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Original Article

Knee position sense: does the time interval at the target angle affect position accuracy?

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Abstract. [Purpose] This study examined whether the interval at the target angle during knee joint position sense (JPS) affected reposition accuracy, and evaluated the consequence of this factor on test-retest reliability. [Subjects and Methods] Twenty healthy subjects participated in this study. Reposition ability was measured after the knee was placed at a target angle (ranging from 40° to 60°) for intervals of 3, 6, 9, and 12 seconds, in randomized order. Two trials were performed for each condition. The measurement was repeated after a week. The absolute error (AE) of each trial and average AE under each condition within the two measures were used for data analysis. [Results] No significant difference was found in comparing the AE or the average AE during all trials and between the two measures. Fair-to-good reliability was found for the AE results of all trials under the conditions of 3, 6, and 12 seconds. Poor reliability was found with time interval of 9 seconds. [Conclusion] The length of time needed to memorize the target angle during knee JPS test might affect test reliability. Practitioners can use this information when collecting JPS data.
Key words: Joint position sense, Knee, Reliability

INTRODUCTION

Proprioception is a fundamental part of the somatosensory system. It enables an individual to determine positions and movements of body parts in space, based on sensory signals provided to the brain[1, 2]. Proprioceptive ability is required for both feedforward (planning and anticipation) and feedback mechanisms that are critical for controlling movement, balance and posture[2, 3].

While there is no single measure to quantify proprioception, joint position sense (JPS) is the most widely-used measure of proprioceptive ability in the literature[1, 2, 4]. The traditional method for measuring JPS is to place the joint at a specific target angle and then, after the limb has been moved back to the starting angle, the subject is asked to actively or passively reproduce the target angle. The outcome of the measurement is the absolute error (AE), which is the difference between the true target angle and the reproduced angle[1, 2].

While JPS can be measured at the spine[5], shoulder[6], elbow[7], hip[8], and ankle joints[9], the knee is most commonly used to evaluate position sense acuity[2, 4]. Abnormal JPS has been demonstrated in people with knee pathologies, such as after anterior cruciate ligament injury[10], in individuals with patellofemoral pain syndrome[11], and with knee osteoarthritis[12]. It was also shown that improved knee JPS ability may reduce the risk for sport injuries[13]. Thus, a reliable, standardized protocol to examine knee JPS is needed.

Protocols for measuring knee JPS have been widely investigated[4, 14–16]. It has been suggested that sitting should be

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preferred to prone, ipsilateral should be preferred to contra-lateral, and the test angle should be in the middle of the knee joint range of motion[15]. In addition, various types of equipment have been used to measure knee JPS, such as image-recorded angulation, electrogoniometry, and dynamometry, all with good reliability[4, 14, 16]. However, while it was shown that without visual input, limb position accuracy appears to drift with time[17, 18], in studies that tested knee JPS, the interval in which the joint was placed in the target angle (ranging from 0° to 100° of flexion) during the test varied greatly[8, 15, 16, 19–24]. While some authors did not report the exact length of this interval[15], there is evidence in the literature for intervals of 3 seconds[19], 4 seconds[8, 20], 5 seconds[16, 21], 6 seconds[22], 10 seconds[25], and even 15 seconds[24]. Moreover, none of the previous reports provided an adequate explanation for the choice of time interval, and information on the effect of this parameter on knee JPS reliability has not been published.

Therefore, the aim of the present study was to evaluate whether the time interval at the target angle during knee JPS test affects reposition accuracy and the test-retest reliability of this assessment. We hypothesized that reposition accuracy will be affected by the time interval at the target angle, but test-retest reliability will not be affected.

SUBJECTS AND METHODS

A sample of 20 healthy participants (average age 20.6 ± 2.1 years, 12 females) participated in the study. The enrollment criteria were no current or previous conditions that could affect proprioception, in particular lower limb joint injuries within the past 6 months, a history of significant knee injury or surgery, or a chronic or neurological disease (e.g., multiple sclerosis, stroke, Parkinson's disease, rheumatoid arthritis, or diabetes). The study was approved by the institutional Ethical Review Board (approval number IDF-1704–2016). All participants provided written informed consent.

