Medical Engineering & Physics 33 (2011) 407–410

Contents lists available at ScienceDirect

Medical Engineering & Physics

journal homepage: www.elsevier.com/locate/medengphy

Investigation to predict patellar tendon reflex using motion analysis technique

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ARTICLE INFO

Article history:
Received 28 January 2010
Received in revised form 3 November 2010
Accepted 5 November 2010

Keywords:
Motion analysis
Kinematics
Patellar tendon reflex

ABSTRACT

The investigation of patellar tendon reflex involves development of a reflex hammer holder, kinematic data collection and analysis of patellar reflex responses using motion analysis techniques. The main aim of this research is to explore alternative means of assessing reflexes as a part of routine clinical diagnosis. The motion analysis system was applied to provide quantitative data which is a more objective measure of the patellar tendon reflex. Kinematic data was collected from 28 males and 22 females whilst subjected to a knee jerk test. Further analysis of kinematic data was performed to predict relationships which might affect the patellar tendon reflex. All subjects were seated on a high stool with their legs hanging freely within the capture volume of the motion analysis system. Knee jerk tests were applied to all subjects, on both sides of the leg, by eliciting hypo, hyper, and normal reflexes. An additional reinforcement technique called the Jendrassik manoeuvre was also performed under the same conditions to elicit a normal patellar tendon reflex. The comparison of reflex response between genders showed that female subjects generally had a greater response compared to males. However, the difference in reflex response between the left leg and the right leg was not significant. Tapping strength to elicit a hyper-reflex produced greater knee-jerk compared to the normal clinical tapping strength. All results were in agreement with clinical findings and results found by some early researchers.

1. Introduction

A reflex is an automatic and involuntary response to specific changes either outside or inside the body [1]. The functional unit of a reflex is the reflex arc, which is made up of a sensory organ, an afferent neuron, one or more synapses in the spinal cord, an efferent neuron, and an effector [2]. The deep tendon reflex can be obtained in a normal person as an immediate muscle contraction when muscle tendon is tapped briskly [3]. Medical practitioners commonly test the function of a human nervous system by eliciting reflexes [4].

Neuromuscular function can be assessed in general by performing reflex assessment. Any abnormality in the reflex response may indicate dysfunction in either the nervous system or the muscular system [5]. However, normal reflex assessments are observed visually by physicians, leading some times to unreliable judgments [6]. Such diagnoses lead to extremely subjective conclusions which may differ between examiners. The diagnostic results are therefore often inaccurate.

A new method is introduced by incorporating the motion analysis system into patellar tendon reflex assessment to obtain sets of accurate measurements for reflex responses which are diagnostically important. The motion analysis system, which involves optical tracking and video recording, provides quantitative data to predict reflexes accurately in a more objective way. This set of quantitative data is then compared between genders, different sides of the body and the effect of different striking forces.

2. Methods

The Queen square reflex hammer having a round rubber ring mounted on long plastic handle with sharpened end was chosen for the project due to its popularity among medical practitioners in the country. This type of reflex hammer has a longer handle and a heavier head than more common sizes of hammer, producing a greater swing force to the tendon and facilitating elicitation of reflexes [7].

A reflex hammer holder was built to hold the reflex hammer at a fixed position. The holder allows the height of the reflex hammer to be adjusted according to the position of the patellar tendon (which varies between subjects). The horizontal shaft of the holder was modified from a commercial tile cutter and functions to clamp the reflex hammer. Holes were drilled on both the cutter head and the

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doi:10.1016/j.medengphy.2010.11.002

end of the Queen square reflex hammer. The reflex hammer was fixed on the tile cutter by a screw. The screw locking the reflex hammer on the cutter restricts movement of reflex hammer to only one plane. The vertical beam is the main structure supporting the horizontal shaft and reflex hammer. Holes were drilled along the length of the beam to enable the position of the reflex hammer to be changed according to the knee position of different subjects. One end of the beam is welded to a metal base to support the whole structure.

