Physical Therapy in Sport 36 (2019) 43–50

Contents lists available at ScienceDirect

Physical Therapy in Sport

journal homepage: www.elsevier.com/ptsp

Original Research

The decline step-down test measuring the maximum pain-free flexion angle: A reliable and valid performance test in patients with patellofemoral pain

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ARTICLE INFO

Article history:
Received 23 August 2018
Received in revised form
14 December 2018
Accepted 14 December 2018

Keywords:
Patellofemoral pain
Reliability
Validity
Decline step-down test
Pain-free flexion angle
Performance-test

ABSTRACT

Objectives: Patients with patellofemoral pain (PFP) experience pain while descending stairs. To date no reliable and valid performance-test exists to assess the maximum pain-free knee flexion angle (MPFFA) as outcome measure during a step-down task. Therefore, the intra- and inter-observer reliability and construct validity of the decline step-down test (DSDT) measuring the MPFFA in patients with PFP were evaluated.
Design: Reliability and construct validity.
Setting: Private practices in Nijmegen and Utrecht, the Netherlands.
Participants: Patients with PFP.
Main outcome measures: The reliability was assessed by repeated measurements of the MPFFA during the DSDT. The construct validity was assessed by correlating the measurements on the DSDT with the Anterior Knee Pain Scale Dutch Version (AKPS-DV) based on a pre-set hypothesis.
Results: Thirty-two participants (forty-eight knees) were eligible for inclusion. The intraclass correlation coefficient (ICC) for intra-observer reliability was $ICC_{2,1} = 0.83$ and $ICC_{2,1} = 0.85$ for inter-observer reliability. The 95% limits of agreement (LoA) showed a width of 27.56° for intra-observer reliability and a width of 24.42° for inter-observer reliability. There was an average positive correlation between the DSDT and the total score on the AKPS-DV ($r_s = 0.31$, $p = 0.030$).
Conclusion: The DSDT measuring the MPFFA is reliable and valid in patients with PFP.

1. Introduction

Patellofemoral pain (PFP) is a common and often longstanding musculoskeletal condition in clinical practice (Barton & Crossley, 2016; Collins et al., 2013; Lack, Neal, De Oliveira Silva, & Barton, 2018; M S; Rathleff et al., 2015; Michael S; Rathleff, Rathleff, Olesen, Rasmussen, & Roos, 2016; Smith et al., 2018). PFP accounts for 11–17% of all knee pain related visits to general practice and 25–40% of those to sports injury clinics (Crossley, van Middelkoop et al., 2016). Up to 40% of patients with a diagnosis of PFP had persistent knee symptoms at 6-year follow-up (Kastelein et al., 2015).

The vast majority (88%) of patients with PFP experiences pain while stair climbing (Post & Fulkerson, 1994). Stair climbing is one of the most painful activities of daily living for patients with PFP (Brechter & Powers, 2002). Descending stairs is especially challenging for the stability of the knee (Selfe, 2000) because of loss of the screw home mechanism, passive stretching of the m. quadriceps femoris, higher knee flexion angles and the increased speed due to gravity (Shinno, 1971). Therefore it is concluded that

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https://doi.org/10.1016/j.ptsp.2018.12.007
1466-853X/

patellofemoral joint reaction forces are higher during descending stairs when compared with ascending stairs (Brechter & Powers, 2002).

PFP is considered when there is pain around or behind the patella that is aggravated by at least one activity that loads the patellofemoral joint with weight-bearing, such as squatting, stair climbing, jogging, running, hopping and jumping (Crossley, Stefanik, et al., 2016). Special orthopedic tests have little additional value in the diagnostic process, as these suffer from low reliability and validity (Crossley, Stefanik, et al., 2016).

Instruments evaluating the treatment effects include pain scores like the visual analogue scale for worst pain (VAS-W), usual pain (VAS-U) and least pain (VAS-L) (Green, Liles, Rushton, & Kyte, 2017). Specific patient related outcome measures (PROMs) like the Anterior Knee Pain Scale (AKPS) (Kujala et al., 1993) also were developed. These PROMs are considered relevant (Patrick et al., 2007) but may not always target the relevant problems at the individual level. Non-athletes for example may achieve high scores on the AKPS if they are successful copers in activities of daily living. The (un-) consciously avoiding of activities of daily living or use of compensational strategies will potentially underestimate pain and disability when assessed by PROMs (Crossley, Cowan, Bennell, & McConnell, 2004). Self-administered questionnaires do not quantify these problems.