The Biodex Multi-Joint System isokinetic dynamometer (Biodex Corp., NY, USA) was used to test position sense. The system includes an electro-goniometer, which is sensitive to 1° increments[26]. The use of isokinetic dynamometry to measure knee JPS is an accepted method that minimizes researcher bias[14].

The test was conducted with the participants seated in the isokinetic dynamometer chair, blind-folded to block visual input. The lower limb was slowly extended from a starting position of 90° of knee flexion to a random flexion angle ranging from 40° to 60°. Participants were asked to concentrate on the sensation of the presented angle and memorize this specific angle. Then, the participant's knee was passively returned to the starting position by the examiner, and the participant was asked to actively reproduce the presented joint angle. Once the participant felt that the knee was in the position of the presented angle, he/she pressed the hold switch, preventing the dynamometer from further movement.

The time in which the joint was placed in the target angle differed between 3, 6, 9, or 12 seconds. Two trials (T1, T2) were taken for each time interval (i.e., 3, 6, 9, or 12 seconds) in randomized order, with a two-minute rest between trials. The measurement was repeated after 7 days, in order to test whether familiarity with the test affected position accuracy in the four intervals protocols and to determine the test-retest reliability.

The AE (week-1 T1, T2; week-2 T1, T2) at each time interval was calculated, as well as the average AE of the two trials at each interval during each week. A repeated-measures analysis of variance (ANOVA) was used to compare the average AE under the four conditions between the two weeks. Another repeated-measures ANOVA was used to compare the AE (T1, T2) at each time interval under the four conditions between the two weeks. Significance was determined at $p < 0.05$. The degree of test-retest reliability was evaluated by using the intraclass correlation coefficient one-way random model ($ICC_{(1)}$). Test-retest reliability was calculated for average AE under the four conditions between the two weeks, as well as for all measurements under the four conditions. $ICC < 0.4$ demonstrates poor reliability; $0.4 < ICC < 0.75$ demonstrates fair to good reliability and $ICC > 0.75$ demonstrates excellent reliability[27]. The analysis was conducted using IBM SPSS V22 (SPSS, Inc., Chicago, IL, USA).

RESULTS

Table 1 presents the mean $\pm$ SD AE (week-1 T1, T2; week-2 T1, T2) at each time interval, as well as the mean $\pm$ SD of the average AE per condition at both weeks. The ANOVA that tested the average AE showed no significant effects of test condition or week, as well as no interaction between these parameters, indicating that it did not differ between conditions or weeks. Similar results were demonstrated in the ANOVA comparing the AE. No significant effects of testing condition, trial, or week were found, as well as no interaction between these parameters, indicating no difference in the AE results during all tests.

Table 2 summarizes the ICC values. The table presents the ICC results of the AE of all trials under each condition, as well the ICC of the average AE between the two weeks. Fair-to-good reliability was found for the AE results of all trials under the 3, 6, and 12 second intervals at the target angle (ICC 0.64, 0.64, and 0.69, respectively). Similarly, fair-to-good reliability was found for the average AE between the two weeks under these three time conditions (ICC 0.60, 0.72, and 0.60, respectively). Poor reliability was found for the AE results, as well as for the average AE under the condition that tested JPS with an interval of 9 seconds at the target angle (ICC 0.26, 0.08, respectively).

A mountain plot demonstrating the differences in the average AE between the two weeks under the four time conditions is shown in Fig. 1. As depicted in Fig. 1 the distribution of the differences was similar under the conditions of 3, 6, and 12 second intervals at the target angle. Under these conditions only one subject presented a difference greater than 4°, whereas under the 9 second condition 6 out of the 20 subjects presented a difference greater than 4°.