Three levels of striking force were applied to the tendon during experiments, enumerated Force 1, Force 2 and Force 3. Force 1 was intended to elicit hypo-reflexes, where the reflex hammer was raised to an angle range up to 22°. In order to elicit a normal reflex, the reflex hammer was raised to an angle in the range of 23–45°, Force 2.

Force 3, meant for hyper-reflex is the greatest hammering strength in which the reflex hammer is raised to an angle between 46° and 90°. The tapping force is derived from the potential energy of the reflex hammer, which depends on the angle to which the reflex hammer is raised.

The effect of the Jendrassik manoeuvre on patellar tendon reflex was investigated in this project. The Jendrassik manoeuvre, a reinforcement technique, is commonly applied in reflex tests when the reflex response is not obvious for a particular subject [8]. When applying the technique, the subject sat with the fingers interlocked in front of the chest and attempted to pull the hands apart.

Fifty subjects comprising twenty eight males and twenty two females, aged from 22 to 24 years participated in this project. All subjects were healthy without any history of neurological disorders. Subjects with neurological disease who might experience an abnormal reflex response were excluded at recruitment. The male subjects had an average height of 1.72 ± 0.07 m and an average body mass of 69.75 ± 12.18 kg. The female subjects had an average height of 1.57 ± 0.06 m and an average body mass of 52.45 ± 9.29 kg. All subjects were selected in groups of similar Body Mass Index (BMI) with an average BMI value of 22.01 ± 1.72 for males and 20.32 ± 2.18 for female subjects.

The experimental setup for the project to tap on the patellar tendon for the collection of mean angle for the knee joints and the ankle joints is shown in Fig. 1.

As reported by the National Aeronautics and Space Administration (NASA, USA), the knee height of a male when sitting averages 52.6 cm [9]. Therefore, a stool with a height of 80 cm was prepared so that all subjects would sit with both legs hanging freely. Sixteen reflective markers were attached to the subject's lower limbs following the Plug-in-Gait Marker Placement [10]. During reflex tests, each subject was seated on a high stool with both legs hanging freely without touching the ground during the entire test. The patellar tendon on the right-hand side was tapped with the Queen square reflex hammer at Force 1 for 5 times. The same procedure was repeated at Force 2, Force 3 and using the Jendrassik manoeuvre. All tests were then repeated on the left patellar tendon. The reflex response was allowed to stop naturally before the next tap was applied. The tapping processes were recorded by the motion analysis system Nexus 1.3, where play back of the experiment allows detailed analysis. Kinematic data was then imported to another program, Vicon Polygon, for further analysis, where kinematic data was extracted in the form of quantitative values and graphs.

The joint mean angles were statistically compared between genders and left and right legs using independent t tests. Statistical significance was set at $P < 0.05$ for all tests. The effect of different striking forces and the Jendrassik manoeuvre was assessed using one-way analysis of variance (ANOVA). As post hoc analysis, Tukey's HSD test was carried out with $P < 0.05$ for multiple comparisons. All data are represented as mean ± standard deviation.

Fig. 1. Experimental setup for reflex assessment tests. The subject sits on a high stool with both feet not touching the ground. The patellar tendon of each leg is tapped using a Queen square reflex hammer. The Queen square reflex hammer is first raised to a certain angle measured using an attached protractor. The hammer is then released to tap on the patellar tendon. The experiment is recorded by the motion analysis system Nexus 1.3.

3. Results

Quantitative kinematic data for the patellar tendon reflex was collected and compared. Table 1 is the comparison of joint mean angle between genders. The mean angle for the knee joint and the ankle joint were labeled Angle 1, indicating flexion–extension for the knee, or dorsiflexion–plantarflexion for the ankle [11]. Angle 2 relates to adduction–abduction for the knee joint and inversion–eversion for the ankle joint [11]. Angle 3 refers to internal rotation or external rotation for the knee and ankle [11]. The reflex amplitude obtained shows that there was generally no statistical significance to the comparison of joint angles between males and females at different forces and the Jendrassik manoeuvre.

