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Effect of heel contact performance on gait of patients with chronic stroke

In Hee Lee, Sang Young Park

Abstract

The purpose of this study was to investigate relationships of heel contact performance (HCP), gait speed, balance function, and step length asymmetry (SLA) ratioinchronic stroke patients.Convenience sample of 30 subjects were enrolled. Subjects pushed the floor by maximal effort through their heel on chairs with height of 50 cm without back or standing position.Subjects walked on a 14m walkway to collect gait speed.SLA was quantified using a step length ratio defined as paretic step length divided by nonparetic step length. To measure balance function, Berg balance scale (BBS) and Timed Up and Go (TUG) were used.According to results of the measurement, correlations of HCP, gait speed, balance function, and SLA ratio were analyzed. There were significant correlations of HCP in sittingwith 10m waking test (MWT) (-0.526), BBS (0.610), and TUG (-0.599). There were significant correlations of HCP in standing with 10MWT (-0.503), BBS(0.485), and TUG (-0.560). There was also a significant correlation between HCP in sitting position and that in standing (0.765).However, there were no significant correlations between HCP in sit or standing position and SLAratio (0.238). There were also significant correlations of 10MWT with BBS (-0.662) and TUG (0.992). There were also significant correlations of BBS with TUG (-0.782) and SLA (0.380). However, there were no significantly correlations among 10MWT, TUG, and SLA (-0.276).Our findings demonstrated associations of HCP withgait speed and balance function in stroke persons. However, HCP was not correlated with SLA.

Keywords: Gait, stroke, balance, symmetry

Introduction

Stroke is caused by vascular problems in the encephalon that lead to hemiparesis and consequent changes in balance, motricity, and motor functions. Functional mobility of a patient is often affected after a stroke due to impaired walking which canrestrict activity and participation.(Andrenelli et al.; Rozanski et al.)A rehabilitation program not only can increase gait function, but alsocan treat functional abilities of balance, movement speed, muscle strength, and range of activities of daily living.

Sit to stand task (STS) is one of the most frequently performed tasks of daily living. Post stroke hemiparetic persons may have difficulty to stand from sitting. It is common for people with hemiplegia to demonstrate considerable asymmetry of weight distribution during rising to stand, with significantly increased weight-bearing on the unaffected side.(Cheng et al.; Durward) Stroke patients also show reduced peak vertical ground reaction force during STS.(Cheng et al.) Recent reports have revealed that vertical ground reaction force parameters in an STS movement are useful for evaluating lower limb muscle strength and power in older adults.(Tsuji et al.; Shen et al.)STS is a three-component vector representing forces in the vertical, anterior-posterior, and medial-lateral planes.(Headon and Curwen)During vertical loading on the paretic heel, we assume that the maximal load amount could be associatedwith walking ability and balance function of a stroke patient on a specific position, such as in sitting position as the start position and in standing position as the last position of STS. Previous studies have shown that posterior position of one foot seems to advantageously increase WB in comparison with an extended foot position.(Boukadida et al.) We assumed that the ability of a stroke patient to have weight bearing/shifting on the heel of the paretic side and muscle strength of paretic side might be related to tasks of daily living.

In this study, vertical force by their heel in sit or stand position was called heel contact performance (HCP).Patients after stroke cannot regain normal speed. They have an asymmetric gait pattern due to weakened muscle activities and an abnormal propulsion force on the paretic limb during walking.Post-stroke hemiparetic subjects typically walk at slow walking speeds with asymmetrical gait patterns.(Nadeau)Although compensatory work by the nonparetic limb can result in more effective walking speed, speed is not a reliable parameter of hemiparetic walking ability. Asymmetry gait pattern has also been used as a parameter of walking ability. It is weakly related to walking speed such that post-stroke hemiparetic persons walking at similar speeds may exhibit different gait asymmetries.(Chitralakshmi K. Balasubramanian et al.)

