Middle-East Journal of Scientific Research 21 (7): 1044-1050, 2014
ISSN 1990-9233

DOI: 10.5829/idosi.mejsr.2014.21.07.83155

Reliability Study of Plantar Pressure Measurement Among Low Back Pain Patients Carrying Different Loads

[1]H. Deepashini, [2]B. Omar, [3]A. Paungmali, [4]S.N. Amaramalar, [4]H. Ohnmar and [1]J. Leonard

[1]Musculoskeletal Laboratory, Program Physiotherapy, School of Rehabilitation Science, Faculty of Health Science, UniversitiKebangsaan Malaysia, Malaysia
[2]Department of Biomedical Sciences, School of Diagnostic and Applied Health Sciences, Faculty of Health Science, UniversitiKebangsaan Malaysia, Malaysia
[3]Department of Physical Therapy, Faculty of Associated Medical Sciences, Chiang Mai University, Chiang Mai, Thailand
[4]Department of Orthopaedics and Traumatology, PusatPerubatanUniversitiKebangsaan Malaysia

Abstract: *Background*: plantar pressure is one of the commonly used biomechanical variables among patients with low back pain. However, the characteristics of reliability of plantar pressure measurement while carrying different loads have not been looked this far. *Methods*: this study aimed to investigate the intra- rater reliability of plantar pressure measurements among patients with low back pain while carrying different loads. A total of 10 subjects (Four male and six female) aged between 30 and 55 years old participated in this study. Plantar pressure measurement was measured at two conditions, standing and walking with no load, while carrying 5kg, 7.5kg and 10kg load, respectively. The intraclass correlation coefficient (ICC), standard error of measurements (SEMs) and coefficient of variation (CV) was calculated. Bland- Altman plot examined the limits of agreement between the two measurements. *Results*: analysis showed that the intra rater reliability was high with ICC ranged from 0.95 to 0.99, SEMs from 0.03 to 1.15 kPa and CV from 0.77% to 4.29% for all different conditions. The Bland- Altman plot indicated that the two measurements taken by the researcher had acceptable agreements. *Conclusion*: the plantar pressure measurements could be reliably performed among patients with low back pain while carrying different loads.

Key words: Intra-Rater · Reliability · Low Back Pain · Plantar Pressure · Foot

INTRODUCTION

Low back pain is one of the most common musculo- skeletal problems and lumbar spine is connected to the foot via the lower limb andone of the important mechanical function is to transmit forces from the upper body to the lower body through sacroiliac joint, hip and knee during daily activities [1, 2]. The human foot plays a vital role in the biomechanical function of the lower extremities mainly to provide support and balance during standing and walking [3]. Several investigators showed that patients with low back pain may often exhibit decrease of speed [4-6]. As such, patients with low back pain experience changes in walking pattern due to the abnormal transmission of the forces from the upper body to the lower body which may lead to changes in the pressure pattern at the foot.

Manual handling jobs such as lifting, lowering, pushing, pulling, carrying and holding are risk factors for the onset of low back pain [8,9]. Eugene etal. suggested that carrying heavy objectswhilstat workplace was associated with low back pain [10]. They also mentioned that carrying weight with improper posture would increase loading force on the spine [10]. As such, manual material handling tasks may potentially lead to the alteration of plantar pressure distribution of the foot in patients with

Corresponding Author: H. Leonard Joseph, School of Rehabilitation Science, Faculty of Health Sciences, Universiti Kebangsaan Malaysia Kuala Lumpur, Malaysia. Tel: +6019-6781935.

low back pain. Carrying unequal distribution of load over body especially the spine caused excessive loading on the spine leading to changes in walking pattern [11]. Different studies investigated the effects of backpack carriage on plantar pressure distribution supported the above biomechanical notions that increase load on the spine had increased plantar pressure distribution at the foot [12,13]. Hence, clinicians may consider the plantar pressure measurement when investigating foot pathological disorders in patients with low back pain.