The mean angles for the knee joint and the ankle joint of both legs were then compared as represented in Table 2. Comparison of reflex responses between the left leg and the right leg shows that there were only slight differences in the reflex amplitude between the left leg and the right leg for all tapping conditions. These differences are not statistically significant except for knee angle 2 at force values 2 and the Jendrassik manoeuvre.

Investigations were also performed for different striking forces on reflex responses as represented in Table 3. The Jendrassik manoeuvre was analyzed in order to observe the effect of reinforcement on reflex response. Tapping at Force 2, equivalent to the standard tapping angle for the normal knee reflex evaluation method, was set as the control condition in the comparisons. Force 1 and Force 3, which aimed to elicit hypo and hyper reflexes in the experiments, were being compared with the mean angles obtained from Force 2. Tests on reflexes using the method of reinforcement by the Jendrassik manoeuvre were done using a tapping force range equal to Force 2 which is the normal reflex. Reflex amplitude for the method used in the Jendrassik manoeuvre was again compared

Table 1
Mean angles of the knee and ankle for the comparison between male and female subjects.

	Mean angle (°)		P value
	Male (N = 16)	Female (N = 22)	
Force 1			
Knee angle 1	0.15 ± 0.19	0.62 ± 0.87	0.041*
Knee angle 2	0.22 ± 0.24	0.65 ± 0.71	0.025*
Knee angle 3	0.36 ± 0.29	1.18 ± 1.20	0.011*
Ankle angle 1	0.13 ± 0.17	0.40 ± 0.44	0.025*
Ankle angle 2	0.09 ± 0.13	0.27 ± 0.29	0.027*
Ankle angle 3	0.27 ± 0.32	0.76 ± 0.99	0.068
Force 2			
Knee angle 1	5.04 ± 4.34	2.41 ± 2.32	0.021*
Knee angle 2	1.50 ± 1.67	1.04 ± 1.08	0.308
Knee angle 3	3.02 ± 2.76	2.55 ± 2.02	0.545
Ankle angle 1	0.32 ± 0.41	0.76 ± 0.87	0.070
Ankle angle 2	0.32 ± 0.62	0.69 ± 0.66	0.089
Ankle angle 3	1.14 ± 1.80	1.77 ± 1.52	0.248
Force 3			
Knee angle 1	9.26 ± 7.23	8.59 ± 7.00	0.775
Knee angle 2	2.47 ± 2.50	3.72 ± 3.13	0.198
Knee angle 3	4.48 ± 3.22	5.63 ± 3.43	0.302
Ankle angle 1	1.49 ± 1.99	4.68 ± 5.14	0.024*
Ankle angle 2	0.32 ± 0.43	1.93 ± 2.01	0.003*
Ankle angle 3	1.21 ± 1.12	4.18 ± 4.01	0.007*
Jendrassik manoeuvre			
Knee angle 1	6.30 ± 4.91	6.53 ± 6.50	0.905
Knee angle 2	1.72 ± 1.61	3.00 ± 3.36	0.167
Knee angle 3	5.41 ± 4.86	4.31 ± 4.01	0.450
Ankle angle 1	1.71 ± 1.76	2.79 ± 3.54	0.270
Ankle angle 2	1.67 ± 2.16	1.31 ± 1.81	0.587
Ankle angle 3	3.38 ± 4.35	2.73 ± 2.67	0.573

* $P < 0.05$: statistically significant differences (independent t tests).

Table 2
Mean angles of the knee and ankle for the comparison between the left leg and the right leg.

