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Effects of a Newly Designed Pelvic Belt Orthosis on Functional Mobility of Adults with Post-Stroke Hemiparesis

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Abstract

Purpose : Lower extremity orthoses have been used as conservative methods to recover gait of the stroke patients. The purpose of this study is to examine how newly designed pelvic belt orthosis can improve gait ability and dynamic balance of adults with Hemiparesis after stroke.

Methods : 22 patients who had hemiparesis after stroke participated in this study. Two groups were randomly created by assigning 10 subjects to the experimental group and the rest of the 12 subjects to the control group. The control group was treated by conventional physical therapy and occupational therapy. Identical therapy protocols were used to treat the experimental group who were assigned to wear the pelvic belt orthosis during post measurement. This study has a group of independent variables including group, gender, age, height, MAS, lesion side, cause and a group of dependent variables including gait speed, cadence, step length, stride length, and dynamic balance. The GAITRite system was used to measure spatial-temporal gain parameters and the balance system SD to measure dynamic balance. The data was analyzed using R version 3.3.1. Random forest, boosting algorithm, and MANOVA test were conducted to determine the effects of independent variables on dependent variables.

Results : This study has a group of independent variables including group, gender, age, height, MAS, lesion side, cause and a group of dependent variables including gait speed, cadence, step length, stride length, and dynamic balance. The independent variable "group" has the most important value, which is approximately 25.42 (%IncMSE) representing a value three times greater than the second important predictor "height."

Conclusion : As a result of this research, the hypothesis is validated with conclusion that Pelvic Belt orthosis could be effectively used for improving gait ability and balance of the patients with post-stroke hemiparesis.

Key Words : balance, gait, pelvic belt orthosis, post-stroke

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Ⅰ. Introduction

1. Research background and needs

Normal gait tends to be symmetrical and rhythmic, following a natural, smooth pattern, both spatially and temporally, towards a forward progression of the body (Kesar et al., 2011). However, the gait of the patients with post-stroke hemiparesis exhibit a poor selective motor control due to damaged upper motor neurons, decreased weight bearing of the paretic limb, and an asymmetrical characteristic that causes disturbance and delay of equilibrium reactions (Balaban & Tok, 2014).

The primary goal of rehabilitation for stroke patients is to recover independent gait in the activities of daily living (ADL) (Rabelo et al., 2016). Lower extremity orthoses have been used as conservative methods to recover gait of the stroke patients (Kim et al., 2015). Specifically, Knee ankle foot orthosis (KAFO) has been used for improving damaged gait caused by knee instability, while ankle foot orthosis (AFO) has been used to improve gait ability of stroke patients who have instability in their ankle and foot (Chen et al., 2010; Fatone et al., 2009). Therefore, most studies have been focused on the intervention of KAFOs and AFOs, while plastic AFOs was the most frequently used intervention. Previous studies in gait analysis have revealed that AFOs improves gait parameters, such as spatial, temporal, and kinematic, in hemiplegia patients (Kim, 2007). Currently, there has been growing interest in research focusing on examining a variety of methods for improving gait ability and balance of stroke patients.

The most important thing for gait ability of the stroke patients is not only controlling knee, ankle, and foot, but maintaining pelvic stability. Kim et al.(2015) and Van Criekinge et al.(2017) denoted that abnormal movements of the trunk's center of mass (CoM) and the pelvis crucially disturbed recovery of gait ability. Katsuhira et al.(2016) studied the effects of trunk orthosis on alignment stability of the pelvis and the trunk. They discovered that trunk orthosis was effective for gait training for stroke patients. Sawle et al.(2016) determined that a pelvic belt reduced athletics' pelvic pain and improved pelvic function.

2. Research purpose

The purpose of this study was to focus on how newly designed pelvic belt orthosis affects gait ability of the patients with post-stroke hemiparesis and dynamic balance using a statistical method.

Ⅱ. Methods

1. Subjects

The study was conducted by 22 subjects who were screened based on the study inclusion criteria. All subjects are patients of K hospital in Incheon diagnosed with post-stroke hemiparesis. Two groups were randomly created by assigning 10 subjects to the experimental group and the rest of the 12 subjects to the control group. The control group was treated by conventional physical therapy and occupational therapy. Identical therapy protocols were used to treat the experimental group who were assigned to wear the pelvic belt orthosis during post measurement.

