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Evaluation of vertical ground reaction force during walking in patients with multiple sclerosis

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Journal of Research & Health
Social Development & Health Promotion Research Center
Vol. 7, No. 5, Sep & Oct 2017
Pages: 988- 993
DOI: 10.18869/acadpub.jrh.7.5.988
Original Article

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Received: 18 Nov 2015
Accepted: 30 Jan 2016

How to cite this article: Payandeh M, Amiri Jomi Lo R, Bakhshi Nezhad Sh, Takizadeh Kh. Evaluation of vertical ground reaction force during walking in patients with multiple sclerosis. *J Research & Health*2017; 7(5): 988- 993.

Abstract

Patients with Multiple Sclerosis (MS) suffer from inabilities such as weakness and muscle fatigue due to the demyelination. The inabilities may result in some disorders in walking. The present study is a clinical trial research conducted on 84 participants in two groups of experimental and control who were randomly selected. The results showed that people with MS apply more force on the ground during the three examined component of stance phase of gait cycle in comparison with those without the disease. Also, the maximum difference was found between the two groups at the mid-stance component that was the only stage in the stance phase in which, the difference between the groups was statistically significant. It can be concluded that the largest amount of pressure and force applied on the limbs of people with MS lies in the mid-stance component of stance phase. According to the results of the study, the lowest amount of force absorption occurs in that stage. The obtained results can be employed in order to design shoes of type suitable for people with MS that are capable to absorb extra vertical reaction force and thus, prevent skeletal-muscle damages.

Keywords: Abnormality, Multi, System Diseases, Weakness

Introduction

Multiple Sclerosis (MS) is one of the most common progressive neurological diseases among the youth [1,2] which is caused by the demyelination. Myelin is a sheath which surrounds nerve fibers and plays an important role in increasing the speed at which the nerve impulses propagate. Naturally, nerve impulses will propagate quickly with the existence of this sheath, and this leads to the body's ability to orchestrate the movements [3].

The symptoms of the disease depend on the place at which demyelination has occurred and also on the extent of the lesion [4]. Demyelination in specific areas such as the optic nerve, brainstem, cerebellum, and corpus callosum will reveal some clinical signs such as sudden blurred vision, inability to move the limbs, loss of balance, double vision, and a kind of sensory impairment in the form of pins and needles [5]. Therefore, the disease leads to some inabilities and also a reduced quality of life for the patients [6]. Some of these inabilities include

muscle fatigue [7,8] and muscle weakness [9]. In addition, by producing a lesion in the ascending sensory pathways, the disease can result in an impaired proprioception and can produce a sense of vibration. Furthermore, muscle weakness and spasticity can affect the patient's walking. This is done through the involvement of the sequence of muscle contractions [10].

Walking disorders can be observed among 10 to 20 percent of patients during the first years of their disease. This rate increases as the disease progresses and may reach to 50%. 18 years after catching the disease, the patients are normally unable to walk without mobility aids such as cane, walker, or wheelchair [11,12]. However, loss of balance, weakness, and muscle fatigue, which are the signs of walking disorder, will increase the possibility of falling and as a result, the patients will lose their self-confidence to move and to be present in public. This, in turn, results in an increased muscle fatigue. Examining walking disorders can play an important role in preventing the patients' falling and occurring bone fractures, especially in the hip bone [13].

Recently, measuring the Ground Reaction Force (GRF) has been considered as a criterion to recognize and categorize people based on their use of the force while walking in a period of time [14]. In fact, the features of GRF in walking are regarded as important demonstrators in the diagnosis of walking disorders [15,16]. While walking forward, the Vertical Ground Reaction Force (VGRF) has two peaks. One of them occurs at the initial stages (a little after heel contact) and the other at the final stages of foot contact (before the heel off stage). At these points, the acceleration of the body's center of gravity in the vertical direction is ascending. Furthermore, there is a concavity in the curve of VGRF at the moment of complete contact of foot with the ground (midstance component). Here, the acceleration of the body's center of gravity in the vertical direction is descending [17].

There are a few studies about examining ground reaction force in people with MS', aiming at having a better understanding about their walking disorders. As mentioned earlier, as the disease progresses, walking disorders increases. Thus, examining walking disorders in people with MS seems essential. By doing so, there can be the maximum possibility of preventing the progress of disorders, leading to some damages and defects in the patients.

The present study aimed to examine the vertical ground reaction force in the three components of heel contact, mid-stance, and terminal stance in the stance phase of gait cycle while the patients were walking and also to compare the results with those of people without the disease.

Method

The present study was a Randomised Controlled Trial (RCT) research. The sample size was determined based on the relevant studies conducted earlier [2,10,18]. The number of participants in each group of case and control with regard to α value= of 0.05 and β value= of 0.1 was calculated to be 42 using the following formula.

