TECHNICAL REPORT 10

http://dx.doi.org/10.1123/jsr.2013-0119

Criterion-Related Validity of Knee Joint-Position-Sense Measurement Using Image Capture and Isokinetic Dynamometry

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Context: Clinicians require portable, valid, and cost-effective methods to monitor knee joint-position-sense (JPS) ability. ***Objective:*** To examine the criterion-related validity of image-capture JPS measures against an isokinetic-dynamometer (IKD) procedure. ***Design:*** Random crossover design providing a comparison of knee JPS measures from image capture and IKD procedures. ***Participants:*** 10 healthy participants, 5 female, age 28.0 ± 13.29 y, mass 60.3 ± 9.02 kg, height 1.65 ± 0.07 m, and 5 male, 29.6 ± 10.74 y, mass 73.6 ± 5.86 kg, height 1.75 ± 0.07 m. ***Main Outcome Measures:*** The dependent variables were absolute error scores (AES) provided by 2 knee directions (flexion and extension). The independent variables were the method (image capture and IKD). ***Results:*** There was no significant difference between clinical and IKD AES into knee-flexion data (P = .263, r = 0.55). There was a significant difference between clinical and IKD AES into knee-extension data (P = .016, r = .70). ***Conclusions:*** Analysis of photographic images to assess JPS measurements using knee flexion is valid against an IKD positioning method, but JPS measurements using knee extension may not be valid against IKD techniques. However, photo-analysis measurements provided a lower error score using knee-extension data and thus may provide an optimal environment to produce maximal knee JPS acuity. Therefore, clinicians do not need expensive equipment to collect representative JPS ability.

Keywords: proprioception, isokinetic dynamometer

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Clinicians use knee joint-position-sense (JPS) measurements to assess static knee proprioception ability.[1] This is an important measurement, as it can either identify patients with a JPS deficiency that may lead to an increased risk of knee injury or progress along a proprioceptive-based rehabilitation program. The traditional clinical JPS measurement technique involves passive knee movement by the clinician to a specific target angle, then active reproduction of this angle by the patient.[1] Image capture can be used to collect knee position and hence knee JPS information. However, as the clinician is part of this data-collection process, measurement bias[2] may be introduced to the data. Therefore, an isokinetic dynamometer (IKD) provides an alternate means to position the knee target angle, removing researcher bias. Kiran et al[3] reported high correlations between concurrent measurement of JPS using an IKD, photo analysis, and electrogoniometry. However, all target knee positions were completed by the IKD arm and therefore did not replicate a typical clinical setting. Grob et al[4] did consider the correlation between a self-built low-speed motor and passive researcher positioning techniques on different occasions. Results indicated a poor correlation between the 2 measurements (r = –.2), suggesting that the methods should not be used interchangeably. It is notable that when the target angle was positioned by the researcher rather than a pulley system, participants produced better JPS acuity results. However, the matching method was produced using a visual analog scale, which has limited ecological validity.[1]

Smith et al[5] produced a systematic review on the reliability of JPS measurement techniques. Their findings suggested that intrarater reliability depended on data-acquisition techniques; image capture produced greater reliability than electrogoniometry and dynamometry. However, no study has considered the concurrent validity of assessment methods using the same participants.[5] An analysis of the validity of JPS techniques is difficult, as there is no universally accepted "gold standard" method of collecting JPS data. However, the use of an IKD to position a limb at a defined angle is accepted. Therefore, criterion-related, specifically concurrent validity was investigated in this study by comparing a clinical JPS measurement technique with an IKD JPS protocol. Concurrent validity is defined as a comparison between 1 previously validated protocol and a new or previously unvalidated procedure.[6] Clinicians use JPS to measure the effectiveness of a rehabilitation program, so it is

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imperative that the measurements have concurrent validity. The aim of the current study was to validate measurement of JPS using a clinical researcher passive-positioning technique versus an IKD-positioning technique.

Methods

A convenience sample of 10 healthy participants took part in the study (see Table 1 and Appendix). All were free from lower-extremity injury and neurological disease and had no previous history of significant knee injury or surgery. Participants read an information sheet and provided written informed consent. This study was approved by the university ethics board. The dependent variables were collected using IKD (Humac Norm 776, CSMi, Stoughton, MA, USA) and image-capture procedures. The image-capture equipment included a camera (Casio Exilim, EX-FC100, Casio Electronics Co, Ltd, London, UK) and a tripod (Camlink TP-2800, Camlink UK, Leicester, UK). The camera setup followed the British Association of Sport and Exercise Sciences (BASES) guidelines.[7]

\<<<<<<<<<<<**TABLE 1**>>>>>>>>>\

Procedures

The study was a random crossover design; hence, participants were tested using both methods, a week apart. Participants wore shorts and removed the sock and shoe from their dominant-leg foot. The participants were prepared for image-capture data collection by placing markers on the following anatomical points: a point on a line following the greater trochanter to the lateral epicondyle, close to the lateral epicondyle (placement of a marker directly on the greater trochanter is difficult due to clothing), the lateral epicondyle, and the lateral malleolus of the dominant leg (following Andersen et al[8]).

