Rheumatology 2000;39:955–961

Range of joint motion and disability in patients with osteoarthritis of the knee or hip

M. P. M. Steultjens, J. Dekker[1], M. E. van Baar, R. A. B. Oostendorp[2] and J. W. J. Bijlsma[3]

Netherlands Institute of Primary Health Care (NIVEL), Utrecht, [1]Institute for Research in Extramural Medicine, Vrije Universiteit, Amsterdam, [2]Netherlands Institute for Allied Health Professions (NPI), Amersfoort, The Netherlands and Faculty of Medicine and Pharmacology, Free University of Brussels, Brussels, Belgium and [3]Department of Rheumatology, Utrecht University Medical Centre, Utrecht, The Netherlands

Abstract

Objective. To establish the relationships between the range of joint motion (ROM) and disability in patients with osteoarthritis (OA) of the knee or hip. Two related issues were addressed: (1) the inter-relationships between ROMs of joint actions, and (2) the relationship between ROM and disability.

Methods. Data on 198 patients with OA of the knee or hip were used. The ROM was assessed bilaterally for the hip and knee, using a goniometer. Disability was assessed using a self-reporting method (questionnaire) and an observational method. Correlation and factor analysis were used to establish the inter-relationships between the ROMs of joint actions. Correlation and multiple regression analyses were carried out to establish the relationships between ROM and disability.

Results. Close inter-relationships were found between the ROMs of the same joint action of the lateral and contralateral joints; inter-relationships between ROMs of different joint actions were substantially weaker. Low ROMs were associated with high levels of disability, both self-reported and observed. Some 25% of the variation in disability levels could be accounted for by differences in ROM. In both knee and hip OA patients, flexion of the knee and extension and external rotation of the hip were found to be most closely associated with disability.

Conclusion. Restricted joint mobility, especially in flexion of the knee and extension and external rotation of the hip, appears to be an important determinant of disability in patients with OA.

KEY WORDS: Osteoarthritis, Range of motion, Disability.

Physical disability is frequently reported in patients with osteoarthritis (OA) [1]. However, the disabled condition of these patients can be explained only partly by the degeneration of joints affected by OA [2–5]. A number of other factors have been proposed as possible explanations for the level of disability in these patients [2, 6]. These include physical factors such as a reduced range of motion (ROM) of the joints [2].

Relationships have been reported between the range of joint motion in general and disability. Dunlop *et al.* [7] identified joint impairment as a predictor of disability. In their study, the presence of an impaired ROM was one of the factors defining joint impairment, but other factors, such as tenderness, swelling and pain during motion, were also used in the assessment of joint impairment. Thus, their study did not identify a separate association between joint mobility and disability. In a study among elderly Swedish people, strong correlations were found between the ROMs of the knee and hip joints and disability [8]. In another population study, Odding *et al.* [9] found that restricted flexion of the hips and restricted flexion of the knees were strong risk factors for locomotor disability (disability in activities primarily involving the lower extremities, such as walking, climbing stairs, and rising from and sitting down in a chair). Recently, Escalante *et al.* [10] reported that impaired hip flexion was associated with a decrease in walking velocity in a population of elderly persons.

The existence of this relationship has also been reported in patients with OA. In a review of previous studies, Dekker *et al.* [2] identified impaired joint

Submitted 17 August 1999; revised version accepted 24 February 2000.

Correspondence to: M. P. M. Steultjens, NIVEL, PO Box 1568, 3500 BN Utrecht, The Netherlands.

© 2000 British Society for Rheumatology

mobility in general as a factor in the development of disability in patients with OA. However, to our knowledge, no further research on this topic has been published in recent years. The role of physical functioning as a determinant of disability in OA has been investigated widely, but research has focused primarily on the effect of decreased muscle strength on disability in OA [4, 5, 11–13]. The relationship between joint mobility and disability in OA has not been established in more detail than in the global statement of Dekker *et al.* [2]. The effect of restricted mobility of specific joint actions on disability has not been established in patients with OA. Establishing these relationships in detail could provide essential information for both the assessment and the management of disability in patients with OA.