2. Procedures

The inclusion criteria were as follows: (1) the sub-acute patient cohort diagnosed with post-stroke hemiplegia that has occurred within 3 months to 6 months, (2) the patient cohort who could walk independently for at least 10 m, (3) the patient cohort who did not have any orthopedic disease, (4) the patient cohort whose modified Ashworth scale (MAS) was less than 2, (5) the patient cohort whose scores on the Korean version of the mini mental state examination were at least 24.

Before the start of the measurements, the participants were given a full explanation of the research purpose and experimental procedure, and signed Institutional Review Board consent forms to comply with the ethical principles of the Declaration of Helsinki (1975, revised 1983).

This study was carried out by pre/post-test control group design. Baseline gait abilities, such as cadence, velocity, step length, stride length, and dynamic balance were evaluated in both groups. The two groups were treated by similar conventional treatment except the experiment group was assigned to wear pelvic belt orthosis. Post measurements were performed using the same methods.

3. Instrumentation

The GAITRite system could compare and analyze cadence, velocity, step length, and stride length among the spatial-temporal factors of the gait factors. Measurement reliability was r = 0.90. A correlation coefficient between comfortable velocity and gait measurement was above 0.96. The electronic gait board (length: 336 ㎝ and 61 ㎝), which had 13,824 sensors, collected information at 80 ㎐ sampling rate per second. This information was transmitted to the computer through a serial interface cable. After that, GAITRite gold version 3.2b S/W was used for information processing.

We used GAITRite (GAITRite, CIR system Inc., USA) for measuring the gait abilities. Before measuring gait factors, we first measured the length from the anterior superior iliac spine to the medial condyle of an ankle joint for measuring the leg length and entered it into the program. Participants were then asked to walk 1 meter on the gait board comfortably.

Dynamic balance ability was evaluated using BIODEX's balance system (BIODEX's balance system, Biodex medical systems Inc., USA). The measurement equipment was composed of a footplate, a monitor, sensors, a computer, and a printer. Through BIODEX's balance system, it was possible to acquire qualitative data in overall balance ability and balance ability in every direction as well. In this equipment, a display console for feedback and around foot plate with 60 ㎝ radius were connected, so that it could quantify data by detecting participants' weight movement in every direction. Since this study was targeted at subjects who had a damaged central nervous system, it was measured at level 8, which indicates minimal movements and minimal risk factors. The measurement was performed twice for 30 seconds, and the mean was calculated. According to balance index, the balance ability in every direction, forward, backward, left, and right was evaluated. The balance ability was provided as the balance index, and it showed the better balance ability, the lower balance index. The reliability of this equipment was r = 0.80 (Pereira et al., 2008).

Newly designed pelvic belt orthosis was invented by an author and consist of double elastic belt and velcro. The length of the elastic belt was determined based on the pelvic circumference of patients (5 ㎝ longer). The width of the belt was 7.5 ㎝ inside and 5 ㎝ outside. The inner and outer elastic belts were secured by double side stitching at the middle of rear part of the orthosis. The resilient material of the belt is Neoprene, which is widely used in the orthopedic braces. Velcro material allows the orthosis easily adjustable on patients, and it is an excellent feature of newly designed pelvic belt orthosis. The orthosis was placed on the between the anterior superior iliac spine and great trochanter of patients. Fixation site was located on the middle of sacrum and velcro was pulled from paretic side pelvic to normal side pelvic to stabilize the device.

4. Statistical analysis

The data was analyzed using R version 3.3.1. The patients' general characteristics were analyzed with some R functions. To find out the effects of independent variables on dependent ones, the random forest, boosting algorithm and MANOVA test were conducted. We compare the result of three statistical approaches to find factors that predict outcomes accurately. We believe random forest (Segal & Xiao, 2009) and boosting (Ganesh, 2010) algorithm are more reliable. A p-value <0.05 was accepted as statistically significant.

Ⅲ. Results

A total of 22 subjects participated in this study. 10 of them were assigned to the experimental group, and the other 12 subjects were assigned to the control group. The general characteristics of the study subjects are summarized in Table 1.

