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published in
Knee Surgery, Sports Traumatology, Arthroscopy
2002

DOI (link to publisher)
10.1007/s00167-002-0279-x

document version
Publisher's PDF, also known as Version of record

citation for published version (APA)
van den Dikkenberg, N., Meijer, O. G., van der Slikke, R. M. A., van Lummel, R. C., van Dieen, J. H., Pijls, B., Benink, R. J., & Wuisman, P. I. J. M. (2002). Measuring functional abilities of patients with knee problems: rationale and construction of the DynaPort knee test. *Knee Surgery, Sports Traumatology, Arthroscopy*, *10*, 204-212. https://doi.org/10.1007/s00167-002-0279-x

Knee Surg, Sports Traumatol, Arthrosc
(2002) 10 : 204–212

KNEE

DOI 10.1007/s00167-002-0279-x

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Received: 2 August 2001
Accepted: 12 December 2001

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Abstract We present the rationale and design of the DynaPort knee test. The test aims at measuring knee patients' functional abilities in an unobtrusive, user-friendly way. Test persons wear several belts around their trunk and legs. The belts contain accelerometers, the signals of which are stored in a recorder, embedded in one of the belts. The knee test consists of a set of 29 tasks related to activities of daily life ("test items"). Accelerometer signals are analyzed in terms of 30 "movement features" (accelerations, angles, durations, frequencies, and some dimensionless numbers). In data analysis, the beginning and end of each test item is marked by hand; otherwise, analysis is automatic. We compared 140 knee patients with 32 healthy controls and found 541 of the 29×30=870 test item × movement feature combinations differed significantly between the two groups. From these 541 combinations the DynaPort knee score is calculated by the weighted averages of movement features per item, then weighted averages of items per cluster (locomotion, rising and descending, transfers, lifting and moving objects), and finally the average of the clusters. In an initial study the test-retest reliability of the knee test proved high, and the test turned out to be sufficiently responsive (0.7 patients' standard deviations improvement after 24 months). However, it remains difficult to interpret the scores in more meaningful terms than merely "better" or "worse." Extensive reliability studies in the future will further assess the validity of the test and provide more insight into the meaning of the scores. The DynaPort knee test may thus become an important instrument for evaluating patients' functional abilities in knee-related clinical practice and research.

Keywords Functional measurement · Activities of daily living · Knee function · Total knee replacement

Introduction

Technically, total knee replacement (TKR) has developed into one of the most successful procedures in modern medicine [6, 17, 21, 23]. Not surprisingly therefore [14, 19, 20, 26] attention in the TKR community is shifting towards quality of life issues. After TKR a majority of patients continue to have problems with everyday movements such as climbing stairs and getting in and out of cars [11]. Thus monitoring functional abilities is currently turning into an important research topic in the field of TKR.

Functional abilities of patients in performing activities of daily living (ADL) can be assessed either subjectively or objectively. Subjective measurement usually relies on visual analogue scales or on questionnaires filled-in by the patient or by the physician. Given the possibility of physician bias and the time demands on the medical system, most authors prefer patient-based assessment [10, 13, 18, 30]. Still, the patients' own reports may also be biased, for instance, when their report on the actual situation is influenced by their expectations [34]. Moreover, patients may confuse the dimensions in question. In the Western Ontario MacMasters Osteoarthritis Index patients with both pain and functional problems were unable to distinguish between the two [27]. Finally, patients' self-reports may be unreliable, for example, in the cognitively impaired [1, 12].

Thus, in addition to patients' self-reports, objective data in monitoring patients' functional abilities [24, 28] is also needed. Current objective measurement systems (such as electromyography, force platforms, optokinematic systems), however, are time consuming and require sophisticated laboratories. In view of this problem an accelerometer-based, user-friendly system was developed, the DynaPort knee test, which objectively assesses functional abilities in a standardized set of tasks, closely related to ADL. In principle the knee test can be used for all kinds of patients with knee problems. Since the test may prove important for clinical practice and research, especially in TKR, the present contribution summarizes the rationale behind and the design of the DynaPort knee test.

The DynaPort knee test

The DynaPort knee test (McRoberts, The Hague, The Netherlands) was developed to objectively assess knee-related functional abilities in an unobtrusive, user-friendly way. Test persons wear five belts around their trunk and legs (Fig. 1), over their clothing. The belts contain sensors (accelerometers), the signals of which are stored in a recorder, embedded in one of the belts. The whole system can easily be transported, and measurement can take place anywhere.

