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Article Title: Inter-Examiner, Intra-Examiner and Test-Retest Reliability of Clinical Knee Joint Position Sense Measurements Using an Image Capture Technique

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Inter-examiner, intra-examiner and test-retest reliability of clinical knee joint position sense measurements using an image capture technique.

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Abstract

Context*:** Knee joint position sense (JPS) plays a critical role in controlled and stable joint movement. Poor ability to sense position of the knee can therefore increase risk of injury. There is no agreed consensus on JPS measurement techniques and a lack of reliability statistics on methods. ***Objective*:** To identify the most reliable knee JPS measurement technique using image capture. ***Design*:** Inter-examiner, intra-examiner and test-retest reliability of knee JPS measurements. ***Setting*:** Biomechanics laboratory. ***Participants*:** Ten asymptomatic participants. ***Interventions*:** None. ***Main Outcome Measures: Relative and absolute error scores of knee JPS in three conditions (sitting, prone, active) through three ranges of movement (10-30°, 30-60°, 60-90°), into two directions (flexion and extension) using both legs (dominant and non-dominant) collected during 15 trials and repeated seven days after the first data collection. ***Results:*** **S**tatistical analysis by intraclass correlations revealed excellent inter-examiner reliability between researchers (0.98) and intra-examiner reliability within one researcher (0.96). Test-retest reliability was highest in the sitting condition from a starting angle of 0°, target angle through 60°-90°of flexion, using the dominant leg and AES variables (ICC = 0.92). However, it was noted smallest detectable differences (SDDs) were a high percentage of mean values for all measures. ***Conclusions:*** The most reliable JPS measurement for asymptomatic participants has been identified. Practitioners should use this protocol when collecting JPS data during pre-screening sessions. However, generalizability of findings to a class/group of clients exhibiting knee pathologies should be done with caution.

Joint position sense (JPS) is defined as the static awareness of limb position in space[1]. Poor knee JPS may result in an increased risk of injury[2]. The use of JPS in a clinical setting is used to identify patients that may be more at risk of injury due to poor JPS ability[3]. It is vital clinicians are confident the data is reliable and results are not masked by measurement error.

Practitioners use a range of equipment to measure JPS, such as isokinetic dynamometer[1], however, this is not considered the most viable or reliable equipment to measure knee JPS[3]. Other techniques include image capture and electrogoniometery[1]. A review[3] evaluated the reliability of these knee joint position assessment methods and concluded reliability was highly variable between all techniques. Each method may measure a different aspect of JPS therefore techniques should not be used interchangeably. However, image capture techniques appear to have the highest feasibility and most consistent knee JPS results[3].

In addition to equipment selection, JPS protocols must also be considered. The most common method of JPS is that of the passive position of a target angle then active reposition to identify knee JPS ability[4]. There are additional variables to consider, such as position of the patient, selected starting and target angles and direction of movement. Previous studies have yielded conflicting results regarding the most representative JPS protocol, due to the apparent inconsistencies in methodological details. For example it has been suggested weight-bearing closed chain tests are more ecologically valid than non-weight-bearing open chain tests as they provide maximal afferent information from adjacent joints and structures[5]. However, not all literature produced optimal JPS performance in weight-bearing conditions[6]. Given the total number of variables practitioners must consider when selecting a JPS protocol it is unsurprising that a comprehensive reliability analysis is absent from the literature. There is a need for a study to consider a large range of dependent variables with the same participants[3]. It is stated "*while the importance of proprioception as a clinical outcome* *measure is becoming well recognised, the best measurement techniques have yet to be define*"[4] (p.128). There is no previous data on the reliability of JPS measurement using image capture within a range of protocols. Therefore the aim of the current study is to identify the most reliable, in terms of test-retest, intra-examiner and inter-examiner, knee JPS measurement technique using image capture equipment.