Clinical performance-tests that evaluate knee function may suit these demands. They are important for analysis, set-up of treatment strategy and evaluation of treatment sessions and can thereby assist in improving rehabilitation strategies. Different reliable performance-tests can be used to assess strength and postural control in patients with PFP (Loudon, Wiesner, Goist-Foley, Asjes, & Loudon, 2002; Otterbach, 2015; Powers, 2003; Sanchis-Alfonso, McConnell, Monllau, & Fulkerson, 2016). Since the single leg squat task shows different movement patterns in the frontal and transverse plane compared to the step down task (Lewis, Foch, Luko, Loverro, & Khuu, 2015) we consider the step down task more appropriate to patients with PFP as it simulates descending stairs more accurately.

In line with previous mentioned demands, new clinical procedures are needed to support clinicians in evaluating knee function in patients with PFP. To date, no reliable performance-test exists that evaluates pain-free knee function in patients with PFP during a step-down movement simulating descending stairs.

The present study aims to evaluate the intra- and inter-observer reliability and construct validity of the step-down test measuring the maximum pain-free flexion angle as a performance-based outcome measure in patients with PFP.

2. Methods

2.1. Study protocol

This study complied with the requirements of the Declaration of Helsinki (World Medical Association, 2013). The study protocol was approved by the local medical ethics committee (HAN – University of Applied Sciences, Nijmegen, The Netherlands) under number EACO 17.10/83. All patients signed informed consent prior to participation. The parents of patients aged <18 signed the informed consent as well.

Reliability (both intra- and inter-tester measures) and construct validity were studied by patients undertaking performance tasks and questionnaires.

A power analysis with g*power (version 3.1.9.2) prior to the study was performed. Based on the literature effect sizes >0.90 could be expected (Ferriero et al., 2013). A lower effect size of 0.75 was chosen to create some contingency. With a pre-set alpha-level of 0.05 and a power of 0.80 (hence a beta-level of 0.20) the minimum sample size was calculated to be n = 9.

2.2. Participants

Patients with PFP were recruited across four private clinics in the Netherlands and from the HAN-University of Applied Sciences in Nijmegen (NL) in November and December 2017.

2.3. Inclusion criteria

Inclusion criteria were:

- Age: 16–40 years.
- Pain:
  - Experienced around and/or behind the patella.
  - Aggravated by stair ambulation.
  - Lasting for at least six weeks.
  - Anterior knee pain episode not as a result from trauma.
- No clinical suspicion of specific knee conditions present.
- No previous knee surgery in the patients' history.
- No clinical suspicion of serious pathology (like malignancy etc.) present.

An experienced physiotherapist (>10 years) specialized in treating patients with PFP (*MO*) checked all participating patients for eligibility through history taking and careful physical examination (preventing any symptom provocation and sensitization of the knee).

2.4. Decline step-down test

Two step boxes (Reebok, Canton, MA, USA) were placed in a decline position (20°, assessed with a digital inclinometer (Baseline, White Plains, NY, USA)) to prevent ankle dorsiflexion being the limiting factor during the step-down task (Fig. 1) (Kongsgaard et al., 2009; Purdam et al., 2004).

The Decline Step-Down Test (DSDT) was then performed on the lower end of the decline step box (height 20 cm) with the toes aligned to the end of the box. The observer palpated the greater trochanter and the patient was instructed to keep the fingertips of the ipsilateral hand on the greater trochanter. The patient was allowed to get support with one fingertip of the contralateral hand against the wall to prevent postural and movement control issues or fear. The patient received instruction to simulate descending

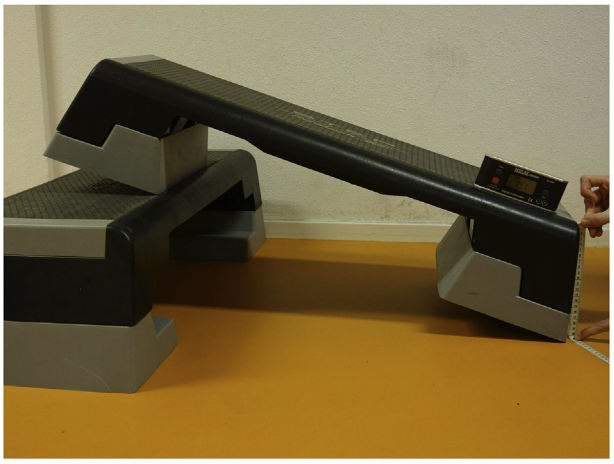

Fig. 1. Step box set up in 20° decline position and 20 cm height on the lower end.

stairs only in the pain-free flexion range by moving the contralateral limb down and forward by flexing the ipsilateral knee as far as pain-free possible (Fig. 2).