In post stroke patients, improvement of walking is conventionally measured by gait speed. As a clinical measure, speed reflects overall gait performance. However, gait velocity could not fully described overall aspect of recovery of gait performance in post stroke patients.(Kim and Eng)For slow walker after increasing stroke walking speeds have been shown to reduce the energy cost of walking, through better compensation for lost neuromotor control, such as compensation for deficits in paretic propulsion.(Roelker et al.)

Gait quality can beassessed by symmetry in the duration of gait phase and step length. Symmetry suggests the likeness in temporospatial, kinematic, or kinetic parameters of both lower limbs. It is an important parameter of gait assessment.(Kara K Patterson, Parafianowicz, et al.)Asymmetric gait can make post-stroke patients become resistant to rehabilitation intervention. Thus, it may worsen over time.(Kara K. Patterson, Gage, Brooks, et al.; Shin et al.; Kara K. Patterson, Mansfield, Biasin, et al.) Spatiotemporal parameters have been used to describe the quality ofhemiparetic gait. They might indicate specific biomechanical deficits or compensations.(Allen et al.)Over 50% of hemiparetic stroke patients can walk unassisted at a later period.(Guzik et al.) Post-stroke hemiparetic persons exhibit slow walking speeds and gait asymmetry.(Padmanabhan et al.)In terms of both temporospatial and kinematic parameters, post-stroke hemiparetic persons frequently present with asymmetric gait patterns.Step length asymmetry (SLA) measured as a ratio of more and less affected side swing (or stance) time is related to paretic ankle muscle strength and spasticity(Hsu et al.; Chan et al.) as well as lower limb impairment due to stroke.(Kara K Patterson, Gage, et al.; Brandstater et al.)Characteristics of hemiparetic gait patterns after stroke include increases or decreases of swing time, stance time, and SLA.(S. Li et al.)Hemiparetic stroke patients walk with SLA that is highly variable between subjects. SLA might be indicative of underlying impairments and compensatory mechanisms used.(Allen et al.)

Gait asymmetry is closely associated with slower gait speed, gait inefficiencies, impaired balance control, and abnormal use of the non-paretic limb.(Chitralakshmi K Balasubramanian et al.; Kara K Patterson, Gage, et al.)Post-stroke hemiparetic persons can recover their capacity to walk with improved SLA.(Sánchez and Finley; Roemmich et al.; Hendrickson et al.)Many studies have reported that gait function can be recovered after stroke with recovery of SLA.(Yen et al.; Roemmich et al.) The reason for recovery of SLA is multi-factorial, including balance function, energy cost for move, and effort for transport.(PLATTS et al.; Stoquart et al.) It is currently unclear whether recovery of SLA alone could lead to improved gait function such as gait speed. Alteration of balance function in this population can induce gait pattern deviation. During walking, weight bearing and propulsion of the non-paretic side are greater than those of the paretic side. Consequently, to maintain balance,ashortened nonparetic swing phase often results in a shortened nonparetic step length.(Lewek et al.; Hsu et al.)

It is assumed that stroke patients with higher vertical load or muscle strength onparetic heelcontactcould walk faster with SLA and well balance function. It is important to clarify relationshipsof HCP, gait speed, balance, andSLA. Thus, the aim of the present study was determination correlations of HCP, gait speed,balance, and SLAin post stroke hemiparetic persons.

Materials and Methods

Participants

This study was approved by the Institutional Animal Care and Use Committee (IACUC) of Daegu University (1040621-201811-HR-020-02). Forty-two persons with hemiparetic stroke were recruited. Subjects were included if they experienced their first stroke 1–4 months prior to this study, presented with hemiparesis, and walked independently for 10 m without aids or physical assistance. Written informed content was obtained from each subject to participate in this study.

Heel contact performance

On sitting and standing, paretic HCP was measured usinga STABILIZER pressure biofeedback (Chattanooga, TN, USA). Post stroke hemiparetic persons was requested to push the floor by maximal effortthrough their heel on a 50 cm height chair without back or standing position. This maximal push movement was repeated three times and the mean load was recorded.

