RESEARCH ARTICLE

Intra- and Inter-Session Reliability of Methods for Measuring Reaction Time in Participants with and without Patellofemoral Pain Syndrome

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Abstract

Background: To evaluate the relative and absolute reliability of reaction time measuring methods during different conditions in participants with and without patellofemoral pain syndrome (PFPS).

Methods: 30 patients with PFPS and 30 healthy controls were recruited in the present study. The upper extremity reaction time, upper extremity error rate, involved and non-involved lower extremity braking reaction times, and involved and non-involved knee extension reaction times were measured. Each condition was repeated three times, 2 sessions with a 5-7 days interval. The intra-session reliability was evaluated in three-trial (A), second- and third-trial (B) modes. In addition, the inter-session reliability was evaluated in mode A, mode B, and best score (C) mode.

Results: The result of inter-session reliability of mode A showed that all measurements except upper extremity reaction time in PFPS group showed high to very high relative reliability (ICC: 0.74-0.94). In mode B, all measurements except non-involved knee extension reaction time in PFPS group showed high to very high relative reliability (ICC: 0.71-0.93). In mode C, all measurements showed high to very high relative reliability (ICC: 0.70-0.94) except upper extremity error rate and non-involved knee extension reaction time in PFPS group. The result of intra-session reliability showed that all measurements had high to very high relative reliability (ICC: 0.78-0.94) in mode A. In mode B, all measurements showed high to very high relative reliability (0.78-0.94).

Conclusion: The braking time seems more reliable than other reaction time tasks. In addition, the results showed that mode A is more reliable than other modes. The newly designed package is a reliable tool to measure the knee extension reaction time in patients with knee musculoskeletal disorders.

Level of evidence: II

Keywords: Knee, Patellofemoral pain syndrome, Reaction time, Reliability

Introduction

Patellofemoral pain syndrome (PFPS) is one of the most common lower extremity conditions affecting one out of four people (1, 2). PFPS is defined as anterior peripatellar or retropatellar pain, worsen by activities such as running, squatting, jumping, and stair climbing (3, 4). Despite the abundance of different studies, the exact etiology is still unknown (5). Studies have demonstrated that improper sensory information, anxiety, and disability could influence cortical function through decreased central processing speed. Diminished central processing speed could make these patients more vulnerable to coordination loss when confronted with the complex environmental cues during complicated tasks (6).

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Reaction time (RT) is one of the most popular methods for measuring central processing speed (7). The reaction time is defined as the time from the appearance of unpredictable stimuli into starting of selected motor response (e.g. pressing a button or pedal) that has been divided into two parts: premotor time that includes sensory input conduction and central processing; and motor time that is defined as the time needed for motor response (8). Impaired reaction time could predispose the musculoskeletal disorders including PFPS individuals to commit more errors, thereby increase the risk of injuries. The reaction time has been demonstrated as the most reliable and sensitive measure of cognitive impairment available to practitioners (7). Various methods are available to evaluate RT such as pressing a button or braking reaction time that is usually used for upper and lower limbs. As PFPS patients have insufficient knee extension mechanism and well-timed quadriceps contraction, measuring knee extension reaction time seems more functional than the other ones.

Despite several studies on RT in musculoskeletal disorders and athletes, the information about the reliability of reaction time in different conditions is yet to be enough. Reliability is defined as the ability of a measurement tool for reporting stable and repeatable results. In addition, it is well-known that reliability is a population-specific property (9). So, we need to assess this parameter in various musculoskeletal disorders. To the best of our knowledge, no study has investigated the reliability of reaction time methods in subjects with and without PFPS. High absolute reliability in terms of minimal metrically detectable change (MMDC) can define the difference between actual treatment changes and measurement error (9). In addition, determining the time back to sport for athletes after sport injuries can be helpfull. Therefore, the first aim of this study was to evaluate the intra- and intersession reliability of different methods for measuring reaction time in participants with and without PFPS. In addition, there are different methods for reporting reaction time. Some studies have reported the best record whereas others rely on the average reaction time. The second purpose of the study was to determine the most reliable method between these reports, explicitly.

