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Reproducibility and Validity of the DynaPort KneeTest

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Objective. To determine the reproducibility and validity of the DynaPort KneeTest, a performance-based test that measures quality of movement of patients undergoing total knee replacement (TKR).

Methods. A total of 92 patients with osteoarthritis (OA) of the knee performed the KneeTest twice on the same day; 94 healthy controls performed the KneeTest once. During the test, 29 activities were performed with accelerometers attached to the body. Relevant functional parameters were extracted from the accelerometers. A selection of parameters was used to calculate activity scores, based on the ability of parameters to discriminate between patients and controls (regression analyses). Based on internal consistency analyses (Cronbach’s α), redundant activities were removed. Four cluster scores and a total KneeScore were calculated from the remaining activity scores. Reproducibility and validity of the cluster scores and the total KneeScore 2 were assessed.

Results. Based on internal consistency analyses, the test was reduced to 23 activities. Inter- and intraobserver reliability using intraclass correlation coefficients were 0.90 (0.83–0.94) and 0.95 (0.83–0.98), respectively. Limits of inter- and intraobserver agreement were –8.3 to 11.3 and –4.2 to 9.0. Construct validity was confirmed by expected correlations with the Western Ontario and McMaster University Osteoarthritis Index physical functioning (0.55), Medical Outcomes Study Short Form-36 Health Survey physical functioning (0.62), and Knee Society Score function (0.64).

Conclusion. The KneeTest is a useful performance-based measure for research in patients with knee OA undergoing TKR, with good reliability and validity. Further research is required to improve its usefulness for clinical practice.

KEY WORDS. Total knee replacement; DynaPort KneeTest; Osteoarthritis.

INTRODUCTION

Functioning is one of the key outcome measures for patients with osteoarthritis (OA) of the knee undergoing total knee replacement (TKR) (1). Functioning can be assessed either by performance-based measures (supervised by a health care professional), or by self-report questionnaires (completed by the patient). Both methods provide information about different aspects of functioning. Performance-based measures intend to measure what a patient can do, while self-report questionnaires measure what a person thinks he or she can do.

A number of arguments have been proposed in favor of both methods. For example, authors have argued that self-report questionnaires (2–5) are easier to use, less time consuming, less of a burden to patients, and cannot be influenced by observer bias (1,6). Performance-based measures are reported to be more objective and less influenced by patient expectations, culture, education, or cognitive impairments (2–5), but they measure functioning in an artificial situation (7,8). We recently showed that self-reported functioning, especially the Western Ontario and McMaster University Osteoarthritis Index (WOMAC) (9), is highly correlated with pain, whereas performance-based functioning is not (Terwee CB: unpublished observation). Because of these differences, it has been suggested that both performance-based measures and self-report questionnaires are required to comprehensively evaluate functioning in TKR (10,11).

Self-report questionnaires such as the WOMAC or the Medical Outcomes Study Short Form-36 Health Survey...
MATERIALS AND METHODS

Design. A cross-sectional study was performed in 2 hospitals, Gemini Hospital, Den Helder and Atrium Medical Centre, Brunssum, the Netherlands. Four test days in each hospital were organized. Preoperative and postoperative patients were asked to perform the DynaPort KneeTest (McRoberts) twice, and healthy controls were asked to perform the KneeTest once. Additional information was collected through a questionnaire and physical examination. The Medical Ethics Committee of the VU University Medical Center, Amsterdam approved the study protocol.

Research population. Inclusion criteria for patients were as follows: diagnosis of knee OA from an orthopedic surgeon; registered on the waiting list for a primary total or unicompact TKR, or had received a TKR 3 months to 5 years ago; able to speak and read Dutch; and have given written informed consent. Inclusion criteria for controls included no indication for TKR (i.e., no OA, rheumatoid arthritis, or severe trauma of the knee), no contraindication for (knee) surgery, between the ages of 45 and 90 years (the common age range for TKR), able to speak and read Dutch, and had given written informed consent.

A total of 96 patients (24 preoperative and 24 postoperative patients in each hospital) were recruited. In addition, 96 age- and sex-matched controls were recruited via patients, employees of the hospital, and acquaintances of the authors in the region of the 2 hospitals.