Gait measurement

Gait speed and step length of gait were collected by 10-m walking test (10MWT). For 10MWT, patients were required to walk wearing shoes to aid their maximum speed along a 14-m along walkway with an extra 2 m for acceleration and deceleration. Step length was analyzed using a Dartfish pro software (Dartfish, SWISS). Walking began 2 m in front of the walking mat upon a verbal signal 'begin walking' from the tester. All participants walked three times. The average of three measurements was used for the analysis.

Symmetry ratio calculation

This study measured speed and temporal parameters during walking. To compare asymmetry of paretic and paretic sides, SLA ratio values were calculated using the following equation.(Hsu et al.)

Step length asymmetry ratio =|1-(Step length (paretic side))⁄(Step length (less paretic side))|

In this equation, "paretic" indicated the paretic lower limb and "less paretic" indicated the less affected lower limb. The larger these ratios, the larger the asymmetry.

Time up & go and Berg balance scale

All enrolled subjects were evaluated with the following tests: (1) timed up and test (TUG) to record the time taken to get up from a chair (height, 50cm), move 3m way, turn around, move back to the chair, and sit down. This test was repeated three times and the mean time was recorded; (2) Berg balance scale (BBS) consisted of 14 functional tasks of increasing difficulty, each scored on a scale ranging from 0 to 4 (0= unable to perform the task; 4 = task is performed independently). The maximum possible score was 56, indicating no identifiable balance difficulty.

Statistical analysis

Descriptive and analytical statics are presented. Data were analyzed using IBM SPSS Statistics ver. 26.0 (IBM Co., Armonk, NY, USA). Relationships of subjects' HCP, gait speed, SLA, and balance function were analyzed using the Pearson correlation analysis. Statistical significance was set at $P<0.05$. Data are presented as mean with standard deviation.

Results

Of 42 screened stroke patients recruited for this research, 30 patients were eligible. Their demographic and clinical features are summarized in Table 1. Correlations of HCP, gait speed, balance function, and SLAratio were analyzed. There were significant correlationsofHCP in sitting positionwith 10MWT (-0.526), BBS (0.610), and TUG (-0.599). There were also significant correlations of HCP in standing positionwith 10MWT (-0.503), BBS(0.485), and TUG (-0.560). There was a significant correlation between HCP in sitting position and that in standing position. (0.765). However, there was no significant correlation between HCP in sitting or standing position and SLA ratio (0.238). There were significant correlations of 10MWT with BBS (-0.662) and TUG (0.992). Furthermore, there were significant correlations of BBS with TUG (-0.782) and SLA ratio (0.380). However, there was no significant correlation among 10MWT, TUG, and SLA (-0.276).(Table 2)

Discussion

Findings of this studysuggested that there wasa relationship between HCP in sitting or standing position and physical activities such as walking speed and balance. To obtain a high score for HCP, subjects must bear their weight or have muscle strengthon the paretic side.In summary, carrying outafaster gait withwell balance function as demonstrated byplentyof muscle strength and weight bearingon theparetic leg is onereason why higherHCPareassociated with better gait speed and balance function. However, this force generation does not contribute to SLA.To perform better functional activities, patients must increasegait speed and keep their balance with weight bearing on their paretic limb. Understanding the relationship between HCP and physical abilities suchas walking speed and balance activities might have therapeutic benefits for controllingweight bearing paretic limbof patients with stroke. Previous studies have reported that functional activities such assit to walkand stair climbing are required to successfully move forward with a paretic side weighted stance.(Kouta et al.; Reid et al.) Therefore, gait speed and balance associated with daily activities requireweight bearing and vertical reaction force on the paretic side. However, post stroke hemiparetic persons who have better HCP might have more symmeric gait pattern because they might have plenty of vertical reaction force. Howere, results of this study revealed that HCP was not related to SLA. To recover symmetrical gait pattern, it is not necessary to attainmoreweight shifting and muscle strengthening on the paretic limb.