Plantar pressure assessment is commonly used in the evaluation of the foot and provides insight into the plantar loading characteristics during functional activities such as walking [14]. Reliability of the plantar pressure measurement is important for the trustworthiness of data among patients with low back pain. The use of pressure assessment is beneficial, however, the reliability of the plantar pressure measurements can be affected by numerous factors. Factors such as walking speed [15], gait protocol [16] and body muscle fatigue [17] were reported. In addition, reliability is influenced by the characteristics of the subjects from a specific disease population [18]. Thus, it is important to establish the reliability of the plantar pressure measurement among patients with low back pain to produce a reliable measurement. Previous reliability studies evaluated the plantar pressure measurement in healthy population and patients with diabetics neuropathy [19, 20]. The study of plantar pressure measurement among patients with low back pain is limited. Therefore, the purpose of this study was to establish the reliability of plantar pressure measurement among low back pain patients while carrying different loads.

MATERIALS AND METHODS

Subjects: A total of 10 participants (Four male and six female) aged between 30 and 55 years participated in this study. They were recruited by convenient sampling method. The mean (SD) of the age, weight and height of the participants were 42.9 (10.1) years, 73.7 (10.6) kilograms and 164.9 (7.2) centimeters, respectively. Participants with duration of low back pain for more than 3 months were recruited from the Physiotherapy Department, UKM Medical Centre. Participants with a history of low back surgery, pregnancy, spondyloarthropathy, rheumatoid arthritis, previous lower limb surgery were excluded from the study. The first author briefed the study procedures to the participants. All participants gave written informed consent prior to participation in the study, which was approved by the institutional review board(Ethics no: UKM 1.5.3.5/244/NN-063-2012).

Equipment: Plantar pressure was measured using Tekscan Mat Scan Pressure Assessment Systems, Sensor Matscan Version 6.3 (TekScanInc, South Boston, USA). This system consists of a floor mat composed of sensors which is made up of over 2,000 individual pressure-sensing locations, which are referred to as "sensing elements" or "sensels." The sensels are arranged in rows and columns on the sensor. The MatScan sensor detects the participants plantar pressure. The software included with the MatScan system is compatible with various versions of Microsoft systems. The software can be used to perform simple calibration. The calibration procedure requires the participant to stand on the sensor for a moment. A calibration is performed for all participants before recording. Each mat is calibrated individually.

Procedure: Plantar pressure was measured in barefoot during two conditions, standing and walking. Participants were instructed to stand and walk with no load, carrying 5kg load, 7.5kg load and 10kg load. Prior to the measurement, participant was given 10 to 20 minutes to familiarize on the platform after a short demonstration from the first author. Participants were instructed to familiarize themselves as though the real procedure was taking place. For the standing trial, participants were instructed to look straight ahead while standing on the platform.For the walking trial, a two-step approach at a normal walking speed was utilized [16]. Once the participants were comfortable with the familiarization procedure, they were told to stand on the platform with no load. Then, the participants was asked to stand on the plantar pressure with carrying three different weights, 5kg, 7.5kg and 10kg, respectively. In two-step approach, each participantwas positioned two-step lengths from the front edge of the pressure platform and was instructed to walk in a normal manner, striking the sensor mat with the second step. Then, each participantwere instructed to use their usual gait. Then, foot pressure analysis was done during walking condition with no loadfollowed by carrying 5kg, 7.5kg and 10kg weight, respectively. The recorded data was considered successful when participants did not look down at the platform, contact with the platform was made on the second step and participants did not pause on the platform while walking. Participants was given 10 minutes break between each task.A single researcher assessed all the participants.

