

# Clinical availability of the deep tendon reflex test using a novel apparatus in healthy subjects

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**Abstract.** [Purpose] The aim of this study was to investigate the clinical usefulness of a novel apparatus intended to improve the consistency and reliability of the deep tendon reflex (DTR) test. [Subjects] The participants included 50 healthy adults (25 male and 25 female) between 20 and 31 years of age who showed no knee abnormalities upon physical examination. [Methods] The intraclass correlation coefficient (ICC) was used to verify inter-rater reliability for two parameters examined in the DTR test using a newly designed apparatus. These parameters were the patellar reflex amplitude and first knee extension angle. Pearson's product correlation coefficient was then used to examine the correlation between these two parameters. [Results] The inter-rater reliability analysis showed a high correlation between the examiners for both DTR parameters (ICCs = 0.91–0.96). In addition, a significant positive correlation was observed between the two parameters ( $r = 0.91$ ). [Conclusion] The results show that it is possible to use the novel apparatus described herein to obtain reliable results in the DTR test.

**Key words:** Deep tendon reflex, First knee extension angle, Reliability

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## INTRODUCTION

The deep tendon reflex (DTR) test is widely used as an initial exam to identify the presence of potential neurological problems and to assess the severity of neurological disease<sup>1,2</sup>. In addition, the DTR test is one of many methods that can be used to diagnose upper and lower motor neuronal disorders<sup>3</sup>. This test is widely used in clinical practice because it is simple and can be performed quickly and easily to assess a patient's neurological condition. However, concerns regarding its consistency have been raised due to the fact that it shows wide variation among human subjects<sup>4,5</sup>. Therefore, improved techniques and tools are required to ensure quantitative consistency among measurements obtained in the DTR test.

Many previous studies have sought to identify quantitative and objective measures for the DTR test<sup>6–8</sup>. Kuruoglu and Oh<sup>6</sup> conducted an electrophysiological study using an electric hammer as a more quantitative means of conducting the DTR test. However, limitations in terms of inter-rater reliability and validity remain, given that the examiners must directly handle the reflex hammer and may unintentionally vary the percussion intensity, direction, and position<sup>9,10</sup>. Indeed, DTR results obtained using an electric hammer in

25 healthy subjects showed very low inter-rater reliability for the various measurements, with intraclass coefficients as low as  $r = 0.280$ <sup>10</sup>. The authors attributed this low correlation coefficient to differences among examiners when striking a given part of the tendon<sup>10</sup>. In more recent studies, quantitative trials of the DTR test have been carried out using motion analysis, which examines angular velocity and acceleration of the relative joints<sup>8,11</sup>.

The reproducibility of measurements is very important for developing objective and quantitative assessment tools for various biological signals measured in the body<sup>12</sup>. Experimental efforts have identified the controllable variation in DTR measurements, but reliability studies are rarely published due to the technical difficulty of performing the measurements in a consistent manner. Therefore, the development of objective and quantitative DTR test tools, as well as studies examining the reliability and validity of these tools, are needed.

The purpose of this study was to investigate inter-rater reliability for the amplitude of compound muscle action potentials and first knee extension angle (FKEA) in the DTR test and to assess the clinical utility of a novel DTR apparatus attached to an electric hammer.

## SUBJECTS AND METHODS

### Subjects

This study was conducted in a silent laboratory environment physically isolated from outside disturbances. The subjects included 50 healthy adults (25 male and 25 female) between 20 and 31 years of age, who had no previous history of neurological disease or knee abnormality upon physical

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**Table 1.** Inter-tester reliability of the amplitude and FKEA of the deep tendon reflex test according to tapping angle (N=50)

Tapping angle	1st tester		2nd tester		ICC(2,k)	95% CI
	Mean±SD	Range	Mean±SD	Range		
Amplitude (mA)						
30°	0.18±0.11	0.08–0.31	0.14±0.10	0.07–0.34	0.96	0.93–0.98
60°	0.29±0.13	0.17–0.50	0.38±0.16	0.20–0.67	0.91	0.87–0.94
90°	0.59±0.21	0.19–0.89	0.71±0.31	0.27–0.92	0.94	0.91–0.97
120°	0.78±0.24	0.31–0.92	0.68±0.22	0.31–1.14	0.95	0.92–0.98
FKEA (°)						
30°	6.84±3.21	3.11–9.64	5.74±3.44	2.37–10.40	0.92	0.89–0.95
60°	15.47±5.01	6.79–21.22	14.74±6.88	7.41–26.22	0.95	0.92–0.98
90°	24.29±10.81	11.47–42.55	28.04±9.84	9.71–45.77	0.95	0.91–0.98
120°	29.73±12.66	13.27–48.49	26.37±11.64	14.11–46.47	0.96	0.93–0.98

FKEA: first knee extension angle; SD: standard deviation; ICC: intraclass correlation coefficient; CI: confidence interval

examination. The average age, height, and weight of the male subjects were  $27.1 \pm 2.7$  years,  $173.5 \pm 5.1$  cm, and  $69.7 \pm 8.1$  kg, respectively; the average age, height, and weight of the female subjects were  $23.6 \pm 3.1$  years,  $163.8 \pm 3.5$  cm, and  $52.7 \pm 3.4$  kg, respectively. The subjects were given a detailed explanation of the study procedure by the researcher and then provided informed consent prior to participation in this study. This study complied with the ethical standards of the Declaration of Helsinki, and the Local Research Ethics Committee approved the study and measurement protocol.