Procedures. Both patients and controls received standardized KneeTest instructions on video. Patients were randomized to either perform the KneeTest twice under supervision of the same physical therapists (intraobserver reliability) or under supervision of 2 different physical therapists (interobserver reliability). In each hospital, 3 different physical therapists supervised the KneeTest.

After each test the physical therapist was asked to give an overall rating of the patients’ quality of movement on a 5-point scale, based on their own interpretation of the quality of the patient performance. Between the 2 tests, patients completed a questionnaire, which consisted of the SF-36 (12), the WOMAC (9), and an overall question about quality of movement on a 5-point scale. A fourth physical therapist per hospital administered the Knee Society Score (KSS) (19,20). Controls performed the KneeTest once, and their age and sex were recorded.

KneeTest. Patients performed the 29 activities of the KneeTest (see Appendix A available at the Arthritis Care & Research Web site http://www.interscience.wiley.com/ijpages/0004-3591:1/suppmat/index.html) while wearing 6 acceleration sensors strapped around the trunk and the legs. The activities were categorized into 4 clusters: locomotion (walking), rising and descending (stair climbing or stepping up blocks), lifting and moving objects (carrying a bag or walking with a shopping trolley), and transfers (sitting down or picking up a weight). Standardized equipment was supplied such as blocks, stairs, and a slope.

Thirty functional parameters per activity (i.e., accelerations, angles, durations, step number, step frequencies, relative speed, and asymmetry) were extracted from the signals of the acceleration sensors (see Appendix B available at the Arthritis Care & Research Web site http://www.interscience.wiley.com/ijpages/0004-3591:1/suppmat/index.html). The values of these parameters were transformed into a score for each activity and a total functional score for the entire test (KneeScore), which is considered to be a measure of quality of movement. The extraction of the parameters and calculation of the KneeScore was performed at McRoberts Company using an automated procedure. The KneeTest has been previously described (13).

Scoring system. The scoring algorithm was modified from the method described by van den Dikkenberg et al (13). Scoring of the functional parameters was based on discrimination between patients and controls. We used
multiple logistic regression analyses, adjusted for age and sex, to select those functional parameters per activity that could significantly separate patients and controls. In advance, a preselection of parameters was made, based on 3 considerations: 1) gait parameters were excluded from the activities “stepping up blocks” and “sit down and stand up” (activities 9–14 and 17,18); 2) if 2 parameters had a high correlation (r > 0.90), the least conceptually-relevant parameter was excluded; and 3) only parameters with P < 0.25 in univariate linear regression analyses were included in the multivariate model (see Appendix C available at the Arthritis Care & Research Web site http://www.interscience.wiley.com/ipages/0004-3591:1/suppmat/index.html for a list of functional parameters).

For the selected parameters, we used norm-based scoring to calculate parameter scores, by subtracting mean parameter values for the control group from each patient’s value and dividing the difference by the SD of the control group. The parameter scores were averaged into a total activity score for each activity. If a parameter score was missing (e.g., due to a detached sensor), the activity score was calculated as the average of the available parameter scores. The activity scores were multiplied by 20 and added up by 50 to achieve positive scores. An activity score of 50 is therefore equal to the mean score of the controls, and an activity score of 30 implies that a person scores one SD below the mean of the patients was assigned, indicating that the patient had a bad score for that activity in comparison with the group of patients.

The activity scores were averaged into 4 cluster scores and a total KneeScore was calculated as the average of the 4 cluster scores. In the original KneeScore method described by van den Dikkenberg et al (13), the assignment of activities to clusters was based on conceptual considerations only. In our modified KneeScore (KneeScore 2), the activities were assigned slightly differently, based on internal consistency analyses (see below).

Assessment of measurement properties. Internal consistency. The Cronbach's alpha and item-total correlations were calculated to determine the internal consistency of the activities within the clusters. In case of a very high Cronbach’s alpha (>0.95), indicating that some activities were redundant (21), the Spearman-Brown formula (22) was used to assess the amount of activities that would be sufficient for adequate internal consistency. In case of a low Cronbach’s alpha (<0.70) or low item-total correlations (<0.40), the Spearman-Brown formula was used to remove activities with a low item-total correlation from the cluster. Cronbach’s alpha between 0.70–0.95 was considered to be adequate.

