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Original Article

Physiotherapy Section

Hand-Held Dynamometer is a Reliable Tool to Measure Trunk Muscle Strength in Chronic Stroke

SURULIRAJ KARTHIKBABU[1], MAHABALA CHAKRAPANI[2]

ABSTRACT

Introduction: Patients with chronic stroke show atypical coordination of trunk movement and they find difficulty during bed mobility and transfer skills due to weakness of trunk muscles. Routine bedside clinical examination fails to quantify the trunk muscle strength in patients with stroke. Handheld dynamometer is widely administered to quantify the strength of extremities, but its reliability on testing the trunk muscles strength is limited.

Aim: This study aimed at examining the reliability of hand-held dynamometer to quantify the strength of trunk muscle groups in chronic stroke.

Materials and Methods: This reliability study was conducted in outpatient clinical settings. Patients with chronic stroke aged between 30 and 80 years and an ambulatory capacity of 10-meter distance volunteered in the study. The strength of trunk flexors, extensors, rotators towards most and least affected sides and bilateral lateral flexors was examined by break test using hand-held dynamometer and the isometric strength was reported in pounds (lb.). These tests were carried out by two physical therapists independently at two time points and the assessment procedure was standardized. Pearson's correlation test was conducted to observe the reliability of dynamometer strength testing i.e., internal consistency of the measure and intra-class correlation coefficient (r).

Results: Of the 85 study participants, 51 of them had most trunk involvement on the left side and 34 had it on the right side. This study showed an excellent intra-rater (0.88-0.98) and inter-rater (0.84-0.96) reliability of trunk muscle strength testing using hand-held dynamometer.

Conclusion: Hand-held dynamometer showed excellent intra and inter tester reliability to quantify the trunk muscle strength in patients with chronic stroke. So this tool can easily be administered in clinical and rehabilitation settings for diagnostic and prognostic purposes.

Keywords: Neuro-physiological procedures, Mobility functioning, Trunk weakness

INTRODUCTION

Trunk involvement in people with stroke was earlier examined using laboratory and neuro-physiological procedures such as isokinetic dynamometer strength testing, motion tracking systems, transcranial magnetic stimulation, analysis of trunk muscular cross-sectional area and electromyography [1-6]. Since majority of these tools require extensive evaluation, skilled work force and high cost, their use in clinical scenario is limited. Clinicians working with patients after stroke should determine the trunk performance in order to establish appropriate treatment strategies for balance and mobility functioning. Following stroke, the bed mobility and sitting balance capacity are largely dependent on the recovery of trunk muscular control and strength. Clinical utility measures such as trunk control test and two trunk impairment scales, proposed by Verheyden and Fujiwara, evaluate the trunk performance in lying and sitting positions [7-9]. To some extent, the trunk muscle strength is qualitatively observed in these measures, but its quantification is less known.

Clinical observation of ambulatory patients with chronic stroke suggest that they show atypical trunk movement coordination and also experience difficulty while getting out of bed and standing up from a chair. Recent cross-sectional study identified that trunk muscle weakness post stroke is related to poor sit to stand ability [10]. Also, trunk weakness measured using isokinetic dynamometer influences the balance and functional capacity in patients with chronic stroke [11]. This necessitates the quantification of trunk muscle strength of patients with chronic stroke in clinical settings. Hand-held dynamometer, being an accurate and affordable instrument could easily be used in clinical settings in order to measure the trunk muscle strength in patients with stroke [12,13]. Hence we attempted to standardize the test procedure in lying and sitting positions and also to examine the reliability of the hand-held dynamometer for measuring trunk muscle strength in patients with chronic stroke.

MATERIALS AND METHODS

This reliability study was approved by Institutional Review Board of School of Allied Sciences, Manipal University and was conducted between July 2013 to August 2016 (CTRI/2017/08/009337). Chronic stroke patients aged between 30 and 80 years with an ability to understand simple verbal instructions, walk 10-meter with or without mobility aid and absence of the low back pain participated in this study. The patients were excluded in the study if they had any medical instability, pusher syndrome and scored more than 21 on trunk impairment scale.

After explaining the purpose and procedure of the study, they were requested to give their informed consent to volunteer in the study. The strength of trunk flexors, extensors, bilateral lateral flexors and rotators towards most and least affected sides was tested using hand-held dynamometer (Fabricatio enterprises incorporation, New York) [13,14]. The isometric strength of trunk muscles was tested using a break test. Patient with stroke had to generate a maximum muscle force against a stationary dynamometer held by therapist and the muscle strength was measured in pounds (lb.) from the maximum needle reflection.