Table 1. Mean ± SD of the absolute error (AE) (week 1 T1, T2 and week 2 T1, T2) at each time interval, and the mean ± SD of the averaged AE per condition at both weeks

Time interval at target angle	Week 1			Week 2		
	AE T1	AE T2	Averaged AE	AE T1	AE T2	Averaged AE
3 seconds	5.73 ± 4.31	3.84 ± 2.97	4.78 ± 2.50	5.10 ± 4.56	4.32 ± 4.26	4.71 ± 4.01
6 seconds	4.31 ± 4.08	3.65 ± 2.84	3.98 ± 2.22	4.73 ± 4.51	3.37 ± 3.04	4.05 ± 3.43
9 seconds	4.02 ± 3.52	3.79 ± 3.53	3.91 ± 2.66	4.38 ± 3.35	3.99 ± 2.62	4.18 ± 2.39
12 seconds	4.37 ± 3.45	3.90 ± 3.16	4.13 ± 2.75	3.92 ± 3.17	3.69 ± 3.66	3.80 ± 2.97

T1: first trial; T2: second trail

Table 2. ICC results of the absolute error (AE) of all trials under each condition and the intraclass correlation coefficient (ICC) of average AE between the two weeks

Time at target angle	AE week 1 (T1–T2)-week 2 (T1–T2)				Average AE week 1–2			
			95% Confidence Interval				95% Confidence Interval	
	ICC	p-value	Lower Bound	Upper Bound	ICC	p-value	Lower Bound	Upper Bound
3 seconds	0.64	0.001	0.29	0.84	0.6	0.026	−0.009	0.84
6 seconds	0.64	0.001	0.29	0.84	0.72	0.004	0.3	0.89
9 seconds	0.26	0.188	−0.46	0.68	0.08	0.426	−1.32	0.68
12 seconds	0.69	<0.001	0.38	0.86	0.6	0.028	−0.02	0.84

T1: first trial; T2: second trail
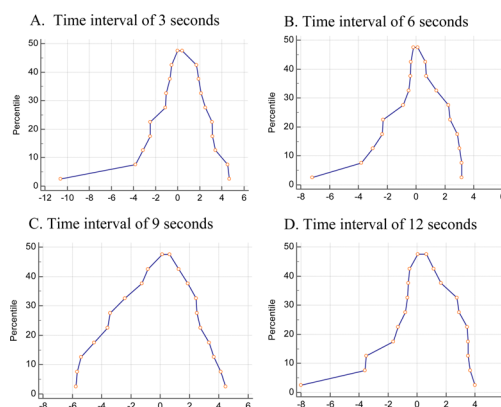
Fig. 1. A mountain plot demonstrating the differences in the average AE between the two weeks under the four time conditions

DISCUSSION

The findings of the present study indicate that the time at the target angle during knee JPS did not affect position accuracy. Similar levels of reposition accuracy were demonstrated when the subject had 3, 6, 9, or 12 seconds to memorize the target angle.

In contrast to the present results, previous studies that tested hand position sense ability reported that in the absence of visual feedback, localizing precision undergoes temporal degradation, termed as position drift[17, 18]. A possible explanation for these inconsistent results may be related to differences in motor control over the upper and lower limbs while performing everyday tasks. During hand activities, such as reaching and grasping, eye movement coordinates control with hand movement and visual input is processed along with proprioception[28]. Consequently, visual feedback is more important in arm and hand movement control and specifically in the preferred arm, than it is in the lower limbs[29]. This may suggest that upper limb JPS tends to rely more on visual information than lower limb JPS does, leading to position drift during the time without visual input. Another explanation for the results might be related to differences in methodology. The studies that reported on limb

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position drift, tested the location ability of one hand by matching its location with the other, while the present study used the ipsilateral angle reproduction test. It has been suggested that different JPS testing protocols, such as ipsilateral or contralateral matching, could result in contradictory findings[30].

It should be noted that position accuracy under the 3, 6, 9, or 12 second time conditions in the present study ranged from 3.37° to 5.73° and is consistent with values reported by previous studies[15, 25, 31]. Using a similar procedure of ipsilateral testing while seated, for knee JPS, Olsson et al.[15] reported a range of 3.05° to 4.51°, and Callaghan et al.[25], reported a range of 2.7° to 6.9°. The similarity to values reported previously enhances the methodology used in the current study.