	Mean angle (°)		P value
	Left (N = 19)	Right (N = 19)	
Force 1			
Knee angle 1	0.63 ± 0.95	0.21 ± 0.20	0.062
Knee angle 2	0.64 ± 0.77	0.30 ± 0.27	0.080
Knee angle 3	0.97 ± 1.24	0.70 ± 0.73	0.418
Ankle angle 1	0.25 ± 0.23	0.32 ± 0.48	0.554
Ankle angle 2	0.22 ± 0.27	0.17 ± 0.22	0.530
Ankle angle 3	0.66 ± 1.01	0.45 ± 0.57	0.431
Force 2			
Knee angle 1	3.90 ± 3.78	3.13 ± 3.31	0.508
Knee angle 2	1.72 ± 1.74	0.75 ± 0.50	0.024*
Knee angle 3	3.07 ± 3.52	2.42 ± 2.16	0.400
Ankle angle 1	0.79 ± 0.99	0.37 ± 0.24	0.082
Ankle angle 2	0.70 ± 0.83	0.36 ± 0.38	0.111
Ankle angle 3	2.01 ± 2.07	1.00 ± 0.87	0.057
Force 3			
Knee angle 1	7.87 ± 5.58	9.88 ± 8.23	0.383
Knee angle 2	3.70 ± 3.01	2.69 ± 2.79	0.289
Knee angle 3	5.24 ± 3.54	5.05 ± 3.24	0.867
Ankle angle 1	2.96 ± 3.49	3.72 ± 5.19	0.602
Ankle angle 2	1.41 ± 1.90	1.09 ± 1.60	0.571
Ankle angle 3	3.22 ± 3.57	2.64 ± 3.38	0.614
Jendrassik manoeuvre			
Knee angle 1	7.05 ± 5.76	5.82 ± 5.95	0.521
Knee angle 2	3.60 ± 3.33	1.32 ± 1.53	0.010*
Knee angle 3	5.37 ± 4.32	4.17 ± 4.44	0.405
Ankle angle 1	2.61 ± 3.21	2.06 ± 2.72	0.570
Ankle angle 2	1.67 ± 2.24	1.26 ± 1.62	0.518
Ankle angle 3	3.23 ± 3.88	2.77 ± 3.03	0.684

* $P < 0.05$: statistically significant differences (independent t tests).

to the reflex amplitude obtained under normal reflex tests (Force 2).

The reflex amplitudes for both knee angle 1 and ankle angle 1 on both legs were significantly higher at Force 3 than at Force 2. All of the mean angles for the knee and ankle joints were smaller at Force 1 than at Force 2.

4. Discussion

The early study of Carel et al. [12] showed that reflex responses for females are lower than those of males [12]. However, almost all significant comparisons for knees and ankles were higher in females than in males. This might be due to a greater sensitivity of female subjects to hammer taps in the experiments. The group of female subjects chosen generally exhibited knee jerk at a lower force than male subjects. On top of that, the results from the small number of subjects might not completely reflect the whole population.

The deep tendon reflexes for both sides of the body are normally symmetrical [8]. The presence of asymmetrical reflexes may serve as an indication of abnormality and neurological disorders [8,7]. However, non-significant differences between left and right are also acceptable. This is due to a strongly dominant side of the body for most normal people, for instance the dominant hand, causing a minor asymmetry in muscle strength [7]. This leads to a slight difference in reflex amplitude for left and right legs.

Applying different striking forces to the patellar tendon affects the reflex amplitude obtained. Tapping with a higher striking force generates a greater stimulus on the tendon and develops an action potential more easily. Low striking force is not sufficient to trigger an action potential in the tendon during tapping and thus knee jerk was not seen in tapping of Force 1. The values of mean angle for both joints in Force 1 were caused by movement by the subjects during recording.

The overall reflex amplitudes of both the knee joint and the ankle joint were greater during tapping with reinforcement by the

Table 3
Comparison of reflex response measured as mean angle between different values of striking force.