Data Analysis: Data were analyzed by using statistical software package SPSS (Version 19.0). Intra- rater reliability were examined by using the intraclass correlation coefficient (ICC), standard error of measurements (SEMs) and coefficient of variation (CV). The ICC value was deemed poor if the correlation ranged from 0 to 0.40; fair to moderate if the correlation ranged from 0.40 to 0.75 and excellent if the correlation ranged from 0.75 to 1.00 [21]. The SEMs were calculated using the following formula, where SD is the standard deviation: SEMs= SD v 1- ICC. CV was often quoted as an estimate of measurement error, particularlywhen multiple repeated tests were performed [22]. The CV of reproducibility was calculated as the standard deviation of the differences between the repeated measurements divided by the average of the averages of the repeated measurements and is quoted as a percentage [22]. The Bland- Altman plot was calculated to analyze the agreement of plantar pressure measurements between the two sessions of measurement. The Bland- Altman method calculated the range within which the difference between the two sessions lied within a probability of 95% [23]. The use of ICC's and Bland- Altman plots provide complementary information for a reliability study [24].

RESULTS

All subjects completed the trials and the data were normally distributed. The mean and SD of plantar pressure measurements in standing and walking condition with no load, while carrying 5kg, 7.5kg and 10kg loadfor trial 1 and trial 2 are presented in Table 1. Table 2 demonstrates the reliability as in ICC, SEM and CV of plantar pressure measurements in different conditions. The relative reliability between sessions for standing and walking condition with different loads was excellent, as evidenced by ICCs ranging from 0.95 to 0.99 (Table 2). The SEM ranged from 0.03 to 1.15 kPa and CV ranged from 0.77% to 4.29% which demonstrated a high level of reliability (Table 2).

The Bland- Altman plot formeasurement of trial 1 and trial 2 during standing with no load revealedthe mean differences of 4.0 with a confidence interval of upper limit 8.9 and lower limit -1.0, respectively (Figure 1). The Bland- Altman plot formeasurement of trial 1 and trial 2 during standing while carrying 10kg load revealed the mean differences of 3.6 with a confidence interval of upper limit 8.1 and lower limit -1.0, respectively (Figure 2). The Bland- Altman plot formeasurement of trial 1 and trial 2 during walking with no load revealed the mean differences of 4.8 with a confidence interval of upper limit 17.1 and lower limit -7.5, respectively (Figure 3). The Bland- Altman plot formeasurement of trial 1 and trial 2 during walking while carrying 10kg load revealed the mean differences of 3.6 with a confidence interval of upper limit 8.1 and lower limit -0.8, respectively (Figure 4). Visual analysis of all the plots showed that all the measurement differences were in between the ± 2SD which indicated that the scores of both the measures had acceptable agreements.

DISCUSSION

This study investigated the reliability of plantar pressure measurements among patients with low back pain while carrying different loads. The reliability of a measurement system used clinically or in research, must be established in order to achieve reproducible and meaningful results. In the current study, the measurement procedure showed an excellent intraclass correlation coefficient (ICC) in assessing plantar pressure measurement during standing and walking with no load, while carrying 5kg load, 7.5kg load and 10kg load, in a sample of people with low back pain. This was interpreted by the results of the ICC value ranging from 0.95 to 0.99 with an acceptable range of the SEM and CV among this patient population. The Bland- Altman plot indicated that the two measurements taken by the researcher had acceptable agreements.

Studies had reported that the use of instruction given to the patients had an influence in human movement [25]. A previous study had indicated that most of the therapists or clinicians used verbal instructions to directattentionfrom patients in order to improve human movements [25]. In particular, previous research had shown that the modulation of attention focus, through the use of external cues and instruction, can influence gait performance [26]. Another study investigated on how different instructions influenced gaitindicated that instructions such as walk while swinging the arms, walk with large steps, walking while counting aloud and walk fast, improved performance to achieve gait [27]. As such, a proper, clear and detailed instruction from the researcher or clinicians to patientsis necessary in improving performance in clinical practice. Thus, in the current study, the reproducibility of the measures may be attributed to the accuracy of the researcher in giving instruction and monitoring the subjects while the measures were taken.