During JPS testing, the limb is held at the target angle for a few seconds to enable the subject to memorize this specific angle. While position accuracy was similar between conditions, the test-retest reliability evaluations indicated different results. Fair-to-good reliability was found under the 3, 6, and 12 second test conditions; however, JPS tests with an interval of 9 seconds at target angle yielded poor reliability, indicating that the results under this condition were not consistent. These reliability findings may be related to different types of memory used during the four test conditions, namely the working memory and the short-term memory. It has been suggested that the superior parietal lobe of the brain is responsible for maintaining the internal representation of the body's state[32]. The superior parietal lobe is strongly related to manipulation of attention-related aspects of memory, also described as working memory[33, 34]. The short-term memory reflects the ability of the human mind to temporarily hold a limited amount of information in a very accessible state. This type of memory is considered less restricted in capacity and duration compared to the working memory and it involves other brain regions, particularly the prefrontal cortex[35]. It is possible that under the 3 and 6 second conditions the subjects used their working memory resources, which are limited to few seconds, whereas for the 12 second condition, additional resources of short-term memory were utilized[36]. The inconsistent results found under the condition of 9 seconds might be because this period falls between the capacity of the working and short-term memories. During this interval, the two memory mechanisms might have been used incoherently, which could explain the inconsistent results. Nevertheless, it should be emphasized that to the best of our knowledge, this is the first study to assess the reliability of knee JPS in relation to the time interval in the target angle. Thus, further research to evaluate JPS test reliability from this perspective is warranted.

Xie and Urabe[22] conducted a study that investigated how long JPS can be retained in memory. Subjects were asked to reproduce knee joint position at 3 time intervals: immediately, 5 minutes and 30 minutes post-memorization. Differences in reproduced JPS between time intervals of immediately and 5 minutes post-memorization were not statistically significant, whereas differences in JPS between the immediate interval and 30 minute interval were statistically significant. Thus, the authors concluded that JPS could be retained in memory for approximately 5 minutes. However, while the study tested the retention of JPS in memory with the passage of time, it did not test the effect of the time interval to memorize the target, as it was 6 seconds under all conditions.

The present results have implications for studies that measure knee proprioceptive ability, as well as clinical settings. Based on the current findings, time intervals to memorize the target angle during JPS should be 3, 6, or 12 seconds. Furthermore, the findings may be applied during motor control learning tasks. It may be assumed that in order to effectively learn a specific posture, such as knee angle during squat, the same time intervals at the target angles (e.g., 3, 6, or 12 seconds) should be used. However, in order to further challenge motor-sensory integration in an advanced level, 9 seconds interval may be applied for learning. Yet, future investigations should confirm these assumptions.

It is important to recognize some limitations of this study. It included young subjects within a narrow age range; however, knee JPS acuity can be affected by age[37], as well as by knee pathologies[10–12]. Further studies with varied populations are warranted. The present study analyzed only the dominant leg; yet, some studies suggested side asymmetry in terms of non-dominant side proprioceptive superiority[30, 38]. Thus, it may be beneficial to examine the effect of the time interval at the target angle on position accuracy between the dominant and non-dominant legs. Also, the test protocol included only 3, 6, 9, and 12 second intervals to memorize the target angle and no more than two trials were performed for each time interval. Although it was suggested that even 10 trials to obtain JPS measure is insufficient to set a gold standard[39], a protocol that includes additional time intervals and more trials could strengthen the current results.

In summary, the present study demonstrated that the time interval at the target angle during knee JPS did not affect position accuracy. However, it affected the test reliability. Fair-to-good reliability for knee JPS tests was found for time intervals of 3, 6, or 12 seconds to memorize the target angle, while poor reliability was found with the 9 second interval. Although additional studies with varied populations should be performed to generalize these findings, practitioners can use this information when collecting JPS data.

Conflict of interests

The authors declare that they have no competing interests.

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