Muscle strength, functional performance and self-reported outcomes four years after arthroscopic partial meniscectomy in middle-aged patients

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ABSTRACT

Objective. To examine thigh muscle strength, functional performance and self-reported outcome in patients with non-traumatic meniscus tears four years after operation. We further studied the impact of a strength deficit on self-reported outcome and evaluated the feasibility of three performance tests in this patient group.

Methods. Patient group: 45 patients (mean age 45.7, 36% women) who had an arthroscopic partial meniscectomy on average 4 (range 1–6) years previously. *Main outcome measures*: Isokinetic strength of knee extensors and flexors, functional performance (one-leg hop, one-leg rising and square-hop) and a self-reported questionnaire, Knee Injury and Osteoarthritis Outcome Score.

Results. We found lower knee extensor strength and worse 1-leg rising capacity in the operated leg, but no difference between operated and non-operated leg for knee flexors, $p \leq 0.004$ and $p>0.3$ respectively. Patients with a stronger quadriceps of the operated leg compared to the non-operated had less pain and better function and quality of life ($r = 0.4$–0.6, $p \leq 0.010$). We found 1-leg rising and 1-leg hop suitable performance tests in middle-aged meniscectomized patients.

Conclusion. Quadriceps strength is reduced in the meniscectomized leg compared to the non-operated leg four years after surgery. This relative quadriceps weakness significantly affects objective and self-reported knee function, pain and quality of life, indicating the importance of restoring muscle function after meniscectomy in middle-aged patients.

Meniscectomy has generally been accepted as a treatment with favourable result, i.e. effective symptom relief and fast improvement of knee function (1, 2). However, functional limitations after meniscectomy have been reported both in short-term (3, 4) and long-term follow-up studies (5, 6). Furthermore, radiographic signs of osteoarthritis (OA) have been reported in about half of the individuals ten to fifteen years after meniscectomy (7-9). Meniscus tears in the middle-aged population, often referred to as degenerative tears, may be associated with incipient OA and represent an early sign of disease (5). The reason for the functional limitations experienced by patients who have undergone meniscectomy is not clear. Strength deficits have been reported two to six months after surgery (10, 11), although the functional implications of a strength deficit have not been elucidated. Accordingly, there is no consensus regarding the importance of restoring muscle function after meniscectomy (12-14). Meniscectomy patients are usually prescribed a home exercise program, but supervised physical therapy is not considered necessary (15).

In the present study, muscle strength, functional performance and self-reported outcome were examined in patients with non-traumatic meniscus tears four years after the meniscectomy. Furthermore, the impact of a strength deficit on self-reported outcome and the feasibility of three performance tests were evaluated.

PATIENTS AND METHODS

Patients

Patients who were arthroscopically meniscectomized at the age of 35-45 were identified through the surgical code system. To be eligible patients had to have been operated on between one and six years prior to the study start. An invitation letter with a questionnaire comprising co-morbid conditions, current activity level of work and leisure time, current walking ability and knee-related problems was sent to 166 patients. Patients had to be able and willing to participate in an exercise intervention during 4 months with physical tests before and after the intervention (16). Patients were excluded if they had a cruciate ligament injury of either knee, had severe cartilage changes at the arthroscopy, steroid medication, physical limitations due to co-morbid condition, depression, sick leave/sick pension caused by knee dysfunction, lack of outdoor walking ability or were competitive athletes. Eighty-one patients accepted the invitation and 56 who fulfilled the inclusion criteria were invited to participate in the study. This study reports patients at baseline. The study was approved by our institutional review board.

Evaluation methods

The evaluation included isokinetic tests of muscle strength, functional performance tests, and a self-reported disease-specific questionnaire. The strength and functional performance of the operated leg was compared to the results of the non-operated leg. Body Mass Index (BMI) was calculated after obtaining height and weight by a wall-mounted ruler and a calibrated scale. The standardized formula for BMI (kg/m^2) was used.