Fig. 1 Test person carrying the measurement system for the DynaPort knee test. The belts contain accelerometers

The belts consist of neoprene straps that can be fixed with Velcro. The data recorder (125×95×34 mm, 295 g) has a 10 Mb PC card on which data are stored at a sample frequency of 32 Hz. There are three penlight batteries. The accelerometers are uniaxial, piezoresistive (IC sensors 3031) with a frequency range of 0–400 Hz and are able to measure up to ±5 *g* (*g* being 9.8m/s^2). Interpretation of the accelerometer signals [32] must consider gravitational acceleration (given the position, that is, the inclination of the sensor).

In the DynaPort knee test the recorder box is stored ventrally in a belt around the waist. User instructions are digitally displayed on the box. There are six accelerometers connected with the recorder through wires. Two of the accelerometers are located in the recorder box; when the test person is standing upright, one of these sensors registers vertical acceleration and the other sagittal acceleration. The remaining four sensors, which in upright stance all register vertical acceleration, are attached over the sternum, around the left thigh and around the two shanks.

A standardized set of 29 test items

Tasks were selected for the DynaPort knee test with the following rationale: The tasks should match as closely as possible ADL that are problematic for patients with knee complaints, or in which the knee plays a central role, while the whole set of tasks should be easy to perform routinely (excluding, for instance, getting in and out of the bath, or in and out of a car). To give one example of how this rationale was used, getting into a bus was "translated" into stepping onto a wooden block 40 cm high.

Based on the literature [2, 25], and using common sense, a list of 29 test items was constructed, grouped into 14 tasks (Table 1). These tasks can be categorized under: locomotion (walking), rising and descending (stairs, slopes, and wooden blocks), lifting and moving (carrying a tray or a bag, picking up a weight, and walking with a shopping trolley), and transfers (going to sit or lie down and then standing up again, as well as bending forwards to pick up a weight and returning to the upright position). To standardize the test a standard package with all equipment is included in the test material (such as wooden blocks, stairs of three steps, a slope, etc.).

The DynaPort knee test, which takes about 30 min to perform, is carried out under supervision, usually by a physical therapist. The supervisor is responsible for proper attachment of the belts, gives the instructions, and com-

Table 1 Test items of the DynaPort knee test. A set of 29 test items was developed, closely related to functional activities that may be problematic for patients with knee problems (*A* affected, *NA* nonaffected)

Number	Name	Specification
1	Walk 9 m	(First time, see item 28)
2	Ascend and descend stairs (three steps, each 20 cm high)	Start with the NA leg
3	–	Start with the A leg
4	Pick up a 4 kg weight	Walk to it, pick it up with NA side, go on walking
5	–	Walk to it, pick it up with A side, go on walking
6	Walk back and forth	Walk 3 m, turn, walk back
7	–	Walk 6 m, turn, walk back
8	–	Walk 9 m, turn, walk back
9	Slalom with shopping trolley (with 50 kg in it)	9 m forwards slalom around 2 plastic cones
10	–	9 m backwards slalom around 2 plastic cones
11	Ascend and descend slope 120 cm long (with 33% inclination)	Start with NA leg
12	–	Start with A leg
13	Walk in a curve around 4 plastic cones (placed in a 6×2 m rectangle)	Towards NA side
14	–	Towards A side
15	Step up and down a block	20 cm, up with NA leg, down with A
16	–	30 cm, up with NA leg, down with A
17	–	40 cm, up with NA leg, down with A
18	–	20 cm, up with A leg, down with NA
19	–	30 cm, up with A leg, down with NA
20	–	40 cm, up with A leg, down with NA
21	Sit down and stand up	On and from block of 40 cm height
22	–	On and from block of 30 cm height
23	–	On and from block of 20 cm height
24	Lie down and stand up	On and from a mattress on the floor
25	Carry a tray with two cups	Walk 9 m straight, carrying the tray
26	Carry a 5 kg shopping bag	Walk 9 m straight, carrying the bag on NA side
27	–	Walk 9 m straight, carrying the bag on A side
28	Walk 9 m	(Second time, see item 1)
29	Walk a longer distance	Walk through a corridor (if available) and back (in total ±50 m)

pletes an observation form, noting which items are not performed by the test person. Test persons are instructed to perform the test items at their own pace, while they are free to skip an item whenever they consider it too difficult.

Semiautomated signal analysis

After the knee test the data from the six accelerometers are transferred from the memory card to a PC software environment, DynaScope (McRoberts; using routines that were originally developed by Inspector Research Systems, Amsterdam, The Netherlands). Data are displayed graphically in DynaScope. The beginning and end of each of the 29 test items is marked by hand.

