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Inter- and intrarater reliability of two proprioception tests using clinical applicable measurement tools in subjects with and without knee osteoarthritis

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ABSTRACT

Background. The therapeutic value of proprioceptive-based exercises in knee osteoarthritis (KOA) management warrants investigation of proprioceptive testing methods easily accessible in clinical practice.

Objective. To estimate inter- and intrarater reliability of the knee joint position sense (KJPS) test and knee force sense (KFS) test in subjects with and without KOA.

Design. Cross-sectional test-retest design.

Method. Two blinded raters performed independently repeated measures of the KJPS and KFS test, using an analogue inclinometer and handheld dynamometer, respectively, in eight KOA patients (12 symptomatic knees) and 26 healthy controls (52 asymptomatic knees). Intraclass correlation coefficients (ICCs; model 2,1), standard error of measurement (SEM) and minimal detectable change with 95% confidence bounds (MDC₉₅) were calculated.

Results. For KJPS, results showed good to excellent test-retest agreement (ICCs 0.70-0.95 in KOA patients; ICCs 0.65-0.85 in healthy controls). A 2° measurement error (SEM 1°) was reported when measuring KJPS in multiple test positions and calculating mean repositioning error. Testing KOA patients pre and post therapy a repositioning error larger than 4° (MDC₉₅) is needed to consider true change. Measuring KFS using handheld dynamometry showed poor to fair interrater and poor to excellent intrarater reliability in subjects with and without KOA.

Conclusions. Measuring KJPS in multiple test positions using an analogue inclinometer and calculating mean repositioning error is reliable and can be used in clinical practice. We do not recommend the use of the KFS test to clinicians. Further research is required to establish diagnostic accuracy and validity of our KJPS test in larger knee pain populations.

Key words. Proprioception – Reliability – Clinical tests – Knee osteoarthritis

INTRODUCTION

Knee osteoarthritis (KOA) is the most common chronic joint disease and major cause of pain and functional limitations [1, 2]. Somatosensory dysfunction has been related to KOA [3]. Proprioception is essential for well-adapted sensorimotor control and involves awareness of joint position (joint position sense), movement (kinaesthesia) and force, heaviness and effort (force sense) [4, 5]. It assists in joint stabilization, coordinating and controlling movement, joint protection and damage prevention [6].

Literature shows that KOA patients have significantly worse proprioception than healthy individuals [7-13]. It is unknown whether proprioceptive deficits *initiate* degeneration through abnormal neuromuscular control resulting in excessive load or otherwise *result* from mechanoreceptor damage due to OA-associated degeneration [14, 15]. Although clarification is needed, there is compelling evidence indicating effectiveness of proprioceptive-based exercises in KOA [16]. Clinicians may include assessment of proprioceptive accuracy in the clinical evaluation of OA patients. Thus, defining clinimetric properties of easily accessible proprioceptive testing methods seems warranted.

To be clinically meaningful, reliability statistics must include a combination of intraclass correlation coefficients (ICCs), standard error of measurement (SEM) and minimal detectable change with 95% confidence bounds (MDC₉₅). Reliability data could provide us with information about the amount of error inherent in its measurement, providing guidance as to whether the measured change is due to measurement error or to real change [17]. The equipment needed to perform proprioceptive tests should be inexpensive and easy attainable in clinical settings [18].

Knee joint position sense (KJPS) tests are frequently used in research and clinical practice. The knee is moved (actively or passively) towards a predetermined angle and patients' accuracy in repositioning the knee into the perceived angle is assessed [14, 19]. Different protocols have been described, mainly using expensive instruments, such as isokinetic dynamometry [20, 21], image capturing [22], electrogoniometry [23] or 3D motion analysis [14]. Although most protocols show acceptable reliability [6], equipments used are typically impracticable in clinical settings.

Other methods include knee force sense (KFS) tests, where patients' ability to perceive and reproduce a previously generated sub-maximal quantity of force (e.g. 50% of 1 repetition maximum (RM)) is determined [24]. KFS tests have only been anecdotally described in literature [9]. To our knowledge, no information about reliability or validity is available.

