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Differences in Leg Length Discrepancy and Weight Distribution between the Healthy and Unhealthy Sides of Hemiplegic Stroke Patients

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Abstract

Weight distribution is often measured for the evaluation of balance. The present study was designed to evaluate the correlation between leg length discrepancy (LLD) and balance as measured by weight distribution after stroke. Twenty-two patients who were hemiplegic after stroke (twelve men and ten women) participated in this weight-distribution measurement and the LLD measurement study. A tape measure was used to measure LLD between the unhealthy and healthy sides. The balance was measured in three different positions (weight distribution while standing quietly, while sit to standing, and while in a maximal weight-shifting position) using the Messen Tairuieren Dokumentieren system. The degree of weight distribution on the unhealthy side was less than on the healthy side in all the positions. The functional and anatomical leg length discrepancy in the lower limb of the unhealthy side was longer than that of the healthy side. In all positions, these LLDs were significantly correlated with balance on the unhealthy side compared with that on healthy side. The present study in part found that after stroke, hemiplegic patients could become more unbalanced because of asymmetry in weight distribution and decreased limits of stability caused by leg length discrepancy.

Keywords: Hemiplegic stroke patients, Leg length discrepancy, Weight distribution

Introduction

In post-stroke patients, a common disorder is sensory impairment and motor weakness, particularly in the affected lower limb[1,2]. A frequently experienced standing balance disorder in hemiplegic patients is the inability to transfer body weight onto the affected lower limb while standing[1]. An asymmetrical weight distribution is related to postural control and abnormal gait, which is a walking and standing balance disorder[1,3]. The loss of balance control in stroke patients can lead to poor performance in functional activities and to a high incidence of falls[3]. Bilateral asymmetry in the lower extremities is called leg length discrepancy (LLD)[4]. Some LLD categorization systems have been suggested, the most typical of which identifies two types of leg length discrepancy: anatomical and functional[4,5]. Anatomical LLD is defined as true or structural LLD, in which a physical shortening occurs between the ankle mortise and the head of the femur. Functional, or apparent, LLD can be explained by one-sided asymmetry in the lower extremities, without any concomitant shortening of the osseous elements in the lower extremity[6]. LLD has been considered the cause of many clinical syndromes[7]. A LLD of sufficient magnitude may cause various problems, including a cosmetically disturbing gait, increased energy expenditure in gait, equinus contracture of the ankle on the short leg, standing balance issues, and pain in the hip, knee, and low back[8]. The assessment of leg length performed clinically in standard medical practice[9]. In addition, many physical therapists participate in diverse procedures to assess leg length[10]. Despite the ubiquity of leg checking, its clinical utility is not well known, that is, the extent to which the results of leg length assessments are linked with pathologies of any kind[11]. However, the degree of LLD itself remains a significantly controversial clinical finding[12]. Few clinical studies have linked LLD with standing balance in patients after stroke. Therefore, it is clinically important that this study demonstrates, for the first time, that standing balance is linked to LLD between the unhealthy and healthy sides in hemiplegic patients. More studies are needed to focus on the comparison between the unhealthy and healthy sides as well as leg length discrepancy in hemiplegic patients.

The purpose of this study is to improve the quality of treatment of patients with leg length discrepancy by comparing the balance of weight distribution in unhealthy and healthy sides in hemiplegic patients after stroke.

