DEVELOPMENT AND EVALUATION OF A NEW INSTRUMENT TO QUANTIFY THE DEEP TENDON REFLEX IN THE ADULT AND ELDERLY

[1]ODEBIYI D.O., [1]AIYEGBUSI A.I., [2]BAKARE A.D., [3]NWOYE E.O.
Departments of Physiotherapy, [1]Faculty of Clinical Sciences College of Medicine, University of Lagos; [2]General Hospital, Ikorodu, Lagos; [3]Department of Biomedical engineering, Faculty of Basic Medical Sciences, College of Medicine of the University of Lagos, Lagos
Correspondence:[μ]D.O. ODEBIYI, PhD (Physiotherapy).
Department of Physiotherapy, Faculty of Clinical Sciences, College of Medicine, University of Lagos. PMB 12003, Idi-Araba, Surulere, Lagos, Nigeria;
E-Mail addresses: dodebiyi@unilag.edu.ng; femiodebiyi@yahoo.com. GSM 2348024717968

ABSTRACT

Introduction: *Deep tendon reflex (DTR) is routinely used to evaluate the nervous system. Majority of the available devices to measure DTR response are not easily accessible, highly cumbersome, and capital intensive. This study sought to develop and evaluate a less cumbersome, cost effective and easily accessible instrument that can objectively quantify DTR.*

Materials and Methods: *A simple DTR device was fabricated and then evaluated. A total of 74apparently healthy individuals and five hemiplegic patients participated in this cross-sectional analytical study. Hemiplegic participants were to determine the criterion-related validity of the device. Of the apparently healthy participants, 69were assigned into three groups according to their age. Angle of knee excursion (patellar DTR response) was measured using the newly developed DTR device. Jendrassik maneuver was introduced in participants who failed to respond to the initial patellar tendon tapping.Pearson correlation was used to determine relationship between variables at P <0.05.*

Result: *The device demonstrated good face and criterion-related validity coupled with high test-retest and inter-rater reliability with coefficient of 0.74 and 0.86 respectively. There was no significant difference between the patellar tendon response for the right and left lower limbs.(p>0.05).Similarly, sex and age has no significant effect on the patellar tendon reflex response respectively (p>0.05).*

Conclusion: *The newly developed instrument is less expensive and less cumbersome, and was found to be valid. Findings of the study are comparable with previous study that age, sex, and handedness had no significant effects on DTR response. It is therefore recommended for the use of clinicians.*

Keywords: Deep tendon reflex, Patellar, Adult, handedness

INTRODUCTION

Tendon reflex response is a clinical parameter commonly used to assess the neurological status of an individual(Lemoyne *et al.,* 2008; Chandrasekhar *et al.,* 2013).Eliciting the deep tendon reflexes (DTR) is one of the main components of the clinical examination of the nervous and musculoskeletal systems. It aids anatomical diagnosis, and is essentially the first step in the neurological diagnostic process; it gives an important pointer to whether a patient's disorder arises from the central or peripheral nervous system (Dick, 2003).

Deep tendon reflex has been found useful clinically; to assess the severity (degree) of peripheral neuropathy, evaluate the status of the nervous system, assess the effect of therapy on altering the reflex arc, and to ascertain the effects of training and aging (Toft *et al.,* 1989; Karandreas *et al.,* 2000; Voerman *et al.,* 2005).Thus, it is useful in evaluating the functional disturbance of either a normal or augmented reflex arc (Karandreas *et al.,* 2000). A hyperactive reflex response is correlated with spasticity, which in turn can be associated with the degree of damage to the supra-spinal input. In some instances, Jendrassik maneuver may be employed when there is no response (Tham *et al.,* 2013).The Jendrassik manoeuvre is a reinforcement technique, which is commonly applied in reflex tests when the reflex response is not obvious for a particular individual. When applying the technique, the individual is required to sit with the fingers interlocked in front of the chest and attempted to pull the hands apart (Tham *et al.,* 2013).