The overall goal of the present study was to further establish the relationship between ROM and disability in patients with OA of the knee or hip. To this aim, two related issues were addressed. First, the inter-relationships between the ROMs of all joint actions of the knees and hips were studied. Before studying the role of ROM as a determinant of disability, it is of vital importance to have insight into the nature of ROM in OA. Can ROM be regarded a unidimensional trait of an OA patient (i.e. are the ROMs of all joint actions closely inter-related and can they be regarded as representations of one trait—a patient's overall sinuosity)? Or must the ROMs of separate joint actions be treated as separate entities, each with its own specific effect on a patient's level of physical ability? Secondly, after the best level of aggregation for ROM data had been established, we studied the relationship between ROM and disability in OA.

Methods

Subjects

Data were obtained from a randomized clinical trial of the effectiveness of exercise therapy in patients with osteoarthritis of the hip or knee [14]. Patients were included if they had been diagnosed as having OA of the knee or hip according to the classification criteria of the American College of Rheumatology [15, 16]. Two hundred patients participated in the trial. Data for the present study were obtained at the onset of the trial (baseline). Data on one or more of the tests presented below were incomplete for two patients. The data for these patients were excluded from the analyses, leaving 198 patients in the analyses.

Range of motion

The assisted active ROM was measured bilaterally for the hip and knee, using a goniometer. ROM measurements were recorded in degrees. Measurements were taken according to Norkin and White [17]. These measurements were taken for all possible actions of the joint, i.e. flexion, extension, internal and external rotation, abduction and adduction of the hip, and flexion and extension of the knee. For each action, the protocol provided starting positions for both patient and therapist, reference points for the pivot and distal points of the goniometer, and a horizontal position (defining positive and negative values for ROM). For patients who were unable to adopt a prescribed starting position, the protocol provided an alternative starting position. By supplying a protocol for starting positions for the patient and therapist and the positioning of the goniometer, the reliability of the ROM measurements was increased [18]. The full protocol for taking ROM measurements can be obtained via the internet, at http://www.nivel.nl/english/range-of-motion/protocol-ROM.html. The tests were carried out by two experienced physical therapists. Before taking the measurements used for the present study, the inter-rater reliability was established using 10 healthy subjects and 10 patients with OA. The inter-rater reliability was satisfactory for all joint actions (Pearson's $R > 0.75$ for all actions).

Disability

Two methods were used for the assessment of disability: one observational method and one questionnaire.

Observed disability was determined by watching videotaped performances of patients in a series of standardized tasks [19]. These standardized tasks included walking, sitting down in a chair, reclining onto a bed and bending over to pick up a weight from the floor. Trained observers scored the performance of the patients. The observers scored five items: three movement times (time taken to walk 5 m, stand-to-sit time and stand-to-recline time) and two measures of the quality of the performance (level of guarding and level of rigidity). Based on these five items, an overall score for observed disability was calculated [19]. A higher overall score indicated a higher level of disability. This overall score has been shown to be internally consistent and valid [19].

In addition to observed disability, self-reported disability was assessed using the mobility subscale of the Influence of Rheumatic Disease on General Health and Lifestyle (IRGL) questionnaire. The IRGL is a Dutch adaptation of the Arthritis Impact Measurement Scales [20, 21]. This IRGL subscale has seven items. Two items are general statements concerning disability in mobility and the remaining five address disability in climbing stairs, riding a bicycle and walking. The IRGL is a 'positive' questionnaire, i.e. it measures ability rather than disability. To facilitate interpretation, scores on this test were reversed to obtain a disability score. After reversal, the scores for this test ranged from -28 (minimal disability) to -7 (maximal disability).

Statistical analyses

To establish the inter-relationships of the ROM scores of the joint actions, Pearson correlation coefficients were computed and factor analysis was performed. Both types of analysis assess the associations between items (in this case, the ROM of joint actions), but correlation coefficients provide information only for pairs of items whereas with factor analysis it is possible to assess the inter-relationships within the complete pool of items. The number of factors resulting from the factor analysis provides information about the dimensionality of ROM. If the analysis produces one factor, containing all ROM items, joint ROM can be regarded as a unidimensional trait of the patient (i.e. the ROMs of different joint actions are all representations of the same trait—the patient's sinuosity). If more factors are identified, effectively isolating subgroups of closely associated items, joint ROM cannot be regarded as a trait of the patient, but a trait at a lower level (e.g. of the joint or the joint action). In the analysis, factors are identified if they can account for a significant amount of variance within the item pool (represented by an eigenvalue >1).