Results

The degree of weight distribution on the unhealthy side (45.1±1.1%) was lower than that to the healthy side (54.9±1.1%) when measured while the patient was standing quietly with both feet on the plates and eyes open for 20 s. It was significant that between the healthy and unhealthy sides, p=0.000 (Figure 2A). The degree of weight transfer to the unhealthy side (67.2±1.8%) was lower that of than healthy side (75.0±1.9%) when the patients transferred as much weight as they could onto one side without lifting the other foot off the ground for 10 s. It was significant that between the healthy and unhealthy sides, p=0.005 (Figure 2B). The degree of weight distribution to the unhealthy side (40.6±1.8%) was lower than that of the healthy side (59.4±1.8%) when both knees were flexed at 30 degrees in sit to standing position for 10 s. It was significant that between the healthy and unhealthy sides, p=0.000 (Figure 2C). There was a significant difference in the length of the legs in hemiplegic patients. The functional leg length for the unhealthy side (912.0±12.4 mm) was longer than that of the healthy side (907.3±12.4 mm). It was significant that between the healthy and unhealthy sides, p=0.016 (Figure 3A). The anatomical leg length in the unhealthy side (817.7±10.8 mm) was longer than in the healthy side (810.2±11.0 mm). It was significant that between the healthy and unhealthy sides, p=0.003 (Figure 3B). Functional and anatomical LLD were significantly correlated with weight distribution with standing, sit to standing, and maximal weight shifting position in unhealthy side compared with the healthy side, respectively (Figure 4). Furthermore, muscle strength to the unhealthy side was significantly decreased than that of the healthy side in both hip and knee muscles (Table 3).

Discussion

The degree of weight distribution on the unhealthy side was lower when quietly standing, sit to standing, and performing maximum voluntary-weight shifting. Because weight bearing is an essential precondition for ambulation, improving this ability is one of the primary treatment goals in physical rehabilitation[13-15]. Post-stroke patients can suffer from difficulty in bearing weight on the lower extremity of the unhealthy side[2,16]. These results concur with those of previous studies that have reported significantly lower weight distribution abilities on the unhealthy side compared with the healthy side[17]. The reasons were visiospatial deficit, contracture, spastic, impaired sensation, and weakness[18]. The loss or impairment of several mechanisms, such as impaired voluntary activation, disuse atrophy, and changes in skeletal muscle structure and composition, occur post-stroke[19]. These neurophysiological and structural alterations have been proposed as the fundamental mechanisms in muscle weakness, which may take place in addition to the disruption of the integrity of the corticospinal tract (CST). Consequently, the extent of CST injury may have an important effect on after-stroke muscle weakness[20]. This study found that anatomical leg length was longer in the unhealthy side than in the healthy side in post-stroke hemiplegic patients. The possible causes of anatomical LLD include congenital or infectious disorders, radiation, neoplasms, trauma, muscle paralysis, normal growth patterns, and degenerative changes[21]. This difference could also result from the weakness or paralysis of the hip joint area muscle and the greater co-contraction needed to hold in the lower limb on the healthy side because of the difficultly of transferring weight to the unhealthy side. In our study, we identified such muscle weakness by applying the manual muscle test to measure the hip and knee muscles on the unhealthy side. This study found that functional LLD was longer in the unhealthy side than in the healthy side in post-stroke hemiplegic patients. There may be greater disparities in functional leg length in LLD patients with not only soft tissue contractures of the ipsilateral or contralateral extremity but also angular and torsional deformities. For example, flexion contractures around the hip and knee joint can cause apparent shortening of the leg, whereas equinus deformity of the ankle and abduction contractures of the hip tends to lengthen the paretic limb[22]. Furthermore, functional LLD is caused by muscle weakness or any joint tightness in the spine or lower extremities. Some frequent causes are knee hyperextension because of weakness of quadriceps femoris muscles, hip abduction/adduction, tightness/contracture or supination of one foot in relation to the other, and lumbar scoliosis[23]. In a previous study, researchers measured changes in postural sway in standing patients, which were related to unnaturally induced LLD. They noticed a significant increase in postural sway with each increase in induced LLD. Even minor LLD may be biomechanically important[24]. Patients with LLD may adapt by altering the kinematic pattern of the lower limb joints, both dynamically during walking and statically during standing. Frequently used

Table 1. Clinical characteristics of hemiplegic stroke patients.