The aim of this study was to estimate inter- and intrarater reliability of a KJPS test and KFS test in subjects with and without KOA using an analogue inclinometer (AI) and handheld dynamometer (HHD), respectively. Both instruments are inexpensive and easily accessible in clinical practice.

MATERIALS AND METHODS

This study was performed following the Guidelines for Reporting Reliability and Agreement Studies (GRRAS) [17] and approved by the Antwerp University Hospital ethical committee (B300201672162).

Written informed consent was obtained from each participant.

Subjects

Thirty-four subjects (8 symptomatic KOA and 26 healthy controls) were recruited by contacting orthopaedic hospital departments, private medical practices, nursery homes and social elderly organizations between November 2015 and February 2016.

Patients were diagnosed with unilateral or bilateral KOA based on American College of Rheumatology (ACR) Clinical Classification Criteria [25]. Healthy controls were older than 50 years without knee complaints. Exclusion criteria for both groups were recent (<3 years) lower limb surgery, history of severe lower limb trauma (e.g. fractures, traumatic cartilage disorders, ligament tears), presence of systemic diseases (e.g. rheumatoid arthritis) and other disorders resulting in lower limb complaints.

Research design

Two raters (GC and VVDL) underwent a three-hours training, supervised by two physiotherapists with minimum 15 years of clinical experience (GP and IB). Raters were instructed to perform accurate measurements, including pilot testing on 4 healthy subjects (not included).

Measurements for an individual participant were carried out on one day, with sufficient rest between trials. The test order (including test positions, target forces and rater choice) was randomized. Raters were blinded to each other's findings, the condition (healthy or KOA) and affected side (in case of KOA).

Proprioception measurement

For both tests subjects were seated on the table with eyes closed, lower legs hanging relaxed and unsupported, not wearing shoes or socks. The upper leg was fully supported by the table and hands were placed behind the body.

Knee joint position sense (KJPS) test

This test measures subject's ability to actively reproduce a passive positioning of the lower leg [14]. The investigator passively extended the knee from the resting position (90° flexion) to one of three test positions: 70° , 45° or 20° flexion (Figure 1). Subjects maintained and mentally visualized this position for five seconds (criterion angle). After returning to the resting position and relaxing for three seconds, subjects were instructed to actively reproduce this criterion angle and to hold this position for five seconds (reproduced angle). No feedback was provided. After familiarization (one repetition), each subject performed this test twice in each of the three positions in a randomized order.

Figure 1 : Illustration of the three test positions for the knee joint position sense (KJPS) test

An AI (Plurimeter Dr. Rippstein, Switzerland) was attached to the flattest side of the lower leg, approximately perpendicular to the knee flexion-extension axis (Figure 2). The absolute difference between criterion and reproduced angle (repositioning error) ($^{\circ}$) was taken as measure for proprioceptive accuracy. Four variables were calculated: mean repositioning error of all six tests together (three test positions twice) and mean repositioning error for three test positions separately.

Figure 2 : Resting position knee joint position sense (KJPS) test

Knee force sense (KFS) test

This test measures subject's ability to actively reproduce target forces with quadriceps muscle contraction (from approximately 90° flexion position). First, subjects performed two maximal quadriceps voluntary contractions. The mean value was used as 1RM (N). Subjects then gradually build up quadriceps force until a target value (25%, 50% or 75% of 1RM) was reached and maintained and mentally visualized this force output for five seconds (criterion force). After ten seconds relaxation, subjects gradually build up quadriceps force and reproduced the criterion force. Subjects confirmed when this force was thought to be reproduced and maintained for five seconds (reproduced force). No feedback was provided. After familiarization (one repetition), each subject performed this test twice for each of the three target values in a randomized order.

A HHD (type microfet 2 Biometrics) was placed just above both malleoli, at the anterior side of the lower leg (Figure 3). The absolute difference between criterion and reproduced force (reproducing error) was taken as measure for proprioceptive accuracy. Four variables were calculated: mean reproducing

error of all six tests together (three target values twice) and mean reproducing error for the three force values separately.

Figure 3 : Resting position knee force sense (KFS) test

Pain and disability assessment

To evaluate pain and disability, KOA patients completed the Lequesne Algofunctional Index (Dutch version), a self-reported 11-item questionnaire with good reliability and validity in KOA [26, 27]. Scores range from 0-24 (> 14: extremely severe pain and disability; 11-13: very severe; 8-10: severe; 5-7: moderate; 1-4: minimal) [26].