Reproducibility. Both reliability and agreement were assessed (23) for the activity scores, the cluster scores, and KneeScore 2. Intraclass correlation coefficients (ICCs) were calculated to assess interobserver reliability and intraobserver reliability (21,24). An ICC >0.70 was considered to be satisfactory (25).

To assess intraobserver and interobserver agreement, mean differences between the 2 measurements were calculated with limits of agreement (defined as mean difference ± 1.96 × SD of the difference) according to the method described by Bland and Altman (26). The limits of agreement define the range within which 95% of the differences between the 2 measurements lie. In the internal consistency and reproducibility analyses, no values were imputed for activities that were not performed by patients, because imputation would artificially increase the internal consistency and reproducibility.

Construct validity. To assess construct validity, KneeScore 2 of the patients was compared with several other measures. Spearman correlations were calculated between KneeScore 2 and the KSS (scores for functioning and pain), the WOMAC (subscores for physical functioning and pain), the SF-36 (subscores for physical functioning and pain), the physical therapists’ opinion of the patients’ quality of movement and the patient’s own opinion of his or her quality of movement, the mean duration of the activities of the test, and the active range of motion of the (to be) operated leg.

Specific hypotheses about the expected relationships between KneeScore 2 and the other measures were specified in advance. In addition, it was expected that postoperative patients would have higher cluster scores and a higher KneeScore 2 than preoperative patients. A moderate to large (>0.50) effect size for TKR was expected (defined as the difference in mean scores between preoperative and postoperative patients, divided by the SD of the mean score of the preoperative patients). Construct validity was considered satisfactory if at least 75% of the hypotheses were confirmed (27).

RESULTS

Participants. During 8 test days, 92 patients (41 preoperative patients and 51 postoperative patients) performed the KneeTest twice, and 101 controls performed the test once. The test of one patient, the retest of another patient, and the test of 4 healthy controls failed because of technical problems. Three controls turned out to be too young and were excluded from all analyses, leaving a total of 94 controls in the analyses. All patients completed the questionnaire. The mean ± SD age of the patients was 67 ± 9.9 years and 66 ± 7.4 years for the controls. The number of men versus women was 25/67 in the patient group and 38/56 in the control group, respectively.

Selection of functional parameters. The number of functional parameters that were considered in the multivariate analyses varied from 9 to 26 per activity. The definite selection of parameters varied from 3 to 10 per activity (see Appendix C).

Internal consistency. The original 8 activities of the locomotion cluster had a high Cronbach’s alpha (0.98) with high item-total correlations (>0.85). It was estimated (based on the Spearman-Brown formula) (22) that 4 activ-
The new locomotion cluster with these 4 activities had a Cronbach’s alpha of 0.95. The original 10 activities of the cluster “rise and descend” had a Cronbach’s alpha of 0.91, with item-total correlations. The new locomotion cluster with these 4 activities had a Cronbach’s alpha of 0.95.

The original 6 activities of the transfer cluster had a Cronbach’s alpha of 0.51. We removed the activities “sit down and stand up from 30 cm” has an item-total correlation of 0.31, but was retained on a conceptual basis.

Originally, 2 activities (“picking up a weight with non-affected and affected leg”) were included in the transfer cluster as well as in the lift and move objects cluster. We removed these activities from the lift and move objects cluster. The new lift and move objects cluster (now containing 5 activities) had a Cronbach’s alpha of 0.93. In total, after removing 6 redundant activities, 23 activities were included in KneeScore 2.

**Reliability.** The ICCs for the cluster scores and KneeScore 2 were >0.80, except for the interobserver reliability of the transfer cluster (0.66, Table 1). Most ICCs (32 of 46, 69%) for the inter- and intraobserver reliability of the individual activity scores were >0.70 (data not shown). The interobserver reliability of 9 activities was <0.70 (range 0.32–0.66), and the intraobserver reliability of 5 activities (4 activities of the rise and descend cluster and one activity of the transfer cluster) was <0.70 (range 0.58–0.69).

**Agreement.** Mean ± SD interobserver difference in KneeScore 2 was 1.5 ± 5.0 points (n = 57). Limits of interobserver agreement ranged from −8.3 to 11.3. Mean ± SD intraobserver difference in KneeScore 2 was 2.4 ± 3.4 points (n = 33). Limits of intraobserver agreement ranged from −4.2 to 9.0 (Table 2).