To examine the intra-rater and inter-rater reliability of dynamometer testing, two physical therapists independently assessed the trunk muscle strength between one hour intervals. The order of the therapists was changed each time by picking-up a lottery chit. Two test trials were conducted for specific trunk muscle groups with 30 seconds rest in between. The therapists were initially trained for a period of one month on how to handle the hand-held dynamometer and conduct the trunk strength measure.

The test positions and procedure were standardized. For measuring trunk flexors and rotators strength, the patient was positioned in supine position with knees slightly bent, arms at side and head in midline. To measure the trunk flexors strength, base of dynamometer was placed on the middle of the sternum and patient was instructed to exert isometric force by lifting both scapula off the plinth. Dynamometer was placed on the myotendinous area of pectoralis muscle and the patient was asked to lift the ipsilateral side scapula off the plinth in order to quantify the trunk rotators strength. Trunk extensor muscle strength was tested in prone position. The base of dynamometer was placed at T4 spine and the patient was instructed to generate an isometric force against it by lifting the chest off from plinth. This test was not performed in case of severe shoulder pain. For measuring the trunk lateral flexors, patient was seated on plinth with feet off the floor and the dynamometer was placed lateral to and against the upper thoracic wall. The patient was then encouraged to bring the elbow towards the plinth by side bending the upper trunk against the base of dynamometer. The dynamometer and trunk strength test positions are shown in [Table/Fig-1a-d]. The sample size was determined based on the number of chronic stroke patients who received mobility training in outpatient settings during three year time-bound study period.

[Table/Fig-1a-d]: Assessment of trunk muscle strength.
a) trunk flexor; b) trunk rotator towards most/least involved side; c) trunk extensor; and d) trunk lateral flexor on most/least involved side.

STATISTICAL ANALYSIS

The SPSS version 16.0 (SPSS Inc. Chicago, USA) was used to analyse the data. Kolmogorov-Smirnov test was used to study the normality of demographic variables. Pearson's correlation test was conducted and reliability of dynamometer strength testing was reported as Cronbach's alpha (α) i.e., the internal consistency of the test measure and intra-class correlation coefficient (r). The reliability was expressed excellent when the r-value is beyond 0.75 points. It was rated good and poor correlation when the r-value ranged 0.5 to 0.75 and below 0.5 points, respectively [15].

RESULTS

Eighty five patients with chronic stroke volunteered in the study. The mean (standard deviation) age of the study participants was 55 (12) years and post-stroke duration was 13 (11) months. Sixty percent of the patients (N= 51) had most muscular involvement on the left side and forty percent of them (N=34) had most involvement on the right side. Fifty patients (59%) suffered from ischemic stroke and 35 patients (41%) experienced a hemorrhagic lesion. The second rater conducted the intra-reliability only in 65 patients with stroke. So the values from corresponding patients were considered for testing the inter-rater reliability. This study showed an excellent intra-rater (1st rater, 0.87-0.97; 2nd rater 0.89-0.98) and inter-rater (0.84-0.96) reliability for measuring the strength of all trunk muscle groups using hand-held dynamometer. The values of trunk strength, internal consistent and intra-class correlation coefficient are present in [Table/Fig-2].

Trunk muscle strength (lb.)	Intra-rater reliability *				Inter-rater reliability*	
	Rater – 1 (N=85)†		Rater – 2 (N=65)‡		Between raters (N=65)‡	
	Mean (SD)	r value	Mean (SD)	r value	Mean (SD)	ICC §
Flexor	35.62 (10.30) 36.53 (10.50)	0.93 (0.90–0.96)	38.38 (9.96) 39.66 (9.49)	0.96 (0.93–0.96)	36.71 (10.64) 39.66 (9.49)	0.92 (0.88–0.95)
Extensor	39.64 (9.69) 41.62 (9.65)	0.95 (0.91–0.97)	43.76 (9.76) 43.07 (9.52)	0.96 (0.92–0.98)	40.26 (9.93) 43.07 (9.52)	0.93 (0.87–0.96)
Rot-MAS	34.71 (9.81) 36.21 (9.68)	0.93 (0.89–0.95)	38.42 (9.14) 38.83 (9.40)	0.94 (0.90–0.94)	35.66 (9.70) 38.83 (9.40)	0.94 (0.89–0.96)
Rot-LAS	32.69 (11.45) 34.06 (11.21)	0.94 (0.91–0.96)	36.34 (10.72) 37.54 (10.77)	0.97 (0.95–0.98)	33.75 (11.27) 37.54 (10.77)	0.94 (0.90–0.96)
LF-MAS	33.31 (7.48) 34.66 (7.99)	0.92 (0.87–0.95)	36.66 (7.47) 37 (8.01)	0.94 (0.89–0.96)	33.78 (7.77) 37 (8.01)	0.91 (0.86–0.95)
LF-LAS	34.07 (7.37) 35.51 (7.76)	0.92 (0.88–0.95)	36.89 (7.57) 37.03 (7.59)	0.96 (0.93–0.97)	34.4 (7.42) 37.03 (7.59)	0.90 (0.84–0.94)