The relationship between joint ROM and locomotor disability was assessed using both bivariate and multivariate analyses. Pearson correlation coefficients were computed to establish the bivariate relationships between ROMs for the joint actions on the one hand and the two disability measures on the other hand. Stepwise multiple regression analyses were also performed, using observed disability and self-reported disability as dependent variables. The ROM scores were the independent variables. Stepwise regression was used to show which of the ROM scores were predominantly responsible for the relationship between joint ROM and disability. The inclusion criterion for the regression analyses was $P < 0.05$ ($P_{in} = 0.05$), the exclusion criterion was $P > 0.10$ ($P_{out} = 0.10$). The bivariate and multivariate analyses were carried out using the total group of patients (including both hip and knee OA patients), and also using subgroups of hip or knee OA patients only. All analyses were carried out using SPSS for Windows, v. 8.0 (SPSS Inc., Chicago, IL, USA).

TABLE 1. Patient characteristics ($n = 198$)

	n	%
Gender		
Male	43	21.7
Female	155	78.3
Osteoarthritis		
Hip	69	34.8
Knee	119	60.1
Hip and knee	10	5.1
	Mean ± S.D.	Range
Age (yr)	68.0 ± 8.9	39 to 84
Disability		
Observed disability	0.0 ± 3.9	− 6.2 to 13.4
Self-reported disability (IRGL)	− 20.3 ± 5.6	− 28 to −7
	Left	Right
Range of motion (°): mean ± S.D. (range)		
Knee flexion	136.3 ± 11.4 (65 to 155)	136.3 ± 10.6 (90 to −153)
Knee extension	0.3 ± 5.3 (− 20 to 13)	0.2 ± 5.2 (− 19 to 12)
Hip flexion	115.4 ± 12.3 (25–146)	115.3 ± 11.7 (60 to 148)
Hip extension	2.3 ± 7.3 (− 18 to 30)	2.2 ± 7.6 (− 15 to 30)
Hip adduction	11.8 ± 4.7 (0 to 25)	12.2 ± 4.6 (− 2 to 22)
Hip abduction	18.3 ± 6.9 (− 3 to 40)	17.2 ± 7.5 (− 7 to 45)
Hip internal rotation	29.4 ± 9.5 (− 5 to 50)	28.6 ± 10.2 (− 15 to 52)
Hip external rotation	34.8 ± 9.6 (− 5 to 60)	34.5 ± 9.2 (10 to 56)

Results

Patient characteristics

Table 1 shows the patient characteristics, average scores on observed and self-reported disability, and average ROM scores for all joint actions. A negative ROM score means a patient was unable to reach the position defined as horizontal by the protocol for ROM measurements [17]. A substantial group of patients was unable to reach the defined horizontal position for extension of the knee or hip. This is known as flexion contracture. Flexion contracture of both the knee and hip was present in 25.5% of patients. Flexion contracture of the knee was present in an additional 31.5% of patients, and flexion contracture of the hip was found in another 15.5%. In total, flexion contracture of either the knee or hip or of both the knee and hip was observed in 72.5% of patients.

Inter-relationships of joint actions

The Pearson correlation coefficients between the ROM values of all joint actions of the knees and hips are presented in Table 2. The highest correlations were found between the identical actions of the lateral and contralateral joints (e.g. flexion of the left hip and flexion of the right hip); these correlations ranged from 0.35 to 0.82. Especially for the joint actions of the hip in the transverse and sagittal planes (flexion, extension and internal and external rotation), these correlations were high, ranging from 0.62 to 0.82. The correlations among other joint actions (i.e. actions other than identical actions of the lateral and contralateral joints) were substantially lower, ranging from −0.16 to 0.44.

In the factor analysis, five factors were identified. In total, these factors accounted for 66.5% of the variance. The factor structure is presented in Table 3. This table shows the factor structure of the variables for joint mobility. Factor loadings of <0.40 are excluded from this table. All five factors are loaded by identical muscle actions of the lateral and contralateral joints (e.g. factor 1 is loaded by flexion of both the left and the right hip). Both joint actions of the knee load on the same factor. The other four factors are loaded by the six joint actions of the hip.