Isokinetic muscle strength testing

Isokinetic muscle strength was tested with a computerized dynamometer, Biodex® (Biodex System III Pro with Biodex Advantage Software, Biodex Medical Systems, Inc., Shirley, New York). Before the test, patients warmed up on a stationary bike for approximately ten minutes. The patient was sitting with the thigh supported with 90° hip flexion and the arms folded over the chest. The body and thigh were fastened to the chair with straps. The instructions given verbally were standardized. The patients were allowed to practise the isokinetic movements before the test. To minimize the risk of bias, the non-operated leg was tested before the operated leg. We measured concentric Peak Torque of knee extensors and knee flexors at angular velocities of 60°/s and at 180°/s in the range of 15 to 95 degrees of flexion. Peak Torque (PT) in Newton metres (Nm) refers to the highest registered muscle contraction, evaluated as force times length of the moment arm over a certain joint. In correlations with functional performance tests peak torque values were calculated as percentages of body weight. Biodex system III has been tested for reliability and validity (17).

Functional performance tests

The 1-leg hop test, described by Tegner et al (18), has shown reliable in healthy volunteers and athletes (19, 20). The subject, standing on one foot, with his hands on his back, was asked to jump as long as possible and land steadily on the same foot. The subject had to be able to land and stand on one leg long enough for the examiner to measure the hop distance. The test was repeated at least three times, or as long as the subject made further progress. The best attempt was recorded.

The 1-leg rising test was designed to evaluate knee and hip extensor strength in a functional position in middle-aged patients (21). The subject was sitting on a 48-centimetre high chair and was asked to rise on one leg as many times as possible in succession, without swinging the body or arms. The number of rises was recorded. The test was terminated when the subject failed to rise or if he either made compensatory arm movements or fell back to the chair during the test. The test was terminated with the last correct rise.

The square-hop test, developed and used in clinical practice by physical therapists, is a measure of dynamic postural balance, coordination and strength in the thigh and calf muscles. It has been tested for intertest and intratest reliability ($r = 0.94$ and 0.74, respectively) in 41 individuals (19 knee-injured individuals and 22 controls) (22, 23). In brief, the patient was standing outside a 30 x 35 cm square marked on the floor with tape and instructed to jump clockwise on the non-operated leg, in and out of the square, all the time facing in the same direction**.** In this way, subjects had to jump first forwards into the square, then sideways to the left out of the square, then sideways to the right into the square again and then forwards out of the square and backwards into the square again, thereafter sideways to the right out of the square and then sideways to the left into the square and finally backwards out of the square to the starting position (Figure 1). Patients were instructed to continue to jump in this pattern as long as they could. The number of times the foot touched inside the square without touching the tape was recorded. Patients were allowed to stand still on one leg to regain their balance, but not to make a double hop or to jump in the wrong direction. The number of correct into-square hops was recorded. The procedure was repeated on the operated leg. After the test the patient was allowed to start over again and have a second try, and finally the best series of each leg was recorded.

Self-reported outcomes

For assessment of knee-related symptoms, function and quality of life, the Knee injury and Osteoarthritis Outcome Score (KOOS) was used (24). The KOOS is a patient-administered questionnaire, which consists of 5 subscales: pain, other symptoms, function in activities of daily living (ADL), function in sport and recreation (Sport/rec) and knee-related quality of life (QOL). The previous week is taken into consideration when answering the questions. Standardized answer options are given (5 Likert boxes) and each question gets a score from 0 to 4. A normalized score (100 indicating no symptoms and 0 indicating extreme symptoms) is calculated for each subscale. The KOOS has high test-retest reproducibility (intraclass correlation coefficient > 0.75) (24, 25). The KOOS is validated for meniscectomy (24) and the Sport and Recreation and Quality of life subscales have been shown to be more discriminative than the subscales Pain, other Symptoms and ADL in patients with post-traumatic OA after meniscectomy (26).

Test procedure

The same examiner (YE) tested all patients. After informed consent, height and weight were obtained. A 10-minute warm-up on a stationary bike was followed by the functional performance testing one-leg hop, one-leg rising and square hop. The non-operated leg was consistently tested before the operated leg**.** Between tests, patients recovered as they answered the self-administered questionnaires. Isokinetic strength of the lower extremities was measured on a separate occasion during the same week.

Statistical analyses

Results are presented as mean values and standard deviations (±SD). Difference between the operated and the non-operated leg was expressed as a percentage, to facilitate comparison with previous studies. A strength and functional performance ratio was calculated by dividing the result of the operated leg by the result of the non-operated. These ratios were used in correlation analyses. In tests where a zero value could occur, 1.0 was first added to all results to avoid division error.