Sex (%)	Age (yr)	Height (cm)	Weight (kg)	BMI (kg/m^2)	Hypertension (%)	
Man 12 (54.5)	52.3 ± 2.1	164.3 ± 1.3	64.2 ± 1.4	23.4 ± 0.3	15 (68.1)	
Women 10 (45.5)	Diabetes Mellitus (%)	Time After Stroke (mo)	Unhealthy Side Right (%)	Unhealthy Side Left (%)	Etiology CH (%)/CI (%)	BBS (Score)
Total 22 (100.0)	4 (18.1)	25.4 ± 2.3	11(50.0)	11(50.0)	14 (63.6)/8 (36.4)	40.1 ± 1.1

Data were presented as the mean ± SE. CH, cerebral hemorrhage; CI, cerebral infarction; BMI, body mass index; BBS, Berg balance scale.

techniques are pelvic tilting in the coronal plane, knee and hip flexing on the long side, and ankle plantar flexing on the short side in the sagittal plane[25]. In our study, the differences in leg length in anatomical LLD and functional LLD were measured at 9.3 ± 1.5 mm and 7.5 ± 1.2 mm on average, respectively. The minimal LLD necessary to cause postural changes has been a matter of discussion[4,23]. Several researchers have suggested that LLD can lead to postural changes at 3 mm, pelvic tilt at 6 mm, and an alteration in the angle of the lumbar facet joints at 9 mm[4,26]. These LLDs negatively affect the limits of stability, which is already reduced is stroke patients[27]. For that reason, it would have a detrimental effect on balance in hemiplegic patients. In various cases of LLD, noninvasive techniques, such as orthotics or shoe lifts, may be more appropriate[4]. An ideal tool for intervention has not been established. However, guidelines regarding the performance of lift therapy have been recommended[5]. Although the data are not suggested as relevant for treatment, some researchers have shown that weight bearing was improved by lifting the shoe on the healthy side in hemiplegic patients[21,28]. In conclusion, before treatment, the observation of the location in the feet and pelvis while measuring LLD is vital for effective treatment. Further studies are needed to create neurophysiotherapies through objective measurements of asymmetric pelvis and leg length discrepancy in hemiplegic patients after stroke.

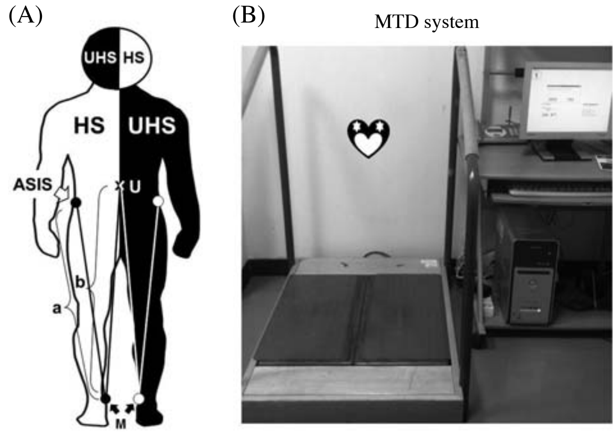

Figure 1. Schematic representation of the measurements of leg length and balance. HS, healthy side; UHS, unhealthy side; ASIS, anterior superior iliac spine; U, umbilicus; M, medial malleolus; a, anatomical leg length; b, functional leg length; MTD system, Messen Tairuieren Dokumentieren system.

Methods

Patients with hemiparesis caused by stroke were recruited (Table 1). The inclusion criteria were a full range of motion in the lower extremity and the ability to stand safely with or without an assistive device. The exclusion criteria were as follows: bilateral hemiparesis, unstable neurological signs, inability to follow commands, cognitive impairment, orthopedic problems, and visual deficits involving the brainstem. Twenty-two patients who were hemiplegic post-stroke (twelve men and ten women) participated in the study. Weight-bearing ability was measured by using a Messen Tairuieren Dokumentieren (MTD) system (MTD Co., Germany) to measure the degree of weight distribution in three different positions (Figure 1B). The loads on the left and right plates are shown as force/time graphs in real time. The following instructions were given by same person: 1) stand quietly with on foot on each plate with eyes open for 20 s; 2) transfer as much weight as possible onto one side for 10 s without lifting the other foot off the ground (also called maximal weight shifting); 3) flex both knees at 30 degrees in a sit to standing position for 10 s. One person performed the tape measure method. LLD was measured with the patients lying comfortably supine on a treatment table. LLD was measured using a tape measure by two methods: 1) from the umbilicus to the medial malleolus (functional leg length); 2) from the anterior superior iliac spine to the medial malleolus (anatomical leg length) (Figure 1A). Two trials of each measurement were performed on both the unhealthy and healthy

Table 2. The grade of muscle strength of lower limb in hemiplegic stroke patients.