Although there are also some significant relationships between different joint actions (e.g. flexion and internal rotation of the hip), the correlation coefficients and factor structure primarily reveal a very close relationship between the ROMs of the same joint action of the lateral and contralateral joints. Because of this finding, the average ROM of the same lateral and contralateral joint actions was calculated and used as the ROM value for that joint action (e.g. the average ROM value for flexion of the left knee and flexion of the right knee was calculated and used as the ROM value for flexion of the knee) in the subsequent analyses of the association between ROM and disability.

TABLE 2. Inter-relationships of ROM of joint actions: Pearson correlation coefficients

		K extension		K flexion		H flexion		H extension		H abduction		H adduction		H ext. rot.		H int. rot	
		L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R
K ext.	L																
	R	0.50															
K flex.	L	0.36	0.19														
	R	0.07	0.41	0.50													
H flex.	L	−0.02	0.07	0.17	0.27												
	R	−0.16	−0.03	0.05	0.14	0.71											
H ext.	L	0.21	0.13	0.13	0.15	0.14	0.16										
	R	0.12	0.14	0.08	0.11	0.08	0.21	0.82									
H abd.	L	0.11	0.07	0.07	0.19	0.33	0.27	0.33	0.30								
	R	−0.11	−0.05	−0.01	0.01	0.20	0.42	0.28	0.39	0.50							
H add.	L	0.07	0.12	0.11	0.08	0.17	0.09	0.07	−0.00	−0.10	0.05						
	R	−0.05	0.08	0.01	0.10	−0.05	0.14	0.12	0.12	−0.05	−0.02	0.35					
H ext. rot	L	0.03	0.07	0.19	0.21	0.41	0.26	0.03	0.01	0.40	0.27	0.07	−0.02				
	R	−0.13	−0.08	0.10	0.16	0.29	0.37	0.01	0.05	0.28	0.41	−0.04	0.10	0.68			
H int. rot	L	0.05	0.07	0.13	0.14	0.36	0.31	0.16	0.09	0.26	0.18	0.40	0.23	0.01	0.05		
	R	−0.07	0.05	0.09	0.16	0.26	0.44	0.12	0.17	0.20	0.40	0.25	0.32	0.19	0.18	0.63	

K, knee; H, hip; L, left; R, right; ext., extension; flex., flexion; abd., abduction; add., adduction; ext. rot., external rotation; int. rot., internal rotation.

Range of joint motion and disability

Pearson correlation coefficients between the ROMs of joint actions on the one hand and disability on the other hand are presented in Table 4. Generally, there was a negative relationship between ROM and disability, i.e. a decreased ROM was associated with an increase in disability. However, not all joint actions seemed to be related to the level of disability in these patients. Extension, abduction and external rotation of the hip and flexion of the knee were associated primarily with disability (both self-reported and observed) in both patients with hip OA and patients with knee OA. To a lesser degree, significant relationships were also found between the ROM of flexion of the hip and disability.

The results of the multiple regression analyses are presented in Tables 5 and 6. Each table shows the results of both the total group and the subgroups comprising only hip or knee OA patients. Again, the level of disability was found to be dependent on the level of joint mobility. For both observed and self-reported disability, between 20 and 25% of the variance in disability was accounted for by the level of joint mobility of the patients. The pattern found in subgroups of hip and knee OA patients was largely equivalent to that found in the total group. Extension and external rotation of the hip were primarily responsible for the association between joint ROM and disability. Flexion of the knee was a third important joint action in this relationship.

The subgroup analyses presented here were repeated excluding all 10 patients diagnosed as having both hip and knee OA. This yielded results equivalent to those shown in Tables 5 and 6. The results of these additional subgroup analyses are therefore not presented here.

To test whether the presence of flexion contractures could be responsible for the relationship between joint ROM and disability, the regression analyses were also repeated with two dichotomous (present/absent) variables for flexion contracture of the knee or hip included as potential independent variables. However, the inclusion of flexion contracture as a potential determinant of disability did not change the outcome of these analyses; the results were equivalent to those presented in Tables 5 and 6.

