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The Effects of Foot Rehabilitation on Weight-Bearing and Gait Velocity in Children with Pervasive Developmental Disorder

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Abstract

Objective: In this study, children with pervasive developmental disorder received foot rehabilitation three times a week for 12 weeks, in order to compare and analyze their gait patterns, feet shapes and balance in comparison to normal children whose daily life was controlled. The purpose was to provide basic data related to foot rehabilitation for children with pervasive developmental disorder by investigating gait stability and kinematic change and, ultimately, help create a clinical intervention program to improve gait of children with pervasive developmental disorder. Design: Cross-sectional study. Methods: The subjects were 10 normal children (normal group) with no particular disorder and 10 children with pervasive disorders (PDD group). For the study, at S sport clinic, foot pressures at static phase and gait phrase of the subjects were measured by using a foot pressure measurement device (Gaitview AFA-50, Korea) and growth index (height, weight, BMI) was measured based on impedance measurement method (Inbody, J10). The foot rehabilitation exercise was performed three times a week for 12 weeks, for 1 hour and 20 minutes per session. The data was processed by using SPSS 22.0 ver. The non-parametric statistical method Kruskal-Wallis Test was used for each group and variable in this study. As a posttest, the difference between the groups was analyzed by using Mann-Whitney U Test. Also, the statistical significance level was set at α=.05. Results: There was a significant difference in the ratio between the two feet of children with developmental disorders, with 4.45±4.56 % decrease, and also in the that of normal children, with 3.66±5.64% decrease. Also, there was a significant difference between the two groups. The gait velocity of children of developmental disorders decreased by 0.27 ± 0.27, with a significant difference, while that of normal children increased by 0.11±0.14. Also, there was a significant difference between the groups ($p<.05$). Conclusions: In this study, the foot rehabilitation exercise had an effect on improving balance in the plantar pressure ratio of children with pervasive developmental disorders as well as gait velocity. The findings suggest the foot rehabilitation exercise improves gait velocity by improving overall physical stability and, thereby, physical control.

Keywords: *Pervasive developmental disorder, Balance, Rehabilitation, Foot, Gait*

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1. Introduction

Pervasive developmental disorders (PDD) refer to a group of chronic disorders found in people aged five and older, including mental retardation, cerebral palsy, epilepsy, autism spectrum disorders, Asperger syndrome, and Tourette syndrome, and are classified as disorders with significant limitations due to mental, physical, or overlapping defects [1]. It has been reported that the increase of children with PDD was caused by socio environmental hazard, among others [2, 3]. Children with PDD are characterized by lack of skills to respond in social relationships or adaptation [4], as well as behavioral limitations. PDD is accompanied by basic intellectual and motor disorders as well as other types of disorders related to social behavior, emotional change, and environmental perception, among others [5]. Due to physical left-right imbalance, children with PDD support 30-40% of their weight with the leg of the affected side. As a result, they have an unstable standing posture, impaired balance, and other problems [6]. Research has shown children with PDD perform a smaller amount of activity in daily life but use a larger amount of energy for the same movements than normally developed children. Therefore, as PDD can lead to secondary diseases, it is important to emphasize balance and gait in the rehabilitation programs [7]. Research on children with PDD focuses on the effects of restrictions caused by the disorders on physical development of the children, and the results suggest participation in early physical activity programs during childhood has positive effects on physical development of children with PDD [1, 8, 9]. As a base structure, feet bear the body weight, maintain balance of human body, absorb shock from the ground while walking, and produce the propulsive force for the next gait [10]. Plantar pressure outside the normal range can cause physiological disorders and muscle and joint fatigue. Repeated application of abnormal shock to the feet can lead to spine diseases or decline of physical growth [11]. Foot exercise strengthens muscular strength of ankles and improves gait velocity and stride [12]. However, in research related to gait observation of people with foot deformity such as pes planus[13], and walking, running, hiking, and other weight bearing exercise can exacerbate leg pain at the arch, heel, etc. Measuring plantar pressure enables observation of pressure applied to specific parts of foot during mundane and functional activities, and is a common method adopted in the field of sports science [14]. Also, gait analysis is an important subject in the field of biomechanics and used in various fields ranging from medical science to ergonomics, sports science, physical therapy, and orthosis design, in order to systematically evaluate gait and objectively and quantitatively determine the effects of treatments [15]. However, appropriate methods of gait rehabilitation exercise for children with PDD have not been clearly established, and the limited research currently available is focused on children with cerebral palsy. Therefore, in this study, children with pervasive developmental disorder received foot rehabilitation three times a week for 12 weeks, in order to compare and analyze their gait patterns, feet shapes and balance in comparison to normal children whose daily life was controlled. The purpose was to provide basic data related to foot rehabilitation for children with pervasive developmental disorder by investigating gait stability and kinematic change and, ultimately, help create a clinical intervention program to improve gait of children with pervasive developmental disorder.

2. Method

2.1. Participants

In this study, 10 normal children with no particular disorder (normal group) and 10 children with PDD who are able to walk (PDD group) pervasive developmental disorders

group) participated. The subjects and their guardians listened to detailed explanation of the purpose and procedure of this study, and consented to participating in the study. Also, none of the subjects had a cardiovascular disease nor was on medication. General characteristics of the subjects was presented.

2.2. Procedure

In this study, by using a foot pressure measurement device, foot pressure of normal children and children with PDD at the static phase and gait phase was measured. Also, the growth index (height, weight, BMI) was measured by using an impedance method (Inbody, J10). Normal children were asked to continue everyday life (with exercise restriction), while children with PDD performed foot rehabilitation exercise three times per week for 12 weeks, 1 hour and 20 minutes per session. The exercise program was based on a program designed by Dupont and Buyukyaz [16-18] and the plyometric consisted of alternate jump with knees up, scissors jump, single leg hops, and spring jump. The rehabilitation exercise program is presented.