Statistical analysis

Analyses were performed using SPSS for Windows (23.0) (0.05 α level). Descriptive statistics summarized study population characteristics. Normality of data was assessed visually and tested with a 1-sample Kolmogorov-Smirnov goodness-of-fit test ($P>0.05$; data not shown).

Differences in proprioceptive measurement between raters were calculated with a paired t-test. Repeated measures ANOVA was performed to assess variance within subjects and to calculate SEM [28].

For assessing inter- and intrarater reliability, ICCs (2-way random-effects ICC model (absolute agreement)) were calculated [28, 29] and interpreted according to specific criteria: poor ($r<0.40$); fair ($r=0.40-0.59$); good ($r=0.60-0.74$) and excellent reliability ($r\geq 0.75$) [30].

MDC₉₅ was calculated using the formula $MDC_{95} = SEM * \sqrt{2} * 1.96$.

For asymptomatic subjects, reliability of bilateral measurements was calculated (N=52 knees) whereas for KOA patients, the affected leg(s) (N=12 knees) were taken into consideration.

RESULTS

Baseline characteristics of eight symptomatic KOA patients and 26 healthy controls are presented in Table 1. Groups were comparable with respect to age, weight, height and BMI. Moderate disability was reported by the KOA group.

Table 1. Baseline characteristics of the study population

Baseline characteristics	Subjects with symptomatic KOA <i>n</i> = 8	Subjects without symptomatic KOA <i>n</i> = 26
Age, years ^b	68 (11)	58 (15)
Weight, kg ^b	77.5 (16.0)	75.0 (15.0)
Height, cm ^a	168 (10)	171 (8)
BMI, kg/m ² ^a	26.3 (3.5)	25.6 (2.9)
Male/female ^c	4/4 (50%/50%)	9/17 (35%/65%)
Pain and disability, LAI (0-24) ^a	7 (3) (Range: 3-11)	

KOA = knee osteoarthritis; BMI = Body Mass Index

Data are presented as Mean (SD)^a, Median (IQR)^b or Frequency (%)^c.

Table 2 presents proprioceptive accuracy of both groups, including interrater reliability analysis.

Intrarater reliability is presented in Table 3.

Table 2. Interrater reliability

			Rater 1 Mean (SD)	Rater 2 Mean (SD)	Difference between raters (<i>P</i>-value)	ICC (95% CI)	SEM	MDC₉₅
Subjects without symptomatic KOA (52 knees)	KJPS test	repositioning error 70° (°)	10 (5)	9 (5)	0.04†	0.81 (0.66-0.89)	2	6
		repositioning error 45° (°)	6 (4)	4 (3)	0.00†	0.68 (0.39-0.82)	2	6
		repositioning error 20° (°)	2 (2)	2 (2)	0.79	0.28 (0.00-0.59)	2	5
		repositioning error All (°)	6 (3)	5 (3)	0.00†	0.82 (0.65-0.91)	1	3
	KFS test	reproducing error 25% (N)	14.0 (11.9)	19.7 (19.7)	0.08	0.00 (0.00-0.39)	16.9	46.7
		reproducing error 50% (N)	14.7 (9.5)	20.3 (17.2)	0.04†	0.15 (0.00-0.50)	13.1	36.2
		reproducing error 75% (N)	23.1 (14.9)	19.0 (12.7)	0.12	0.17 (0.00-0.52)	12.7	35.1
		reproducing error All (N)	17.2 (7.3)	19.7 (14.0)	0.26	0.08 (0.00-0.47)	10.7	29.6
Subjects with symptomatic KOA (12 knees)	KJPS test	repositioning error 70° (°)	10 (6)	8 (5)	0.46	0.71 (0.01-0.92)	3	8
		repositioning error 45° (°)	7 (5)	6 (5)	0.26	0.92 (0.72-0.98)	1	4
		repositioning error 20° (°)	2 (2)	2 (2)	0.78	0.45 (0.00-0.85)	2	4
		repositioning error All (°)	6 (3)	6 (3)	0.28	0.88 (0.59-0.96)	1	3
	KFS test	reproducing error 25% (N)	20.7 (19.3)	21.7 (15.5)	0.86	0.54 (0.00-0.87)	11.6	32.2
		reproducing error 50% (N)	29.9 (20.2)	23.7 (19.0)	0.40	0.35 (0.00-0.82)	15.6	43.3
		reproducing error 75% (N)	18.1 (10.4)	21.0 (14.8)	0.58	0.10 (0.00-0.75)	12.0	33.1
		reproducing error All (N)	22.9 (12.6)	22.1 (9.3)	0.84	0.53 (0.00-0.87)	7.4	20.6