Grade	Score	Degree of strength in manual muscle testing[a]
5	5.5	Normal strength
−5	5	Barely detectable weakness
+4	4.5	[Able to move the joint against combination of gravity, A] and maximal resistance
4	4	[A] and moderate resistance
−4	3.5	[A] and minimal resistance
+3	3	[A] and transient resistance but collapses abruptly
3	2.5	Active movement full against gravity
−3	2	Able to move the joint against but not through full range
2	1.5	Able to move with gravity eliminated
1	1	Trace contraction
0	0	No contraction

[a], modified from Florence *et al.*[31].

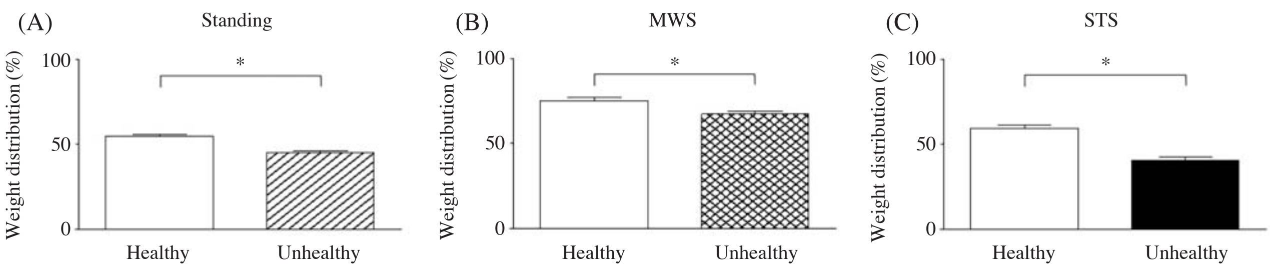

Figure 2. Differences in weight distribution between unhealthy and healthy sides of stroke patients on standing, maximal weight shifting, and squatting positions. Standing, standing position; MWS, maximal weight shifting position; STS, sit to standing position; Healthy, non-affected side; Unhealthy, affected side. *, $p < 0.05$.

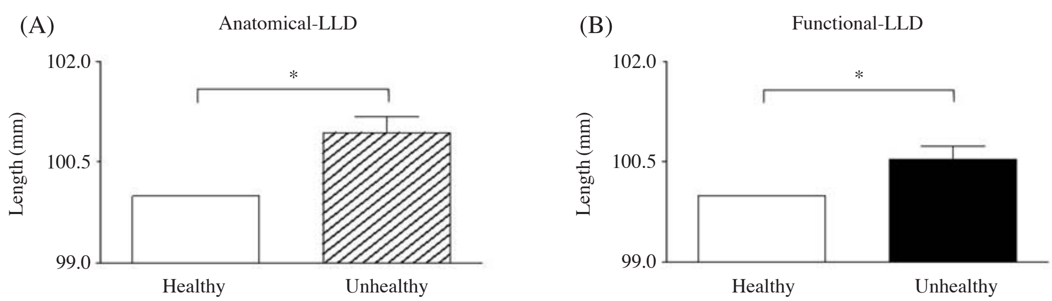

Figure 3. Difference in the leg length discrepancy between unhealthy and healthy sides of hemiplegic stroke patients. LLD, leg length discrepancy; Healthy, non-affected side; Unhealthy, affected side. *, $p < 0.05$.