2.3. Measurement

The gait pattern, foot shape, and balance of the subjects were measured before and after the 12-week foot rehabilitation program by using a plantar pressure measurement device (Gaitview AFA-50, Korea) [Figure 1]. During the measurement, the subjects did not wear shoes, were in comfortable postures, and, for static phase, stood straight still on a pad for 30 seconds, with their eyes fixed and without carrying any object. For gait phase, the subjects were asked to step on the device first with their left foot and then turn around to step on the device with the right foot, in order to ensure the same stride among the subjects.

2.4. Statistics

The data was analyzed by using SPSS 17.0 ver. (SPSS Inc., Chicago, IL, USA). Characteristics of subjects in each group were analyzed based on descriptive statistics. Each study group and variables were analyzed by using the non-parametric statistical method Kruskal-Wallis Test, and difference in results between the two groups was analyzed based on Mann-Whitney U Test. Also, the statistical significance level at which to accept a hypothesis was set at α=.05.

3. Results

Regarding difference in plantar pressure ratio of children with PDD, the difference between the two feet was reduced by 4.45±4.56% in the experimental group ($p<.05$), while it increased by 3.66±5.64% in the control group, suggesting a significant difference. Also, there was a significant difference between the two groups ($p<.05$).

Table 1. Changes in the foot pressure ratio difference at pre- and post-program (N = 20)

		Experimental group (n = 10)	Control group (n = 10)	Difference(post-pre)		*t*(p)
				Experimental group	Control group	
Foot pressure ratio difference (%)	Pre	7.11±5.30	2.90±2.56	-4.45±4.56	3.66±5.64	3.531(0.003)
	Post	2.66±2.18	6.56±4.36			
	t(p)	3.081(0.013)	-0.050(0.071)			
Values are presented as mean ± standard deviations						

Regarding variables related to change in gait velocity of children with PDD, the gait velocity decreased by 0.27 ± 0.27 seconds in the experimental group, with a significant difference ($p<.05$), and increased by 0.11±0.14 seconds in the control group, with a significant difference. Also, there was a significant difference between the two groups ($p<.05$).

Table 2. Changes in the gait velocity at pre- and post-program (N = 20)

		Experimental group (n = 10)	Control group (n = 10)	Difference(post-pre)		*t*(p)
				Experimental group	Control group	
Gait velocity (sec)	Pre	0.94±0.22	0.77±0.14	-0.27±0.27	0.11±0.14	3.272(0.006)
	Post	0.73±0.11	0.88±0.08			
	t(p)	2.388(0.041)	-2.501(0.034)			
Values are presented as mean ± standard deviations						

4. Discussion

Most people desire to have a good posture for aesthetical reasons. While good posture improves physical appearance, balanced posture has more significance in terms of spine health. Because of the erect standing, humans receive a substantial amount of gravity and stress on the normal physical structure (spine) and people with imbalanced spinal structure are more likely to develop problems related to tissues and organs connected with the spinal nerves than people with a normal spine [19].Feet act as post stones of our body, supporting the body weight, and when impaired, can destroy the balance of the organic axis of human body from the two lower limbs to the pelvis and spine, and cause chronic pain and diseases in foot, lower limb, pelvis, and spine [10]. Feet have great influence on the arrangement of the body. In this study, the weight-bearing ratio between the two feet decreased by 4.45±4.56 % in the experimental group, with a significant difference, and also showed a significant difference from the control group. The findings in this study suggest foot rehabilitation exercise has an effect on improving the foot arch and, although the results are not consistent with the studies of Olmstead and Hertel and Kelaher[20-22], support Mcmillan and Collins, and Landorf et al. who suggested improved sole structure has effects on balance and gait of people with foot deformity [23-26]. Therefore, it seems that the foot rehabilitation exercise had significant effects on balance because it helped the subjects develop the ability to balance the two feet and create an arch on the sole that helps feet support body weight. The sole arch contributes to stable weight-bearing by providing stability to the feet. However, because it is possible that the exercise had effects on motility and psychological state in addition to improving left-right balance, future research will need to take into account motility, psychological state, and spinal arrangement as well.

Foot deformities such as pes planus and pes cavus are serious health issues that cause damaged gait posture and balance in all age groups and can lead to leg pain [10, 27]. In general, the center of pressure in feet is the temporary point where ground reaction force (GRF) is produced [28]. Feet are the most important means of transportation for human beings, and the only part of the body that come into contact with the supporting ground as well as play an important role in weight-bearing. Also, feet provide propulsion required for body movement during gait, absorb physical shock produced while walking, and help adapt to irregular surfaces [29]. Acceleration and deceleration patterns during stance phase while walking vary according to the center of gravity [15]. In this study, the gait velocity in the experimental group decreased by 0.27 ± 0.27 seconds, showing a significant difference from the control group. This result is consistent with Chen[30] related to increase of gait velocity and decrease of cadence according to use of arch support. In other words, use of arch support and performance of foot rehabilitation exercise showed similar results. This seems to be because children with PDD have deteriorated ability to absorb shock with feet, and the foot rehabilitation exercise increased vertical repulsive force and stability of both feet, increasing the gait velocity as a result [31]. Also, in children with normal development show, when standing up, higher pressure on the rear foot than on the fore foot leads to more stability while lower pressure on the rear foot implies more instability [32]. In this study, considering the significant difference that resulted from foot rehabilitation exercise of children with PDD, the center of pressure seems to have shifted forward and that seems to be related not only to the change in gait patterns but also to increase of stability. Future research will need to analyze more detailed gait patterns such as pelvis and neck movements, and take into account improvement of physical stamina and functions.

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