Therefor 42 participants were selected in each group to participate in this study, including 42 male participants with the disease who referred to Iran's MS Society (as the test group) and 42 male participants of general population (as the control group). All procedures of the research were approved by the Ethics Committee of the Ferdowsi University of Mashhad (The Code of Ethics: 91/5-43675). The control group was selected randomly and matched with the test group based on age, gender, height, and weight. The participants in the control group were examined by a specialist to ensure that they are not suffering from MS. The participants in the control group were approved with MS by a neurologist using clinical diagnostic tests and MRI. The patients participating in the study should have the expanded disability status scale equal to pr below 4. In addition, the patients and the members of control group were not supposed to have any damage or bone fracture in their trunk and lower extremities, nor any skeletal and muscle abnormalities, and any dizziness during the time of the experiment.

Those patients who had any disease other than

MS, including orthopedic or other neurologic diseases, were excluded from the study. Before starting the study, voluntary-informed-consent forms were given to people who were invited to participate in the study.

Data acquisition and analysis: vertical ground reaction force was measured in all the participants throughout the times of weight transfer in the three components of heel contact, mid stance, and terminal stance of stance phase while they were walking. The measurements were carried out by using an Advanced Mechanical Technology Inc. (AMTI) force plate, MA USA at the frequency of 1000 Hz. Two Vicon MX three-dimensional motion analysis systems were implemented in the internal and external directions to identify different components of stance phase. The motion capture systems were synced with the force plate instrument.

The starting point was designated at the distance of seven paces with the force plate so that one could reach a normal gait cycle. For preventing error in measuring the force, the participants were asked to do not put their feet completely on the force plate. If some factors disrupted the data output of a movement, the movement was repeated. After finishing the measurements, the threshold vertical ground reaction force of 10 N was used in order to determine the heel-contact and heel-off. Then, the data were low-pass filtered using a 20 th-order Butterworth filter. Then, to compare vertical ground reaction force among the participants, the time of these variables' happening was determined according to a percentage of the total time using Matlab 7.10.0.499 (R2010 B) software [17] (Figure 1).

In order to statistical analysis, the mean value of each component of stance phase was measured separately for each person when walking forward. This was performed four times per each person. After that, in order to standardize the findings of the ground reaction force, the obtained values were divided by the weight of the participants (based on N) and multiplied by 100 so that the weight factor would be regarded as an ineffective factor in statistical calculations [19].

Statistical analysis: Before selecting a statistical method, Shapiro-Wilk test was implemented to assess the normal distribution of variables, and then. Levene's test to examine the homogeneity of variances. Since the data were normal, an independent t-test was performed. Data analysis was conducted at the significance level of $p<0.05$ using SPSS (Version 21, 2012, IBM, the US) and Excel (Version 14.0.4760, 2010, Microsoft, the US).

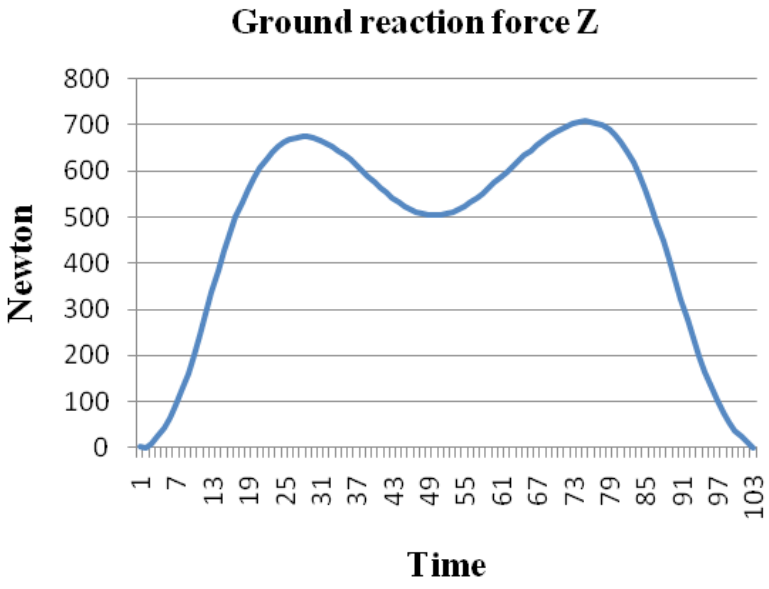

Figure 1 *Vertical ground reaction force (VGRF) in walking.*

Results

The findings of the present study on vertical ground reaction force at the three components of stance phase of gait cycle, including heel contact, mid stance, and terminal stance, indicated that participants with MS (Table 1 shows the individual features of participant) applied statistically more force on the ground during the mid-stance stage in comparison with those without the disease (p=0.02). Furthermore, although participants with MS applied more force on the ground during the heel-contact and terminal stance in comparison with those without the disease, the difference among the groups was not significant (p>0.05) (See Table 2). Additionally, as Table 2 shows, it took shorter time for participants with MS to reach the heel contact moment in comparison with participants without the disease. This was true in the other moments of walking in participants with MS compared to participants without the disease.

Table 1 *Clinical and demographic characteristics of participants*

	Multiple sclerosis group	Normal group	p-value
Number of members	42	42	
Age (years)	29.96 ± 6.43	29.80 ± 6.13	0.92
Height (cm)	177.28 ± 6.93	176.42 ± 7.05	0.68
Body weight (kg)	74.92 ± 7.71	75.20 ± 8.65	0.52

All data in the table are reported as mean ± standard deviation.