sides. In this study, a tape measure was used to measure LLD because of its frequent use in clinical settings, in addition to previous reports of the reliability and validity of these methods[29]. By using a tape to measure LLD, Hoyle *et al.* found intra-class correlation coefficients of .90 to .95 for intra-rater reliability and .98 to .99 for inter-rater reliability[30]. A manual muscle test was evaluated using a modified medical research council grading scale (Table 2)[31]. This method was first performed on the healthy and then on the unhealthy side for each patient. The Wilcoxon test was used to compare the balance and the LLDs on unhealthy and healthy sides. All statistical analyses were performed using SPSS Version 18.0 (International Business Machines, Armonk, USA). The data were expressed as means ± standard errors. A p value of 0.05 was used to indicate significance. The protocol for the study was approved by the Committee of Ethics in Research of the University of Yongin, in accordance with the terms of Resolution 5-1-20, December 2006. Furthermore, all volunteers or their next of kin provided informed consent for participation in the study.

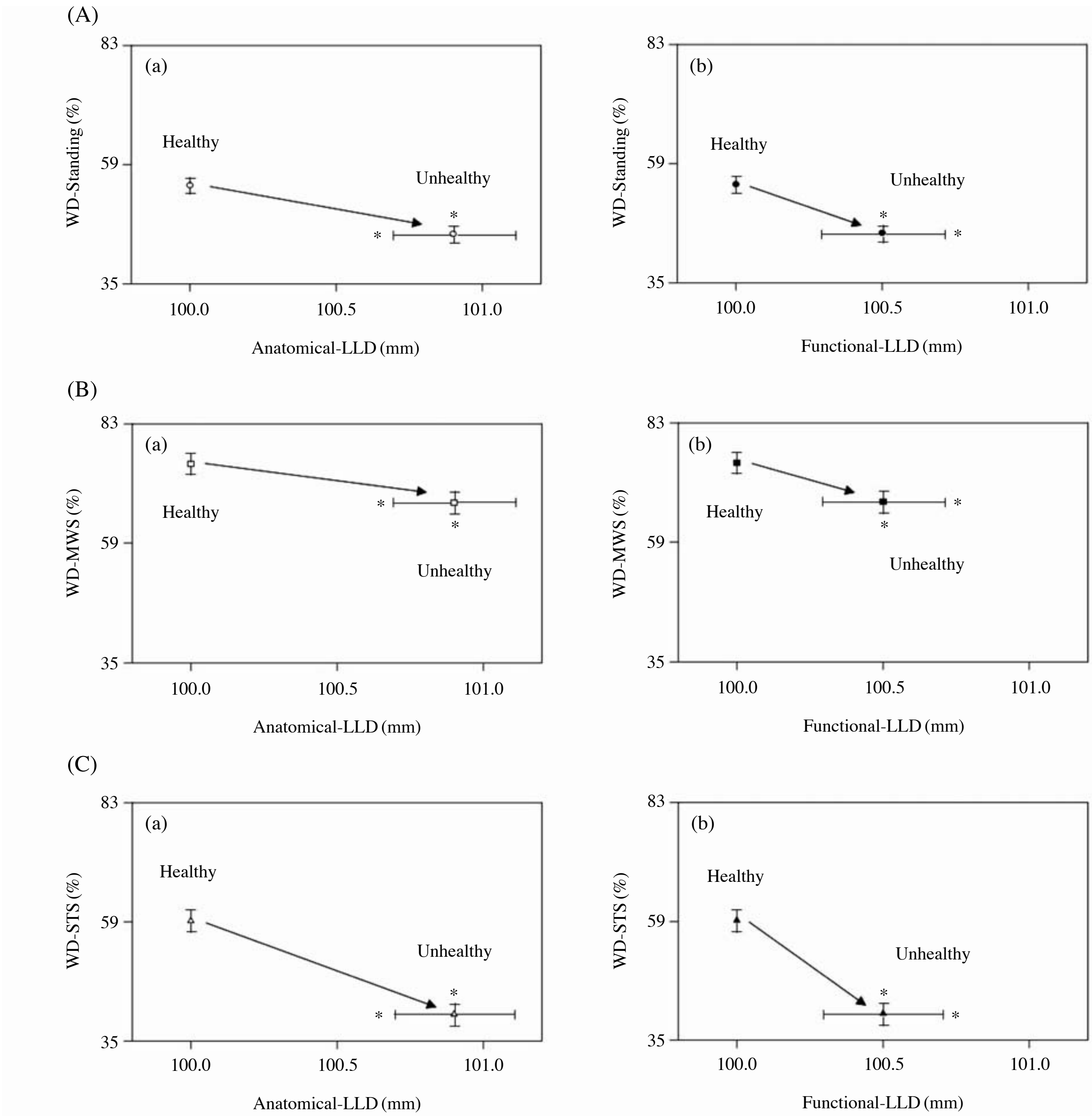

Figure 4. Correlation of weight distribution and leg length discrepancy between unhealthy and healthy sides on standing, maximal weight shifting, and squatting positions. LLD, leg length discrepancy; WD, weight distribution; Standing, standing position; STS, sit to standing position; MWS, maximal weight shifting position; Healthy, non-affected side; Unhealthy, affected side. *, $p < 0.05$.

Table 3. Difference in muscle strength between unhealthy and healthy sides of stroke patients.

Stroke Patients	Muscle Strength in MMT					
	Hip Joint of Stroke				Knee Joint of Stroke	
	Flexion	Extension	Abduction	Adduction	Flexion	Extension
Unhealthy	3.4±0.2*	3.3±0.2*	3.1±0.2*	3.1±0.2*	3.2±0.2*	3.2±0.2*
Healthy	5.5±0.0	5.5±0.0	5.5±0.0	5.5±0.0	5.5±0.0	5.5±0.0

Data were presented as the mean±SE. MMT, manual muscle testing. *, $p < 0.05$.