	Mean angle (°)						
	Force 2 (control)	Force 1	P value	Force 3	P value	Jendrassik manoeuvre	P value
Left knee angle 1	3.90 ± 3.78	0.63 ± 0.95	0.117	7.87 ± 5.58	0.038*	7.05 ± 5.76	0.139
Left knee angle 2	1.72 ± 1.74	0.64 ± 0.77	0.518	3.70 ± 3.01	0.069	3.60 ± 3.33	0.093
Left knee angle 3	3.07 ± 3.52	0.97 ± 1.24	0.172	5.24 ± 3.54	0.152	5.37 ± 4.32	0.116
Right knee angle 1	3.13 ± 3.31	0.21 ± 0.20	0.338	9.88 ± 8.23	0.001*	5.82 ± 5.95	0.412
Right knee angle 2	0.75 ± 0.50	0.30 ± 0.27	0.827	2.69 ± 2.79	0.002*	1.32 ± 1.53	0.694
Right knee angle 3	2.42 ± 2.16	0.70 ± 0.73	0.288	5.05 ± 3.24	0.040*	4.17 ± 4.44	0.275
Left ankle angle 1	0.79 ± 0.99	0.25 ± 0.23	0.904	2.96 ± 3.49	0.035*	2.61 ± 3.21	0.102
Left ankle angle 2	0.70 ± 0.83	0.22 ± 0.27	0.772	1.41 ± 1.90	0.487	1.67 ± 2.24	0.218
Left ankle angle 3	2.01 ± 2.07	0.66 ± 1.01	0.477	3.22 ± 3.57	0.571	3.23 ± 3.88	0.559
Right ankle angle 1	0.37 ± 0.24	0.32 ± 0.48	1.000	3.72 ± 5.19	0.004*	2.06 ± 2.72	0.296
Right ankle angle 2	0.36 ± 0.38	0.17 ± 0.22	0.959	1.09 ± 1.60	0.222	1.26 ± 1.62	0.089
Right ankle angle 3	1.00 ± 0.87	0.45 ± 0.57	0.889	2.64 ± 3.38	0.139	2.77 ± 3.03	0.096

* $P < 0.05$: statistically significant differences (one-way analysis of variance (ANOVA)) compared to reflex response at Force 2.

Jendrassik manoeuvre. This suggests that the Jendrassik manoeuvre is able to trigger greater reflex responses compared to normal reflex tests without reinforcement. A few possible mechanisms have been suggested for the Jendrassik manoeuvre. It was suggested that the Jendrassik manoeuvre increases the sensitivity of muscle spindle to the tendon tap [13]. Tapping with the Jendrassik manoeuvre results in the generation of greater stimulus from the afferent fibers of muscle spindle compare to tapping without reinforcement [14]. Another possible mechanism suggested that the technique of the Jendrassik manoeuvre removes the presynaptic inhibition which suppresses the motor neuron leading to an increase in the reflex response [15]. The Jendrassik manoeuvre was also suggested to facilitate the activation of the motor neurons instead of the afferent fiber [14]. All suggested mechanisms received comments, either supporting or disagreeing from some other researchers [14,16–18]. Although the exact mechanism is unknown, the effect of the Jendrassik manoeuvre on eliciting greater reflex responses is recognized. However, the differences in mean angle of the comparison between the Jendrassik manoeuvre and Force 2 were not significant. This again may be due to the small sample size which does not represent the overall population.

All significant results were obtained for the comparisons at joint angle 1. Most differences of mean angle at joint angles 2 and 3 were not statistically significant. This is probably due to the nature of movement displayed for the respective angle. The major concern of the range of motion for the knee and ankle during knee jerk was in the sagittal plane designated as the *x*-axis, Angle 1 in the system, where the flexion and extension [11] of the joints could be studied. The graph of Angle 2 shows movements in the frontal plane, which displays the adduction and abduction of the knee joint [11]. There was not much movement in the frontal plane of the leg during knee jerk regardless of the briskness of the reflex. In the same way, the graph of Angle 3 shows movements in the transverse plane, which is either internal or external rotation of the joint [11]. Transverse plane movement of the knee and ankle joints were also not obvious during the experiment. Thus, joint angles for the graphs of Angles 2 and 3 did not differ much with different force values or following the Jendrassik manoeuvre, leading to results which were not significant.

5. Conclusion

The application of motion analysis techniques to obtaining quantitative data for the patellar tendon reflex serves as a new method in attempts to develop objective measures of reflex functionality. Results obtained from this research are in agreement with the clinical findings and other earlier research, proving that the technique is capable of obtaining quantitative values which might eliminate subjective judgement during clinical diagnosis. Kinematic data could be obtained for other reflexes through further studies, and the results of the current study could be generalised by involving subjects sufficient to represent the population at large.

Conflict of interest

The authors have no known affiliations that present a conflict of interest.

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