Paired samples *t*-test was used to determine differences in outcome between the operated and the non-operated leg and the 1-sample *t*-test was used to compare self-reported outcome between the study group and two reference groups (26)**.** Correlation analyses were performed according to Spearman. All statistical analyses were performed with the Statistical Package for the Social Sciences, version 11.5 (SPSS, Chicago, IL).

RESULTS

Eleven of the 56 subjects who had accepted to participate in the study failed to attend due to work or other commitments. Characteristics of the 45 subjects examined are shown in table 1. There were no differences between men and women in age (P = 0.21), follow-up time (P = 0.39), or BMI (P = 0.69). The mean BMI for the group was 26.5 kg/m^2 (Table 1).

Muscle strength

Isokinetic knee extensor strength, at angular velocities 60°/second and 180°/second, was lower for the operated than for the non-operated leg ($P \leq 0.002$) (Table 2). At 60°/second and 180°/second, the mean difference of the quadriceps muscle strength compared with the contra-lateral leg was 9% and 6% respectively. With respect to knee flexors, there was no difference between the operated and non-operated leg ($P > 0.3$) (Table 2).

Functional performance

For the 1-leg rising test, the result of the operated leg was worse than that of the non-operated leg, (mean ± SD rises 12 ± 10 and 15 ± 11, respectively ; P = 0.004) (Table 2). The mean difference was 10%. For the other two functional performance tests, square-hop and 1-leg hop for distance, no differences were seen between the operated and non-operated leg (Table 2).

Self-reported symptoms, knee-related function and quality of life

Patients reported symptoms and functional limitations on the KOOS, with mean scores for different dimensions varying between 63 and 89. The mean ± SD subscale scores were: 83 ± 14 for pain, 83 ± 14 for other symptoms, 89 ± 13 for ADL, 63 ± 26 for sport and recreation function, and 64 ± 20 for knee-related quality of life. The KOOS results compared with 2 reference groups from a previous study (26) are shown in Figure 2. Patients with radiographic OA who underwent meniscectomy 17 years ago (-▲-), n = 41, mean age 57, and age- and sex-matched controls without OA or known knee injury (-○-), n =50, mean age 53, were used for comparison. The 1-sample *t*-test was used to determine differences between groups. Our study group scored worse than the aged-matched healthy control group in all 5 scales ($P < 0.001$). In comparison with the post-meniscectomy group with OA, our group scored better in the symptoms, ADL, and sport and recreation scales ($P = 0.002$, $P < 0.001$, and $P = 0.006$, respectively), but scored at the same level as the OA group in the pain scale ($P > 0.5$) and quality of life scale ($P = 0.1$).

Relationship between muscle strength and self-reported outcomes

The quadriceps ratio between the operated and non-operated leg at 60°/second and 180°/second angular velocities correlated moderately with all five KOOS subscale scores (r = 0.38 - 0.60, $P \leq 0.010$), whereas the hamstrings ratio only correlated significantly with one subscale, KOOS symptoms (r = 0.39, $P = 0.009$) (Table 3).

Relationship between muscle strength and performance-based function

The quadriceps ratio at 60°/second and at 180°/second angular velocities showed a moderate correlation to the 1-leg rising ratio (r = 0.4 and 0.5, respectively; $P \leq 0.004$). The hamstring strength ratio at 180°/second showed a low correlation to the 1-leg rising ratio (r = 0.3, $P = 0.029$). There was no significant correlation between the quadriceps strength ratio and the 1-leg hop ratio or the square-hop ratio, r ≤ 0.2, $P > 0.1$).

Feasibility of performance tests

Most subjects could perform the 1-leg rising test, although 7 patients failed to rise on one leg. The test identified differences between the operated and the non-operated leg, and correlated moderately with quadriceps strength adjusted for body weight and with hamstring strength adjusted for body weight in the operated leg at 60°/second (r = 0.4, *P* = 0.010). All patients performed the 1-leg hop test, which correlated strongly with isokinetic quadriceps strength adjusted for body weight at 60°/second in the operated and the non-operated leg (r = 0.7 - 0.8, *P* < 0.001) and with hamstring strength adjusted for body weight in the operated and the non-operated leg (r = 0.7, *P* < 0.001). The square-hop test was performed by all but one patient and results ranged from 0 to 17 hops for the operated leg. Some patients found it difficult to follow the instructions. The square-hop test demonstrated a moderate correlation to isokinetic quadriceps strength adjusted for body weight on the operated and the non-operated leg (r = 0.5 and 0.4, respectively; *P* < 0.001).