[Table/Fig-2]: Reliability of trunk muscle strength testing using hand-held dynamometer in chronic stroke.
lb. = Pounds; Rot-MAS = Rotator towards most affected side; Rot-LAS = Rotator towards least affected side; LF-MAS = Lateral flexor on most affected side; LF-LAS = Lateral flexor on least affected side;*p-value statistically significant at < 0.001;†, ‡ All measures except trunk extensor strength (N = 55 and 46); § ICC = Intra-class Correlation Coefficient.

DISCUSSION

This study examined the reliability of hand-held dynamometer to quantify the strength of trunk muscle groups in chronic stroke and found that it has excellent intra-rater and inter-rater reliability to measure the trunk muscle strength in lying and sitting positions. The order of the raters were changed at each assessment so as to minimize the measurement error. Cronbach's alpha value of 0.88-0.98 points and ICC value of 0.84-0.96 points infer that the hand-held dynamometer has the ability to quantify the trunk muscle strength and is also an excellent reliable tool for use in chronic stroke.

Trunk muscles are involved bilaterally as opposed to extremities following stroke [12]. The assessment of extremities post stroke is appropriate in clinical settings as the neurological examination such as assessment of tone, reflex testing and atypical synergy are easy to get administered and well established over time. Also, the strength of extremities is assessed by medical research council grading and dynamometer testing to determine the prognosis of patients with stroke. Whereas, the assessment of trunk is given less emphasis in routine neurological examination due to its complex muscular attachments with fascia, failure to undress the part of trunk and lack of standardized tests. Additionally, the patients in chronic stage stroke shall attribute their limitations in daily living to the structural changes of the affected extremities. Since majority of trunk muscles are not directly attached to the bone, but continued as fascial expansions bilaterally, the trunk performance shall influence that of extremities recovery post stroke [16]. As a result, the trunk muscles play a key role in maintaining dynamic postural stability and selective activity depends on the body part that is moving. Clinical utility scales such as trunk control test and trunk impairment

scale identified that the poor trunk control during bed mobility and dynamic sitting balance are responsible for the concurrent compensatory/atypical motor coordination of the limbs in chronic stroke [6-8]. Trunk muscle strength being the major determinant of balance and mobility in chronic stroke, its assessment is vital in clinical and rehabilitation settings.

Due to poor core strength and trunk control in patients with chronic stroke, there are two possible ways of atypical trunk coordination seen in them while getting out of bed from supine position. They shall exhibit either excessive anterior pelvic tilt with increased lumbar extension or mass trunk flexion patterns that are associated to the extensor synergy of lower extremity. Likewise, the atypical pattern of extremities would further reinforce the trunk into either mass flexion or extension during bed mobility and dynamic weight transfers in sitting [17]. Nevertheless, the lower trunk and pelvis should remain dynamically stable in an ideal functional scenario so that the upper trunk can selectively move in different directions and planes, and vice-versa. There are certain assessment principles that need to be considered to minimize the test and retest measurement error. The placement of base of dynamometer must be constant at each measurement time and the dynamometer is then held at an angle that should be in the opposite direction of patient's trunk movement. Also, the good ergonomics of the therapist's posture and stance are essential to keep the dynamometer stable during strength testing.