In open discussions, using clinical reasoning, common sense, and considerations of programming efficiency, relevant signal properties of each of the 29 time series were selected. Per item the same 30 “movement features” (Table 2) are calculated by dedicated software (written in signal processing language as used in DynaScope), yielding a total of 29×30=870 data per DynaPort knee test. In general, a large number of independent estimators enhance the reliability of a test [8], but the movement features of the DynaPort knee test are expected to have a definite dependence structure, which remains to be investigated, while the reliability of the knee test as a whole deserves separate attention (see below).

All signal properties are derived from the original accelerometer signals, while several movement features are calculated in terms of angle, duration (time), frequency, or a dimensionless number (Table 2). By way of example of a calculation, Fig. 2 presents the procedure for movement features 9 and 10 (forward acceleration right and left). Right and left step are differentiated by using the synchro-

Table 2 Signal properties that are calculated (the "movement features"). In total 30 movement features are calculated from the raw accelerometer signals. These movement features are accelerations (1–10), angles (11–14), durations (15–25), and other variables (26–30)

	Name	Specification
Accelerations (m/s^2)		
1	Movement intensity	Mean length of vector between the two waist signals[b]
2	Movement intensity left thigh	Mean absolute signal left thigh[b]
3	Movement intensity left shank	Mean absolute signal left shank[b]
4	Movement intensity right shank	Mean absolute signal right shank[b]
5	Movement intensity thorax	Mean absolute signal thorax[b]
6	Maximum impact	Highest vertical peak in waist signal[c]
7	Maximum impact left shank	Highest vertical peak in left shank signal[c]
8	Maximum impact right shank	Highest vertical peak in right shank signal[c]
9	Forward acceleration right	Forward acceleration from right heelstrike until peak[d]
10	Forward acceleration left	Forward acceleration from left heelstrike until peak[d]
Angles (°)		
11	Waist range of motion	Difference between maximum and minimum[e]
12	Maximum angle left thigh	Maximum[e]
13	Maximum angle left shank	Maximum[e]
14	Maximum angle right shank	Maximum[e]
Durations (ms[a])		
15	Duration	Duration of selection for test item(s)[f]
16	Movement duration	Total duration of samples in which movement intensity >0.5 m/s^2(s)
17	Transfer duration	Duration of longest action(s)[g]
18	Double support right	After right heelstrike
19	Double support left	After left heelstrike
20	Step left	From right to left heelstrike
21	Step right	From left to right heelstrike
22	Stance left	Heel strike to toe off left[h]
23	Stance right	Heel strike to toe off right[h]
24	Swing left	Toe off to heel strike left[h]
25	Swing right	Toe off to heel strike right[h]
Other variables		
26	Step number	Number of maxima in forward acceleration signal
27	Mean step frequency	Mean number of steps per minute
28	Maximum step frequency	Expressed as number per minute
29	Relative speed	Duration compared to that of test item #1 (%)
30	Asymmetry	Step left minus step right (as % of mean step time)

[a] Unless indicated otherwise

[b] After high-pass filtering (2 Hz); before calculating the mean, values ≤0.5m/s^2 are discarded; for movement feature 1, vector length is calculated as the square root of the sum of the squares of the two signals

[c] Minus 1 *g* (to correct for normal gravity)

[d] Mean difference between signal at heel strike and the ensuing peak (since it is assumed that heel strike occurs at a minimum, this is a peak to peak amplitude)

[e] After low-pass filtering (1 Hz); angles are calculated with respect to the horizontal axis; an interpolation algorithm is used that assumes 1 *g* in the vertical sensor to be 90°, and 0 *g* to be 0°

[f] Per test item, the selection is made by hand

[g] The relationships between leg and waist angles plus the deviation of waist position from the vertical axis (all after low pass filtering) are used to pinpoint sitting (or going to sit/going to stand up), lying down (or going to lie down/getting up), and bending

[h] Toe off is assumed to occur at a maximum in the forward acceleration of the waist

nous left thigh signal, the vertical distance is calculated from the minimum to the first ensuing maximum ("peak to peak amplitude"), and these differences are then averaged over the entire time series.

During the development of the procedures to calculate the movement features, these were given provisional names (Table 2). Such names facilitate communication, but are not necessarily meaningful. "Step left" (movement feature 20) during "lie down and stand up" (Table 1, item 24), for instance, can be calculated without problems, but remains at present impossible to interpret meaningfully. Instead of directly entering the analysis of the "meaning" of the scores, however, it was decided to first focus on more technical properties of the DynaPort knee test: discrimination, reliability, responsiveness.