Table 1: Descriptive characteristics for plantar pressure measurements in different conditions

	Standing Mean (SD)		Walking Mean (SD)	
Condition	Trial 1	Trial 2	Trial 1	Trial 2
No load	98.58 (18.00)	94.60 (16.97)	128.19 (20.35)	123.41 (21.49)
5kg	132.96 (40.18)	129.30 (39.35)	138.93 (16.21)	137.56 (16.58)
7.5kg	151.62 (53.11)	145.92 (52.38)	152.99 (21.19)	148.31 (19.88)
10kg	161.46 (55.31)	157.88 (53.76)	145.99 (30.21)	142.36 (28.87)

Table 2: Reliability analysis of plantar pressure measurements in different conditions

Condition		ICC	SEMs (kPa)	CV (%)
Standing	No load	0.99	0.33	3.39
	5 kg load	0.99	0.09	2.20
	7.5 kg load	0.99	0.49	3.91
	10 kg load	0.99	0.09	1.86
Walking	No load	0.95	1.15	4.29
	5 kg load	0.99	0.03	0.77
	7.5 kg load	0.99	0.36	2.53
	10 kg load	0.99	0.16	2.07

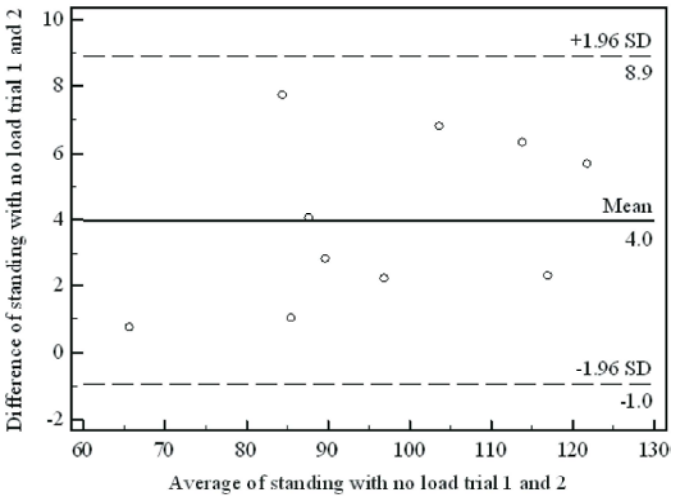

Fig. 1: Bland- Altman plot of standing with no load

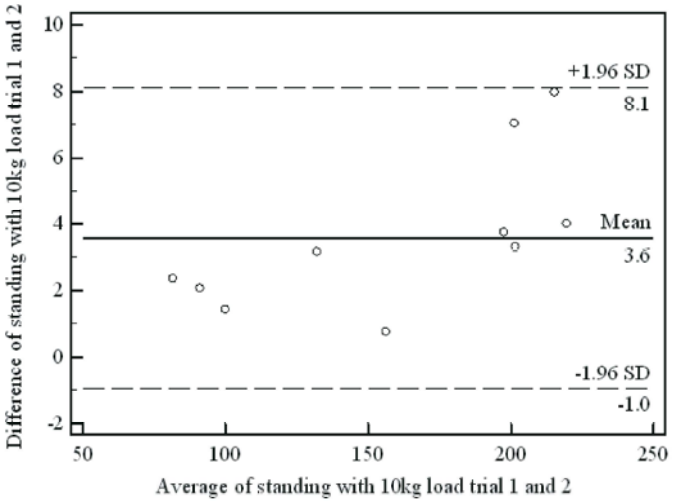

Fig. 2: Bland- Altman plot of standing with 10kg load

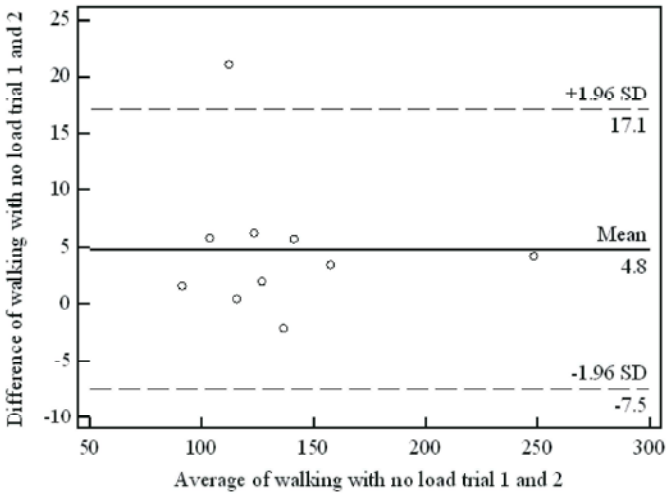

Fig. 3: Bland- Altman plot of walking with 10kg load

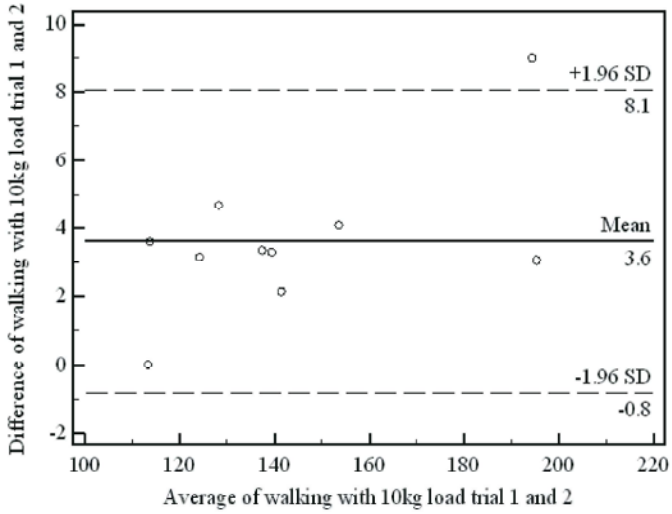

Fig. 4: Bland- Altman plot of walking with no load

Several factors were reported to influence the measurement of plantar pressure of the foot which includes walking speed [15], gait protocol [16] and fatigue [17]. Patients with low back pain typically walk slower [4-6] and with shorter steps [4]. It has been suggested that slower walking speed is due to the presence of pain and/ or fear- avoidance behavior associated with pain [28]. A previous study has indicated that a natural walking speed gave more accurate pressure pattern in different subject [15]. As such, normal walking speed was utilized in this study in order to maintain the natural stride of the subjectwas proven to be highly reliable.

In clinical practice, there are various gait protocols that can be used in plantar pressure assessment such as 1-step protocol, 2-step protocol, 3-step protocol and the mid-gait protocol [16]. A study suggested that the midgait method required a relatively large number of barefoot steps, thus, this method are not recommended for testing [29]. Another study suggested that the 2- step protocol required the least amount of trials in order to obtain reliable barefoot plantar pressure data [16]. Therefore, in the current study, 2-step protocol are chosen as it closely resembles a normal walking pattern.Hence, it could be said that such standardization procedure yielded high reliability of plantar pressure measurement.

In clinical practice, low back pain patients are vulnerable to measurement errors due to fatigue. In the current study, patients with low back pain are required to perform multiple tasks by carrying different loads. A previous study suggested that load carriage and fatigue as two major tasks related risk factor that had effects on gait [17]. Another study demonstrated that changes could

be seen in muscle activity following short or long duration of exercise which led to fatigue and changes in movement patterns [30]. As such, establishing the intra- rater reliability was important to minimize errors in measurements due to fatigue. Thus, subjects were given 10 minutes break between each task to minimize the effect of fatigue on the reliability of plantar pressure measurement.