Methods

Using a repeated measures design, ten participants (age 30.2±8.87years, mass 71.5±18.30kg, height 1.71±11.23m, Tegner 5.3±2.50) took part in the study. All were free from lower extremity injury and neurological disease. Participants provided written informed consent and the study was approved by institutional research ethics committee.

Procedures

Markers were placed on anatomical points; a point on a line following the greater trochanter to the lateral femoral epicondyle, close to the lateral femoral epicondyle, the lateral femoral epicondyle and the lateral malleolus of both legs. Testing was conducted in three conditions, sitting, prone and active. The sitting and prone conditions took place on an orthopaedic plinth with the participant blindfolded. Each leg was passively moved through either 10°-30°, 30°-60° or 60°-90° of knee flexion (from a starting angle of 0°) or knee extension (from a starting angle of 90°) to a randomized target angle at an angular velocity of approximately 10°/s. The participant was instructed to focus on the position of the knee and actively hold the leg in this position for 5s. A photograph of the leg was taken using a camera (Casio Exilim, EX-FC100, Casio Electronics Co.,Ltd. London, UK) placed 3m from the sagittal plane of movement on a fixed level tripod (Camlink TP-2800, Camlink UK, Leicester, UK). The leg was then passively returned to the starting angle and the participant was instructed to actively move the same leg to the target angle and hold the leg in this position whilst another photograph was taken.

For the active condition, the participant was positioned supine on a "Total Trainer" (Model TT2500P, Bayou Fitness, Louisiana, USA; see Figure 1) and blindfolded. The equipment was set at level 1 incline, providing 10% body weight (BW) resistance. Each leg was actively moved to the same random order range of target angles as in the previous conditions using the sliding seat on the "Total Trainer" at approximately 10°/s. The participants were instructed to actively contract into flexion or extension until verbally told to stop by the experimenter and hold that position for 5s whilst a photograph was taken. The participant then returned the leg to the starting position and was instructed to actively move the same leg to the target angle without verbal cues. Another photograph was taken. The process was repeated 15 times for each target angle on both dominant and non-dominant legs in all three conditions. The protocol was repeated seven days later.

Analysis

Knee angles were measured using open access digitizing software (ImageJ, U. S. National Institutes of Health,, Maryland, USA, http://imagej.nih.gov/ij/, 1997-2013). Knee JPS was calculated from the average delta scores between target and reproduction angles across 15 trials, producing real (magnitude and direction) error scores (RES) and absolute (magnitude only) error scores (AES)[4].

Statistical analysis used SPSS (Version 19, IBM Corporation, New York, USA). The Shapiro-Wilk test examined normality of data, which was confirmed. Inter-examiner and intra-examiner reliability was confirmed using intra-class correlation coefficients (ICC 2,1), 95% Confidence Intervals and Cronbach's Alpha[7]. A randomly selected data set of 30 trials was analysed by the researcher and then by an independent rehabilitation practitioner. The researcher repeated the analysis of the randomly selected data set of 30 trials.

Test-retest reliability was assessed using intra-class correlation coefficients (specifically ICC, 3,1). Standard Error Mean (SEM) (standard deviation x ($\sqrt{1} - ICC$) 95% Confidence Intervals (CIs) (1.96xSEM) and Smallest Detectable Difference (SDD) (1.96x$\sqrt{2}xSEM$). ICC results greater than 0.75 are excellent, between 0.40-0.75 are modest and less than 0.40 are poor[8].

Results

The ICC value corresponding to inter-examiner reliability was 0.98 and 95% CIs ranged from 0.96-0.99. Cronbach's Alpha value was 0.99. The ICC value for intra-examiner reliability was 0.96 and 95% CIs ranged from 0.91-0.98. Cronbach's Alpha value was 0.98.

