively (Fig. 1).

The disability statues of the subjects was evaluated by use of the Expanded Disability Statues Scale (EDSS) (Kurtzke, 1983). EDSS is an eight functional system scale that includes motor, sensory, cerebellar, brain stem, visual, mental, and sphincters parameters. Each domain was graded from 0=no disability, to 6 or 6.5=maximal disability based on history and physical examination. According to this scale, 0 was scored as normal and 10 was scored as death from MS (Kurtzke, 1983). The spasticity of lower extremity musculatures was evaluated by use of the modified Ashworth scale, which is considered to be a validated clinical measurement to grade spasticity (Bohannon and Smith, 1987). This involves mobilization of individual joints to provide a clinician-based assessment with an ordinal outcome. The scale ranges from a score of 0=no increase in tone to 4=limb rigid in flexion or extension. Four groups of lower extremity musculatures were evaluated in right and left sides separately (ankle plantar flexor, knee flexor and extensor, and hip adductor). The mean values of both right and left sides in every joint and total mean of both of the leg muscle groups were recorded for final analysis. Ataxia was scored using the Brief Ataxia Rating Scale (Schmahmann et al., 2009) which is graded from 0=Normal, to 30=high disability.

2.4. Test protocol

The subjects were instructed about the testing procedure, then they had their mass and height measured and recorded. In order to measure the energy consumption of the subjects, the subjects' Heart Rate (HR) was monitored. A Heart Rate Polar Electro Finland was used to record the heart rate during resting and walking. The energy consumption was measured based on Physiological Cost Index (PCI) by use of the following equation (McGregor, 1979).