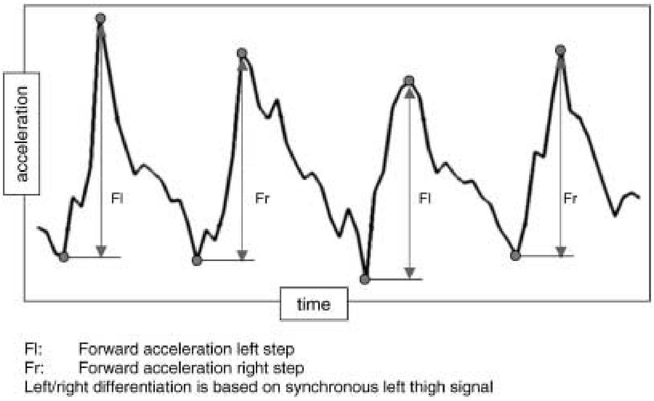

Fig. 2 A calculation example: movement features 9 and 10 (see Table 2). Right and left step are differentiated by using the synchronous left thigh signal, the vertical distance is calculated from the minimum to the first ensuing maximum (“peak to peak amplitude”), and these differences are then averaged over the whole time series

Discrimination between healthy subjects and knee patients

“Discrimination” by the DynaPort knee test was operationalized tautologically: Only those test item × movement feature combinations are used to calculate the final test scores that were shown to significantly discriminate between healthy subjects and knee patients (unpaired *t* tests, $P<0.01$). In principle, such a circular definition may allow for using the knee test as “gold standard” for ADL problems in knee patients.

At four general hospitals in The Netherlands a total of 140 persons with knee problems volunteered to undergo a DynaPort knee test. Most of them had been diagnosed with osteoarthritis of the knee and were waiting for TKR. Of their partners, 32 persons without knee problems agreed to be tested as well. Gender, age, height, and weight were noted. Testing was conducted at the Physical Therapy Departments of the participating hospitals. At final analysis (Table 3) data on age, height, and weight were missing from two healthy subjects, height of five TKR subjects, and weight of three TKR subjects.

Table 3 Test persons in the discrimination study: demographic characteristics (gender, age, height, and weight) of 32 healthy subjects and 140 persons who were awaiting TKR. Data of these 172 subjects were used to determine which test item × movement feature combinations differed significantly (unpaired *t* test, $\alpha=0.01$) between healthy subjects and patients

	Healthy subjects (*n*=32)	TKR patients (*n*=140)
Men	18 (56%)	34 (24%)
Women	14 (44%)	106 (76%)
Age	62±11	68±10
Height	173± 8	168± 8
Weight	80±12	81±13

The majority of item × movement feature combinations (541/870, Table 4) discriminated significantly between the healthy subjects and the TKR patients. The number of significant differences per item ranged from 10 to 24 (out of 30) and per movement feature from 1 to 29 (out of 29). Almost always, when significantly different accelerations were found, the healthy subjects had higher values than the TKR patients (213/ 216 times). This was less so for the angles (38/52 significant differences revealed higher values for the healthy subjects), while almost all significantly different durations (195/198) revealed longer durations for the patients.

It is important to note that a relatively large proportion of the TKR patients were women, which may render the interpretation of the statistical results ambiguous. Other healthy persons and other TKR patients may have yielded a slightly different subset of the test item × movement feature combinations to be used. Thus the validity of the DynaPort knee test needs to be studied separately (see below).

Calculation of the scores

For ease of interpretation each of the 541 scores (the significant differences in Table 4) is transformed to a scale of 0–100. In this scalar transformation, performed automatically in Microsoft Excel, “0” represents the mean score of the TKR patients (see above) minus 1 SD (or, if the patient scores exceeded those of the healthy subjects, plus 1 SD) while “100” represents the mean score of the healthy subjects plus one standard-deviation (or, as in the above, minus one standard-deviation). Scores below 0 and above 100 are cut off at 0 and 100. Scores for items that were not performed by the test person, are set at 0.

Item scores are weighted averages of their movement features. On theoretical grounds, subsets of movement features (see Table 2) were expected to be strongly correlated: 3–4, 7–8, 9–10, 13–14, 15–16, 18–19, 20–25, and 27–28. Therefore the subsets in question are first replaced by their mean value before calculating the item score as an overall average. Cluster scores are then calculated as weighted averages of item scores (Table 5): locomotion, rising and descending, transfers (changes in posture), and lifting and moving objects. Finally, the four cluster scores are averaged to calculate the overall DynaPort knee score.