The assessment of DTR is essential to make accurate diagnosis of neurological and neuromuscular disorders (Tham *et al.,* 2013). Consequently, several scales and instruments have been developed to clinically and objectively evaluate and report DTR, although most of these devices/instruments are qualitative and subjective, leading to a great variation in the assessment of DTR (Lebiedowska and Fish, 2003; Mamizuka *et al.,* 2007). The National Institute of Neurological Disorders and Stroke (NINDS) developed an ordinal scale of 0 to 4to clinically evaluate myotatic stretch reflex. The NINDS Myotatic Reflex Scale was found to vary in terms of interpretation, it also lacks temporal data (Lemoyne *et al.,* 2008).It was also found to demonstrate a fair inter-observer agreement (Manshot *et al.,* 1998). Pagliaro and Zamparo (1999) developed a device which incorporated the use of instrumentation (hammer) to elicit DTR. Cozens *et al.* (2000) developed a device that incorporated surface electromyography (EMG) to record the amplitude of the stretch reflex; one limitation of this device is its usefulness in acute brain injury of individuals who are in intensive care and comatose (Cozens *et al.,* 2000). Lebiedowska and Fish (2003) incorporated a biofeedback, and included a sweep-triggering hammer equipped with a strain-gauge accelerometer in their own device. Although this was reported to be a fundamental improvement in the quantification of DTR but the sweep triggered hammer quantified input device lacks variability of the swing arm potential energy therefore it was unable to obtain a temporal data. Mamizuka *et al.* (2007) incorporated motion analysis and triaxial accelerometer to quantify the DTR response objectively in degrees and meter per seconds squared units respectively. But they lack a predetermined quantified input setting (Chandrasekhar *et al.,* 2013).Also, they are highly cumbersome, capital intensive, not easily carried and not readily accessible. Therefore this study was designed to develop a less cumbersome, readily available and accessible instrument that will objectively quantify DTR.

Development of the New DTR Instrument

This new instrument was conceived, and then designed and developed in conjunction with the Biomedical Engineering Department of the Faculty of Basic Medical Sciences, College of Medicine of the University of Lagos to quantify the deep tendon reflex (DTR) in degrees. Figure 1shows the 3-D diagram of the newly developed device i.e. Knee Jerk Deflector Meter (or simply jerkometer). The instrument was designed using a calibrated Perspex material (ruler) and a wool strap Velcro (Figure 2). In the configuration, it has two longitudinal arms: the movable i.e. the deflector arm (2B&C) and fixed arms i.e. the disc arm (2A), which measured 30cm each; and are both attached at the fulcrums. A semi-circular protractor (i.e. disc) graduated in degrees is attached to the fixed arm, while a perpendicular short arm i.e. the stud (2D) emerges from the deflector arm. The perpendicular arm is located at a point which is two third distal to the fulcrum. The fixed(disc) arm of the device has two Velcro straps (2E),with which the instrument is fastened to the body during usage. The two Velcro straps are 15cm apart and away from the fulcrum. During use, the newly developed DTR device is fastened to the body (part of the body requiring assessment of DTR with these two Velcro straps.

Application/Usage

This instrument was designed to measure the amplitude of limb movement which is one of the components of DTR. During usage, the newly developed DTR device was strapped to the body parts to be tested: the fixed arm (i.e. disc arm) was strapped to the lateral surface of the proximal part of the thigh (lower limb) with the fulcrum resting on the knee joint laterally while the movable arm (i.e. deflector arm) was strapped to the lateral part of the legbone. Then the perpendicular arm, which emerges from the movable arm (i.e. the stud), is rotated to rest on the anterior surface of the distal part of the limb such that when the tendon is struck, the response of the limb will push the movable arm (i.e. deflector arm) forward and the change in degree on the protractor was read (Figures 3). The values obtained were then compared between genders, age groups, different sides of the body knee jerk or the patella tendon reflex were considered with the view to validate and determine its reliability.

Limitation of the newly developed DTR device

It does not measure the latency period and the magnitude of the input force on the patellar tendon. However, it has been suggested that varying the magnitude of the input force does not have a significant effect on the amplitude of the tendon contraction (Chandrasekhar *et al.,* 20013). According to Chandrasekhar *et al.* (2013), there is no association between varying angle of release of patellar hammer and DTR of the patellar tendon.

MATERIALS AND METHODS

Participants: The study was divided into three phases.
Phase I: Consisted of five (5) apparently healthy adults, without any underlying pathology especially neurological and musculoskeletal. This phase was used to determine the inter-rater and test-retest reliability of the instrument.