KOA = knee osteoarthritis; KJPS = Knee Joint Position Sense; KFS = Knee Force Sensation; ICC = Intraclass Correlation Coefficient; CI = Confidence Interval; SEM = Standard Error of Measurement (for KJPS test (°); for KFS test (N)); MDC₉₅ = Minimal Detectable Change with 95% CI (for KJPS test (°); for KFS test (N))
 ICC-values < 0.00 have been transformed to 0.00

The *P*-value corresponds to a Paired t-test. †Significant difference between groups (*P* < 0.05)

Table 3. Intrarater reliability

			<u>Rater 1</u>			<u>Rater 2</u>		
			ICC (95% CI)	SEM	MDC₉₅	ICC (95% CI)	SEM	MDC₉₅
Subjects without symptomatic KOA (52 knees)	KJPS test	repositioning error 70° (°)	0.66 (0.40-0.81)	3	9	0.77 (0.60-0.87)	3	7
		repositioning error 45° (°)	0.80 (0.65-0.89)	2	6	0.65 (0.40-0.80)	2	5
		repositioning error 20° (°)	0.23 (0.00-0.55)	2	6	0.51 (0.14-0.72)	2	5
		repositioning error All (°)	0.76 (0.57-0.86)	2	4	0.79 (0.64-0.88)	1	4
	KFS test	reproducing error 25% (N)	0.52 (0.16-0.72)	10.0	27.7	0.78 (0.61-0.87)	10.2	28.3
		reproducing error 50% (N)	0.49 (0.12-0.70)	8.4	23.3	0.77 (0.61-0.87)	9.1	25.3
		reproducing error 75% (N)	0.00 (0.00-0.38)	22.3	61.8	0.31 (0.00-0.61)	13.7	37.9
		reproducing error All (N)	0.00 (0.00-0.38)	10.8	29.9	0.81 (0.67-0.81)	6.6	18.3
Subjects with symptomatic KOA (12 knees)	KJPS test	repositioning error 70° (°)	0.94 (0.81-0.98)	2	4	0.73 (0.15-0.92)	3	8
		repositioning error 45° (°)	0.70 (0.00-0.91)	3	8	0.95 (0.85-0.99)	1	3
		repositioning error 20° (°)	0.65 (0.00-0.90)	1	4	0.79 (0.26-0.94)	1	3
		repositioning error All (°)	0.93 (0.77-0.98)	1	3	0.80 (0.30-0.94)	1	4
	KFS test	reproducing error 25% (N)	0.45 (0.00-0.83)	17.9	49.5	0.77 (0.20-0.94)	8.1	22.5
		reproducing error 50% (N)	0.65 (0.00-0.90)	13.7	38.0	0.77 (0.05-0.94)	10.0	27.8
		reproducing error 75% (N)	0.34 (0.00-0.81)	10.8	30.0	0.55 (0.00-0.87)	11.8	32.7
		reproducing error All (N)	0.58 (0.00-0.88)	9.6	26.7	0.78 (0.23-0.94)	4.8	13.2

KOA = knee osteoarthritis; KJPS = Knee Joint Position Sense; KFS = Knee Force Sense; ICC = Intraclass Correlation Coefficient; CI = Confidence Interval; SEM = Standard Error of Measurement (for KJPS test (°); for KFS test (N)); MDC₉₅ = Minimal Detectable Change with 95% CI (for KJPS test (°); for KFS test (N))
 ICC-values < 0.00 have been transformed to 0.00

DISCUSSION

We aimed to assess reliability of two proprioceptive tests. Measuring KJPS using an AI shows good to excellent inter- and intrarater reliability in KOA patients and healthy subjects. Measuring KFS using a HHD shows poor to fair interrater and poor to excellent intrarater reliability.