This study showed that gait speed was closely related to balance function in post hemiparetic stroke persons. Thus,the fasterthe gait speed, the better the dynamic balance. A previous meta-analysis has reported that good balance is a prerequisite for regaining the ability to walk independently.(J. Li et al.)This findingcorresponds to results of previous studies showing thatgait speed is associated with BBS in individuals poststroke.(Lewek et al.; Liston and Brouwer).Another study has also found a negative correlation between stabilometric data and speed, suggesting that the less the stabilomovement oscillation, the faster the walker.(Britto et al.)This result was corroboratedby another study showingthat walking ability of post hemiparetic stroke persons was related to control of their balance function.(Bohannon)

TUG has shown varying degrees of inter- and intra-rater reliability in patients with chronic stroke.(Faria et al.) TUG test is a commonly used screening tool for fall risk in a community setting. The use of TUG for assessing gait and balance in the prevention of falls in older people has been advocated by the National Institute of Clinical Evidence.(*Overview | Falls in Older People: Assessing Risk and Prevention | Guidance | NICE*)Our study also showed that gait speed and balance function of post stroke hemiparetic persons were strongly correlated with TUG.

Our data showed a comparable relationship between balance function and SLA ratio.Thus, SLAratio, one of gait quality, doesnot directly reflect balance function.Our result is consistent with a previous study onrelationships between SLA and balance measures during dynamic tasks using BBS.(Lewek et al.)It has been demonstrated that temporospatial gait asymmetry is associated with impaired static and dynamic balance in individuals with chronic stroke.(27)BBS was significantly correlated with swing time asymmetry (no double support times), but not stance time asymmetry ratios, suggesting that swing time asymmetry might be more important as a marker for diminished balance.(Kara K Patterson, Gage, et al.)This is consistent with previous findings showing thatpost hemiparetic stroke persons whokeep a standing position show increased weight bearing on the non-paretic limb ina standing position. This tendency Is related to theIR temporal gait asymmetry features.(Hendrickson et al.; Barra et al.; An et al.)

We assumed that post stroke hemiparetic persons who were faster walkershad more symmeric gait pattern. The relationship betweenwalking speedand SLAwas investigated in this study. This study revealedthat gait speed was not related to SLA.To recover symmetrical gait pattern, it is not necessarily to attainwalking speed. This is consistent with a previous study on quality of gaitmeasured by spatial and temporal symmetry over time.(Kara K. Patterson, Gage, Brooks, et al.)That study suggested a dissociation between gait speed and gait symmetry. Consistent with our findings, a prior study has reported thatincreasing in gait speed is not always linked to an improvement of gait symmetry.(Roerdink et al.) Other studies haveshowed that there are weakly related to gait speed and gait pattern such that post-stroke hemiparetic patient's walking with different speeds may exhibit different SLA.(Chitralakshmi K. Balasubramanian et al.; Nadeau).These authors have suggested that SLA may limit walking speed which should be considered as a compensatory mechanism.However, others have found a significant relationship between gait speed and gait pattern.(Kim and Eng; Alexander et al.; De Bujanda et al.)A recent study has suggested that abnormalities in spatiotemporal parameters of hemiparetic gait should be interpreted in relation to gait speed.(Wang et al.)These inconsistencies might be related to differences in gait speed.Another studyhas reported that these differences may only be seen in patients with lower gait speed.(Titianova et al.)It is clear that SLAcan be improved by reducing paretic step length which may decrease gait speed.

This study has some limitations, including its relatively small sample size. In addition, enrolled patients had relatively good balance levels. However, these subjects were representatives of this category of stroke patients. Even so, Cohen's d effect size calculations suggested robust results. Another limitation of this study was that coping mechanisms were not targeted in this study. Therefore, findings of this study should be interpreted with caution.Nonetheless, results of this study can be used to inform rehabilitation practice with the goal of promoting symmetry and avoiding negative outcomes after stroke.

Conclusion

There are strong relationshipsof balance functionwith gait speed andSLA. However, the relationship between gait speed and SLAis weak. Based on these results, gait symmetry may be recognized as an important indicator of the level of gait control in post-stroke patients because it enables unique gait assessment independent of other parameters.

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