Each participant was seated on the end of an orthopedic assessment plinth and blindfolded (see Figure 1). The dominant leg was passively moved by the researcher through 30° to 60° of knee extension from a starting knee angle of 90° or through 60° to 90° of knee flexion from a starting angle of 0° to a target angle at an angular velocity of approximately 10°/s. The order of the target angles was randomly allocated using randomly generated numbers. The participant then actively held the leg in this position for 5 seconds. A photograph of the leg in the target position was taken using the camera placed 3 m from the sagittal plane of movement on the fixed-level tripod. The leg was then passively returned to the starting angle, and the participant was instructed to actively move that leg to the target angle and hold it in this position. Another photograph was taken, and the participant instructed to move the leg back to the starting position. The process was repeated 5 times for each target angle on the dominant leg.

\<<<<<<<<<<<**FIGURE 1**>>>>>>>>>\

Knee JPS measurements were also collected using an IKD. A specific protocol was written (see Table 2) to ensure that the IKD passively moved the participant's dominant leg to the predetermined target angles. The participant was seated in the IKD chair but not secured in the chair, as this may have introduced sensory feedback from the popliteal fossa, which was not present in the clinical trials. Once the center of rotation of the dominant knee had been correctly aligned to the center of rotation of the IKD lever axis, the leg was strapped to the lever and the participant blindfolded. The IKD protocol then passively moved the leg through 30° to 60° of extension from a starting knee angle of 90° or through 60° to 90° of flexion from a starting angle of 0° to a specified target angle at an angular velocity of 2°/s. Target angles were randomly selected across the range of motion. The leg was held in this position for 5 seconds and then returned to the starting angle. The participant was then instructed to move the leg to the target angle and hold, at which point the experimenter noted the knee angle using the IKD software. This process was repeated 5 times for both knee extension and flexion.

\<<<<<<<<<<<**TABLE 2**>>>>>>>>>\

Data Reduction

Knee angles were measured from the image-capture data using 2-dimensional manual digitizing software (ImageJ, US National Institutes of Health, Bethesda, MD, USA, http://imagej.nih.gov/ij/, 1997). Knee JPS was calculated from the average delta scores between target and reproduction angles across 5 flexion and 5 extension trials, producing absolute error scores (AES) in which only magnitude was measured. Interexaminer and intraexaminer reliability were confirmed using intraclass correlation coefficients (ICC 2,1).[9] The ICC value corresponding to interexaminer reliability was .98, and 95% confidence intervals ranged from .96 to .99. The ICC value for intraexaminer reliability was .96, and 95% confidence intervals ranged from .91 to .98. Therefore it can be confirmed that interreliability and intrareliability of the data-analysis method were at an acceptable level. Test–retest reliability was confirmed before the current study; knee-extension trials provided an ICC of .89 and knee-flexion trials an ICC of .92.

AES scores from IKD data were calculated by subtracting the reproduction angle from the target angle set in the protocol. The averages of the 5 extension trials and 5 flexion trials were used for further analysis in each condition (photo analysis and IKD).

All statistical analysis was completed in SPSS (Version 19, IBM Corp, Armonk, NY, USA). The Shapiro-Wilk test was used to examine normality of data, which was confirmed. Related-samples *t* tests were used to compare clinical and IKD JPS scores. An alpha level was set at $P < .05$. The corresponding *t* statistic and degrees of freedom were used to calculate effect size (*r*).[9]

Results

There was no significant difference between image-capture AES (3.7° ± 1.4°) and IKD AES (4.3° ± 1.8°)

knee-flexion data (P = .263, r = .55). There was a significant difference between image-capture AES (2.5° ± 0.7°) and IKD AES (4.3° ± 1.9°) knee-extension data (P = .016, r = .70).