TABLE 3. Factor analysis of inter-relationships of ROMs of joint actions

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Left knee extension	–	0.70	–	–	–
Right knee extension	–	0.72	–	–	–
Left knee flexion	–	0.70	–	–	–
Right knee flexion	–	0.64	–	–	–
Left hip flexion	0.82	–	–	–	–
Right hip flexion	0.74	–	–	–	–
Left hip extension	–	–	–	0.88	–
Right hip extension	–	–	–	0.93	–
Left hip adduction	–	–	0.62	–	–
Right hip adduction	–	–	0.87	–	–
Left hip abduction	–	–	–	0.44	–
Right hip abduction	–	–	–	0.52	–
Left hip internal rotation	0.75	–	–	–	–
Right hip internal rotation	0.57	–	–	–	–
Left hip external rotation	–	–	–	–	0.85
Right hip external rotation	–	–	–	–	0.92

Discussion

The overall goal of the present study was to assess the relationship between joint ROM and disability in patients with OA of the hip or knee. To this end, the inter-relationships of ROMs for all joint actions of the knee and hip were first established in patients with OA. Clearly, joint ROM cannot be regarded as a unidimensional physical characteristic of patients with OA: close relationships were found for the same joint action on

TABLE 4. Pearson correlation coefficients between ROMs and disability

	Observed disability			Self-reported disability		
	Total group ($n = 198$)	Hip OA ($n = 79$)	Knee OA ($n = 129$)	Total group ($n = 198$)	Hip OA ($n = 79$)	Knee OA ($n = 129$)
Knee flexion	− 0.28**	− 0.34**	− 0.23*	− 0.32**	− 0.34**	− 0.29*
Knee extension	− 0.07	− 0.16	− 0.01	− 0.19	− 0.20	− 0.13
Hip flexion	− 0.25*	− 0.15	− 0.26*	− 0.16	− 0.09	− 0.23*
Hip extension	− 0.35**	− 0.52**	− 0.29**	− 0.34**	− 0.29*	− 0.30**
Hip adduction	− 0.03	− 0.01	− 0.05	− 0.02	− 0.04	− 0.08
Hip abduction	− 0.33**	− 0.33*	− 0.36**	− 0.23*	− 0.16	− 0.30**
Hip internal rotation	− 0.16	− 0.07	− 0.22	− 0.09	− 0.30*	− 0.20
Hip external rotation	− 0.31**	− 0.26	− 0.23*	− 0.31**	− 0.20	− 0.35**

*$P < 0.01$; **$P < 0.001$.

the lateral and contralateral sides, but relationships between the ROMs of different joint actions were much weaker. Because of this result, the ROMs of the same joint action on the lateral and contralateral sides were summed and used in subsequent analyses. The range of joint motion was found to be closely associated with the level of disability in these patients. On average, 20–25% of the variance in disability was attributable to differences in ROM. The ROMs of three specific joint actions showed the strongest relationships with disability. These were extension and external rotation of the hip and flexion of the knee.

The inter-relationships between the ROMs of different joint actions were assessed using correlation and factor analyses. The most important finding was the clear inter-relationship found for the same joint action of the lateral and contralateral joints. High correlations between identical actions of the lateral and contralateral joints have also been reported by Escalante *et al.* [10]. In the factor analysis, the six different joint actions of the hip were clustered into four factors. Extension and abduction loaded on the same factor, while flexion and internal rotation loaded on another factor. The other two factors found for hip ROM were both loaded by a single joint action of the hip. The clustering of two different joint actions into one factor may be explained by the dependence of both joint actions on the same muscles. A number of muscles are responsible for more than one joint action of the hip, mainly combining flexion or extension with medial or lateral rotation [22].

No major differences were found between patients with hip and knee OA with regard to the relationships of joint ROM with disability. The results were similar for the two subgroups of patients. Extension and external rotation of the hip showed significant relationships with disability in patients with knee OA. Likewise, flexion of the knee was associated with disability in hip OA patients. Although the study population included some patients (10 in total) with both types of OA (who were therefore included in both subgroups), these patients were not responsible for the existence of these relationships in this population. The results of the subgroup analyses did not change significantly when patients with both types of OA were excluded.