Phase II : Consisted of five (5) right hemiplegic individuals with spastic motornicity. The readings obtained here were used to determine the validity of the device. According to Siegel (2014) an instrument can be validated concurrently by administering it to two groups who are known to differ on the trait being measured by the instrument. The study reported that there would be support for concurrent validity if the scores for the two groups were very different.

Phase III: A total of 69 apparently healthy individuals (29 males and 40 females); with age ranged between 18 to 80 years, were recruited for this phase. Participants for this phase were recruited for the evaluation of the newly developed device. The participants in phase three were assigned to three different groups on the basis of age: Group 1 (18–40years), Group 2 (41–60 years), and Group 3 (61–80 years).Each participant was checked for any known existing neurological conditions or diseases. The knee jerk or the patella tendon reflex was considered for the purpose of this study.

Research Procedure:

Prior to the commencement of the study, the aim and objectives of the study were adequately explained to the participants, as contained in an informed consent form. Participants were free to withdraw from the study at any point. Participants were then requested to seat upright comfortably on a high platform such that both knees are allowed to swing freely Figure 3.The mid-point of the patellar tendon between the lower border of the patella and the tibial tuberosity, which exhibited the greatest reflex response, was identified. The location was marked as the target spot for tapping (the most sensitive region that elicits the greatest reflex response). The contraction of the quadriceps was ascertained by palpation before the fixed arm of the newly developed DTR device was strapped on the lateral part of the thigh of the participants, with the fulcrum at the knee joint on the lateral condyle of the femur. The movable arm (i.e. deflector arm) lies parallel to the leg bone (resting on the lateral surface of the leg), and the stud emerging from it and lying perpendicular toit (Figure 3).The deep tendon reflex was elicited by striking the Queen Square reflex hammer on the patellar tendon; the degree to which the movable arm pushed forward was measured on the semi-circular protractor and recorded. Queen square reflex hammer was used to elicit the DTR because it has a longer handle and a heavier head than most other common sizes of hammer (Tham *et al.,* 2011).In the participants where there were no responses after striking with the reflex hammer, Jendrassik manoeuvre was performed, as recommended by Tham *et al.* (2011).This is a reinforcement technique when the participants interlocked the fingers of both hands in front of the chest and attempted to pull the hands apart. The reading for the contra-lateral part of the body was also taken. For the new device validation, measurements were taken from the right side of the hemiplegic participants using both affected and unaffected limb.

RESULTS

A total of 69 participants were recruited for this study, but only the data of 64 participants (males = 28, 44% and Females = 36, 56%) were analyzed, five (5) recorded zero response on the scale and were excluded from the study. The mean height, weight and BMI for participants were 1.66±0.07m, 70.80±12.93kg and 25.58±4.51kh/m^2 respectively. The participants were assigned to three different groups on the basis of age: Group 1 (20–40 years old) (30%), Group 2 (41–60 years old) (20%), and Group 3 (61–80 years old) which was 50%**.**Out of the participants, 1 out of 32 of the adult(i.e. 41–60 years old)required Jendrassik maneuvers before reflex response while 12 of the 32 elderly(i.e. 61–80 years old)required the same maneuver before response**.**

Validity and Reliability:

Table 1 showed Pearson correlation for validity, test-retest reliability and inter-rater reliability of the newly developed DTR device. The newly developed device demonstrated poor coefficient (r = 0.127) for the validity; High test retest reliability (r = 0.74 for left, r = 0.75.3 for right) and high inter-rater reliability (r = 0.866).

Comparison of mean knee angle (deep tendon reflex response):

One-way analysis of variance (ANOVA) showed that there was no significant difference (P>0.05) in the knee angle, i.e. deep tendon reflex (DTR) responses among the three different age groups for both right and left sides (Table 2). There was no significant difference(p>0.05) in the mean knee deep tendon reflex (DTR) responses between the right and left side of the body as well as between the male and the female group (Table 2).There was no significant difference(p>0.05) in the mean knee angle deep tendon reflex (DTR) responses between the adult and the elderly group for both right and left side of the body (Table 2).

DISCUSSION

The aim of this study was to develop and evaluate a newly developed device that can be used to objectively quantify deep tendon reflex (DTR) responses. This instrument was designed to measure the displacement of the knee, with the reflex responses measured in terms of knee angles. The newly developed instrument was successfully validated and it demonstrated good face and criterion-related validity. Also it demonstrated high test-retest reliability (0.74) as well as high inter-rater reliability (0.87).

