Exercise and Functional Performance in Middle-aged Patients with Knee Osteoarthritis

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Thesis 2005
It’s our choices that show what we truly are, far more than our abilities.

From “Harry Potter - The Chamber of Secrets” by J. K. Rowling
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List of papers


Some additional data, not previously presented, have been included in the results and discussion sections of this thesis.
Thesis at a glance

Paper I – Is reduced functional performance a risk factor for development of knee osteoarthritis?

Patients: 148 persons with chronic knee pain.

Methods: Prospective design, 5-year follow-up, tests of functional performance, radiographs.

Conclusions: Reduced functional performance increased the risk of incident knee osteoarthritis five years later, also when controlled for age, sex, BMI and pain.

Characteristics of the 94 subjects without radiographic OA at baseline

<table>
<thead>
<tr>
<th></th>
<th>Incident OA (n=41)</th>
<th>No OA (n=53)</th>
<th>OR (95% CI)</th>
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</thead>
<tbody>
<tr>
<td>Age, median (range)</td>
<td>48 (35–54)</td>
<td>44 (35–54)</td>
<td>1.58 (0.69–3.60)</td>
</tr>
<tr>
<td>Sex (women/men)</td>
<td>18/23</td>
<td>21/32</td>
<td>0.84 (0.37–1.92)</td>
</tr>
<tr>
<td>Body Mass Index, median (range)</td>
<td>25.2 (19.3–37)</td>
<td>25.4 (18.3–34)</td>
<td>0.96 (0.42–2.20)</td>
</tr>
<tr>
<td>Pain VAS 0-100, median (range)</td>
<td>3 (0–51)</td>
<td>0 (0–84)</td>
<td>1.33 (0.52–3.44)</td>
</tr>
<tr>
<td>Maximum number of one-leg rises, median (range)</td>
<td>17 (0–99)</td>
<td>25 (1–229)</td>
<td>2.55 (1.08–6.02)</td>
</tr>
</tbody>
</table>

Paper II – Is it possible to reduce knee adduction moment by exercise, and to estimate knee adduction moment with maximum number of one-leg rises?

Patients: 13 patients from paper I.

Methods: Uncontrolled, prospective design, exercise intervention, 8 week follow-up, 3-dimensional movement analysis, maximum number of one-leg rises.

Conclusions: Peak adduction moment could be reduced by exercise. Higher adduction moment was related to reduced maximum number of one-leg rise.

![Test of maximum number of one-leg rises](image)
Paper III – Does intensive exercise reduce pain and improve function in middle-aged patients with moderate to severe knee osteoarthritis?

Patients: 61 patients with knee pain and significant radiographic osteoarthritis.

Methods: RCT, 6 week exercise intervention vs. non-intervention, 6 months follow-up, KOOS and SF-36.

Conclusions: No improvements were seen in pain or function. Despite this, quality of life improved after 6 weeks of intensive exercise, and was maintained at 6 months. We found no significant predictor of the large variations in the inter-individual responses in pain and function.

Change in KOOS pain at 6 weeks

Paper IV – How do middle-aged patients with moderate to severe knee osteoarthritis conceive exercise as treatment?

Patients: 16 patients from exercise group in paper III.

Methods: Qualitative design, interviews.

Conclusions: The degree of motivation to exercise varied. The patients were aware of health benefits from exercise, but felt doubts about exercise as treatment, even when they had benefited from an exercise programme. Continuous support was considered necessary to comply with exercise.
# Description of contributions

<table>
<thead>
<tr>
<th>Paper I</th>
<th>Paper II</th>
<th>Paper III</th>
<th>Paper IV</th>
</tr>
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</table>
| **Study design:** Carina Thorstensson  
Ewa Roos  
Ingemar Petersson  
Lennart Jacobsson | **Study design:** Carina Thorstensson  
Ewa Roos  
Ingemar Petersson  
Charlotte Ekdahl | **Study design:** Carina Thorstensson  
Ewa Roos  
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| **Data collection:** Carina Thorstensson  
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Torsten Boegård | **Data collection:** Carina Thorstensson  
Ingemar Petersson  
Anette von Porat | **Data collection:** Carina Thorstensson  
Ingemar Petersson | **Data collection:** Carina Thorstensson  
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Anette von Porat | **Manuscript revision:** Ewa Roos  
Ingemar Petersson | **Manuscript revision:** Ewa Roos  
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Definitions and abbreviations

ACR  American College of Rheumatology
BMI  body mass index
IASP  International Association for the Study of Pain
KOOS  Knee injury and Osteoarthritis Outcome Score
MRI  magnetic resonance imaging
OA  osteoarthritis
OARSI  Osteoarthritis Research Society International
RCT  randomized controlled trial
SF-36  Short-Form 36-item Health Survey
VAS  visual analogue scale
WHO  World Health Organisation
WOMAC  Western Ontario and McMaster Osteoarthritis Index

Definitions used in this thesis:

Adduction moment – in this thesis I refer to external adduction moment (ground reaction force x perpendicular distance from ground reaction force to the axis of knee ab- adduction movement), i.e. the angular force acting on the medial compartment of the knee, compressing the joint surfaces of tibia and femur. The external adduction moment corresponds to an equally sized internal abduction moment, produced by the active and passive soft tissues, preventing the knee from lateral gapping.