The patient was instructed to keep the ipsilateral knee above the foot, preventing excessive knee valgus. Patients with bilateral symptoms performed the DSDT with both knees, always starting with the right knee first.

3. Clinical measures

3.1. Goniometer

The Maximum Pain-Free Flexion Angle (MPFFA) of the knee was measured with a photographic-based-goniometry app called Dr.Goniometer (DrG) (CDM s.r.l., Milano, Italy), installed on an iPad Air 2 (Apple Inc., Cupertino, California, USA). The observer took a photo of the limb while the camera was positioned parallel to the body's sagittal plane (Vercelli, Sartorio, Bravini, & Ferriero, 2017). An inclinometer as part of the DrG guided the observer to find the perpendicular line to the ground. After saving the photo the observer dragged three red cursors connected by two lines to the body landmarks. The landmarks were the lower point of the malleolus lateralis, half the distance between patella and the hollowest point of the knee cavity and the middle finger of the patient marking the center of the greater trochanter (Fig. 3).

This app is reliable and valid for measuring knee flexion angles (Ferriero et al., 2013; Milani et al., 2014). Observers were blinded for the results of the DSDT measures by a post-it on the iPad covering the numeric output of the DrG app (Fig. 3). After the test the iPad was handed over to a third observer (AW) who registered the displayed maximum pain-free flexion angle. Patients were blinded for their test results by withholding information by the same third assessor until last measurement was undertaken.

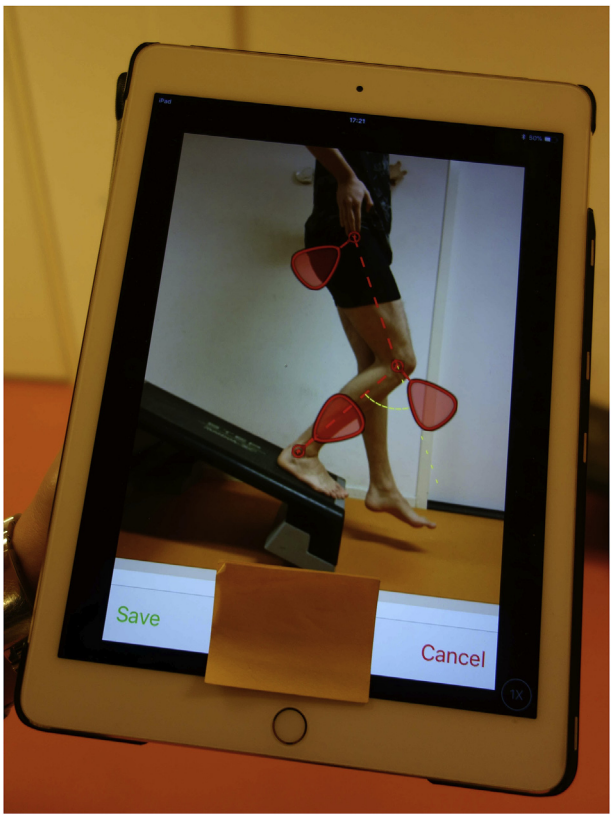

Fig. 3. Blinded measurement with iPad Air 2 and DrG app measuring flexion angle of the right knee.

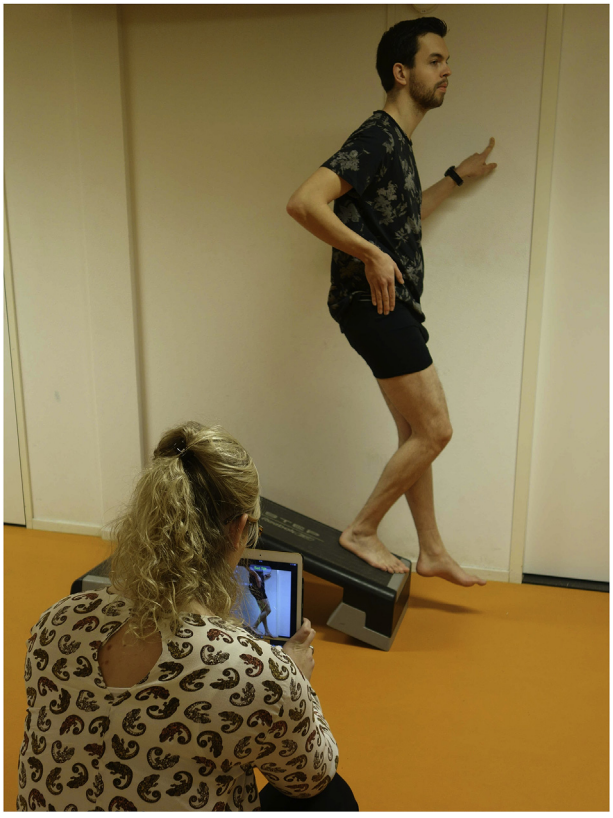

Fig. 2. Subject positioning at DSDT. The subject points the fingertips of the ipsilateral hand towards the greater trochanter and is allowed to get wall support with one fingertip of the contralateral hand.