Preliminary data on reliability and validity (responsiveness)

In view of the methodological problems mentioned above, it was deemed necessary to obtain preliminary information on the reliability and validity (responsiveness) of the

Table 4 Significant differences between healthy subjects and TKR patients. The 29 tasks (“items”; see Table 1) of the DynaPort knee test were performed by healthy subjects (n=32) and by patients with knee problems, awaiting TKR (n=140; see Table 3). All 30 movement features (Table 2) were calculated from the raw data for each item. An unpaired *t* test (α=0.01) was used for each of the 29×30=870 item × movement feature combinations to pinpoint significant differences between healthy subjects and patients. (*c* controls significantly higher/larger/longer than patients, *p* patients significantly higher/larger/longer than controls, *blank* no significant difference (P=0.01)

	Test items																												
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
Accelerations																													
1	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c
2	c	c	c	c	c	c	c	c			c	c	c	c		c	c	c	c	c		c	c	c	c	c	c	c	c
3	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c		c	c	c	c	c	c
4	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c			c	c	c	c	c	c		c	c	c
5	c	c	c	c	c	c	c	c	c	c	c	c	c	c		c	c			c	c	c	c	c	c	c	c	c	c
6	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c		c				c	c	c	c	c
7			c		c					c	c								c			c						c	
8					c					c								p											
9	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c		c		c	c	c	c	c	c	c	c
10	c	c	c	c	c	c	c	c	c		c	c	c	c							p			p	c	c	c	c	c
Angles																													
11															p	p	p	p	p	p	p	p	p	p					
12	c	c	p		c		c	c			c			c		p	p	p			c		c		p				c
13	c	c	c	c	c	c	c	c	c		c	c	c	c		c				c								c	c
14	c			c	c	c	c	c			c			c														c	c
Durations																													
15	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p
16	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p
17	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p
18	p						p	p				p		p														p	p
19																							p				p		
20	p	p	p	p	p	p	p	p	p	p	p	p	p	p											p	p	p	p	p
21	p		p				p	p	p			p	p	p						c				p	p	p	p	p	p
22	p		p	p	p	p	p	p				p	p	p						c				p	p	p	p	p	p
23	p	p	p	p	p	p	p	p	p		p	p	p	p											p	p	p	p	p
24	p	p	p	p	p	p	p	p	p		p	p	p	p											p	p	p	p	p
25	p		p				p	p		p		p	p	p						c				p	p	p	p	p	p
Others																													
26	p	p	p	p	p	p	p	p			p	p	p	p										p	p	p	p	p	p
27	c	c	c	c	c	c	c	c	c	c	c	c	c	c								c	c		c	c	c	c	c
28	c	c		c	c	c	c	c	c	c	c	c	c	c											c	c	c	c	c
29		c	c	c					p		c	c			c	c	c	c	c	c	c	c	c	c		c			
30																						c							

Table 5 Calculation of cluster scores from item scores. Specific cluster scores are calculated as the weighted mean of specific item scores. The DynaPort knee score is the mean value of the cluster scores

Cluster	Score calculated as mean values of the following (combinations of) items				
Locomotion	1	6–8 mean	13, 14 mean	28	29
Rising and descending	2, 3 mean	11, 12 mean	15–17 mean	18–20 mean	–
Transfers	4, 5 mean	21	22	23	24
Lifting and moving objects	4, 5 mean	9	10	25	26, 27 mean

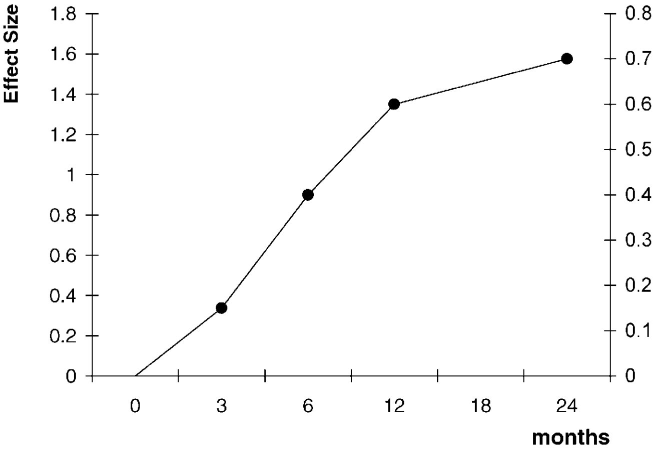

Fig. 3 Responsiveness of the DynaPort knee score after TKR, expressed in standard deviations of the healthy subjects (*left axis*), and in preoperative standard deviations of the TKR patients (*right axis*). *0* months just before the operation

DynaPort knee test before actually using it. The studies in question, already published in abstract form [31], will be reported elsewhere in more detail (29).