References

1. Kim, M. Y. *et al*. The effects of functional electrical stimulation on balance of stroke patients in the standing posture. *J. Phys. Ther. Sci*. **24**, 77-81 (2012).
2. Lee, W. D. *et al*. Differences in rheobase and chronaxie between the paretic and non-paretic sides of hemiplegic stroke patients: a pilot study. *J. Phys. Ther. Sci*. **25**, 717-719 (2013).
3. McCaw, S. T. & Bates, B. T. Biomechanical implications of mild leg length inequality. *Br. J. Sports Med*. **25**, 10-13 (1991).
4. Blake, R. L. & Ferguson, H. Limb length discrepancies. *J. Am. Podiatr. Med. Assoc*. **82**, 33-38 (1992).
5. Danbert, R. J. Clinical assessment and treatment of leg length inequalities. *J. Manipulative Physiol. Ther*. **11**, 290-295 (1988).
6. Brady, R. J., Dean, J. B., Skinner, T. M. & Gross, M. T. Limb length inequality: clinical implications for assessment and intervention. *J. Orthop. Sports Phys. Ther*. **33**, 221-234 (2003).
7. Vogel, F. Jr. Short-leg syndrome. *Clin. Podiatry*. **1**, 581-599 (1984).
8. Song, K. M., Halliday, S. E. & Little, D. G. The effect of limb-length discrepancy on gait. *J. Bone Joint Surg. Am*. **79**, 1690-1698 (1997).
9. Jonson, S. R. & Gross, M. T. Intraexaminer reliability, interexaminer reliability, and mean values for nine lower extremity skeletal measures in healthy naval midshipmen. *J. Orthop. Sports Phys. Ther*. **25**, 253-263 (1997).
10. Cooperstein, R., Morschhauser, E., Lisi, A. & Nick, T. Validity of compressive leg checking in measuring artificial leg-length inequality. *J. Manipulative Physiol. Ther*. **26**, 557-566 (2003).
11. Cooperstein, R., Morschhauser, E. & Lisi, A. Cross-sectional validity study of compressive leg checking in measuring artificially created leg length inequality. *J. Chiropr. Med*. **3**, 91-95 (2004).
12. Hanada, E., Kirby, R. L., Mitchell, M. & Swuste, J. Measuring leg-length discrepancy by the "iliac crest palpation and book correction" method: reliability and validity. *Arch. Phys. Med. Rehabil*. **82**, 938-942 (2001).
13. Brunt, D., Vander Linden, D. W. & Behrman, A. L. The relation between limb loading and control parameters of gait initiation in persons with stroke. *Arch. Phys. Med. Rehabil*. **76**, 627-634 (1995).
14. Kim, M. Y. *et al*. The effect of low frequency repetitive transcranial magnetic stimulation combined with range of motion exercise on paretic hand function in female patients after stroke. *Neurosci. Med*. **4**, 77-83 (2013).
15. Lee, W. D., Lee, J. U. & Kim, J. Differences in amplitude of functional electrical stimulation between the paretic and nonparetic sides of hemiplegic stroke patients. *Toxico. Environ. Health. Sci*. **5**, 82-85 (2013).