3.2. Anterior Knee Pain Scale Dutch Version (AKPS-DV)

The AKPS is a 13-item patient related outcome measure (PROM) (Green et al., 2017). The items were scored on 3–5 response options, depending on the item. To each response a score is allocated. The scores range between 0 and 10. The overall score was then normalized on a 0–100 score where 100 indicates no problems at all and 0 indicates the maximum of knee problems experienced (Kujala et al., 1993). Two studies reported reliability of ICC3,1 = 0,81-0,90 (Bennell, Bartam, Crossley, & Green, 2000; Crossley, Bennell, Cowan, & Green, 2004) and moderate structural validity (r = 0.58) (Bennell et al., 2000). The Dutch Version of the AKPS (AKPS-DV) is reliable with a test-retest reliability comparable to the English version (ICC = 0.98) and valid with an internal consistency of 0.78–0.80 (Ummels, Lenssen, Barendrecht, & Beurskens, 2015). Patients answered the AKPS-DV after inclusion and before conducting the DSDT.

3.3. Numeric Pain Rating Scale (NPRS)

To make sure that patients performed a pain-free DSDT they were asked to rate potential knee pain on a 10-point Numeric Pain Rating Scale (NPRS) where 0 is no pain. At the maximum knee flexion position where the NPRS remained 0 the observer took the picture with the iPad.

3.4. Observers

A performance-test that addresses a category of patients that is highly prevalent should be feasible to all physical therapists. To avoid the interference of clinical experience resulting in good reliability outcomes, we chose to have two physical therapy students in their last year of study (KB and FK) as observers. Students can reliably measure knee flexion angles (Ferriero et al., 2013; Weeks, Carty, & Horan, 2012). They had two training sessions together for the test procedures.

After inclusion patients conducted the step-down test four times with 10 min rest in between. Patients did get standardized instructions to slowly bend their knee, simulating a stair descent, until they started to feel knee pain. Then they were asked to quantify the maximum pain free flexion angle on a NPRS. Patients always started with the first test with observer 1 (*KB*), followed by the first test with observer 2 *(FK)*, followed by the second test with observer 1 and finishing with the second test with observer 2. Observers 1 and 2 assessed independently the DSDT and were not aware of each other's test results. The instructional procedure was standardized and documented to ensure that both observers gave identical information and instructions. In a pilot with twelve participants without PFP, test procedure and instruments with both observers were evaluated. The intra- and inter-observer reliability was excellent. Additional tests with four patients with PFP prior to this study revealed that no sensitization of the knee resulting in a gradually decrease in MPFFA would occur if a rest of 10 min between tests is applied.

3.5. Statistical analysis

Normality of the data distribution was investigated using the Kolmogorov-Smirnov test. Intra-observer reliability was assessed by calculating the Intra-Class-Correlation Coefficient $ICC_{2,1}$ two-way random effects model for absolute agreement. Inter-observer reliability was assessed by calculating the mean of both measurements from each observer and comparing the observers' means between observers. For inter-observer reliability, the $ICC_{2,1}$ two-way random effects model for absolute agreement was used. The ICC is a good indicator for reliability (Bruton, Conway, & Holgate, 2000; de Vet, Henrica C W; Terwee, Caroline B.; Mokkink Lidwine B.; Knol, 2017; Rankin & Stokes, 1998) with values from 0.0 to 0.2 indicating slight agreement, 0.21 to 0.40 indicating fair agreement, 0.41 to 0.60 indicating moderate agreement, 0.61 to 0.80 indicating substantial agreement, and 0.81 to 1.0 indicating almost perfect agreement (Landis & Koch, 1977). ICCs >0.75 are indicated as good for inter-observer reliability (Portney & Watkins, 2015) and above 0.90 are deemed appropriate for individual clinical application (de Vet, Henrica C W; Terwee, Caroline B.; Mokkink Lidwine B.; Knol, 2017).