Some issues need to be addressed concerning the methods used in this study and their effect on the results presented here. Joint ROM can depend on factors other than articular deformation. Certain motions may be too painful for the patient to complete, or the patient may lack the muscle strength to maintain the joint action. This results in impaired ROM without a clear articular cause for this impairment. In the present study, the effect of muscle strength on ROM was minimized by

TABLE 5. Multiple regression analyses with observed disability as the dependent variable

	Total group ($n = 198$)	Hip OA only ($n = 79$)	Knee OA only ($n = 129$)
Fraction of variance accounted for (r^2)	0.239	0.272	0.232
β			
Knee flexion	− 0.183**	NS	− 0.154
Knee extension	NS	NS	NS
Hip flexion	NS	NS	NS
Hip extension	− 0.313**	− 0.516**	− 0.201*
Hip adduction	NS	NS	NS
Hip abduction	NS	NS	− 0.186
Hip internal rotation	NS	NS	NS
Hip external rotation	− 0.263**	− 0.244**	− 0.224*

NS, not significant; variable was not entered into the equation; *$P < 0.05$; **$P < 0.01$. β, regression coefficient.

TABLE 6. Multiple regression analyses with self-reported disability (IRGL) as the dependent variable

	Total group ($n = 198$)	Hip OA only ($n = 79$)	Knee OA only ($n = 129$)
Fraction of variance accounted for (r^2)	0.248	0.206	0.255
β			
Knee flexion	− 0.221**	− 0.197	− 0.195*
Knee extension	NS	NS	NS
Hip flexion	NS	NS	NS
Hip extension	− 0.298**	− 0.232*	− 0.279**
Hip adduction	NS	NS	NS
Hip abduction	NS	NS	NS
Hip internal rotation	NS	NS	NS
Hip external rotation	− 0.256**	− 0.229*	− 0.331**

NS, not significant; variable was not entered into the equation; *$P < 0.05$; **$P < 0.01$. β, regression coefficient.

determining the assisted active ROM. This means that the therapist provided support against the pull of gravity but no support for the completion of the joint action. The patient had to carry out the motion by himself, using muscle strength to increase the angle, but did not have to use his muscle strength to keep his limb in position. Of course this minimizes, but does not eliminate, the effect of muscle strength on ROM. Neither does it eliminate the influence of pain during motion on ROM, and it does not take the clinical status of the joint (whether or not it is diagnosed as having OA) into account. However, the aim of the present study was to reveal the role of ROM as a determinant of functional disability. Joint ROM has its own determinants, but whether an impaired ROM is caused by pain during motion, insufficient muscle strength or intra- and periarticular deformation due to OA is a question beyond the scope of this study. More in-depth research needs to be carried out to provide insight into this complex matter.

To our knowledge, other research on the topic of joint mobility, especially the range of joint motion of specific joint actions in patients with OA, and disability has been scarce. In a population survey, Odding *et al.* [9] found that restricted ROM of a number of joint actions was associated with the presence of locomotor disability. The strongest relationships were found for flexion of the knee and flexion of the hip. Significant, but weaker, relationships with disability were also found for internal and external rotation of the hip. This is partly consistent with the findings of the present study. Both studies found a relationship between the presence of disability and the restricted range of joint motion in the sagittal (flexion of the knee and flexion or extension of the hip) and transverse planes (internal and external rotation of the hip). One major difference, however, is that in the present study extension of the hip was found to be closely associated with disability, whereas Odding *et al.* [9], and also Escalante *et al.* [10], identified impaired flexion of the hip as a strong risk factor for disability. This may be attributable to differences between the studies in the population under survey: for the present study the data were from patients with OA of the hip or knee, whereas the other two studies were surveys of a general population of elderly people. It is possible that, in patients with OA, the relationship between joint ROM and disability differs from that in the general population, perhaps because of the presence of flexion contractures in patients with OA. Another possibility is that differences between the studies in the protocol for taking ROM measurements (in defining the horizontal, starting positions, etc) have led to different results.

We conclude that there is a clear relationship between joint ROM and disability in patients with OA of the knee or hip. However, the relationship does not apply to all actions of the knee or hip joints. Flexion of the knee and extension and external rotation of the hip were found to be most strongly associated with disability. Restricted joint ROM appears to be an important risk factor for the occurrence of locomotor disability in patients with OA.