### Methods

To assess the reliability of DTR measurements, we examined inter-rater reliability for the patellar tendon reflex of the knee joint, one of the most widely tested parameters in clinical practice. The reflex response was measured as the amplitude of the action potential evoked in the rectus femoris muscle and the FKEA. Percussion was performed using a newly designed apparatus in which an electric reflex hammer (Medelec Corp., Germany) was suspended from a metal frame ( $30 \times 40 \times 82$  cm); a goniometer was then used to modulate the tapping intensity. Surface electrodes attached to the rectus femoris were used to measure the reflex response, and a polygraph with digital processing capability (Model MP150WSW, Biopac Systems Inc., Santa Barbara, CA, USA) was used to examine the amplitude and FKEA signal processing throughout the patellar tendon reflex<sup>13</sup>. The head of the electric hammer used to lightly strike the tendon has a piezoelectric device that transmits the moment of reflex initiation to the polygraph, which is necessary to properly capture the complex evoked potential.

Inter-rater reliability analyses were performed with the participation of two trained physical therapists. The DTR test was performed using the method described by Kuruoglu and Oh<sup>6</sup>. After the patient was comfortably seated on a table with the knee bent at 90°, a surface electrode was attached to the skin overlying the rectus femoris muscle on the center line connecting the anterior superior iliac spine and the patellar superior border; a reference electrode was placed on the patella. AE-131 circular surface EMG disposable

electrodes (NeuroDyne Medical Corp., Cambridge, MA, USA) were used to measure electromyographic signals. To alter the tapping intensity of the electric hammer, the tapping angle was adjusted to 30°, 60°, 90°, or 120°. The mean amplitude of three taps at each angle was used in the data analysis<sup>4,6</sup>. Amplitude was defined as the voltage difference between two positive and negative peaks. Each of these tapping angles was performed at random, with a 10-s interval between settings to avoid habituation.

In addition to the patellar reflex amplitude, the FKEA was also examined as a quantitative measurement of the DTR test. The FKEA was measured after patellar tapping using a TSD130B twin-axis goniometer (Biopac Systems Inc., Santa Barbara, CA, USA) as an accessory device to the MP150WSW polygraph. Inter-rater reliability for the FKEA was calculated using the mean of three trials from each examiner. One channel of the electrical goniometer was attached to the midline of the calf, and the other channel was attached parallel to the lateral midline of the femur above the patella<sup>13</sup>. FKEA was defined as the minimum angle of knee extension after patellar percussion.

Intraclass correlation coefficients (ICCs) were calculated in order to assess inter-rater reliability for the patellar reflex amplitude and FKEA at each tapping angle using the ICC(2, k) method. Pearson's correlation coefficients were used to examine the correlation between the patellar reflex amplitude and FKEA in the DTR test.

## RESULTS

Inter-rater reliabilities for patellar reflex amplitude and FKEA during the DTR test were obtained under several conditions in which the tapping angle of the electric hammer was modified (Table 1). For examiner 1, the mean amplitudes of the complex evoked potential elicited under each percussion angle were  $0.18 \pm 0.11$  mV at 30°,  $0.29 \pm 0.13$  mV at 60°,  $0.59 \pm 0.21$  mV at 90°, and  $0.78 \pm 0.24$  mV at 120°. For examiner 2, the mean amplitudes were  $0.14 \pm 0.10$  mV at a 30° tapping angle,  $0.38 \pm 0.16$  mV at 60°,  $0.71 \pm 0.31$  mV at 90°, and  $0.68 \pm 0.22$  mV at 120°. For both examiners,

greater percussion angles elicited larger mean amplitudes for the patellar reflex. For examiner 1, the mean FKEA was  $6.84 \pm 3.21^\circ$  at  $30^\circ$ ,  $15.47 \pm 5.01^\circ$  at  $60^\circ$ ,  $24.29 \pm 10.81^\circ$  at  $90^\circ$ , and  $29.73 \pm 12.66^\circ$  at  $120^\circ$ . For examiner 2, the mean FKEA was  $5.74 \pm 3.44^\circ$  at  $30^\circ$ ,  $14.74 \pm 6.88^\circ$  at  $60^\circ$ ,  $28.04 \pm 9.84^\circ$  at  $90^\circ$ , and  $26.37 \pm 11.64^\circ$  at  $120^\circ$ . As the percussion angle increased, the mean value of FKEA also increased for both examiners. ICC(2,k) values for the amplitude of the complex evoked potential ranged from 0.91–0.96 for the different percussion angles; ICC(2,k) values for FKEA ranged from 0.92–0.96 for the different percussion angles (Table 1).