In a test-retest study with 37 healthy subjects, measured twice after an interval of 1 week the reliability of the DynaPort knee test was found to be high, with an overall intraclass correlation of 0.81 (95% confidence interval 0.69–0.93) and values for the clusters ranging from 0.73 (95% CI 0.58–0.89) to 0.84 (95% CI 0.73–0.94). Note that all these values are significant.

In a longitudinal study of 244 knee patients DynaPort knee scores were collected before TKR and 3, 6, 12, and 24 months after the operation. Not all patients could be measured at all time points. There was a clear trend to improvement (Fig. 3), with an average size of effect after 24 months (mean improvement) of 0.7 (when expressed in preoperative standard deviations of the TKR patients) or 1.5 (standard deviations of the healthy group). Such responsiveness is satisfactory [4], to say the least.

Discussion

The DynaPort knee test was developed to bridge the gap between subjective clinical assessment of patients with knee problems and objective data from the movement analysis laboratory. The knee test aims at being both objective and easy to use. The test is portable, can be applied easily by health care workers, and is unobtrusive for the patient. Test persons wear belts which contain accelerometers, used to register movements during a set of task items that is closely related to ADL. Movement features are calculated from the raw data. A predetermined set of item × movement feature combinations is used to calculate the DynaPort knee score on a scale from 0 to 100, cluster scores aiming to give specific information on locomotion, rising and descending, transfers, and lifting and moving objects.

Present problems

If the DynaPort knee test fulfills its promise, we feel that it will be an important instrument in both clinical practice and research. However, this is not at all unproblematic. Presently, the knee test relies only on accelerometers and does not specifically analyze angular rotations. The importance of angular rotations in, for instance, walking has been established [15, 16], and presently the use of gyroscopes (angular velocity) is under investigation. So far about 250 TKR patients have been measured with the DynaPort knee test in a total of about 1,000 measurements. During these measurements, there has been no accident whatever, confirming that the knee test is safe. Patients, however, often complain that they have trouble with test items in which they must sit deeply and then get up again. Thus, these items are often omitted. Measurements have been performed in about ten hospitals, the first being the Gemini Hospital, Den Helder, The Netherlands. Physiotherapists reported substantial satisfaction because it helped them to communicate with orthopedic surgeons about objective patient characteristics. In view of the importance of (quantity and quality of) communication in TKR care [5, 9], this effect may positively contribute to quality of care. So far, however, the experiences of the health care workers involved have been reported only in an informal manner.

The DynaPort knee test aims at being objective. While data acquisition and score calculation are largely straightforward, the beginning and the end of a test item are presently determined by hand in DynaScope. Procedures are under development to completely automate data analysis.

The test items of the DynaPort knee test are clearly ADL related. Still, the test is performed in a special setting and does not reveal how much the patients move about in actual life. In terms of quality of life there is the problem of elderly TKR patients who are able to move around but prefer to remain relatively immobile. These patients are at risk of becoming dependent, trapped in a vicious cycle of immobility, locomotor problems, increased immobility, etc. Comparison of DynaPort knee test scores with actual ADL monitoring [3, 32] may reveal how sensitive the knee test is to this problem.

As to the problem of the "meaning" of the scores, health care workers have informally reported that they find it difficult to relate the scores to variables that are known already. So far, the scores of the knee test can only be interpreted in terms of themselves (that is, in the time series of the individual patient, or in mutual comparison among patients). In order to develop a more meaningful interpretation of the scores, specific studies on construct validity will be needed.

Future development

A major problem in the development of the DynaPort knee test was that the majority of the reference group of healthy subjects were men, while most knee patients are women. This could in theory suggest that the knee test actually measures "being female" rather than "having knee problems," were it not for the fact that, fortunately, scores improved after TKR. Still, comparison between scores of patients and those of a large group healthy persons matched for age, gender, height, and weight clearly remains a first priority. Similarly, measurement with various groups of patients (for instance, patients with hip problems, or with low back problems) may reveal the specificity of the knee test.

Reliability studies must include patient groups (which will probably lead to even higher intraclass correlations [8]) and allow determination of the various sources of variance, such as the test leader (who may or may not decide to encourage the patient).