Coordination – activating the right muscles with right force at the right time.

Exercise – “a subset of physical activity that is planned, structured, and repetitive and has as a final or an intermediate objective the improvement or maintenance of physical fitness” (Caspersen et al. 1985).

Functional performance – muscle function in physical activities.

HKA – hip-knee-ankle angle. Radiographic assessment of alignment, defined as the lateral angle between the lines from the centre of the tibial spines to the centre of the femoral head and the talus respectively. An angle of more than 180° denotes a varus alignment (Odenbring et al. 1993).

Kellgren and Lawrence – radiographic osteoarthritis classification system, based on joint space narrowing and osteophytes (Kellgren and Lawrence 1957):

grade 0 – normal radiographs,
grade 1 – minute osteophytes, doubtful significance,
grade 2 – definite osteophytes,
grade 3 – joint space narrowing,
grade 4 – joint space greatly impaired, sclerosis of subchondral bone.

Knee osteoarthritis – in this thesis; radiographic features of osteoarthritis of the tibiofemoral joint, with or without knee symptoms.

Kinetics – movements including forces and moments.

Kinematics – movements including spatiotemporal parameters, excluding forces and moments.

Laxity – insufficient tension in the passive soft tissues, causing displacement or mediolateral rotation of the tibia in relation to the femur.

Middle-aged – in this thesis; individuals aged between 35 and 65 years.

Muscle function – a combination of strength, endurance and coordination.

Physical activity – “any bodily movement produced by skeletal muscles that result in energy expenditure” (Caspersen et al. 1985).

1 RM – one repetition maximum, the highest weight possible to lift once, but not twice.
**Introduction**

**Knee osteoarthritis – diagnosis**

According to the World Health Organisation, osteoarthritis is one of the ten most disabling diseases in adults over thirty years (WHO). Knee osteoarthritis is common and presents with insidious onset, unclear prognosis and large consequences for the individual as well as for the society. Currently there is no cure for osteoarthritis. Treatments focus primarily on relieving symptoms and preventing progress (Altman et al. 2000; Jordan et al. 2003; Läkemedelsverket 2004).

Knee osteoarthritis can be conceptualized in different ways; 1) as a biochemical process, characterized by disequilibrium between cartilage synthesis and degradation (Andriacchi et al. 2004; Lohmander et al. 2003); 2) as radiographic or MR detected features typical of knee osteoarthritis (Ahlback 1968; Altman et al. 1995; Boegard et al. 1998; Kellgren and Lawrence 1957); or 3) as a disease causing pain and disability to the patient (Dieppe et al. 2000; Felson et al. 2000a; McAlindon et al. 1993; Peat et al. 2001) (Figure 1). The choice between these concepts depends on the context in which they are used. The American College of Rheumatology have developed a set of criteria to clinically verify the osteoarthritis diagnosis; age > 38, presence of knee pain, morning stiffness and joint crepitus (Altman et al. 1986). The ‘classic’ diagnosis of osteoarthritis is based on the contemporary presence of radiographic features and symptoms (Lohmander 2002).

The natural course of osteoarthritis is not well explored in longitudinal studies. A study evaluating the radiographic progression of knee osteoarthritis after 11 years found that about 30% deteriorated, but 10% improved (Spector et al. 1992). Another study, exploring the natural course of pain severity and disability after 8 years revealed that about 60% of the patients with knee osteoarthritis deteriorated, however 20% perceived less severe pain and overall condition (Dieppe et al. 2000).