DISCUSSION

The findings that isokinetic and performance-based knee extensor strength is lower in the operated leg than the contra-lateral leg four years after meniscectomy due to a non-traumatic tear, have not been reported previously. The postoperative rehabilitation program aims to decrease the strength difference between the limbs to that found in healthy individuals (18). Testing strength in healthy controls, Petschnig et al. found five percent or less difference between the right and left leg (27), whereas Borges (28) did not find any significant differences. In persons who have undergone meniscectomy, quadriceps strength deficits of 12−18% have been found two to six months after surgery (10, 11, 29), but reports of muscle strength deficits in the long term are scarce. Holder-Powell et al (30), who examined young subjects with various knee injuries, found deficits of 20% in subjects five years postinjury.

They concluded that after knee injuries, the strength of the quadriceps muscle does rarely return to the pre-injured state (30). In the present study, we found a deficit of 9% in isokinetic quadriceps strength and a functional deficit of 10% in the 1-leg rising test. As in our study, other studies have demonstrated that the quadriceps muscles are usually more affected than the hamstrings after knee injury and surgery (12, 31).

Few studies have examined the relationship between strength deficits and function. With isokinetic tests it is possible to quantify muscle strength, but the significance of other aspects of muscle function such as coordination and timing is not measured. Functional performance tests are designed as attempts to mimic natural movements of sports or every-day life. They are complex because they challenge strength and endurance as well as coordination and involve multiple joints and muscle groups. Accordingly, functional tests cannot separately measure the different components that constitute performance. In a previous study, the complexity of this issue has been examined. Approximately one-third of the variation of functional capacity can be explained by the variation of isokinetic strength (32). Moffet et al. (29) found that patients with strength deficits >25 % had locomotor abnormalities in movements and muscle activations that affected stair-climbing performance. In patients with anterior cruciate ligament-reconstructed knees, Wilk et al. (33) found a positive correlation between quadriceps strength and subjective knee scores and functional hop tests. In the present study, the association between the quadriceps strength deficits and self-reported symptoms and function suggests a close relationship between muscle strength and functional limitations in middle-aged patients who have undergone meniscectomy. Furthermore, the relationship between the quadriceps strength ratio and the 1-leg rising test ratio may indicate that decreased quadriceps strength is a contributing factor to these patients' limited knee function.

Different factors may influence knee joint structures negatively following knee injuries. The thigh muscles play an important role in stabilizing the knee joint and distributing the loads evenly across the joint (34, 35). Insufficient muscle strength likely leads to greater physical stress with more cartilage impact loading as the muscles fail to absorb forces during gait (36). Decreased proprioceptive acuity may affect the maintenance of joint stability as coordination of limb position and muscle activity is dependent of adequate sensory input from the knee joint structures (37, 38). Becker et al. (39), who investigated quadriceps strength and maximal voluntary activation in patients four years after menisccetomy, found decreased quadriceps activation and muscle strength in both legs of their patients compared with a healthy control group. Regarding the relationship between limb muscle impairment and future joint disease, Hurley (40) hypothesized that muscle dysfunction is an important factor in the pathogenesis of osteoarthritis. Results of two longitudinal studies suggest that quadriceps weakness may predict radiographic OA development (41, 42). A nine percent quadriceps deficit four years after meniscectomy as in the present study may seem small, but in the perspective of a disease that develops over ten to fifteen years, even subtle muscle impairments may prove significant. Meniscectomy, that decreases the joint weightbearing area and increases femorotibial loading (43) is associated with OA (5, 8, 9). Muscle impairment with poor joint stabilization and decreased muscular shock absorption may make the knee cartilage in a meniscetomized joint even more vulnerable. It is noteworthy that patients in the present study displayed low self-reported outcome scores, with respect to pain and quality of life, similar to meniscectomy patients with radiographic OA (26).