Discussion

Clinicians use JPS to measure the effectiveness of a rehabilitation program and identify patients who may be more at risk for knee injury, so it is imperative that the measurements be valid. Criterion-related validity was confirmed for knee-flexion JPS; there were no differences between JPS in a clinical and IKD setting (P = .263, r = .55). However, knee-extension JPS using an image-capture technique was different than an IKD-based technique (P = .263, r = .7). The IKD data provided significantly greater error scores than the image-capture data for knee extension. This supports previous evidence that JPS measurement techniques should not be used interchangeably; however, passive positioning by a researcher may provide a more optimal environment for maximal JPS performance.[4] It is possible in the IKD setting that participants had to adapt to the addition of the lever arm increasing the mass of the leg and the torque required to extend the knee; hence, effort was not as natural when compared with the image-capture setting and ecological validity was reduced. This may not have the same effect on knee flexion, as the torque required in this direction would be assisted by gravity. Another feasible explanation was the seating in both tests. In the image-capture test condition participants were seated on the edge of a plinth and hence were not conscious of a back rest and could use pelvis rotation to assist knee extension and the associated hamstring lengthening. Previous research suggests heightened afferent information when muscles are lengthened.[10] In the IKD setting participants were seated on the edge of the seat and not supported by the back rest but may have been less likely to use pelvis rotation to assist knee extension and hence perhaps use a less natural (more resistance to) knee-extension movement. Therefore, a clinical setting may provide a more "optimal" environment for knee-extension JPS measurement, as ecological validity is increased.

Results of this validity study have important implications for clinicians. The image-capture measurement of knee JPS with passive positioning of target angles produced similar (knee flexion) and improved (knee extension) AES compared with the IKD setting. This suggests that a clinical measurement technique provides a more optimal environment and "best scores" for JPS than an IKD setting. Therefore, knee JPS can be measured in a clinical setting using cheap and easily accessible equipment; expensive IKD equipment is not necessary.

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Appendix: Questionnaires Used to Define Participants' Knee-Function Score (KOOS and Lysholm) and Activity Level (GPPAQ and Tegner)

General Practice Physical Activity Questionnaire

Date.....

Name.....

1. Please tell us the type and amount of physical activity involved in your work.

		Please mark one box only
a	I am not in employment (e.g. retired, retired for health reasons, unemployed, full-time carer etc.)	
b	I spend most of my time at work sitting (such as in an office)	
c	I spend most of my time at work standing or walking. However, my work does not require much intense physical effort (e.g. shop assistant, hairdresser, security guard, childminder, etc.)	
d	My work involves definite physical effort including handling of heavy objects and use of tools (e.g. plumber, electrician, carpenter, cleaner, hospital nurse, gardener, postal delivery workers etc.)	
e	My work involves vigorous physical activity including handling of very heavy objects (e.g. scaffolder, construction worker, refuse collector, etc.)	

2. During the *last week*, how many hours did you spend on each of the following activities?
Please answer whether you are in employment or not

Please mark one box only on each row

		None	Some but less than 1 hour	1 hour but less than 3 hours	3 hours or more
a	Physical exercise such as swimming, jogging, aerobics, football, tennis, gym workout etc.				
b	Cycling, including cycling to work and during leisure time				
c	Walking, including walking to work, shopping, for pleasure etc.				
d	Housework/Childcare				
e	Gardening/DIY				

3. How would you describe your usual walking pace? Please mark one box only.

Slow pace (i.e. less than 3 mph)		Steady average pace	
Brisk pace		Fast pace (i.e. over 4mph)	

Appendix Figure 1 — GPPAQ.

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Knee injury and Osteoarthritis Outcome Score (KOOS), English version LK1.0

KOOS KNEE SURVEY

Today's date: _____/_____/_____ Date of birth: _____/_____/_____

Name: _____

INSTRUCTIONS: This survey asks for your view about your knee. This information will help us keep track of how you feel about your knee and how well you are able to perform your usual activities.
Answer every question by ticking the appropriate box, only one box for each question. If you are unsure about how to answer a question, please give the best answer you can.

Symptoms
These questions should be answered thinking of your knee symptoms during the **last week**.

S1. Do you have swelling in your knee?

Never	Rarely	Sometimes	Often	Always
☐	☐	☐	☐	☐

S2. Do you feel grinding, hear clicking or any other type of noise when your knee moves?

Never	Rarely	Sometimes	Often	Always
☐	☐	☐	☐	☐

S3. Does your knee catch or hang up when moving?

Never	Rarely	Sometimes	Often	Always
☐	☐	☐	☐	☐

S4. Can you straighten your knee fully?

Always	Often	Sometimes	Rarely	Never
☐	☐	☐	☐	☐

S5. Can you bend your knee fully?

Always	Often	Sometimes	Rarely	Never
☐	☐	☐	☐	☐

Stiffness
The following questions concern the amount of joint stiffness you have experienced during the **last week** in your knee. Stiffness is a sensation of restriction or slowness in the ease with which you move your knee joint.