Random forest is a very effective method to find variable importance. This study has a group of independent variables including group, gender, age, height, MAS, lesion side, cause and a group of dependent variables including gait speed, cadence, step length, stride length, and dynamic balance. Variable importance is measured using the random forest as shown in Table 2. The group having the most impactful independent variable indicated 25.42 (%IncMSE) which is three times greater, than the second significant predictor, height. Age, and MAS (7.74, 6.44, and 4.47 respectively) was revealed as other significant predictors. The rest of the predictors; weight, lesion side, and gender, are of minimal importance. Moreover, from the result of MANOVA we can see that the most important variable is "group" selection (cohort) but we cannot say anything conclusive about the rest of the predictors. Finally, as illustrated in figure 1, the boosting algorithm decides that "group" variable is the most useful predictor for all dependent variable except step length, 100 % for gait speed, 91.6 % for stride length and more than 60 % for cadence and dynamic balance. While the most predictors for step length is height, it also has considerable importance approximately 40 % for cadence. Besides, the second most important predictors for dynamic balance and step length are weight (around 32 %) and age (around 28 %).

Table 1. Subject characteristics

Variable	Experimental group (n=10)	Control group (n=12)
Gender (male/female)	5/5	9/3
Age (years)	56.40±14.29	51.00±8.93
Height (㎝)	163.70±6.88	166.33±8.18
Weight (㎏)	62.00±11.00	67.66±11.13
Lesion side (left/right)	7/3	7/5

Values are expressed as the mean ± SD(standard deviation)

Table 2. Effects of independent variables on dependent variables

Independent Variables	% IncMSE	F-value for MANOVA
Group	25.41	0.01*
Gender	0.59	0.20
Age	6.44	0.08
Height	8.90	0.39
Weight	1.51	0.62
MAS	4.47	0.80
Side	0.61	0.65

%IncMSE; %Increase in MS(mean squared error)

*p≤0.05

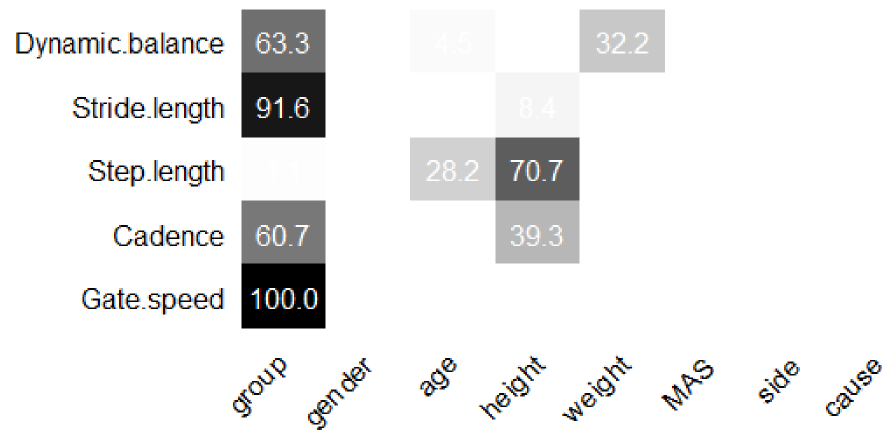

Fig 1. Result of boosting algorithm

Ⅳ. Discussion

The purpose of the current study was to determine the effect of new designed pelvic belt orthosis intervention in balance and gait ability of post-stroke patients. As a result, the balance and gait ability of the experimental group dramatically improved compared with the control group. Two different measuring equipment was used for this experiment. GAITRite system measured spatial-temporal and gait parameters of experimental and control groups, while balance system SD was used to measure dynamic symmetry.

Wist et al.(2016) reported that balance ability, joint contracture, paraplegia voluntary control ability, MAS, consciousness of joint, space's orientation and consciousness, and use of orthosis support are the crucial factors influencing gait ability of the hemiparesis patient. In this experiment, these parameters were analyzed by equivalent independent variables of the current study.