In the present study three performance tests were included, as a complement to the strength tests. The 1-leg rising test, which has been suggested to predict the development of radiographic knee OA (42), detected differences between the operated and the non-operated leg. Seven patients failed to rise one time on the operated leg, and an association between the test and quadriceps and hamstrings strength was seen. The other two performance tests, square-hop and 1-leg hop for distance, were originally designed and validated for young athletes with an anterior cruciate ligament injury (22). The older and less fit patients in the present study had problems coordinating their movements in the square-hop test. Results demonstrated a moderate correlation to quadriceps strength, implying that the square-hop test is related to thigh muscle strength. The 1-leg hop test was easier to perform because everyone could hop in a forward direction. The 1-leg hop test gives an indication of the amount of confidence the patient has in his or her knee. This test has recently been tested and recommended for use in middle-aged patients who have undergone meniscectomy (44).

In clinical work, meniscectomy patients often state that their knees are unstable. This is not necessarily due to increased knee joint laxity, but might be caused by altered lower-extremity muscle strength and neuromuscular control (45). Interestingly, patients with meniscus injury or anterior cruciate ligament deficiency show similar self-reported score for instability (24). In the present study, the 1-leg hop in the operated and the non-operated legs correlated strongly with thigh muscle strength, indicating that strength is an important factor for achieving a good hop length. The functional performance test results had a wide range. Some patients performed better on the operated leg than on the non-operated. Leg dominance may have played a role, but as only one-third of the patients could state which leg that was the dominant leg, separate analyses with respect to leg dominance were not possible. Based on our results, the 1-leg rising and 1-leg hop tests seem suitable to assess functional performance in middle-aged meniscectomy patients. Both tests are feasible, as they require a minimum of equipment.

A limitation of our study is the lack of a healthy control group. We chose to use the contra-lateral leg as a reference leg, well aware of the discussion about this procedure in the literature (5, 22, 27). Changes in joint cartilage metabolism in both injured and uninjured knee have also been demonstrated after unilateral knee injury (46). However, the difference between a healthy control group and our study group would probably have been bigger than that between the operated and contra-lateral leg in the same individual. Another limitation is the relatively small study group. This is however compensated for by a rather homogeneous study group (middle age, isolated meniscal injury, degenerative tear, partial resection) and the combination of objective and patient-relevant outcome measures. The patients were not familiar with isokinetic testing before the study, but they were allowed to practise before measurements were obtained and they consistently started the test with the nonoperated leg. If a training effect did occur, this would have been to the advantage of the operated leg and would have resulted in a smaller deficit. Pain may affect the results in isokinetic testing, by reflexive inhibition of muscles (37). In the study group, four patients experienced pain in the operated knee during this test. Subgroup analyses, comparing groups with or without pain during tests, did not show any differences between patients with or without pain regarding knee extensor deficits.

In summary, the present study demonstrated that four years after meniscectomy, patients had reduced quadriceps strength in the operated leg compared with the nonoperated leg. We conclude that this relative quadriceps weakness significantly affects objective and self-reported knee function, pain and quality of life, indicating the importance of restoring muscle function after meniscectomy in middle-aged patients.

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TABLES

Table 1. Characteristics of the study group*

Characteristic	
Age, mean ± SD years	
Total group	45.7 ± 3.2
Men	46.1 ± 2.9
Women	44.8 ± 3.5
Men/Women, no.	29/16
Mean time since surgery, mean ± SD years	4 ± 1.3
Higher/Lower activity level, no.	30/15
BMI, mean ± SD kg/m^2	26.5 ± 3.3
Knee pain? no. yes/no	33/12
Operated knee, no. right/left	26/19

*Higher activity level = recreational sports such as golf, hiking, biking; lower activity level = yard work, shopping etc; BMI= body mass index.