S6. How severe is your knee joint stiffness after first wakening in the morning?

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

S7. How severe is your knee stiffness after sitting, lying or resting **later in the day**?

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

Appendix Figure 2(a) — KOOS.

Knee injury and Osteoarthritis Outcome Score (KOOS), English version LK1.0

Pain

P1. How often do you experience knee pain?

Never ☐ Monthly ☐ Weekly ☐ Daily ☐ Always ☐

What amount of knee pain have you experienced the **last week** during the following activities?

P2. Twisting/pivoting on your knee

None ☐ Mild ☐ Moderate ☐ Severe ☐ Extreme ☐

P3. Straightening knee fully

None ☐ Mild ☐ Moderate ☐ Severe ☐ Extreme ☐

P4. Bending knee fully

None ☐ Mild ☐ Moderate ☐ Severe ☐ Extreme ☐

P5. Walking on flat surface

None ☐ Mild ☐ Moderate ☐ Severe ☐ Extreme ☐

P6. Going up or down stairs

None ☐ Mild ☐ Moderate ☐ Severe ☐ Extreme ☐

P7. At night while in bed

None ☐ Mild ☐ Moderate ☐ Severe ☐ Extreme ☐

P8. Sitting or lying

None ☐ Mild ☐ Moderate ☐ Severe ☐ Extreme ☐

P9. Standing upright

None ☐ Mild ☐ Moderate ☐ Severe ☐ Extreme ☐

Function, daily living

The following questions concern your physical function. By this we mean your ability to move around and to look after yourself. For each of the following activities please indicate the degree of difficulty you have experienced in the **last week** due to your knee.

A1. Descending stairs

None ☐ Mild ☐ Moderate ☐ Severe ☐ Extreme ☐

A2. Ascending stairs

None ☐ Mild ☐ Moderate ☐ Severe ☐ Extreme ☐

Appendix Figure 2(b) — KOOS.

Knee injury and Osteoarthritis Outcome Score (KOOS), English version LK1.0

For each of the following activities please indicate the degree of difficulty you have experienced in the **last week** due to your knee.

A3. Rising from sitting

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A4. Standing

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A5. Bending to floor/pick up an object

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A6. Walking on flat surface

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A7. Getting in/out of car

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A8. Going shopping

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A9. Putting on socks/stockings

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A10. Rising from bed

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A11. Taking off socks/stockings

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A12. Lying in bed (turning over, maintaining knee position)

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A13. Getting in/out of bath

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A14. Sitting

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A15. Getting on/off toilet

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

Appendix Figure 2(c) — KOOS.

Knee injury and Osteoarthritis Outcome Score (KOOS), English version LK1.0

For each of the following activities please indicate the degree of difficulty you have experienced in the **last week** due to your knee.

A16. Heavy domestic duties (moving heavy boxes, scrubbing floors, etc)

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A17. Light domestic duties (cooking, dusting, etc)

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

Function, sports and recreational activities

The following questions concern your physical function when being active on a higher level. The questions should be answered thinking of what degree of difficulty you have experienced during the **last week** due to your knee.

SP1. Squatting

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

SP2. Running

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

SP3. Jumping

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

SP4. Twisting/pivoting on your injured knee

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

SP5. Kneeling

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

Quality of Life

Q1. How often are you aware of your knee problem?

Never	Monthly	Weekly	Daily	Constantly
☐	☐	☐	☐	☐

Q2. Have you modified your life style to avoid potentially damaging activities to your knee?

Not at all	Mildly	Moderately	Severely	Totally
☐	☐	☐	☐	☐

Q3. How much are you troubled with lack of confidence in your knee?

Not at all	Mildly	Moderately	Severely	Extremely
☐	☐	☐	☐	☐

Q4. In general, how much difficulty do you have with your knee?

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

Thank you very much for completing all the questions in this questionnaire.

Appendix Figure 2(d) — KOOS.

Lysholm Knee Questionnaire / Tegner Activity Scale

Name: First Last **Date:** 09 01 14

Physician:

1. Limp:
- ◯ a) None
- ◯ b) Slight or periodical
- ◯ c) Severe and constant

2. Support:
- ◯ a) None
- ◯ b) Stick or crutch
- ◯ c) Weight-bearing impossible

3. Locking:
- ◯ a) No locking and no catching sensations
- ◯ b) Catching sensation but no locking
- ◯ c) Locking occasionally
- ◯ d) Locking frequently
- ◯ e) Locked joint on examination

4. Instability:
- ◯ a) Never giving way
- ◯ b) Rarely during athletics or other severe exertion
- ◯ c) Frequently during athletics or other severe exertion (or incapable of participation)
- ◯ d) Occasionally in daily activities
- ◯ e) Often in daily activities
- ◯ f) Every step

