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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 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...
The DynaPort KneeTest (McRoberts, The Hague, The Netherlands) is a promising performance-based measure because of its apparent content validity for patients with knee OA undergoing TKR (13). Patients perform a standardized set of 29 activities in 15–30 minutes, while accelerometers are used to measure functional parameters. The KneeTest is more economical and easier to use than gait analysis. In contrast to gait analysis or more simple performance-based tests, the KneeTest contains multiple activities (e.g., walking, stair climbing, sitting and rising, lifting and carrying objects, and picking up objects from the floor) that were selected to represent activities of daily living that are considered difficult for patients with knee problems and that patients in focus-group discussions have identified as being important (2). Unlike other performance-based tests (except gait analysis), the KneeTest also measures different aspects of functioning than just the time it takes to perform the test, e.g., movement intensity, accelerations, and joint angles during movement. Time alone has been suggested to be inadequate to represent the concept of functional status (17). Finally, the scoring of the KneeTest is based on identification of the most significant test parameters to separate patients and controls, an approach that has been shown to be useful for the evaluation of functioning in patients undergoing TKR (18). Therefore, the KneeTest appears to have good content validity. The aim of this study was to determine the reproducibility and construct validity of the DynaPort KneeTest.

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 unicompartmental 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/jpages/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/jpages/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). The 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 x 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-
Correlations had a Cronbach's alpha of 0.91, with item-total activities had a Cronbach's alpha of 0.95.

The new locomotion cluster with these 4 longer distance on the basis of conceptual and practical meters (twice), “walk 9 meters and back,” and “walk a consistency. We chose to retain the activities “walk 9 activities would be sufficient to get a scale with a good internal cluster. The new lift and move objects cluster (now containing 5 activities) had a Cronbach’s alpha of 0.93. In removed these activities from the lift and move objects 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       | −8.3, 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 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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### Table 3. Construct validity of KneeScore 2 in 92 patients, based on prior hypotheses about the expected correlations*

<table>
<thead>
<tr>
<th>Prior hypotheses</th>
<th>Results</th>
<th>Hypothesis confirmed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$r_s$, direction</td>
<td>$r_s$, magnitude†</td>
</tr>
<tr>
<td>Range of motion</td>
<td>Positive</td>
<td>Moderate</td>
</tr>
<tr>
<td>KSS functioning</td>
<td>Positive</td>
<td>High</td>
</tr>
<tr>
<td>WOMAC physical functioning</td>
<td>Positive</td>
<td>High</td>
</tr>
<tr>
<td>SF-36 physical functioning</td>
<td>Positive</td>
<td>High</td>
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<tr>
<td>QOM physical therapists</td>
<td>Positive</td>
<td>High</td>
</tr>
<tr>
<td>QOM patient</td>
<td>Positive</td>
<td>Moderate</td>
</tr>
<tr>
<td>Mean duration of activities</td>
<td>Positive</td>
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</tr>
<tr>
<td>KSS pain</td>
<td>Negative</td>
<td>Low</td>
</tr>
<tr>
<td>SF-36 pain</td>
<td>Negative</td>
<td>Low</td>
</tr>
<tr>
<td>WOMAC pain</td>
<td>Negative</td>
<td>Low</td>
</tr>
</tbody>
</table>

* 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 $0.35–0.50$, low $r < 0.35$.

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### Table 4. Effect sizes of KneeScore 2 in 92 patients*

<table>
<thead>
<tr>
<th></th>
<th>Preoperative</th>
<th>Postoperative</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Locomotion</td>
<td>25.2 ± 14.5</td>
<td>39.2 ± 14.0</td>
<td>0.97</td>
</tr>
<tr>
<td>Rise and descend</td>
<td>20.4 ± 13.6</td>
<td>31.1 ± 15.0</td>
<td>0.79</td>
</tr>
<tr>
<td>Transfers</td>
<td>28.0 ± 12.7</td>
<td>35.1 ± 14.0</td>
<td>0.56</td>
</tr>
<tr>
<td>Lift and move objects</td>
<td>27.6 ± 13.3</td>
<td>38.4 ± 12.9</td>
<td>0.81</td>
</tr>
<tr>
<td>KneeScore 2</td>
<td>25.3 ± 11.9</td>
<td>35.9 ± 12.8</td>
<td>0.89</td>
</tr>
</tbody>
</table>

* Values are mean ± SD. Effect size is mean difference between preoperative and postoperative patients divided by the SD of preoperative patients.
ACKNOWLEDGMENTS

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