Table 2. Isokinetic strength and functional performance tests (n=45)*

	Operated leg	Non-operated leg	Difference	% Difference	*P*
Isokinetic strength, Nm					
PT ext 60°/second	161 ± 49	179 ± 47	16.5 ± 25	9 ± 14	< 0.001
PT ext 180°/second	113 ± 31	122 ± 30	7 ± 14	6 ± 11	0.002
PT flex 60°/second	86 ± 28	89 ± 27	2 ± 15	1 ± 18	0.311
PT flex 180°/second	84 ± 25	87 ± 24	1.7 ± 11	1 ± 17	0.329
Functional performance					
Square hop (max reps)	6 ± 4	6 ± 6	0.2 ± 5	−19 ± 88	0.786
1-leg hop (cm)	108 ± 33	111 ± 32	3.6 ± 15.5	2 ± 18	0.126
1-leg rising (max reps)	11.5 ± 10	15 ± 11	3.8 ± 8.5	10 ± 87	0.004

* Values are the mean ± SD unless otherwise indicated. The paired *t*-test was used to compare the operated and nonoperated limb. PT = peak torque; Ext = Extension; Flex = Flexion; Max reps = maximum number of repetitions

Table 3. Spearman's correlation between ratio of strength and the five subscales of the Knee Injury and Osteoarthritis Outcome Score (KOOS)*

	KOOS subscale				
Strength ratio†	Symptoms	Pain	ADL	Sport/rec	QOL
PT E60	0.38	0.49	0.55	0.47	0.43
P value	0.010	0.001	< 0.001	0.001	0.004
PT E180	0.51	0.54	0.54	0.55	0.60
P value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
PT F60	0.39	0.18	0.12	0.13	0.12
P value	0.009	0.256	0.453	0.406	0.438
PT F180	0.06	−0.06	−0.10	−0.13	−0.11
P value	0.682	0.676	0.506	0.416	0.468

* ADL = activities of daily living; Sport/rec = sport and recreation; QOL = quality of life; see Table 2 for additional definitions.

† Result of the operated leg divided by the result of the non-operated leg.

FIGURE LEGENDS

Figure 1. Square-hop

Figure 2. Knee Injury and Osteoarthritis Outcome Score (KOOS) results for the study group versus 2 reference groups from a previous study (26). Mean scores are reported as an outcome profile of the five dimensions of the KOOS. A score of 100 represents no knee problems, and 0 represents extreme problems. ADL= activities of daily living; Sport/rec= sport and recreation; QOL= quality of life; (-●-) = present study group; -↖- = patients with radiographic osteoarthritis who underwent meniscectomy 17 years ago; -↓- = age- and sex-matched controls without osteoarthritis or known knee injury.

Figure 1. Square-hop

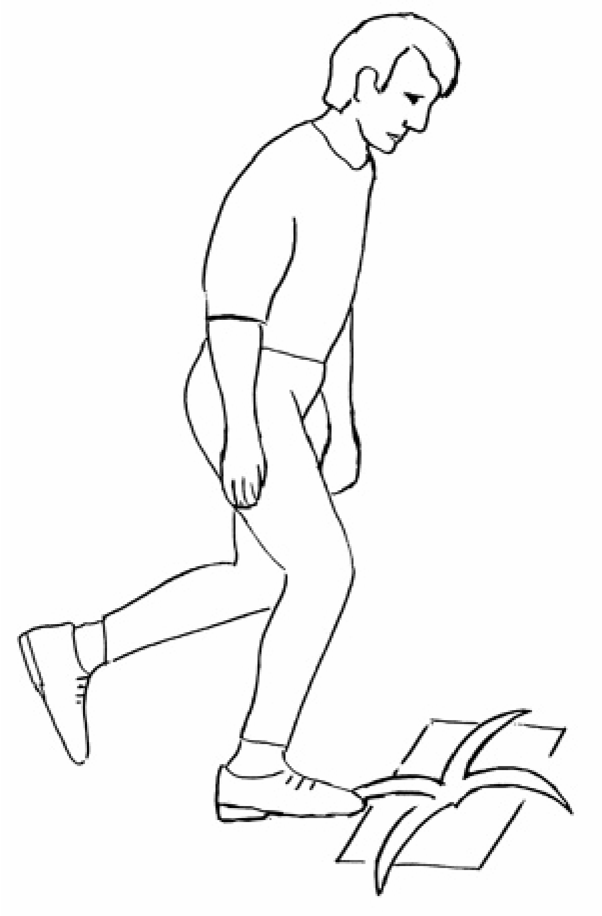

Figure 2. KOOS results for study group versus two reference groups