The finding of this study was clinically significant for clinicians who would like to consider measurement of plantar pressure among low back pain patients. The current study result supported that plantar pressure measurement can be performed reliably among low back patients. As such, clinicians and researchersmight be able to more reliably evaluate possible changes in plantar pressure among low back pain patients to design an effective intervention.

Further research should explore on other parameters such as maximum force and contact area of the foot and not only investigating the total foot parameters but also considering the different anatomical areas of the foot which can be analyzed using the plantar pressure measurement system. This parameters and the different anatomical areas of the foot are equally important when evaluating different types of foot deformities. Future investigations including varieties of foot pathologies from different populations should be investigated as well, to provide additional benchmark data. This will give an opportunity for researcher and clinicians to fully appreciate the plantar pressure measurement techniques as a tool to report on different clinical applications since in this study, the reliability was only tested in patients with low back pain. However, the plantar pressure measurement techniques in this study can be used as a guidance for clinicians and researchers in their future research.

CONCLUSION

The reliability ofplantar pressure measurement among patients with low back pain carrying different loadsin this study is high. Hence, the plantar pressure measurement could be used as a simple and useful parameter for exploring and investigating biomechanical changes at foot among low back pain patients.

Competing Interests: Nil. The authors hereby declares that there is no financial assistance involved in this study. There is no competing interests to declare in this study.

REFERENCES

1. Da Fonseca, J.L., M. Magini and T.H. De Freitas, 2009. Laboratory gait analysis in patients with low back pain before and after a pilatesintervention. Journal of Sport Rehabilitation, 18: 269-82.
2. Bussey, M.D., M.L. Bell and S. Milosavljevic, 2009. The influence of hip abduction and external rotation on sacroiliac motion. Manual Therapy, 14: 520-525.
3. Monteiro, M., R. Gabriel, J. Aranha, M. Nevese Castro, M. Sousa and M. Moreira, 2010. Influence of obesity and sarcopenic obesity on plantar pressure of postmenopausal women. Clinical Biomechanics, 25: 461-467.
4. Khodadadeh, S. and S.M. Eisenstein, 1993. Gait analysis of patients with low back pain before and after surgery. Spine, 18: 1451-1455.
5. Selles, R.W., R.C. Wagenaar and T.H. Smit, 2001. Disorders in trunk rotation during walking in patients with low back pain: a dynamical systems approach. Clinical Biomechanics, 16: 175-181.
6. Lamoth, C.J.C., A. Daffertshofer and O.G. Meijer, 2006. How do persons with chronic low back pain speed up and slow down? trunk- pelvis coordination and lumbar erector spinae activity during gait. Gait and Posture, 23:230-239.
7. Shelokov, A., N. Haideri and J. Roach, 1993. Residual gait abnormalities in surgically treated spondylolisthesis. Spine, 1 8: 2201-2205.
8. Larivière, C., D. Gagnon and P. Loisel, 2002. A biomechanical comparison of lifting techniques between subjects with and without chronic low back pain during freestyle lifting and lowering tasks. Clinical Biomechanics, 17: 89-98.
9. Yang, H.L., S.C. Chen, J.C. Wen and K.C. Cheng, 2002. Characteristics of manual lifting activities in the patients with low- back pain. International Journal of Industrial Ergonomics, 29: 101-106.
10. Wai, E.K., D.M. Roffey, P. Bishop, B.K. Kwonand S. Dagenais, 2010. Causal assessment of occupational carrying and low back pain: results of a systematic review. Spine, 10: 628-638.
11. Madhu, S.P., M. Deepti, B. Moushum, K. Rakesh and M. Dhurjati, 2009. Optimum load for carriage by soldiers at two walking speeds on level ground. International Journal of Industrial Ergonomics, 39: 68-72.