16. Dickstein, R., Nissan, M., Pillar, T. & Scheer, D. Foot-ground pressure pattern of standing hemiplegic patients: Major characteristics and patterns of improvement. *Phys. Ther*. **64**, 19-23 (1984).
17. Goldie, P. A. *et al*. Maximum voluntary weight-bearing by the affected and unaffected legs in standing following stroke. *Clin. Biomech. (Bristol, Avon)*. **11**, 333-342 (1996).
18. Kitisomprayoonkul, W., Cheawchanwattana, S., Janchai, S. & E-Sepradit, P. Effects of shoe lift on weight bearing in stroke patients. *J. Med. Assoc. Thai*. **88**, S79-S84 (2005).
19. Hafer-Macko, C. E., Ryan, A. S., Ivey, F. M. & Macko, R. F. Skeletal muscle changes after hemiparetic stroke and potential beneficial effects of exercise intervention strategies. *J. Rehabil. Res. Dev*. **45**, 261-272 (2008).
20. Madhavan, S. *et al*. Corticospinal tract integrity correlates with knee extensor weakness in chronic stroke survivors. *Clin. Neurophysiol*. **122**, 1588-1594 (2011).
21. Reid, D. C. & Smith, B. Leg length inequality: review of etiology and management. *Physiotherapy Canada*. **36**, 177-182 (1984).
22. Sabharwal, S. & Kumar, A. Methods for assessing leg length discrepancy. *Clin. Orthop. Relat. Res*. **466**, 2910-2922 (2008).
23. Gurney, B. Leg length discrepancy. *Gait Posture* **15**, 195-206 (2002).
24. Mahar, R. K., Kirby, R. L. & MacLeod, D. A. Simulated leg-length discrepancy: its effect on mean center-of-pressure position and postural sway. *Arch. Phys. Med. Rehabil*. **66**, 822-824 (1985).
25. Walsh, M., Connolly, P., Jenkinson, A. & O'Brien, T. Leg length discrepancy-an experimental study of compensatory changes in three dimensions using gait analysis. *Gait Posture*. **12**, 156-161 (2000).
26. Cummings, G., Scholz, J. P. & Barnes, K. The effect of imposed leg length difference on pelvic bone symmetry. *Spine* **18**, 368-373 (1993).
27. Nichols, D. S. Balance retraining after stroke using force platform biofeedback. *Phys. Ther*. **77**, 553-558 (1997).
28. Aruin, A. S. *et al*. Compelled weightbearing in persons with hemiparesis following stroke: the effect of a lift insert and goal-directed balance exercise. *J. Rehabil. Res. Dev*. **37**, 65-72 (2000).
29. Gogia, P. P. & Braatz, J. H. Validity and reliability of leg length measurements. *J. Orthop. Sports Phys. Ther*. **8**, 185-188 (1986).
30. Hoyle, D. A., Latour, M. & Bohannon, R. W. Intraexaminer, interexaminer, and interdevice comparability of leg length measurements obtained with measuring tape and metrecom. *J. Orthop. Sports Phys. Ther*. **14**, 263-268 (1991).
31. Florence, J. M. *et al*. Intrarater reliability of manual muscle test (Medical Research Council scale) grades in Duchenne's muscular dystrophy. *Phys. Ther*. **72**, 115-122 (1992).