**Construct validity.** Correlations between KneeScore 2 and other measures were generally as anticipated (Table 3). We found high correlations with other measures of functioning and low correlations with measures of pain, although the correlation with the Knee Society Pain Score and with the mean duration of the activities was higher than expected. The correlation with the patient’s rating of his or her quality of movement was lower than expected. As expected, postoperative patients had higher cluster scores and KneeScores than preoperative patients, and effect sizes were >0.50 (Table 4).

In an attempt to explain the high correlation between

| Table 1. Reliability of cluster scores and KneeScore 2 in 90 patients* |
|-----------------------------|-----------------------------|
|                             | Interobserver reliability   | Intraobserver reliability |
|                             | ICC (95% CI) | n | ICC (95% CI) | n |
| Locomotion                  | 0.88 (0.80–0.93) | 57 | 0.94 (0.86–0.97) | 33 |
| Rise and descend            | 0.85 (0.75–0.91) | 56 | 0.87 (0.82–0.96) | 32 |
| Transfers                   | 0.66 (0.48–0.79) | 56 | 0.89 (0.78–0.94) | 32 |
| Lift and move objects       | 0.84 (0.75–0.90) | 56 | 0.93 (0.85–0.96) | 33 |
| KneeScore 2                 | 0.90 (0.83–0.94) | 57 | 0.95 (0.83–0.98) | 33 |

* ICC = intraclass correlation coefficient; 95% CI = 95% confidence interval.

| Table 2. Limits of interobserver (n = 57) and intraobserver (n = 33) agreement for the KneeScore 2 in 90 patients* |
|---------------|-----------------------------|
|               | Measurement 1 | Measurement 2 | Difference | Limits of agreement, range |
| Interobserver agreement |           |               |            |                          |
| Locomotion    | 34.7 ± 14.3   | 35.5 ± 15.1   | 0.8 ± 7.3  | −13.5, 15.1             |
| Rise and descend | 32.2 ± 11.0   | 34.3 ± 11.7   | 1.7 ± 6.0  | −10.1, 13.4             |
| Transfers     | 35.7 ± 10.4   | 38.6 ± 11.1   | 2.5 ± 8.6  | −14.3, 19.4             |
| Lift and move objects | 34.7 ± 13.0   | 36.2 ± 13.6   | 1.1 ± 7.5  | −13.5, 15.8             |
| KneeScore 2   | 43.3 ± 11.1   | 35.9 ± 11.8   | 1.5 ± 5.0  | −6.3, 11.3              |
| Intraobserver agreement |           |               |            |                          |
| Locomotion    | 32.0 ± 16.2   | 34.9 ± 17.1   | 2.4 ± 5.6  | −8.6, 13.3              |
| Rise and descend | 30.3 ± 12.2   | 35.1 ± 10.4   | 4.4 ± 4.2  | −3.8, 12.5              |
| Transfers     | 34.4 ± 11.5   | 35.5 ± 10.6   | 1.0 ± 5.3  | −9.3, 11.3              |
| Lift and move objects | 33.2 ± 13.5   | 35.2 ± 12.3   | 1.6 ± 4.7  | −7.7, 10.8              |
| KneeScore 2   | 31.8 ± 13.6   | 34.6 ± 12.6   | 2.4 ± 3.4  | −4.2, 9.0               |

* Unless otherwise indicated, values are the mean ± SD.
KneeScore 2 and the mean duration of the activities, we subsequently calculated the correlations between the cluster scores and the mean duration of the activities in the cluster, the correlations between the activity scores and the duration of each individual activity, and the correlations between the functional parameter scores of each activity and the duration of the activity. Correlations between the cluster scores and the mean duration of the activities in the cluster ranged from 0.84 to 0.91. Correlations between the activity scores and the duration of the activities ranged from 0.39 to 0.91 (mean 0.77). Six percent of the functional parameter scores correlated >0.90 with the duration of the activity in which the parameter was assessed.

**DISCUSSION**

To our knowledge, the DynaPort KneeTest is one of the best validated, performance-based measures for the assessment of functioning of patients with knee OA, undergoing TKR. We shortened the KneeTest from 29 to 23 activities and the internal consistency of 3 out of 4 clusters of activities was considered to be good. KneeScore 2 was found to be highly reliable, but the limits of agreement were rather wide. Construct validity of the KneeTest was supported by expected correlations with other measures of functioning and pain. Correlations of 0.55–0.64 with self reports show that, although the concepts are related, the KneeTest measures a different aspect of functioning.