The measurement error as indicator of the measurement's precision was assessed by the standard error of measurement (SEM) and calculated according to the formula: SD x $\sqrt{}$(1-ICC), the SD being the standard deviation from mean scores and ICC for intra- and inter-observer reliability (de Vet, Henrica C W; Terwee, Caroline B.; Mokkink Lidwine B.; Knol, 2017; Portney & Watkins, 2015). The smallest detectable change (SDC) was then calculated as SEM x 1.96 $\times$ $\sqrt{2}$ at an individual level (SDC_{ind}) and SEM x 1.96 $\times$ $\sqrt{2}/\sqrt{n}$ at the group level (SDC_{group}) (Weir, 2005).

A Bland-Altman limits of agreement (LoA) analysis was carried out to visually quantify the measurement error (Bland, 1986). The standard deviation (SD) of differences between measurements was calculated and then multiplied by 1.96 to obtain the 95% random error component (LoA).

To assess the construct validity, we hypothesized that a positive correlation between the DSDT and the AKPS-DV ($r = 0.3–0.5$) would be found. This was formulated based on the assumption that a larger MPFFA is associated with a better patient reported outcome score. Therefore, correlation between the mean of all four measurements of the DSDT (number of included knees) and the corresponding total score of the AKPS-DV was calculated by using the Spearman's correlation coefficient (r_s). An $r_s < 0.3$ is assumed to be a weak correlation, between 0.3 and 0.6 an average correlation, and between 0.6 and 0.8 a strong correlation (de Vet, Henrica C W; Terwee, Caroline B.; Mokkink Lidwine B.; Knol, 2017).

A critical level of $p < 0.05$ was considered statistically significant. Statistical analyses were performed using the SPSS software package version 25.0 (SPSS Inc., Chicago, IL, USA).

4. Results

Of thirty-six patients who were invited four patients were excluded because of history of trauma or other specific knee conditions (e.g. meniscus and jumpers knee). Thirty-two patients with PFP were ultimately included. Twenty-seven patients (84%) were women and sixteen (50%, eight women and eight men) had bilateral symptoms. Demographic data are presented in Table 1.

All patients ($n = 32$) conducted the four repeated measurements as planned (forty-eight PFP knees). There were no drop-outs.

Data were normally distributed. The ICC analysis for observer 1 and 2 and the overall analysis for intra-observer reliability revealed almost perfect intra-observer reliability with $ICC_{2,1}$ for absolute agreement of 0.83 (95% confidence interval [CI] = 0.75–0.88) for overall intra-observer reliability (Table 2).

Likewise, inter-observer reliability was almost perfect, with $ICC_{2,1}$ for absolute agreement of 0.85 (95% CI = 0.75–0.91). The standard error of measurement was 2.72° and the minimal detectable change at groups level was 1.10° and at individual level 7.53° (Table 2).

The Bland-Altman plot for intra-observer reliability showed a mean difference between repeated measurements of 0.20° and the 95% LoA were between −13.58° and 13.81° (Fig. 4).

The Bland-Altman plot for inter-observer reliability showed a mean difference between observers of 1.20° and the 95% LoA were between −11.01° and 13.41° degrees (Fig. 5).

The mean score on the AKPS-DV was 74.50 points indicating pain and disability. The mean MPFFA of all four measurements was 38.67° (Table 3).

Correlation between the DSDT and the AKPS-DV was $r_s = 0.31$ with $p = 0.030$ revealed an average but statistically significant correlation (Fig. 6).

5. Discussion

In this study we found the DSDT measuring the MPFFA to be reliable and valid in patients with PFP. This is a relevant outcome parameter as the vast majority of these patients suffer problems going up and down a flight of stairs (Post & Fulkerson, 1994).

We found the ICC values for intra- and inter-observer reliability to be almost perfect (≥0.83) indicating the applicability of the test

Table 1
Patients' characteristics (n = 32) presented as mean (±SD, range).

	Mean (SD; range)
Age (y)	22.6 (4.2; 18–39)
BMI (kg/m^2)	23.1 (5.0; 17,6–42,9)
Symptom duration (mos)	47.0 (43.0; 1,5–144)

Abbreviations: SD, standard deviation; y, year; BMI, body mass index; kg/m^2, kilogram per square meter of body length in meters; mos, month.

Table 2
Clinimetric properties of the DSDT. SEM and SDC_{group} and SDC_{ind} present degrees of knee flexion at testing.