The data of such reliability studies can also be used to address the issue of validity more specifically. Factor analysis or similar techniques can be used to pinpoint redundant items and/or movement features and to reveal the actual dimensionality of the knee score. The dimensions thus found can be related to variables from the movement analysis laboratory, particularly coordination [15, 16]. Moreover, knee test scores can be related to ADL (24- h monitoring [3, 32]), and to radiographic fluoroscopy, the latter to assess the relationship between properties of the prosthesis and patients' functional abilities.

In our opinion, the DynaPort knee test should be used together with self-reported quality of life. It is important to note that such different levels of organization are usually (29) not correlated more strongly than at approx. 0.4 (i.e., 16% common variance). Because of pain reduction self-reported quality of life may increase more quickly after TKR than the knee score. On the other hand, it is known from the literature that even 1 year after surgery TKR patients still have problems with everyday movements [7, 22, 33]. To monitor such problems the knee test may become the instrument of choice for movement-oriented health professionals dealing with TKR patients.

In addition to monitoring, an interesting question is whether the DynaPort knee test can discriminate between different groups of patients (for instance, osteoarthritis versus rheumatoid arthritis). Moreover, the prognostic value of the knee score needs to be established (presently under investigation). Finally, the knee score will, we think, prove to be a useful dependent variable for orthopedic surgery to determine the effects of TKR in terms of the patient's functional abilities. Presently, in cooperation with the European Society for Sports Traumatology, Knee Surgery and Arthroscopy (ESSKA), data are being analyzed comparing different types of knee prosthesis (presented at the 9th ESSKA Congress, London, September 2000). Again, the kinematics of the prosthesis and the patient's functional abilities are variables at different levels of organization, suggesting that low correlations should to be expected. Indeed, with the small groups studied so far (about 10 patients per prosthesis), no significant differences have been found. Still, there was a significant effect of weight, with heavier patients having lower knee scores. In our opinion, the latter finding suggests that the knee test has sufficient discriminative power to be used as a dependent variable in intervention studies.

Acknowledgements The authors acknowledge Ortomed/Biomet for financial support. Harry Busser was helpful in interpreting the software. Hans van den Berg (Zwijndrecht), Kimi Uegaki (Amsterdam), and René Verdonk (Ghent) offered useful suggestions concerning an earlier version of this paper.

References

1. Barck AL (1997) Patient's memory or repeated pain and function scores as index for major clinical change caused by knee replacement? Arch Orthop Trauma Surg 116:484–485
2. Bellamy N, Buchanan WW (1986) A preliminary evaluation of the dimensionality and clinical importance of pain and disability in osteoarthritis in the hip and knee. Clin Rheumatol 5: 231–241
3. Busser HJ, De Korte WG, Glerum EB, Van Lummel RC (1998) Method for objective assessment of physical work load at the workplace. Ergonomics 41: 1519–1526