Materials and Methods

Participants

A total of 30 healthy adults (6 male and 24 female) and 30 PFPS patients (6 male and 24 female) aged between 18 to 35 years were recruited in the present study. All PFPS participants were referred from orthopedic center of Ghaem university hospital. The healthy individuals were invited through flyers and telephone contact. The PFPS participants were included if they had the following criteria: onset of pain more than 6 months, clinical signs of the PFPS e.g. retropatellar pain, Clark sign, crepitation, pain with patellar grinding, patellar compression test, palpation tenderness in lateral and medial border of the patella. Also, pain should have been worsened by at least two of the following activities: (1) ascending or descending stairs; (2) jumping and running; (3) squatting; (4) prolonged sitting with bent knees and (5) kneeling. The exclusion criteria for all participants were any history of neurologic and musculoskeletal disorders except PFPS, amnesia, vertigo, cognitive problems, sedative drug or alcohol usage 48 hours before the test (10-13). All participants were informed about experimental protocol and asked to sign written informed consent form approved by the local Institutional Review Board. The present study was approved by the ethical committee of the Mashhad University of Medical Sciences, Mashhad, Iran. (Ethical number: IR.MUMS.REC.1398.022)

Measurement tools

The Deary-Liewald reaction time (DLRT) task was used to measure the reaction time. This software is a free, easy-to-use, computer-based program capable of measuring both simple and choice reaction time (14). The computer keyboard and specially designed package was used to evaluate the choice and simple reaction time, respectively. In choice reaction time mode, the participants had to press the Z, X, . and , keys corresponded to the correct response as soon as the cross mark appeared in most left, middle left, middle right, and most right, respectively [Figure 1]. The specially designed package included a foot pedal along with a knee extension reaction time package. The knee extension reaction time package included an accelerometer attached to the ankle and a measurement tool put and fixed in 75° knee flexion. The accelerometer could detect the minimal possible ankle movement as soon as the knee extension initiated and sent a signal to the DLRT software. The time from appearance of the cross mark into the button pressing, pedal pressing, or extending the knee was determined as the reaction time [Figures 2; 3]. The involved and non-involved lower extremities were tested by DLRT program in simple reaction time mode. A 10-minute familiarization period as well as a 4-minute period of resting between conditions were used for all participants to eliminate any learning bias regarding the reaction time tasks. The total session lasted for 35 minutes. Each condition was repeated three times. In addition, the order of conditions was fully randomized. In order to evaluate the inter-session reliability, all tests were repeated in the second session with a 5-7 day interval. The reaction time measurement was assessed by one of the authors (Karimpour, S) in both sessions. The assessor ensured if any relevant event occurred between the test-

Figure 1. Upper extremity choice reaction time test condition.

Figure 2. Braking reaction time test condition.

Figure 3. Knee extension reaction time test condition.

retest intervals through asking a question.

Statistical analysis

A series of paired t-tests were carried out to compare the differences in reaction time scores in test-retest sessions to check the absence of systematic bias. No significant difference was seen in demographic variables between the groups. A two-way random model of intra-class correlation coefficient (ICC) was used to assess the relative reliability, with $ICC_{2,1}$ model for intra-session reliability and ICC2,3 model for inter-session reliability (9). The reported confidence interval (CI) was 95% to indicate the precision of the estimates. Munro's classification was used for describing the degree of reliability: 0.00-0.25 indicate very low correlation; 0.26-0.49, low correlation; 0.50-0.69, moderate correlation; 0.70-0.89, high correlation; and 0.90-1.00, very high correlation (15).

Standard error of measurement (SEM) was used to assess the absolute reliability. SEM was calculated as the square root of the mean square error term derived from analysis of variance (16). MMDC was considered as 95% CI of SEM (1.96 SEM) to estimate the changes between each 2 measurements that might be clinically significant (17). In order to compare the SEM values of neurocognitive reaction time and knee extension reaction time, the coefficient variance (CV) was determined (CV=SD/mean × 100). CV values in the range of 10-15% were considered as acceptable (18).