The finding from this study suggests that there was no statistically significant difference on the knee tendon reflex response among the three age groups (young adult, old adult and elderly), this implies that age may not influence the DTR response. This finding agrees with that of deVries *et al.* (2013) who in their study exploring changes with age in monosynaptic reflexes elicited by mechanical and electrical stimulation, reported that age does not affect the DTR response. However, in about forty percent (37.5%) of the participants in the elderly group (61-80), Jendrassik maneuver was performed as an assistance to elicit the DTR response after patellar tendon tapping; whereas, none of the young adult group (18-40) required this maneuver while only 3.13% of the old adult group (41-60) required this type of assistance.

The observed higher percentage of the participants in the elderly group who required the performance of Jendrassik maneuver in order to elicit the DTR response may be a contributing factor to the finding that there was no significant difference among the group. This finding is consistent with findings from the literature, and it agrees with the findings of Chandrasekhar *et al.* (2013) and Tham *et al*. (2013) who in their separate studies reported that there was a difference in the knee DTR from patellar tendon tapping between the young adult and the elderly. Furthermore, the outcome of the study by Kallio *et al*. (2010), on the effects of ageing on motor unit activation patterns and reflex sensitivity in dynamic movements, reported that there is a decline in reflex response as age progresses and this is distinct after the age of 50. Weaker muscle contraction has been recorded among the elderly group, and this has been suggested to result from the progressive decrease in the number of muscle fibers as individuals grow older; also ageing is often associated with a loss of muscle mass that leads to a decrease in muscle force and power (Kallio *et al*., 2010). In another study by Moore *et al.* (2002), exploring the gender effects of fatigue on reflex response, it was concluded that there is a significant degradation in knee and ankle muscle strength with an increase in age; and that younger adult have stronger muscle strength compared with the elderly, whereas middle-aged adults did not have statistically different muscle strength compared with the elderly participants.

The findings of this study also showed that there was no significant difference in the DTR response between the female and male participants. This suggests that gender have no influence on the response of the DTR. This finding agrees with the trend of the reports in the literatures by Moore *et al* (2002); Chung *et al* (2005); Tham *et al* (2011); Vickery and Smith (2012)which indicated that there was no difference in the response to DTR between females and males. The finding that there was no significant difference on the patellar tendon reflex response for the right and left side of the body suggests that dominance (i.e. sides of the body) may not have an influence on the DTR response. This finding therefore corroborates the finding of the study by Chandrasekhar *et al.* (2013), who in their study on the influence of age on patellar tendon reflex response reported that there was no significant difference on the DTR response between the right and left sides of the body.

CONCLUSION AND RECOMMENDATION

The findings of this study demonstrated that the newly developed instrument for measuring the DTR is valid and reliable. Despite the difference in methodology from previous studies; vis-à-vis motion analysis techniques, triaxial accelerometer, surface electromyography and hammer sweep, the findings from this study suggest that the newly developed instrument is capable of quantifying the deep tendon reflex response. Findings from this study are comparable with previous study that age, sex, and handedness (dexterity) had no significant effects on the DTR response. This less expensive and less cumbersome device is therefore recommended for use, by clinicians to assess DTR response to complement the rehabilitation of their patients. In future, further research work shall be carried out to upgrade and improve this simple tool by developing and producing a digital electronic version to automatically display the results in order to prevent instrument reading error due to parallax. Flash memory shall be integrated so that this device can store more data which can be downloaded at convenience for analysis.