Tables one-three display all data. ICCs ranged from 0.03-0.80 in RES data and 0.65-0.92 in AES data in the sitting condition. In the prone condition ICCs ranged from 0.53-0.79 in RES data and 0.27-0.90 in AES data. For the active condition ICCs ranged from -0.18-0.89 in RES data and-0.13-0.82 in AES data. Furthermore, SDDs ranged from 2.26°-5.48° in RES data and 1.10°-2.45° in AES data in the sitting condition. In the prone condition SDDs ranged from 2.37°-8.71° in RES data and 1.65°-8.37° in AES data. For the active condition SDDs ranged from 0.85°-5.39° in RES data and 1.23-3.14 in AES data. The results indicated the test of knee JPS with the highest ICC value is the sitting condition from a starting angle of 0°, target angle through 60°-90°of flexion, using the dominant leg and calculating absolute error scores.

Discussion

This is the first study to comprehensively consider reliability of knee JPS using image capture data acquisition techniques. The inter-examiner reliability results were "excellent" indicating it may be appropriate for different practitioners to analyze images collected during JPS testing. The test-retest reliability results indicate a large range of ICCs. The highest ICC score and hence "excellent" reliability measure of knee JPS was tested in a sitting condition, dominant leg, from a starting angle of 0°, into flexion through 60°-90° of movement, calculating absolute error scores (ICC=0.92). Practitioners should adopt the techniques with "excellent" levels of test-retest reliability when using JPS to screen asymptomatic populations.

The sitting condition provided the most reliable position for JPS data collection, 11 out of 24 JPS measurements had "excellent" ICC scores. However, the active condition presented the poorest level of test-retest reliability, with only two out of 24 measures producing "excellent" test-retest reliability results. It has been suggested active positioning-active repositioning weight-bearing JPS measures may illicit maximum JPS performance due to an increase of mechanoreceptor activity across the kinetic chain[9]. However, authors have criticised weight-bearing conditions as it is not a true representation of isolated knee JPS[10]. Therefore we aimed to create a "semi-weight bearing" condition in which the participant was under 10% body weight in order to increase ecological validity, but still isolate knee joint proprioceptors by minimizing movement in adjacent joints. However, the motor control needed to complete this procedure may require greater learning time before data collection begins. Longer practice sessions and also individualised loading rates may be necessary to ensure participants are accustomed to this JPS protocol.

Results suggest absolute error scores were more consistent than relative error scores in all three conditions. Therefore practitioners should use absolute error scores in asymptomatic JPS testing. This is perhaps unsurprising due to the additional dimension provided by relative error scores (direction of error), consistency is harder to attain. There is little evidence to suggest direction in which the error occurs will influence an increased injury risk. For example we do not know if over estimating the position of a limb in any worse than underestimating. It has also been suggested average relative error scores mask JPS ability, as the average of repeated trails can incorrectly reduce the error score[11]. Therefore, it is appropriate to use magnitude of error (AES) only in JPS testing.

An important finding in this study was the high SDD scores within all JPS measurements. The most reliable measurement had a SDD value which was 34% of the AES and some SDDs were more than the mean scores. To our knowledge SDD scores for JPS testing using image capture techniques have not been previously reported. Previous research[12] reported standard error of measurement values of up to 50% of the mean knee JPS error score, however testing was completed using a perturbation protocol not reproduction of an angle as in the current study. Future studies need to confirm SDD values so practitioners can be confident athlete progression in screening programmes is not masked by measurement error.

A limitation of this study is the sample did not include symptomatic patients. Therefore results should not be generalized to knee pathology groups. Future research should collect normative JPS data from both uninjured and injured populations. However, practitioners should use the results to review reliability of their chosen knee JPS measurement technique. It is suggested a method that seats the patient, uses a starting position of 0° , through flexion to a target angle between 60°- 90° will yield the highest test-retest reliability data. It is also recommended AES be used rather than relative error scores to collect consistent data. However, practitioners should consider the high SDD figure if using measurements of knee JPS in longitudinal screening. It may be that measurement error masks true improvement of JPS acuity. The results of this study indicate the type of JPS protocol using image capture techniques that provide excellent reliability are in a sitting position, passive then active knee positioning to a target near the end range of movement at approximately 10°/s.