Relative and absolute inter-session reliabilities were assessed in three modes: (1) three trial mode (mode A), (2) second- and third-trial mode (mode B), and (3) the best score (mode C). Relative and absolute intra-session reliabilities were assessed in two modes: (1) mode A, and (2) mode B. All data analysis was performed using SPSS Version 20.0 (SPSS Inc., Chicago, IL).

Results

Demographic characteristics are shown in Table 1. No significant difference in demographic variables was seen between the two groups. In addition, Table 2 demonstrates the mean and standard deviation (SD) of reaction time measurements during test and retest sessions. All participants completed test-retest assessments.

Inter-session reliability

In mode A, all measurements showed high to very high relative reliability according to Munro's classification (ICC: 0.74-0.94) except for upper extremity reaction time in PFPS group that had moderate reliability (ICC: 0.62). The highest reliability value was related to non-involved lower extremity braking reaction time and involved knee extension reaction time in healthy group [Table 3].

All measurements in mode B showed high to very high relative reliability according to Munro's classification (ICC: 0.71-0.93) except for non-involved knee extension reaction time in PFPS group that showed moderate reliability (ICC: 0.58). The highest reliability value was for involved lower extremity braking reaction time in healthy group [Table 4].

All measurements in mode C showed high to very high relative reliability according to Munro's classification (ICC: 0.70-0.94) except for upper extremity error rate (ICC: 0.55) and non-involved knee extension reaction time (ICC: 0.65) in PFPS group that showed moderate

Table 1. Demographic characteristics of subject with PFPS and healthy controls

Variables	PFPS (n=30)		Healthy (n=30)	
	Mean	SD	Mean	SD
Age (year)	29.32	5.305	29.28	5.587
Height (m)	1.63	0.095	1.66	0.86
Weight (kg)	11.8	66.24	11.62	63.68
Sex (M/F)	6 Male 24 Female		6 Male 24 Female	

Table 2. Mean and standard deviation of reaction time measurements during test and retest sessions

		Test session		Retest session	
		Mean	SD	Mean	SD
Upper extremity reaction time	Patient	573.89	94.4	555.23	84.29
	Healthy	552.78	89.3	541.42	79.15
Involved lower extremity braking reaction time	Patient	524.71	120.74	514.55	104.03
	Healthy	462.94	72.85	459.61	62.16
Non-involved lower extremity braking reaction time	Patient	520.95	117.24	514.24	102.36
	Healthy	466.44	66.47	461.17	57.35
Involved knee extension reaction time	Patient	437.97	94.31	444.01	92.02
	Healthy	454.71	110.17	429.59	94.39
Non-involved knee extension reaction time	Patient	438.37	134.9	445.45	96.46
	Healthy	454.35	108.46	421.37	96.9

Abbreviations: SD: Standard deviation

Table 3. Inter- and intra-session reliability of reaction time parameter in upper and lower extremities in three-trial mode (mode A)

ICC		Inter-session reliability				Intra-session reliability			
		SEM	MMDC	CV	ICC	SEM	MMDC	CV	
Upper extremity reaction time	Patient	0.62	51.95	144.02	15.18	0.89	27.95	77.48	15.18
	Healthy	0.92	22.38	62.05	14.61	0.82	33.58	93.07	14.61
Upper extremity error rate	Patient	0.78	0.43	1.21	107.11	0.91	0.28	0.77	107.11
	Healthy	0.93	0.32	0.90	133.80	0.78	0.57	1.59	133.80
Involved lower extremity braking reaction time	Patient	0.91	31.20	86.50	20.21	0.94	25.48	70.63	20.21
	Healthy	0.89	20.61	57.14	13.52	0.94	15.22	42.20	13.52
Non-involved lower extremity braking reaction time	Patient	0.88	35.45	98.28	19.90	0.87	36.90	102.29	19.90
	Healthy	0.94	14.04	38.93	12.43	0.91	17.20	47.68	12.43
Involved knee extension reaction time	Patient	0.88	31.87	88.35	20.72	0.88	31.87	88.35	20.72
	Healthy	0.94	23.12	64.08	21.97	0.86	35.31	97.89	21.97
Non-involved knee extension reaction time	Patient	0.74	49.18	136.33	21.65	0.78	45.24	125.40	21.65
	Healthy	0.89	32.13	89.08	22.99	0.85	37.52	104.02	22.99

Abbreviations: ICC: Intra-class correlation coefficient, SEM: Standard error of measurement, MMDC: Minimal metrically detectable change, CV: Coefficient variance

relative reliability [Table 5].