REFERENCES

1. Chandrasekhar A, Abu Osman NA, Tham LK, Lim KS, Wan Abas WAB (2013).Influence of Age on Patellar Tendon Reflex Response. *Public Library of Science (PLoSONE)* **8(11).**
2. Chung SG, Rey EM, Bai Z, Rogers MW, Roth EJ (2005). Aging-related neuromuscular changes characterized by tendon reflex system properties. *Archives of Physical Medicine Rehabilitation* **86:** 318–327.
3. Cozens JA, Miller S, Chambers IR, Mendelow AD (2000).Monitoring of head injury by myotatic reflex evaluation. *Journal of Neurological Neurosurgery Psychiatry* **68**:581–588.
4. deVries HA, Wiswell RA, Romero GT, Heckathorne E (1985). Changes with age in monosynaptic reflexes elicited by mechanical and electrical stimulation. *America Journal of Physical Medicine***64:** 71–81.
5. Dick JPR (2003). The deep tendon and the abdominal reflexes. *Journal of Neurology Neurosurgical Psychiatry***74:**150–153.
6. Kallio J, Avela J, Moritani T, Kanervo M, Selänne H (2010). Effects of ageing on motor unit activation patterns and reflex sensitivity in dynamic movements. *Journal of Electromyography and Kinesiology* **20:** 590–598.
7. Karandreas N, Piperos O, Dimitriou D, Kokotis P, Zambelis T (2000). Electrophysiological recording of the tendon reflexes in cervical myelopathy. *Electromyography Clinical Neurophysiology* **40:** 83–88.

8. Lebiedowska MK, Fisk JR (2003). Quantitative evaluation of reflex and voluntary activity in children with spasticity. *Archives of Physical Medicine and Rehabilitation* **84**:828–837.
9. Lemoyne R, Dabiri F, Jafari R (2008). Quantified Deep Tendon Reflex Device, Second Generation. *Journal of Mechanics in Medicine and Biology* **8 (1): 75-85.**
10. Mamizuka N, Sakane M, Kaneoka K, Hori N, Ochiai N (2007). Kinematic quantitation of the patellar tendon reflex using a tri-axial accelerometer. *Journal of Biomechanics* **40:**2107–2111.
11. Manschot S, van Passel L, Buskens E, Algra A, van Gijn J (1998). Mayo and NINDS scales for assessment of tendon reflexes: between observer agreement and implications for communication. *Journal of Neurological Neurosurgery* **64:** 253–255.
12. Moore BD, Drouin J, Gansneder BM, Shultz SJ (2002). The differential effects of fatigue on reflex response timing and amplitude in males and females. *Journal of Electromyography and Kinesiology***12**: 351–360.
13. Pagliaro P, Zamparo P (1999). Quantitative evaluation of the stretch reflex before and after hydrokinesy therapy in patients affected by spastic paresis. *Journal of Electromyography Kinesiology***9**:141–148
14. Siegel D (2014). Validity. Retrieved @ www.delsiegle.info. Accessed on 15/09/2014.
15. Tham LK, Abu Osman NA, Wan Abas WAB, Lim KS (2013). The validity and reliability of motion analysis in patellar tendon reflex assessment. *Public Library of Science (PLoS ONE)* ***8(2).***
16. Tham LK, Abu Osman NA, Lim KS, Pingguan-Murphy B, Wan Abas WAB, Zain NM (2011). Investigation to predict patellar tendon reflex using motion analysis technique. *Medical Engineering and Physics***33:** 407–410.
17. Toft E, Sinkjaer T, Espersen GT (1989).Quantitation of the stretch reflex. Technical procedures and clinical applications. *Acta Neurology Scandinavian* **79**:384–390.
18. Vickery HSF, Smith PA (2012). Surface electromyography reveals males have a slower patellar reflex than females. *Journal of Electromyography and Kinesiology*.
19. Voerman GE, Gregoric M, Hermens HJ (2005). Neuro-physiological methods for the assessment of spasticity: The Hoffmann reflex, the tendon reflex, and the stretch reflex. *Disability Rehabilitation* **27:**33–68.