Table 2 *Statistical results in three components of heel contact, mid stance and terminal stance of stance phase between two groups of with and without multiple sclerosis.*

Component of stance phase	mean ± standard deviation Based on the percentage of weight (kg)		(%Stanse)		T	Levene test		Sig.
	Multiple sclerosis group	Normal group	Multiple sclerosis group	Normal group		F	P	
HCa	102.27 ±12.74	99.78 ±9.67	%30.73	%31.93	0.65	0.17	0.67	0.52
MSb	78.47 ±9.53	71.1 ±7.07	%50.06	%52.2	2.41	0.37	0.56	0.02*
TSc	110.14 ±12.31	105.27 ±10.08	%76.6	%76.73	1.27	0.52	0.94	0.26

All data in the table are reported as mean ± standard deviation. The asterisk (*) indicates the use of independent t-test analysis and significance at the p<0.05 level. Indication (a) = Heel Contact, Indication (b) = Mid Stance and Indication (c)=Terminal Stance.

Discussion

MS is a progressive neurological disease, which can lead to walking disorder in an advanced state [20]. This abnormality is an inseparable feature in people with MS [21] involving almost 80% of them [22,23]. In fact, walking disorder is one of the most important problems affecting people with MS. Also, it has an important impact on their performance and quality of life [24].

Studying the components of vertical ground reaction force gives useful information about walking in people with MS', which can serve as a good tool for differential diagnosis of such disorders [20]. The present study aimed at examining vertical ground reaction force in people with MS'. The findings of the study showed that people with MS apply more force on the ground during the three components of heel contact, midstance, and terminal stance of stance phase of gait cycle in comparison with those without the disease. The study of Wurderman et al [20] is the only research found in this context which dealt with the issue precisely. In that study, vertical ground reaction force was examined among 18 people with MS and 18 people without the disease. However, they have dealt with the issue in general and did not examine the stance phase in detail. Wurderman et al [20] have pointed

out that there is a significant difference in vertical ground reaction force among people with MS and those without the disease.

The obtained results in the present study indicated that among the three components of stance phase, the greatest difference between the groups existed in the middle of stance phase, i.e. the mid-stance component, which was statistically significant. The larger amount of pressure and force applied on the limbs of people with MS in mid-stance can be explained according to the data obtained in the present study. As Table 2 shows, the time period between the two components of heel contact and mid stance in people with MS is almost 2% less than those in people without the disease. This means that mid stance in people with MS has occurred in a shorter period of time which in turn, has led to decreased force absorption. This can be regarded as a risk factor for damage in MS patients [19]. The answer to the questions why did the three measured components of stance phase, especially the mid-stance moment, last shorter in people with MS compared to those without the disease", and as a result the question "why did the time of force absorption decrease and that of force applied to the foot increase?" lies in weakness, especially in the muscles of lower extremities, lack of adequate support in walking and therefore, improper functioning of the muscles. Several muscles are involved in the process of walking, especially in the stance phase of gait cycle, in order for body to move smoothly and in a controlled way. However, this study did not examine the functioning of the muscles directly that can be considered one of the limitations of this study.

In a study conducted by Payandeh et al [17] on people with foot arch drop who were suffering from muscle weakness, especially weakness in tibialis posterior muscle, it was clarified that muscle weakness could lead to improper functioning of muscles and some fine motor disorders. This, in turn, leads to decreased absorption of the ground force. The decreased absorption and increased force applied to the foot can be regarded as a damaging factor to people. In healthy people, all the components of stance phase are performed in an efficient and controlled way due to the proper functioning of muscles. According to the data obtained in the present study, it should be stated that the stance phase of gait cycle in people with MS, due to the demyelination and therefore some disorders in various body parts, especially in muscles as weakness [9], occurs in a faster and more uncontrolled way in comparison with people without the disease. This, in turn, leads to an increase in vertical ground reaction force, and the increased vertical ground reaction force can result in skeletal-muscle damage in such people. Therefore, it can be said that an increase in vertical ground reaction force can be a demonstrator of muscle weakness in people with MS.

Conclusion

It can be concluded that the people with MS applyed more force on the ground during the three components of heel contact, midstance, and terminal stance of stance phase of gait cycle in comparison with those without the disease.

Also the research findings can be concluded, that the largest amount of pressure and force applied on the limbs of people with MS lies in the mid-stance component of the stance phase of gait cycle.

The results can be used in order for shoe designers to design some types of shoes suitable for people with MS which are capable to transfer the extra vertical reaction force and thus, prevent skeletal-muscle damages.

Acknowledgements

Authors wish to express their gratitude to all the participants.

Contribution

Study design: MP, RA, SB, KT
Data collection and analysis: MP
Manuscript preparation: MP, RA, SB, KT

Conflict of Interest

"The authors declare that they have no competing interests."

Funding

The author (s) received no financial support for the research, authorship and/or publication of this article.

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