**Radiographic changes in knee osteoarthritis**

Knee osteoarthritis affects body structure components through cartilage degradation, bone remodelling and soft tissue weakness (Brandt et al. 1998). Structural changes in knee osteoarthritis are usually verified through radiographic imaging, and there are several classification systems to grade osteoarthritis severity. The most commonly used classification was described by Kellgren and Lawrence in 1957 (Kellgren and Lawrence 1957). The severity of radiographic changes is graded from 1 to 4, where grade 1 corresponds to doubtful osteophytes and 4 is classified as severe radiographic changes, with impact on bone formation, joint space width and subchondral bone thickness (Table 6, see page 19). The most common cut-off used to define knee osteoarthritis is Kellgren and Lawrence grade 2, i.e. definite osteophytes. However, less significant osteophytes, grade 1, have been found to correlate with cartilage changes detected with magnetic resonance imaging (MRI) (Boegard et al. 1998), and seem to predict radiographic progression of knee osteoarthritis (Hart and Spector 1998). The Ahlbäck classification system (Ahlback 1968) incorporates joint space width and bone attrition. The atlas of Osteoarthritis Research Society International (OARSI) scores the joint space width and osteophytes separately (Altman et al. 1995).
Radiographic changes develop slowly (Gandy et al. 2002), and only a minority of patients with knee osteoarthritis will ever develop a severe stage requiring knee surgery (Peat et al. 2001). The prognostic factors are not clear, but it has been suggested that overweight (Dougados et al. 1992; Schouten et al. 1992), local joint load (Miyazaki et al. 2002) and knee malalignment (Sharma et al. 2001) are associated with progression of radiographic changes.

Radiographic knee osteoarthritis in the middle-aged

The prevalence of osteoarthritis varies between studies, depending on the population studied and the criteria used to define knee osteoarthritis. The presence of osteoarthritis is strongly related to age. From the age of 55 years and older the prevalence of radiographic knee osteoarthritis ranges from 4 to 45%, with higher percentages present in older ages (Davis et al. 1991a; Felson et al. 1987; Hernborg and Nilsson 1973; Stauffer et al. 1977; van Saase et al. 1989). However, knee osteoarthritis is not only a disease of the elderly. A cross sectional study of a community based sample with knee pain did not show increased joint space narrowing in older age-groups (Lanyon et al.). A population based survey of people aged 35–54, with chronic knee pain without major knee trauma, showed a prevalence of radiographic features corresponding to knee osteoarthritis of 1.5% (Petersson et al. 1997). Injury to the meniscus or anterior cruciate ligament is related to an increased risk of knee osteoarthritis 10–15 years later (Roos et al. 1995), and studies involving patients 12–14 years after anterior cruciate ligament injury reveal a prevalence of radiographic and symptomatic knee osteoarthritis exceeding 40% in a population younger than 40 years (Lohmander et al. 2004; Von Porat et al. 2004). In meniscectomized patients with a mean age of 54, 43% had radiographic changes 16 years after meniscectomy (Englund et al. 2003).

Pain and function in knee osteoarthritis

The most common complaint of patients with knee osteoarthritis is pain, continuous or during weight bearing activities. Pain is the reason why patients with osteoarthritis seek medical care. Osteoarthritis pain can increase or decrease without relationship to radiographic changes (Dieppe et al. 1997). The cartilage has no pain receptors. Pain in osteoarthritis may arise in synovium, joint capsule, bone, periosteum or soft tissues like muscle, tendons and ligaments (Brandt et al. 1998; Creamer 2000). Normally these structures are relatively insensitive. It has been suggested in osteoarthritis that certain mediators possibly arising from bone or synovium, increase the sensitivity of joint nociceptors, thus enabling mechanical stimuli to be perceived as local pain (Kidd 1998). The increased frequency of input from peripheral nociceptors contributes to an increased sensitivity of the central nervous system, therefore the mechanical input from normal activities of daily living can trigger pain in wider areas or as referred pain (Kidd 1998). Pain is subjective and individually interpreted, and defined by the International Association for the Study of Pain as “an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage”(IASP). Pain intensity can fluctuate, but over the years most patients with osteoarthritis experience increased pain. In the Bristol OA500 study 69/111 (62%) of patients with knee osteoarthritis reported worsening in pain over 8 years, while 22 (20%) reported improvement (Dieppe et al. 2000).

Perceived pain and reduced muscle function contribute to limitations in activities related to mobility and transfer in daily living, for example walking, stair climbing or rising from a chair (Davis et al. 1991a; Dieppe et al. 2000; Hurley et al. 1997; McAlindon et al. 1993). More generalized knee pain is associated with worse physical function than medial knee pain alone (Creamer et al. 1998). Knee osteoarthritis is further related to several aspects of physical function, such as increased knee joint laxity (Sharma et al. 1999b), stiffness (Altman et al. 1986), reduced range of motion (Al-Zahrani and Bakheit 2002), altered joint load (Sharma et al. 1998), and reduced muscle function (Hurley et al. 1997). Psychological factors are also affected in knee osteoarthritis (Dieppe et al. 2000; Keysor et al. 1998).