5. Pain:
- ◯ a) None
- ◯ b) Inconstant and slight during severe exertion
- ◯ c) Marked during severe exertion
- ◯ d) Marked on or after walking more than 2 km
- ◯ e) Marked on or after walking less than 2 km
- ◯ f) Constant

6. Swelling:
- ◯ a) None
- ◯ b) On severe exertion
- ◯ c) On ordinary exertion
- ◯ d) Constant

7. Stair-climbing:
- ◯ a) No problems
- ◯ b) Slightly impaired
- ◯ c) One step at a time
- ◯ d) Impossible

8. Squatting:
- ◯ a) No problems
- ◯ b) Slightly impaired
- ◯ c) Not beyond 90°
- ◯ d) Impossible

Appendix Figure 3(a) — Lysholm/Tegner.

Activity Level Before Injury	Current Activity Level	Activity Level Following Surgery if applicable	
○	○	○	Competitive sports Soccer - national and international elite
○	○	○	Competitive sports Soccer, lower divisions Ice hockey Wrestling Gymnastics
○	○	○	Competitive sports Bandy Squash or badminton Athletics (jumping, etc.) Downhill skiing
○	○	○	Competitive sports Tennis Athletics (running) Motorcross, speedway Handball Basketball Recreational sports Soccer Bandy and ice hockey Squash Athletics (jumping) Cross-country track findings both recreational and competitive
○	○	○	Recreational sports Tennis and badminton Handball Basketball Downhill skiing Jogging, at least five times per week
○	○	○	Work Heavy labor (*e.g.*, building, forestry) Competitive sports Cycling Cross-country skiing Recreational sports Jogging on uneven ground at least twice weekly
○	○	○	Work Moderately heavy labor (*e.g.*, truck driving, heavy domestic work) Recreational sports Cycling Cross-country skiing Jogging on even ground at least twice weekly
○	○	○	Work Light labor (*e.g.*, nursing) Competitive and recreational sports Swimming Walking in forest possible
○	○	○	Work Light labor Walking on uneven ground possible but impossible to walk in forest
○	○	○	Work Sedentary work Walking on even ground possible
○	○	○	Sick leave or disability pension because of knee problems

Tegner: ☐ ☐ ☐ Lysholm Score: 0 Print Form Submit

Appendix Figure 3(b) — Lysholm/Tegner.

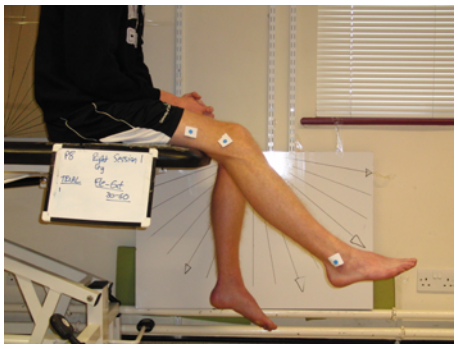

Figure 1 — Typical setup for image-capture knee-joint position-sense measurements.

Table 1 Participant Characteristics (Mean ± SD)

	Age (y)	Mass (kg)	Height (m)	BMI	GPPAQ range	KOOS	Lysholm	Tegner
Females (n = 5)	28.0 ± 13.29	60.3 ± 9.02	1.65 ± 0.07	22.1 ± 1.80	Inactive to active	98.6 ± 3.18	98.8 ± 2.68	5.0 ± 1.22
Males (n = 5)	29.6 ± 10.74	73.6 ± 5.86	1.75 ± 0.07	24.1 ± 1.97	Active	92.5 ± 10.87	87.6 ± 17.5	7.8 ± 1.30

Abbreviations: BMI, body-mass index; GPPAQ, General Practitioner Physical Activity Questionnaire; KOOS, Knee injury and Osteoarthritis Outcome Score (the closer the score to 100, the better the knee condition); Lysholm, Lysholm Knee Score (the closer the score to 100, the better the knee condition); Tegner, Tegner Activity Scale (the closer the score to 10, the more physically active) (see Appendix for more details).

Table 2 Isokinetic Dynamometer Protocol

Action	Angle (°)	Hold time (s)
From 0° (full extension) into knee flexion		
passive	90/80/70/90/75	5
passive	0	2
active	Replication	5
passive	0	Back to step 1
From 90° into knee extension (0°)		
passive	30/45/60/45/45	5
passive	90	2
active	Replication	5
passive	90	Back to step 1

Note: Passive action defines isokinetic dynamometer lever movement. Active motion defines participant muscle contraction.