Pearson's correlation coefficient for the relationship between amplitude and FKEA was  $r = 0.91$  ( $p < 0.01$ ), indicating a significant positive correlation between these two parameters. Significant differences were observed between the  $30^\circ$  and  $60^\circ$  and  $60^\circ$  and  $90^\circ$  tapping angles ( $p < 0.01$ ) but not between the  $90^\circ$  and  $120^\circ$  tapping angles ( $p > 0.05$ ). Furthermore, in the case of FKEA, significant differences were observed between the  $30^\circ$  and  $60^\circ$  and  $60^\circ$  and  $90^\circ$  tapping angles ( $p < 0.01$ ) but not between  $90^\circ$  and  $120^\circ$  ( $p > 0.05$ ).

## DISCUSSION

Although the DTR test is widely used in clinical practice, there tends to be confusion regarding its exact definition among experts, who may have difficulties conducting this test in a quantitative and consistent manner<sup>14</sup>. The previous research into DTR reliability is insufficient. Accordingly, this study used a novel test apparatus to examine inter-rater reliability for two DTR measures (patellar reflex amplitude and FKEA), as well as the correlation between these two parameters. The results indicate that this device generated highly reliable results. Regarding inter-rater reliability, the ICCs for the patellar reflex amplitude and FKEA ranged from 0.91 to 0.96 and from 0.92 to 0.96, respectively, for the different percussion angles examined ( $30^\circ$ ,  $60^\circ$ ,  $90^\circ$ , and  $120^\circ$ ).

The objective and quantitative reproducibility of the measurement tool is a very important issue<sup>15, 16</sup>. Because of the scarcity of measurement tools that can quantitatively evaluate the DTR test, results such as these that assess the reliability and validity of the DTR test are very rare. In a recent paper, the reliability and validity of DTR data were verified through motion analysis of the patellar tendon reflex; variation in percussion speed and angle were also incorporated into that study<sup>8</sup>. Consistent with our study, the authors found that the amplitude of the response increased linearly in accordance with increased percussion angle, and a concomitant motion analysis confirmed the high reliability of the DTR data<sup>8</sup>. However, this previous work exhibited several differences in comparison with the present study. First, in the present study, DTR testing was carried out using the natural pendulum motion of a reflex hammer suspended from a metal frame, to which a goniometer was attached in order to adjust the tapping angle. Because we avoided the use of a handheld hammer, in contrast to previous studies, hammer strikes were delivered in a much more consistent and precise fashion. Second, the previous study used an indirect method to measure the amplitude of response, whereas

the present study exploited the aforementioned apparatus to obtain direct reflex response measurements. Because the location, intensity, and direction of percussion were constant, our results show very high measures for inter-rater reliability for both parameters examined (patellar reflex amplitude and FKEA). Previous research has shown DTR test results to be affected by a number of factors, including the examiner's emotional state, level of training, smoking, and respiration<sup>17–19</sup>. Our research suggests that variation in the stimulus applied, for whatever reason, could be minimized through the use of the device described here.

In the present study, the correlation between the patellar reflex amplitude and FKEA was  $r = 0.91$  ( $p < 0.01$ ), a strongly significant correlation. When the knee joint is free of pathology, the FKEA resulting from percussion is considered to be a quantitative and objective measurement of tendon reflex. Our novel DTR device elicited significant differences in FKEA values between the tapping angles of  $30^\circ$  and  $60^\circ$  and  $60^\circ$  and  $90^\circ$  ( $p < 0.01$ ) but not between the tapping angles of  $60^\circ$  and  $90^\circ$  ( $p > 0.05$ ). These results indicate that percussion angles  $> 90^\circ$  are sufficient to induce an appropriate tendon reflex when using the equipment described in this study. In contrast, Tham et al.<sup>8</sup> reported that an appropriate tendon reflex was only induced if a tapping angle of  $> 60^\circ$  was used.

This study had several limitations. First, we examined only healthy subjects; the equipment was not tested on patients with neurological abnormalities who would typically be examined using the DTR test. Second, the test was conducted at four different tapping angles at intervals of  $30^\circ$ ; therefore, quantitative changes in reflex response at more detailed percussion angles were not examined. Accordingly, additional research is necessary to examine the clinical usefulness of this apparatus for more detailed angles in patients with neurological abnormalities (e.g., spasticity), which consequently might affect the outcomes of the DTR test.

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