For KJPS, results show that repositioning error is position dependent and larger when tested in 70° than in 45° flexion (for healthy subjects $P<0,01$; for KOA subjects not significant) or 20° flexion (for both groups $P<0,01$). The error was larger when tested in 45° than in 20° flexion (for both groups $P\leq 0,01$ (rater 1) or not significant (rater 2)). Similar to previous findings [14], results indicate more proprioceptive accuracy in more extended positions (20° flexion). Measuring KJPS in midrange positions (45° and 70° flexion) might be more challenging and more useful to discriminate between KOA patients who present or lack potential proprioceptive disturbances. Future studies may explore these hypotheses.

With the exception of the 20° flexion position (inter ICCs 0.28-0.45; intra ICCs 0.23-0.79), results indicate good to excellent reliability (inter ICCs 0.68-0.92; intra ICCs 0.65-0.95) with low spreading of measurement errors (SEMs 1°-3°).

SEM and MDC_{95} are smallest measuring mean repositioning error of all six tests together (SEM 1° - MDC_{95} 3°-4°), indicating that this is clinically the most useful method. So, we recommend clinicians to measure KJPS with an AI in three test positions (twice in each position) and calculate the mean repositioning error of all six tests together.

SEMs can be used as an estimate of error of a single measurement score. It provides clinicians with 95% confidence that the true measurement score lies between 2 SEMs from the measurement made (2° error associated with the method used). SEMs can also be used to calculate MDC_{95} , which can be of great value when using repeated measures. When clinicians measure a change in repositioning error larger than MDC_{95} in KOA patients (4°) (pre and post therapy measurement), they can be 95% sure that this change is larger than the measurement error and thus true change has occurred.

KFS was measured with a HHD, with evaluation of three target values. Overall, intrarater reliability was poor to excellent in healthy (ICCs 0.00-0.81) and in KOA subjects (ICCs 0.34-0.78) and interrater reliability was poor in healthy (ICCs 0.00-0.17) and poor to fair in KOA subjects (ICCs 0.10-0.54). Intrarater reliability was higher for rater 2 (ICCs 0.31-0.81) compared to rater 1 (ICCs 0.00-0.65), which indicates that reliability of the KFS test might be rater-dependent.

Some limitations should be addressed. Both raters underwent the same three-hours training, but it might be possible that they differed in skills or personal characteristics, explaining reliability differences. Previous researchers used three to five trials to generate reliable values of proprioception tests [24]. Performing only two repetitions might have been insufficient to reach a reliable mean value. Furthermore, some difficulties came up to the investigators performing KFS tests. Using the HHD the investigator has to resist muscle force with maximal wrist dorsiflexion which was sometimes painful, especially performing repeated measurements. Factors such as inadequate examiner strength and excessive patient strength have been reported as limitations in previous studies [31]. In future reliability studies, it might be useful to employ a modified HHD protocol with fixed instrumentation (i.e. belt or strap) [32, 33]. Training longer than the used three-hours could also be encouraged.

Based on our results, we do not recommend the use of KFS test to clinicians. Calculated SEMs range from 4.8N to 22.3N, indicating that clinicians can only be confident that a change in reproduction error in KOA patients (pre and post therapy measurement) is true change when it exceeds 49.5N.

In general, intrarater ICCs were higher in KOA patients compared to healthy controls. As all participants were tested in a randomized order, there was no possibility of a learning effect that could explain this observation. Lower variability in proprioceptive accuracy found in healthy controls compared to KOA subjects might explain the lower ICCs.

In conclusion, measuring KJPS in different test positions using an AI and calculating the mean repositioning error is reliable and can be used in clinical practice. Further research is needed to determine validity and discriminative ability of this measurement technique in different knee pain populations and to investigate diagnostic accuracy of the test.

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FIGURE LEGENDS

Figure 1 : Illustration of the three test positions for the knee joint position sense (KJPS) test

Figure 2 : Resting position knee joint position sense (KJPS) test

Figure 3 : Resting position knee force sense (KFS) test