Discrepancy between radiographic changes and symptoms/function

The relationship between radiographic changes and pain is weak. A longitudinal study, including

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patients aged 24–88 years referred to a rheumatology clinic with symptomatic knee osteoarthritis, found no significant association between change in pain and change of radiographic features, neither for improvement nor worsening (Dieppe et al. 1997). In a population based study including subjects aged 25–74, less than 50% of those with radiographic changes corresponding to mild to severe radiographic knee osteoarthritis reported symptoms, and among the subjects reporting knee pain, radiographic features of knee osteoarthritis were found in less than 20% (Hannan et al. 2000). The relationship between pain and radiographic features becomes stronger with increased disease severity (Cooper et al. 2000; Felson et al. 1987).

Some of the discrepancy between radiographic changes and knee symptoms might be explained by psychological factors. Anxiety and depression are strong predictors of pain (Creamer et al. 1999; Salaffi et al. 1991; Summers et al. 1988). The disability associated with knee osteoarthritis is more related to pain, strength, age, and obesity than to radiographic features (Creamer et al. 2000; McAlindon et al. 1993). However, individuals with both pain and radiographic changes seem to have a worse disability score (Williams et al. 2004). Elderly patients with arthritis are usually less physically active than younger patients (Fontaine et al. 2004), and inactivity is also associated with increased disability (Steultjens et al. 2002). Effective coping strategies among patients with self-reported osteoarthritis and osteoporosis have been suggested to mediate the relationship between activity limitations and perceived disability (Wang et al. 2004).

Non-modifiable and modifiable risk factors

The risk factors for development of incident knee osteoarthritis and progression of established knee osteoarthritis may be different, and the interrelationship between these factors is not clear (Andriacchi et al. 2004; Cooper et al. 2000) (Table 1).

Non-modifiable risk factors for development of incident knee osteoarthritis include genetic factors (Spector et al. 1996), older age (Felson et al. 1987; Hart et al. 1999; Hernborg and Nilsson 1973; van Saase et al. 1989), and female sex (Felson et al. 1987; Manninen et al. 1996). There seems to be an inverse relationship between osteoporosis and osteoarthritis, indicating that high bone mineral density might contribute to osteoarthritis development (Dieppe et al. 1993; Hart et al. 1999; Radin and Rose 1986). The inverse relationship has only been studied in cross-sectional studies, including patients with established osteoarthritis, and is thus still a matter of debate (Dequeker et al. 2003).

Genetic factors are important determinants of osteoarthritis in the hand and knee, and a study on female twins estimated the genetic influence of osteoarthritis development to be between 35-65% (Spector et al. 1996). The influence of age on osteoarthritis development could be related to degeneration of cartilage, increasing the vulnerability to biomechanical risk factors.

### Table 1. Risk factors associated with incident radiographic knee osteoarthritis, i.e. osteophytes and radiographic progression, i.e. joint space narrowing.

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>Osteophytes</th>
<th>JSN</th>
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<tbody>
<tr>
<td>Age</td>
<td>•</td>
<td></td>
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<tr>
<td>Sex</td>
<td>•</td>
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<tr>
<td>(Felson et al. 1987; Manninen et al. 1996)</td>
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<tr>
<td>Genetic influence</td>
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<tr>
<td>(Spector et al. 1996)</td>
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<tr>
<td>Bone mineral density</td>
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</tr>
<tr>
<td>(Dieppe et al. 1993; Hart et al. 1999; Radin and Rose 1986)</td>
<td></td>
<td></td>
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<tr>
<td>Obesity</td>
<td>• •</td>
<td></td>
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<tr>
<td>(Felson et al. 1988; Felson et al. 1997; Hart et al. 1999; Manninen et al. 1996; Sandmark et al. 1999)</td>
<td></td>
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<tr>
<td>Joint injury</td>
<td>•</td>
<td></td>
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<tr>
<td>(Gelber et al. 2000; Lohmander et al. 2004; Roos et al. 1995; Von Porat et al. 2004)</td>
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<tr>
<td>Muscle weakness</td>
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<td>(Slemenda et al. 1998)</td>
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<tr>
<td>High impact joint load</td>
<td>• •</td>
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<tr>
<td>(Miyazaki et al. 2002; Radin et al. 1991)</td>
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<td></td>
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<tr>
<td>Biomechanical factors</td>
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<tr>
<td>(Cicuttini et al. 2004; Felson et al. 2004; Miyazaki et al. 2002; Sharma et al. 2003; Sharma et al. 2001)</td>
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</tbody>
</table>
At ages below 50 years the prevalence of knee osteoarthritis is somewhat higher in men, however as age progresses the prevalence becomes more common in women (Davis et al. 1991a; Felson 1988; Felson et al. 2000a; Felson et al. 1987). The increased rate of knee osteoarthritis among men at younger ages could be related to a higher physical activity level, and thereby an increased frequency of activity related injuries.