	ICC (95%CI)	p value	SEM (deg)	SDC_{group} (deg)	SDC_{ind} (deg)
Intra-observer reliability					
Observer 1	0.78 (0.63–0.87)	<0.001*	3.38	1.35	9.37
Observer 2	0.86 (0.77–0.92)	<0.001*	2.59	1.04	7.18
Overall	0.83 (0.75–0.88)	<0.001*	2.72	0.61	7.54
Inter-observer reliability	0.85 (0.75–0.91)	<0.001*	2.72	1.10	7.53

Abbreviations: DSDT, decline step-down test; ICC, intraclass correlation coefficient; CI, confidence interval; SEM, standard error of measurement; SDC_{group}, smallest detectable change at group level; SDC_{ind}, smallest detectable change at individual level; deg, degrees. * = indicates p value reaches level of statistical significance ($p < 0.05$).

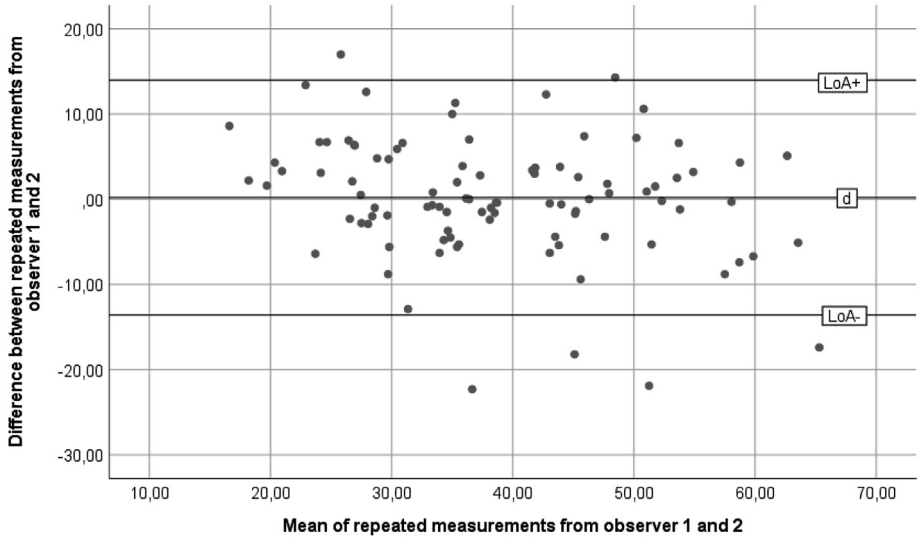

Fig. 4. Bland-Altman plot for intra-observer reliability.
Plot of difference between repeated measurements against mean from repeated measurements (in degrees) with mean difference "d" and 95% limits of agreement (LoA+ and LoA-).

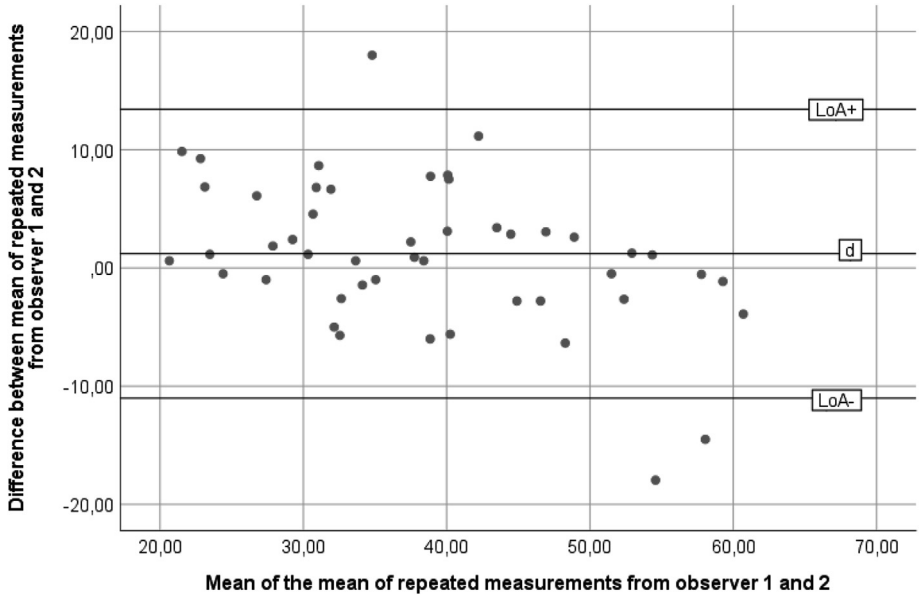

Fig. 5. Bland-Altman plot for inter-observer reliability.
Plot of difference between mean of repeated measurements from two observers against mean from measurements (in degrees) with mean difference "d" and 95% limits of agreement (LoA+ and LoA-).

in clinical practice. The ICC values for intra- and inter-observer reliability found in the present study are slightly lower than in the study of Ferriero et al. (Ferriero et al., 2013). The higher ICC values for intra- and interobserver reliability of both 0.99 (95% CI = 0.99–0.99) are a result of them evaluating repeated measurements on healthy participants in a sitting position with the

Table 3
AKPS-DV and MPFFA scores and the results of construct validity testing.