Two previous studies provide some evidence on the reproducibility and construct validity of the KneeTest. Van den Dikkenberg et al reported an ICC of 0.81 for interobserver reliability of the original KneeScore in a group of 37 healthy controls (13). Witvrouw et al provided some evidence for construct validity, by comparing the original KneeScore with the WOMAC subscores for physical functioning and pain (11).

No previous studies reported the absolute measurement error (e.g., limits of agreement) of the KneeTest. We found rather wide limits of agreement, indicating that the absolute measurement error of one individual measurement is quite large. The absolute measurement error might be decreased by repeating activities and improving standardization of test performance. Although the high reliability indicates that the test is useful for research purposes, the wide limits of agreement limit the use of the test for individual patient monitoring.

In fact, many performance-based tests as well as self-report questionnaires have large absolute measurement error. However, this is often not reported. In our systematic review (Terwee CB: unpublished observation), absolute measurement error was reported for only 10 of 24 (42%) performance-based tests, and only 1 test (the Iowa Level of Assistance Scale) (3) received a satisfactory rating. Limits of agreement of the WOMAC ranged from mean difference ±17–29 points (scale 0–100) in previous studies (28,29). In the only Dutch validation study of the WOMAC (30), the limits of agreement ranged from −10.7 to

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<th>Table 3. Construct validity of KneeScore 2 in 92 patients, based on prior hypotheses about the expected correlations*</th>
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* KSS = Knee Society Score (ref. 19, 20); WOMAC = Western Ontario and McMaster University Osteoarthritis Index; SF-36 = Medical Outcomes Study Short Form-36; QOM = quality of movement (scored on a 5-point scale by the physical therapist after the first test and by the patient in the questionnaire); range of motion = active range of the (to be) operated leg.
† Spearman correlation magnitude high ≥ r > 0.50, moderate = r 0.35–0.50, low = r < 0.35.

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<th>Table 4. Effect sizes of KneeScore 2 in 92 patients*</th>
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* Values are mean ± SD. Effect size is mean difference between preoperative and postoperative patients divided by the SD of preoperative patients.
18.7 (data obtained from LD Roorda). This measurement error is much larger than the minimal important difference, defined as 6–7 points for the WOMAC (31), which limits the use of the WOMAC for individual patient monitoring. We did not find any data on the reproducibility of the SF-36 in patients with knee OA.

We agree with other authors (10,11) that performance-based measures and self-report questionnaires are complementary and both useful to comprehensively evaluate functioning in TKR. Although the KneeTest requires special equipment and takes 15–30 minutes to perform, the KneeTest provides a more comprehensive and valid assessment of functioning as compared with simple tests due to the multiple activities that are assessed. In this study, these aspects were all summarized into KneeScore 2, but individual item scores and specific parameter scores for each activity are available and can be used to assess specific aspects of functioning. The value of the KneeTest could be further improved by developing clinically relevant subscores that can reveal which aspects of quality of movement are affected (e.g., endurance, coordination, or range of motion).

A limitation of our study should be acknowledged. To assign activities to the clusters, ideally factor analyses should have been performed, but this was not possible because of a lack of statistical power. Other divisions of activities into clusters may be possible, but a different cluster division will have no implications for the total KneeScore 2.

KneeScore 2 was found to have a high correlation with the mean duration of the 23 activities, which therefore seems to be a good predictor of the KneeScore. Because time alone has been reported to be an inadequate representation of concept of functional status (17), a lower correlation is desirable. The high correlation might be due to the scorings algorithm. The correlations between the selected functional parameters of each activity and the duration of that activity were moderate (mean 0.49; range 0.27–0.69), and only 6% of these correlations were >0.90. After averaging the selected parameter scores into activity scores, the correlation between those activity scores and the duration of the activities increased (mean 0.77; range 0.39–0.91). Further study of the scoring algorithm is recommended. Furthermore, it might be interesting to extract other parameters from the signals of the accelerometers (i.e., coordination or energy expenditure) that are not related to duration.

The shortened version KneeTest is a useful performance-based measure for research in patients with knee OA undergoing TKR, with good reliability and validity. Further research is required to improve its usefulness in clinical practice.

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