Intra-session reliability

All measurements in mode A showed high to very high relative reliability according to Munro's classification (ICC: 0.78-0.94). The highest value of ICC was related to involved lower extremity braking reaction time in both groups [Table 3].

Table 4. Inter-session reliability of reaction time parameter in upper and lower extremities in best score mode (mode C)

		Inter-session reliability				Intra-session reliability			
		ICC	SEM	MMDC	CV	ICC	SEM	MMDC	CV
Upper extremity reaction time	Patient	0.91	24.90	69.01	15.31	0.94	20.33	56.35	15.31
	Healthy	0.90	24.34	67.49	14.39	0.93	20.37	56.46	14.39
Upper extremity error rate	Patient	0.84	0.37	1.03	108.77	0.78	0.43	1.21	108.77
	Healthy	0.91	0.34	0.96	155.36	0.78	0.54	1.51	155.36
Involved lower extremity braking reaction time	Patient	0.89	34.21	94.84	20.30	0.90	32.62	90.43	20.30
	Healthy	0.93	16.91	46.89	13.90	0.87	23.05	63.91	13.90
Non-involved lower extremity braking reaction time	Patient	0.87	33.92	94.03	18.48	0.88	32.59	90.34	18.48
	Healthy	0.92	17.37	48.16	13.08	0.86	22.98	63.71	13.08
Involved knee extension reaction time	Patient	0.71	52.85	146.50	21.80	0.81	42.78	118.58	21.80
	Healthy	0.88	34.36	95.26	22.87	0.85	38.42	106.50	22.87
Non-involved knee extension reaction time	Patient	0.58	61.62	170.81	21.39	0.84	38.03	105.42	21.39
	Healthy	0.89	33.10	91.75	23.30	0.86	37.34	103.51	23.30

Abbreviations: ICC: Intra-class correlation coefficient, SEM: Standard error of measurement, MMDC: Minimal metrically detectable change, CV: Coefficient variance

Table 5. Inter- and intra-session reliability of reaction time parameter in upper and lower extremities in second- and third-trial (mode B)

ICC		Inter-session reliability			
		SEM	MMDC	CV	
Upper extremity reaction time	Patient	0.92	22.34	61.93	15.01
	Healthy	0.90	23.08	63.98	14.23
Upper extremity error rate	Patient	0.55	0.54	1.50	218.64
	Healthy	0.88	0.38	1.06	235.31
Involved lower extremity braking reaction time	Patient	0.87	35.00	97.02	20.47
	Healthy	0.91	17.03	47.20	13.07
Non-involved lower extremity reaction time	Patient	0.89	29.83	82.70	18.97
	Healthy	0.93	13.75	38.12	12.07
Involved knee extension reaction time	Patient	0.70	48.65	134.87	21.26
	Healthy	0.88	33.39	92.55	23.63
Non-involved knee extension reaction time	Patient	0.65	50.53	140.07	21.33
	Healthy	0.94	22.23	61.64	23.51

Abbreviations: ICC: Intra-class correlation coefficient, SEM: Standard error of measurement, MMDC: Minimal metrically detectable change, CV: Coefficient variance

All measurements in mode B showed high to very high relative reliability according to Munro's classification (0.78-0.94). The highest value was for upper extremity reaction time in patient group [Table 4].