4. Cohen J (1977) Statistical power analysis for the behavioral sciences. Academic, New York
5. Dowsey MM, Kilgour ML, Santamaria NM, Choong PF (1999) Clinical pathways in hip and knee arthroplasty: a prospective randomised controlled study. Med J Aust 170:59–62
6. Ewald FC, Wright RJ, Poss R, Thomas WH, Mason MD, Sledge CB (1999) Kinematic total knee arthroplasty: a 10- to 14-year prospective follow-up review. J Arthroplasty 14:473–480
7. Finch E, Walsh M, Thomas SG, Woodhouse LJ (1998) Functional ability perceived by individuals following total knee arthroplasty compared to age-matched individuals without knee disability. J Orthop Sports Phys Ther 27:255–263
8. Fleiss JL (1986) Reliability of measurement. In: Fleiss JL (ed) Design and analysis of clinical experiments. Wiley, New York, pp 1–32
9. Gittell JH, Fairfield KM, Bierbaum B, Head W, Jackson R, Kelly M, Laskin R, Lipson S, Siliski J, Thornhill T, Zuckerman J (2000) Impact of relational coordination on quality of care, postoperative pain and functioning, and length of stay: a nine-hospital study of surgical patients. Med Care 38:807–819
10. Guyatt GH, Naylor CD, Juniper E, Heyland DK, Jaeschke R, Cook DJ (1997) Users' guides to the medical literature. XII. How to use articles about health-related quality of life? JAMA 277:1232–1237
11. Hawker G, Wright J, Coyte P, Paul J, Dittus R, Croxford R, Katz B, Bombardier C, Heck D, Freund D (1998) Health-related quality of life after knee replacement. J Bone Joint Surg Am 80: 163–173
12. Hoeymans N, Wouters ER, Feskens EJ, Van den Bos GA, Kromhout D (1997) Reproducibility of performance-based and self-reported measures of functional status. J Gerontol 52A:363–368
13. Hoher J, Bach T, Munster A, Bouillon B, Tiling T (1997) Does the mode of data collection change results in a subjective knee score? Self-administration versus interview. Am J Sports Med 25: 642–647
14. Jette AM (1995) Outcomes research: shifting the dominant research paradigm in physical therapy. Phys Ther 75:965–970
15. Lamoth CJC, Beek PJ, Meijer OG (2002) Pelvis-thorax coordination in the transverse plane during gait. Gait Posture (in press)
16. Lamoth CJC, Meijer OG, Wuisman PIJM, Van Dieën JH, Levin MF, Beek PJ (2002) Pelvis-thorax coordination in the transversal plane during walking in subjects with non-specific low back pain. Spine (in press)
17. Le Fanu J (1999) The rise and fall of modern medicine. Little Brown, London
18. Lieberman JR, Dorey F, Shekelle P, Schumacher L, Thomas BJ, Kilgus DJ, Finerman GA (1996) Differences between patients' and physicians' evaluations of outcome after total hip arthroplasty. J Bone Joint Surg Am 78:835–838
19. Lingard EA, Berven S, Katz JN, the Kinemax Outcomes Group (2000) Management and care of patients undergoing total knee arthroplasty: variations across different health care settings. Arthritis Care Res 3:129–136
20. Lingard EA, Hashimoto H, Sledge C (2000) Development of outcome research for total joint arthroplasty. J Orthop Sci 5:175–177
21. Malkani AL, Rand JA, Bryan RS, Wallrichs SL (1995) Total knee arthroplasty with the kinematic condylar prosthesis: a ten-year follow-up study. J Bone Joint Surg Am 77:423–431
22. March LM, Cross MJ, Lapsley H, Brnabic AJM, Tribe KL, Bachmeier CJM, Courtenay BG, Brooks PM (1999) Outcomes after hip or knee replacement surgery for osteoarthritis: a prospective cohort study comparing patients' quality of life before and after surgery with age-related population norms. Med J Aust 171:235–238
23. Moran CG, Horton TC (2000) Total knee replacement– the joint of the decade: a successful operation, for which there's a large unmet need. BMJ 320:820
24. Myers AM, Holliday PJ, Harvey KA, Hutchinson KS (1993) Functional performance measures: are they superior to self-assessments? J Gerontol 48: 196–206
25. Rejeski WJ, Ettinger WH, Schumaker S, James P, Burns R, Elam JT (1995) Assessing performance-related disability in patients with knee osteoarthritis. Osteoarthritis Cartilage 3:157–167
26. Relman AS (1988) Assessment and accountability: the third revolution in medical care. N Engl J Med 319:1220–1222
27. Ryser L, Wright BD, Aeschlimann A, Mariacher-Gehler S, Stucki G (1999) A new look at the Western Ontario and McMaster Universities Osteoarthritis Index using Rasch analysis. Arthritis Care Res 12:331–335
28. Sager MA, Dunham NC, Schwantes A, Mecum L, Halverson K, Harlowe D (1992) Measurement of activities of daily living in hospitalized elderly: a comparison of self-report and performance-based methods. J Am Geriatr Soc 40:457–462
29. Terwee CB, Van der Slikke RMA, Benink RJ, Meijers WGH, Schillemans PF, Meijer OG, Van den Dikkenberg N, Van Lummel RC (2002). Performance-based methods or self-report questionnaires to asses functional outcome of total knee replacement? A comparision of the newly developed DynaPort knee test with the Knee Society Score, WOMAC, and the SF-36. Journal of Arthroplasty (accepted)
30. Testa MA, Simonson DC (1996) Assessment of quality of life outcomes. N Engl J Med 334:835–840
31. Van Lummel RC, Van der Slikke RMA, Benink RJ, Meijer OG (2001) A new objective method for functional assessment before and after TKR: DynaPort knee test. In: Control of posture and gait, Symposium of the International Society for Postural and Gait Research, Maastricht, The Netherlands, pp 666–670
32. Veltink PH, Bussmann HB, De Vries W, Martens WL, Van Lummel RC (1996) Detection of static and dynamic activities using uniaxial accelerometers. IEEE Trans Rehabil Eng 4:375–385
33. Walsh M, Woodhouse LJ, Thomas SG, Finch E (1998) Physical impairments and functional limitations: a comparison of individuals 1 year after total knee arthroplasty with control subjects. Phys Ther 78:248–258
34. Watson D, Pennebaker JW (1989) Health complaints, stress and distress: exploring the central role of negative affectivity. Psychol Rev 96:234–254