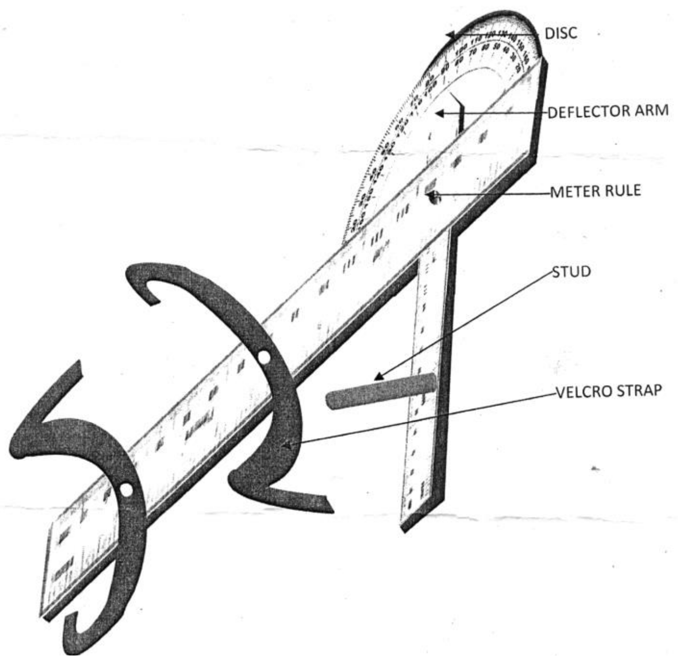

Figure 1:3D diagram of the Newly Developed Device (made up of a disc graduatedin degrees; the deflecting arm; meter rule, stud and Velcro straps).

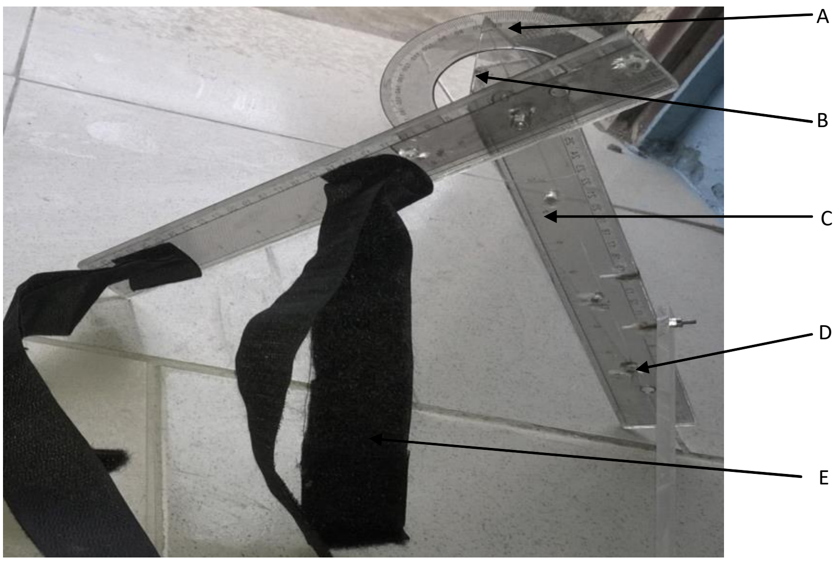

Figure 2: Photograph of the Newly Developed Device (A = the protractor graduated in degrees (the arm); A= the immovable arm (disc); E = the Velcro straps, D = the perpendicular arm (stud) and B = the movable arm).

Figure 3: Illustration of the device in use (The Patellar Tendon Tapping to Elicits the Deep Tendon Reflex Response, as measured by the deflection of the perpendicular arm (stud) on the movable arm of the device - as indicated by the arrow).

Table 1: Pearson correlation for validity, test-retest reliability and inter-rater reliability of the newly developed DTR device

	N	Coefficient(r)
Validity:		
Non- Affected Side	5	0.127
Affected Side	5	0.127
Test-retest:		
Right Side	5	0.753
Left Side	5	0.740
Inter-rater:		
Researcher A	5	0.866
Researcher B	5	0.866

Table 2: Comparison of variables – affected sides, Gender, age categories and distribution of mean knee angle

	Right (X±SD)	Left (X±SD)	t-value	p-value	
Sideof the Body:	3.81±2.78	4.04±2.32	0.402	0.221	
Age Category:	***Adult (X±SD)***	***Elderly (X±SD)***			
Right	3.88±2.89	3.59±2.70	0.402	0.689	
Left	4.47±2.44	3.63±2.17	1.460	0.148	
Gender:	**Male (X±SD)**	**Female (X±SD)**	**t-value**	**p-value**	
Gender(All)	3.89±1.80	3.89±2.80	0.007	0.995	
Gender(Right)	3.88±2.31	3.63±3.13	0.309	0.758	
Gender (left)	3.93±1.76	4.14±2.71	0.356	0.723	
Age distribution:	**18-40**	**41-60**	**61-80**	**t-value**	**p-value**
Right Side	4.21±3.23	3.39±2.36	3.59±2.70	0.415	0.662
Left Side	5.05±2.46	3.62±2.22	3.63±2.17	2.660	0.780

*Significant at $p<0.05$