References

1. Dieppe P. Osteoarthritis. In: Klippel JH, Dieppe PA, eds. Rheumatology. St Louis: Mosby, 1994.
2. Dekker J, Boot B, van der Woude L, Bijlsma JWJ. Pain and disability in osteoarthritis: a review of biobehavioral mechanisms. J Behav Med 1992;15:189–214.
3. Bagge E, Bjelle A, Eden S, Svanborg A. Osteoarthritis in the elderly: clinical and radiological findings in 79 and 85 year olds. Ann Rheum Dis 1991;50:535–9.
4. McAlindon TE, Cooper C, Kirwan JR, Dieppe PA. Determinants of disability in osteoarthritis of the knee. Ann Rheum Dis 1993;52:258–62.
5. Madsen OR, Bliddal H, Egsmose C, Sylvest J. Isometric and isokinetic quadriceps strength in gonarthrosis: inter-relations between quadriceps strength, walking ability, radiology, subchondral bone density and pain. Clin Rheumatol 1995;14:308–14.
6. Guccione AA. Arthritis and the process of disablement. Phys Ther 1994;74:408–14.
7. Dunlop DD, Hughes SL, Edelman P, Singer RM, Chang RW. Impact of joint impairment on disability-specific domains at four years. J Clin Epidemiol 1998;51:1253–61.
8. Bergström G, Aniansson A, Bjelle A, Grimby G, Lundgren-Lindquist B, Svanborg A. Functional consequences of joint impairment at age 79. Scand J Rehabil Med 1985;17:183–90.
9. Odding E, Valkenburg HA, Algra D, Vandenouweland FA, Grobbee DE, Hofman A. The association of abnormalities on physical examination of the hip and knee with locomotor disability in the Rotterdam study. Br J Rheumatol 1996;35:884–90.
10. Escalante A, Lichtenstein MJ, Dhanda R, Cornell JE, Hazuda HP. Determinants of hip and knee flexion range: results from the San Antonio Longitudinal Study of Aging. Arthritis Care Res 1999;12:8–18.
11. Hurley MV, Scott DC. Improvements in quadriceps sensorimotor function and disability of patients with knee osteoarthrits following a clinically practicable exercise regime. Br J Rheumatol 1998;37:1181–7.
12. Slemenda C, Brandt KD, Heilman DK, Mazzuca S, Braunstein EM, Katz BP *et al.* Quadriceps weakness and osteoarthritis of the knee. Ann Intern Med 1997;127: 97–104.
13. Ettinger WH, Afable RF. Physical disability from knee osteoarthritis: the role of exercise as an intervention. Med Sci Sports Exerc 1994:26;1435–40.
14. Van Baar ME, Dekker J, Oostendorp RAB, Voorn TB, Lemmens JAN, Bijlsma JWJ. The effectiveness of exercise therapy in patients with osteoarthritis of the knee or hip: a randomized clinical trial. J Rheumatol 1998;25:2432–9.
15. Altman R, Asch E, Bloch D, Bole G, Borenstein K, Brandt K *et al.* Development of criteria for the classification and reporting of osteoarthritis: classification of osteoarthritis of the knee. Arthritis Rheum 1986;29: 1039–49.
16. Altman R, Alarcon G, Appelrouth D, Bloch D, Borenstein

D, Brandt K *et al*. The American College of Rheumatology criteria for the classification and reporting of osteoarthritis of the hip. Arthritis Rheum 1991;34:505–14.
17. Norkin CC, White DJ. Measurement of joint motion: a guide to goniometry. Philadelphia: F. A. Davis, 1986.
18. Oerlemans HM, Goris JA, Oostendorp RAB. Impairment level sumscore in reflex sympathetic dystrophy of one upper extremity. Arch Phys Med Rehabil 1998;79:979–90.
19. Steultjens MPM, Dekker J, van Baar ME, Oostendorp RAB, Bijlsma JWJ. Internal consistency and validity of an observational method for assessing disability in mobility in patients with osteoarthritis. Arthritis Care Res 1999;12:19–25.
20. Huiskes CJAE, Kraaimaat FW, Bijlsma JWJ. De ontwikkeling van de IRGL: een instrument om gezondheid te meten bij patienten met reuma. [Development of the IRGL: a health status measure for rheumatic patients]. Gedrag Gezondheid 1990;18:78–89.
21. Evers AWM, Taal E, Kraaimaat FW, Jacobs JWG, Abdel-Nasser A, Rasker JJ *et al.* A comparison of two recently developed health status instruments for patients with arthritis: Dutch AIMS2 and IRGL. Br J Rheumatol 1998;37:157–64.
22. Staubesand J, ed. Sobotta atlas of human anatomy: Volume 2: thorax, abdomen, pelvis, lower limbs. Munich: Urban & Schwarzenberg, 1989.