	Median/Mean	Range/SD	Min	Max
AKPS-DV, 0–100	74.50	48.00	43.00	91.00
MPFFA, deg	38.67	11.90	12.30	74.00
r_s AKPS-DV/MPFFA	0.31*	p = 0.030		

Abbreviations: AKPS-DV, Anterior Knee Pain Scale Dutch Version ordinal scale with 100 points indicating no disability; Median and range as difference between minimum (Min) and maximum (Max) for AKPS-DV; MPFFA, maximum pain-free flexion angle with mean and standard deviation for MPFFA; deg, degrees; r_s, Spearman correlation coefficient; * = indicates p value reaches level of statistical significance ($p < 0.05$).

knee in a fixed position. In the present study ICC values for intra- and inter-observer reliability are lower because of more sources of error. We show that a single measure can be used reliably, increasing user friendliness.

Measurement errors as indicators for precision with SEM (2.72°), SDC_{group} (1.10°) and SDC_{ind} (7.53°) are acceptable, indicating that any change of <7.53° in individual measurements are due to error. The mean difference on the Bland-Altman plots (1.20°) were very small implying a small systematic error component.

The random error component expressed by the lower and upper 95% LoA showed a width of 27.39° (95%LoA = −13.58°-13.81°) for intra-observer reliability and a width of 24.42° (95%LoA = −11.01°-13.41°) for inter-observer reliability. The random error component consists of artificial and biological sources of error. Artificial sources of error are due to the measurement process of using the DrG app, for instance when taking the picture the iPad has to be held both parallel and perpendicular to the sagittal plane and secondly when placing the cursors in the photo after taking. Previous studies on reliability of measuring knee flexion angles in healthy subjects with the DrG app found perfect agreement between observers (Ferriero et al., 2013; Milani et al., 2014).

Thus, the lower ICC values and greater LoA width found in the present study may be caused mainly by a biological source of error, for example difficulties of patients in repeatedly finding their individual MPFFA, because they did not experience on/off pain but a rather diffuse range between no pain rated NPRS 0 and NPRS ≠ 0. When measuring the MPFFA in clinical practice results of the DSDT in patients with a diffuse range of pain should we interpreted with caution.

There was no trend in either increasing flexion ranges due to learning effects nor decreasing flexion ranges due to sensitization during the four measurements indicating that test procedure of the DSDT, blinding of the patients and rest interval between measurements were appropriate.

Physical therapy students, clinically inexperienced but trained on performing the test procedures conducted the DSDT. The reliability was almost perfect. It is unclear whether or not the random error component is smaller when experienced physical therapists conduct the DSDT. We expect this not to be the case since the results of our pilot study on participants without PFP showed reliable results. Furthermore, as discussed, the primary random error component is biological and not artificial in nature. Nevertheless, this should be confirmed in future studies.

Construct validity expressed by our pre-set hypothesis was confirmed. Correlation between mean MPFFA and AKPS-DV score was average ($r_s = 0.31$) but statistically significant ($p = 0.030$). Pain and disability as part of PFP are highly subjective and multidimensional in nature. Therefore a single objective parameter like the MPFFA will not show strong correlation. We suggest that measuring the MPFFA during the DSDT is of additional value together with other PROMs like the AKPS to get a more comprehensive profile of pain and disability in patients with PFP.

The mean MPFFA in the present study was 38.67°. A mean critical angle of 61.3° where healthy participants (n = 100) lost control during a step-down task was previously reported (Selfe, 2000). When this is considered a reference value, PFP patients in this study had a loss of 37% in maximum pain-free knee flexion during the DSDT. Therefore, an additional outcome in patients with unilateral PFP could be comparing the MPFFA for the limb with PFP with the critical angle of the pain-free limb (limb symmetry index for PFP).

In a randomized clinical trial evaluating effectiveness of taping, stretching and exercise in patients with PFP, the MPFFA during a step-down task has been used to evaluate treatment effects (Mason, Keays, & Newcombe, 2011). The mean MPFFA of forty-one patients (sixty PFP knees) was 48.5° before start of the interventions. That study did not provide information about reliability or validity of the step-down procedure used. To our knowledge, the present study is the first evaluating the reliability and validity of the MPFFA as performance-based outcome measure on patients with PFP.