For examining the strength of trunk flexor and rotator groups in supine position, the patient was instructed to curl-up the upper trunk by clearing the inferior angle of both scapula and ipsilateral scapula respectively, without any efforts from lower trunk and pelvis. Over the stable lower trunk and pelvis, the patient then generated a maximum isometric muscle force from upper trunk against the stationary dynamometer. The isometric strength was measured in the inner range of upper oblique abdominal and trunk flexor muscle groups i.e., the maximum possible active or physiological range of trunk movement. Contraction of ipsilateral oblique abdominals are greatly dependent on the static holding of line alba by the muscles of contralateral side. Following stroke, the oblique trunk muscles can't contract effectively neither in shorten nor in lengthen positions, thus evaluation of trunk rotator on both sides are recommended. We attribute this patho-mechanics to the bilateral trunk rotator weakness in the study participants. Prior to trunk rotator strength testing in people with chronic stroke, the evaluation of thoracic restrictions and soft-tissue stiffness of posterior-lateral aspect of trunk need to be considered. These features might possibly limit the contraction of the oblique abdominal muscles and show differences between right and left sides. Study on isokinetic dynamometer strength testing indicated that the trunk rotator weakness in chronic stroke is possible due to disuse atrophy and inadequate recruitment of high threshold motor units [18].

The trunk extensor strength was 4-7 pounds greater than that of flexor strength. As majority of patients with chronic stroke have the tendency to use excessive lumbar extension while in standing and walking, the greater contraction of trunk extensor is anticipated as compared to abdominals. So it is assumed that the abdominal muscles responsible for pelvic stability might show weakness post stroke resulting in hyperextension of lumbar spine with excessive anterior pelvic tilt. In a recent cross-sectional study, the pelvic instability in standing was related to poor trunk control in chronic stroke [19]. While examining the trunk extensor strength in chronic stroke, the involved shoulder should be guarded for those who experience moderate shoulder pain and subluxation. Extensor strength test was not performed in patients who can't tolerate prone position and complained of severe shoulder pain.

It was observed that the trunk lateral flexor strength is equally involved on both sides in the study participants. The strength of upper trunk in sitting depends on the lower trunk and pelvis stability and the synergist contraction of both flexor and extensor muscle groups. Such aspects of co-activity or core stability are missing in chronic stroke. Since the trunk flexor group is being approximated in slouched sitting posture with posterior pelvic tilt [2], the abdominals cannot generate sufficient muscle force. Whenever the patients attempt to move the trunk up against gravity, they show atypical trunk extension along with associated reaction of the lower extremity. The pelvic instability in chronic stroke had shown to be related with poor lateral balance control and inadequate weight shift ability onto most involved side [20,21]. To minimize the measurement error of upper trunk lateral flexor strength, we suggest that the patient needs to be instructed to align the trunk as erect as possible and bear the weight symmetrically on buttocks.

LIMITATION

The major limitation of this study is that the strength measures from healthy individuals were not reported which might have allowed interpreting the extent of trunk muscles weakness in chronic stroke. Furthermore, the study participants had completed the structured trunk exercises program when they got enrolled in this reliability study. Majority of them were males and they were able to walk with or without walking aid, so the trunk strength might not be much lower. Hence, it's cautioned to interpret the trunk strength values that can't be generalized to whole population with chronic stroke. Measurement of trunk flexor and rotator muscle strength at different angles, for example in semi-reclined sitting, might be critical in patients who are confined to wheel chair. Although trunk regimes showed beneficial improvements on trunk control, balance and function in chronic stroke [22,23], till date the trunk strength was never reported as an outcome measure in core stability regimes. Clinicians and rehabilitation experts might use the hand-held dynamometer to examine the prognosis of trunk recovery post stroke and treatment efficacy of core stability in future clinical and/or interventional trials.

CONCLUSION

Hand-held dynamometer is a reliable tool to measure the trunk muscle strength in patients with chronic stroke. In future, the trunk muscle strength can be considered as an outcome measure to test the efficacy of core stability regimes in chronic stroke.

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PARTICULARS OF CONTRIBUTORS:
1. Associate Professor, Department of Physiotherapy, School of Allied Health Sciences, Manipal University, Bengaluru, Karnataka, India.
2. Associate Dean and Professor, Department of Internal Medicine, Kasturba Medical College, Manipal University, Mangalore, Karnataka, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Suruliraj Karthikbabu,
Associate Professor, Department of Physiotherapy, SOAHS, Manipal University,
Manipal Hospital, HAL Airport Road, Bengaluru-560017, Karnataka, India.
E-mail: karthikbabu78@gmail.com

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