12. Castro, M., S. Abreu, H. Sousa, L. Machado, R. Santos and J.P. Vilas-Boas, 2013. Ground reaction forces and plantar pressure distribution during occasional loaded gait. Applied Ergonomics, 44: 503-509.
13. Pau, M., F. Corona, B. Leban and M. Pau, 2011. Effects of backpack carriage on foot-ground relationship in children during upright stance. Gaitand Posture, 33: 195-199.
14. Cousins, S.D., S.C. Morrison and W.I. Drechsler, 2012. The reliability of plantar pressure assessment during barefoot level walking in children aged 7-11 years. Journal of Foot and Ankle Research, 5: 8.
15. Rosenbaum, D. and H.P. Becker, 1997. Plantar pressure distribution measurements. Technical background and clinical applications. Foot and Ankle Surgery, 3: 1-14.
16. Bus, S.A. and A. De Lange, 2005. A comparison of the 1-step, 2-step and 3-step protocols for obtaining barefoot plantar pressure data in the diabetic neuropathic foot. Clinical Biomechanics, 20: 892-899.
17. Bisiaux, M. and P. Moretto, 2008. The effects of fatigue on plantar pressure distribution in walking. Gait and Posture, 28: 693-698.
18. Kottner, J., L. Audige, S. Brorson, A. Donner, B.J. Gajewski, A. Hrobjartsson, C. Roberts, M. Shoukri and D.L. Streiner, 2011. Guidelines for reporting reliability and agreement studies (GRRAS) were proposed. International Journal of Nursing Studies, 48: 661-671.
19. Akins, J.S., K.A. Keenan, T.C. Sell, J.P. Abt and S.M. Lephart, 2012. Test–retest reliability and descriptive statistics of geometric measurements based on plantar pressure measurements in a healthy population during gait. Gait and Posture, 35: 167-169.
20. Gurney, J.K., U.G. Kersting and D. Rosenbaum, 2008. Between-day reliability of repeated plantar pressure distribution measurements in a normal population. Gait and Posture, 27: 706-709.
21. Shrout, P.E. and J.L. Fleiss, 1979. Intraclass correlations: Uses in assessing rater reliability. Psychological Bulletin, 86: 420-428.
22. McLaughlin, S.C., T.C. Aitchisont and P.W. Macfarlane, 1998. The value of the coefficient of variation in assessing repeat variation in ECG measurements. European Heart Journal, 19: 342-351.
23. Bland, J.M. and D.G. Altman, 1999. Measuring agreement in method comparison studies. Statistical Methods in Medical Research, 8: 135-160.
24. Rankin, G. and M. Stokes, 1998. Reliability of assessment tools in rehabilitation: an illustration of appropriate statistical analyses. Clinical Rehabilitation, 12: 187-199.
25. Durham, K., P.M. Van Vliet, F. Badger and C. Sackley, 2009. Use of information feedback and attentional focus of feedback in treating the person with a hemiplegic arm. Physiotherapy Research International, 14: 77-90.
26. Thaut, M.H., G.C. McIntosh, R.R. Rice, R.A. Miller, J. Rathbun and J.M. Brault, 1996. Rhythmic auditory stimulation in gait training for Parkinson's disease patients. Movement Disorders, 11: 193-200.
27. Behrman, A.L., P. Teitelbaum and J.H. Cauraugh, 1998. Verbal instructional sets to normalize the temporal and spatial gait variables in Parkinson's disease. Journal of Neurology, Neurosurgery and Psychiatry, 65: 580-582.
28. Vlaeyen, J.W. and S.J. Linton, 2000. Fear avoidance and its consequences in chronic musculoskeletal pain: a state of the art. Pain, 85: 317-332.
29. Harrison, A.J. and J.P. Folland, 1997. Investigation of gait protocols for plantar pressure measurement of non-pathological subjects using a dynamic pedobarograph. Gait and Posture, 6: 50-55.
30. Nicol, C., P.V. Komi and P. Marconnet, 1991. Fatigue effects of marathon running on neuromuscular performance. I. Changes in muscle force and stiffness characteristics. Scandinavian Journal of Medicine and Science in Sports, 1: 10-7.