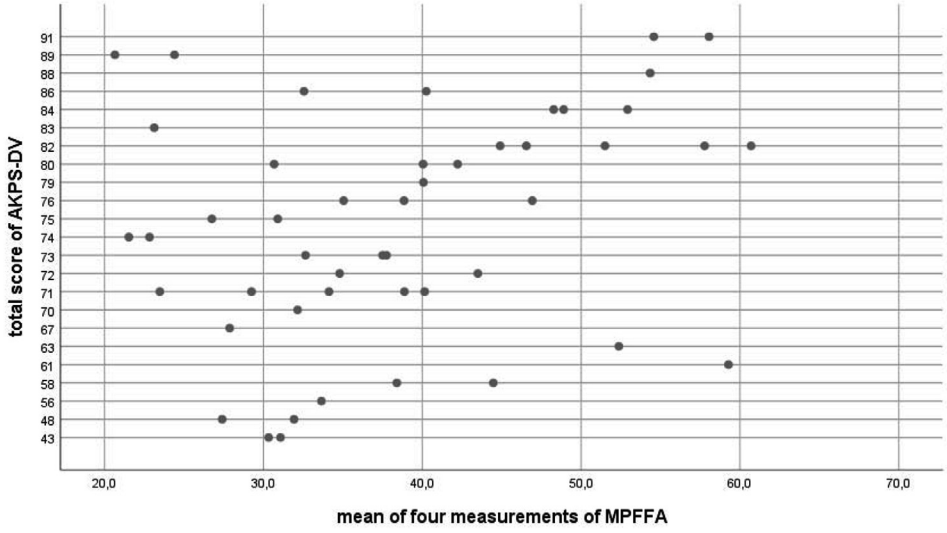

Fig. 6. Scatterplot of MPFFA and AKPS-DV.
Mean of all four measurements of MPFFA on the x-axis and total score on the AKPS-DV on the y-axis.

In this study the step-down test was performed in a 20° decline position to prevent ankle dorsiflexion being the limiting factor. While this decline position reduces hip and ankle moments during the step-down test knee moments are increased due to higher ground reaction forces (Richards, Selfe, Sinclair, May, & Thomas, 2016; Zwerver, Bredeweg, & Hof, 2007). In patients with PFP these higher knee moments could cause higher patellofemoral joint compression and therefore could result in a lower MPFFA when compared with a step down in 0° decline position or more general while descending stairs.

The DSDT is easy to use, since the two step boxes are available in many of the clinical settings. Unfortunately the DrG app is only available on Apple devices. In the present study, an iPad Air 2 (9.7 inch, 2.048 × 1.536 pixels) was used. It is unclear what the effect on reliability using smaller iPad's or iPhones with lesser pixels would be. The DrG app is affordable and easily accessible via the Appstore (Apple Inc., Cupertino, California, USA) (Vercelli et al., 2017). The DSDT is considered safe for the patient because the set-up of the two steps is stable and located close to the wall. The physical therapist supports the patient while going into start-position there are no safety concerns for the patient.

Although this procedure was tested with this specific app, many such apps for photo/video analysis are widely available for different platforms (iOS, Android). Although not tested we expect these to show similar psychometric properties when applied according the described protocol (Milani et al., 2014).

Non-systematic observations suggest that the DSDT is also reliable in patients with PFP secondary to reconstruction of the anterior cruciate ligament and patients with jumpers knee if the level of irritability is acceptable. A high level of irritability could cause further sensitization of the anterior knee making the condition less stable and therefore will affect reliability and validity of the MPFFA as performance-based outcome measure negatively. Further research is needed to evaluate reliability and validity of the DSDT in these other painful conditions of the anterior knee.

6. Conclusion

The newly developed DSDT measuring the MPFFA as a performance-based outcome measure in patients with PFP is reliable and valid. Measuring the MPFFA during the DSDT adds value in creating a more comprehensive profile of pain and disability in patients with PFP and may be used in the evaluation of treatment strategies.

Conflict of Interest

None declared. The authors certify that they have no affiliations with or financial involvement in any organization or entity with a direct financial interest in the subject matter or materials discussed in the article. The authors received no financial support for conducting this research project.

Ethical approval

Obtained by the Ethical Scientific Advisory Board of the HAN – University of Applied Sciences (EACO 17.10/83), Nijmegen, the Netherlands. All participants signed informed consent prior to participation. The parents of patients aged <18 signed the informed consent as well. This study complied with the requirements of the Declaration of Helsinki.

Declarations of interest

None.

Data statement

Research data will be available.

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