In the present study, the random forest was conducted to determine the effects of independent variables on dependent variables. We have a group of independent variables, represented by group, gender, age, height, MAS, lesion side, and cause, and a group of dependent variables represented by gait speed, cadence, step length, stride length, and dynamic balance. We found that "group" has the most important value at approximately 25.42 (%IncMSE) which is three times greater than the second significant predictor, height. Also, the Boosting algorithm analysis demonstrated that pelvic belt orthosis enhanced gait speed by 100 % compared with baseline, 91.6 % for stride length, and 60 % for dynamic balance and cadence, respectively in the intervention group. Chen et al.(2010) reported that the use of an anterior AFO might assist stroke patients with hemiplegia to improve their postural stability in the early stage of recovery. However, Fatone et al.(2009) reported that articulated AFOs with plantar flexion stops improve sagittal plane stance and ankle joint orientation of swing phase and knee early stance phase in adults with hemiplegia after stroke, but did not increase walking speed.

Furthermore, Katsuhira et al.(2016) reported that step length of the paretic limb tended to increase even after removing after newly designed trunk orthosis. Maguire et al.(2010) reported that a Thera Togs with elasticated strapping was useful for regulating the hip joints on increasing hemiplegic hip abductor activity. Additionally, the gait speed was faster (0.49 m/s) when walking with the Thera Togs compared with baseline (0.44 m/s). Thijssen et al.(2007) reported that the result of wearing newly invented orthosis to post-stroke patients was that the step length increased in both regular side and affected side during swing phase.

Schmid et al.(2012) reported that there are correlations among gait speed, walking ability, and balance to post-stroke activity and participation. Kim et al.(2015) reported that elastic band-type AFOs are a useful intervention to improve postural stability and walking ability. Also, overall stability index (OSI) of the group who wore elastic band-type AFOs increased from 3.51±0.83 to 2.24±1.22 after wearing the AFOs. In this experiment, the OSI of experimental group increased by 1.1 from 3.42±2.39 to 2.32±0.89 ($p<.001$), but the OSI of the control group increased 0.4 from 2.25±0.69 to 1.82±0.46 ($p<.001$). In the current study, the pelvic belt orthosis affected dynamic balance ability of post-stroke patients by comparing the experimental group and control group. These results are considered attributable to the fact that the pelvic orthosis improves the stability of the flexor movement in the hip joints for post-stroke patients.

Random Forest is a bagging algorithm which reduces the variance of a large number of "complex" models with low bias, while boosting. This approach utilizes a set of weak classifiers while combining them to derive a strong classifier that reduces bias for a large number of "small" models with low variance. Random forest is an excellent method to determine variable importance, as it fits several decision tree classifiers on various sub-samples of the dataset and uses averaging to improve the predictive accuracy and control over-fitting. However, it is difficult to interpret results with multiple outcome variables using random forest analysis. For this purpose, using multivariate tree boosting as a method for non-parametric regression is beneficial. In this paper, we are extending these two methods along with linear regression for a group of independent variables and a group of dependent variables to analyze the dataset and find the importance of independent variables in order to predict the dependent variables as well as illustrate the correlation between dependent variables. The purpose of this study is to realize the effect of applying the pelvic belt in stroke patients using some specific methods.

Various statistical methods were used to find the best classification of the specific independent variables that affected the dependent variables. One of the popular statistical methods is Random Forest in which Random is a bagging algorithm that reduces the variance of many "complex" models with low bias. Boosting uses a set of weak classifiers while combining them to derive a strong classifier, which reduces bias for many "small" models with low variance. Based on the current findings, the pelvic belt orthosis proved to enhance gait ability.

This experiment was performed to determine if the intervention of the newly designed pelvic belt orthosis improves gait ability and balance ability. In conclusion, the hypothesis was validated.

Ⅴ. Conclusion

A total of 22 post-stroke patients participated in this study. 10 of them were assigned to the experimental group wearing orhosis, and the other 12 were assigned as controls. We used GAITRite for measuring the gait abilities. Dynamic balance ability was evaluated using BIODEX's balance system. We found that "group" has the most important value at approximately 25.42 (%IncMSE) which is three times greater than the second significant predictor, height. These results suggest that pelvic belt orthosis can be useful for preventing falls and improving gait and balance.

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