Discussion

The present study examined intra- and inter-session reliability of different methods for measuring reaction time in subjects with and without PFPS. To the best of the authors' knowledge, no study has been conducted on the reliability of reaction time measurements in subjects with and without musculoskeletal disorders. Our results showed high to very high reliability (ICC: 0.70-0.94) for knee extension reaction time package in most conditions. In addition, the ICC values of mode A were higher than other modes. The ICC values obtained from test-retest reliability of healthy individuals were higher than the PFPS patients. In addition, the ICC values of reaction times were higher than error rates in choice reaction time condition except for mode A of PFPS patients. The upper extremity reaction time and lower extremity braking reaction time were more reliable than knee extension reaction time.

Mode A had higher reliability than the two other modes. This can be attributed to the learning effects that were higher in mode A together. One of the strengths of the present study was to report the reaction time in different modes to see which one is of higher reliability. Previous studies on reliability of reaction time have not reported the reliability in modes A, B, and C, separately. In a research on healthy young adults, Wells et al. evaluated the reliability of three reaction time tasks with increasing complexity within six sessions (19). The authors reported a statistically significant difference between the scores of each session. Therefore, they analyzed and reported the ICC values between two sessions with the least significant difference score. In addition, Picha et al. reported that the reliability of 5 novel reaction time protocols in healthy adults increased during three sessions (20). Their ICC values for reaction time measurements ranged between 0.75 and 0.90. There were no significant differences between scores obtained from three sessions, they reported the ICC values in three trials, exclusively (20). In addition, Well et al. examined the reliability of dynavision™ D2 for assessing reaction time performance in recreationally active young adults (21). The ICC values of reaction time measurements in their population ranged between 0.675 and 0.835. As our results demonstrate, the ICC values of the present work are in agreement with the results of those studies. Although different methods have been used in the relevant studies, the present results suggest that the reaction time could be used as a reliable measure for examining neurocognitive assessment in both PFPS patients and healthy individuals.

Higher ICC values obtained from healthy individuals compared with PFPS patients can be explained by the greater heterogeneity among healthy group. In the current study, PFPS participants were closely matched by the means of inclusion and exclusion criteria and patients with the least heterogeneity were selected while the control group had greater between-subject differences. Therefore, according to ICC calculation formula, the greater between-subject differences result in higher ICC values in healthy individuals (16).

In addition, the ICC values for reaction times were higher than the error rates in choice reaction time condition except for mode A of PFPS patients. This is in accordance with those studies that investigated the reliability of auditory Stroop task measures in subjects with anterior cruciate ligament deficiency, non-specific low back pain and ACL reconstruction (9, 22-25). Moreover, Zeinalzadeh et al. reported a higher reliability for reaction time than error rate in patients with PFPS (2).

The upper extremity reaction time and the braking reaction time had higher reliabilities as compared with knee extension reaction time. However, this difference seems to be neglectable. It seems that the braking reaction time is a more appropriate parameter for evaluating the reaction time. According to our results, the braking time is suggested to be used for measuring the effectiveness of rehabilitation in PFPS and healthy individuals.

The first limitation of the present study may be related to small sample size. The relevant studies demonstrate that it needs fifty participants for each group minimally to better estimate the reliability of the reaction time measures (15). In addition, women in the preset study constitute eighty percent of each group. Although this distribution is mostly in agreement with the prevalence of the PFPS community, generalizability of these results into the men should be interpreted with caution (26). Another limitation was that the reliability of the reaction time measures was not calculated in patients with variety of musculoskeletal disorders. However, to generalize these results to other musculoskeletal disorders, further studies should be conducted on the reliability of reaction time in athletes with musculoskeletal disorders.

It seems necessary to conduct the reliability of reaction time measures before using it in the cross-sectional and clinical trial studies. Reliability studies provide attitude to identify the best conditions determining between-groups differences. Our findings showed that the braking time is more reliable than other tasks measures reaction time. Moreover, this study demonstrates that three-trial mode is a good choice for measuring reaction time in the future studies.

The present study showed that braking time is more reliable than other reaction time tasks. Also, the three-trial mode is a little more reliable than other methods. The newly designed package seems to be a reliable tool to measure the knee extension reaction time in patients with knee disorders.

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