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Figure 1. The Total Trainer Model TT2500P, Bayou Fitness, Louisiana, USA

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Table 1. Mean (°), standard deviation (SD), 95% confidence intervals (CI), standard error of measurement (SEM), smallest detectable difference (SDD) and intraclass correlation coefficient (ICC) values in a sitting condition.

Relative Error Scores (RES)									
Test	**Mean[1]**	**SD[1]**	**Mean[2]**	**SD[2]**	**ICC**	**95% CI**		**SEM**	**SDD**
Dominant Leg									
Extension 10°-30°	2.0	1.20	2.4	1.18	0.54	-0.08	0.86	0.82	2.26
Extension 30°-60°	2.0	1.83	1.5	2.25	0.78	0.36	0.94	0.96	2.65
Extension 60°-90°	-0.1	1.50	-0.3	2.06	0.80	0.38	0.95	0.83	2.31
Flexion 10°-30°	-0.8	1.88	-1.2	1.27	0.03	-0.65	0.63	1.58	4.38
Flexion 30°-60°	-1.0	1.83	-2.0	1.91	0.67	0.09	0.91	0.94	2.59
Flexion 60°-90°	-1.7	1.53	-0.8	2.20	0.40	-0.20	0.80	1.45	4.02
Non-dominant Leg									
Extension 10°-30°	2.4	1.77	2.1	2.24	0.75	0.27	0.93	1.04	2.87
Extension 30°-60°	1.9	1.64	1.2	2.09	0.66	0.15	0.90	1.05	2.91
Extension 60°-90°	0	1.46	0	1.72	0.51	-0.18	0.86	1.14	3.17
Flexion 10°-30°	-0.2	1.83	-0.8	1.57	0.62	0.08	0.89	1.01	2.81
Flexion 30°-60°	-2.1	3.11	-2.1	1.79	0.58	-0.07	0.88	1.68	4.66
Flexion 60°-90°	0.2	2.72	-0.9	2.00	0.30	-0.31	0.76	1.98	5.48
Absolute Error Scores (AES)									
Test	**Mean[1]**	**SD[1]**	**Mean[2]**	**SD[2]**	**ICC**	**95% CI**		**SEM**	**SDD**
Dominant Leg									
Extension 10°-30°	2.5	1.09	2.5	1.06	0.76	0.26	0.93	0.55	1.53
Extension 30°-60°	2.6	1.49	2.4	1.63	0.86	0.54	0.96	0.60	1.67

Extension 60°-90°	1.7	0.89	2.1	0.98	0.70	0.20	0.91	0.49	1.35
Flexion 10°-30°	2.3	1.05	2.4	0.97	0.79	0.37	0.94	0.47	1.31
Flexion 30°-60°	3.1	1.27	3.3	1.00	0.86	0.54	0.96	0.44	1.23
Flexion 60°-90°	3.2	1.40	3.3	1.35	0.92	0.72	0.98	0.40	1.10
Non-dominant Leg									
Extension 10°-30°	2.9	1.45	2.8	1.84	0.73	0.22	0.93	0.88	2.45
Extension 30°-60°	2.4	1.27	2.4	1.34	0.87	0.55	0.97	0.50	1.38
Extension 60°-90°	1.9	0.82	2.0	1.27	0.76	0.31	0.76	0.53	1.47
Flexion 10°-30°	2.2	0.64	2.2	1.04	0.65	0.05	0.90	0.52	1.45
Flexion 30°-60°	4.0	1.80	3.6	1.54	0.79	0.38	0.94	0.75	2.09
Flexion 60°-90°	3.8	1.89	3.5	2.08	0.84	0.50	0.96	0.80	2.23

[1]Session One Data; [2]Session Two Data