Modifiable risk factors include obesity (Felson et al. 1988; Felson et al. 1997; Hart et al. 1999; Manninen et al. 1996; Sandmark et al. 1999), injury to the menisci or cruciate ligament (Gelber et al. 2000; Lohmander et al. 2004; Roos et al. 1995; Von Porat et al. 2004), and factors related to heavy joint load at work or leisure (Coggon et al. 2000; McAlindon et al. 1999; Sandmark et al. 2000). Recently, reduced muscle function has been suggested as a risk factor of knee osteoarthritis development in women (Slemenda et al. 1998). Moderate weight loss has been suggested to reduce the risk of developing incident knee osteoarthritis in women (Felson et al. 1992). The effects from injury prevention programmes, reduced joint load or increased muscle function on development of knee osteoarthritis are not documented.

The role of muscle weakness in knee osteoarthritis could be related to biomechanical factors. During gait a weaker quadriceps muscle is related to higher knee joint load in healthy women (Mikesky et al. 2000). It is suggested that muscle weakness could cause a shift in the mechanical axis, moving joint load to areas not capable of coping with the increased compression, causing a local over-load (Andriacchi et al. 2004). Experimental models have demonstrated that repetitive impulsive joint load could cause ‘micro traumas’ in the cartilage, and increase the sclerosis of the underlying bone, leading to an increase in shear stress of cartilage (Radin et al. 1991a; Radin and Rose 1986).

It has been suggested that biomechanical factors, such as knee malalignment contribute to radiographic progression of knee osteoarthritis (Cicuttini et al. 2004; Felson et al. 2004; Miyazaki et al. 2002; Sharma et al. 2001). Strong quadriceps muscles may contribute to the risk of radiographic progression in mal-aligned knees through increased compressive forces in the medial joint compartment (Sharma et al. 2003b). Exercise may have the potential to normalize the mechanical axis, and reduce the impulsive joint load. The impact of exercise on joint load needs to be confirmed in longitudinal studies.

Joint cartilage is dependent on dynamic joint load to get nutrition. Under-use of the knee joint could disturb the equilibrium of cartilage repair and degradation (Carter et al. 2004) (Figure 2). Animal models have demonstrated a regress of cartilage when limbs are immobilized (Brandt 2003; Jortikka et al. 1997), while moderate exercise reduced structural lesions and too extensive exercise seemed to abolish the positive effects in experimentally induced osteoarthritis (Galois et al. 2004). Healthy cartilage may recover with resumed activity, but osteoarthritis affected cartilage may not (Brandt 2003). In hamsters, daily exercise seems to improve the quality of cartilage (Otterness et al. 1998). These findings are not yet proved to be valid in humans. However, it has been suggested that increased physical activity is related to improvement in knee cartilage structure in patients at risk of osteoarthritis development (Dahlberg and Roos 2003), confirming the previously found effects from moderate physical activity in dogs (Kiviranta et al. 1988).

**Joint load in knee osteoarthritis**

Patients with knee osteoarthritis walk with reduced stance phase (Schipplein and Andriacchi 1991), shorter stride length, slower walking speed (Al-Zahrani and Bakheit 2002; Stauffer et al. 1977), and greater medial-to-lateral forces (knee adduction moment) during gait compared to knee-healthy subjects (Baliunas et al. 2002; Schipplein...
and Andriacchi 1991). Severe radiographic knee osteoarthritis is associated with higher peak adduction moment during gait (Sharma et al. 1998). Young individuals, with previous episodes of knee pain, and therefore assumed to be predisposed to knee osteoarthritis development, have increased impulsive joint-load during heel-strike compared to age-matched subjects without a history of knee pain (Radin et al. 1991b). This cross-sectional study suggested that increased joint load during gait might precede osteoarthritis development. However, the association has not been established in prospective longitudinal studies. Patients with symptomatic knee osteoarthritis seem to walk ‘carefully’, since pain reduction has been associated with an increased joint load during gait (Hurwitz et al. 1999; Hurwitz et al. 2000; Schnitzer et al. 1993; Shrader et al. 2004). It has been suggested that patients adapt their movement pattern to reduce the knee adduction moment (Andriacchi 1994; Kaufman et al. 2001; Mundermann et al. 2004; Stauffer et al. 1977). The effects of these strategies on pain, function or disease progression however have not been confirmed in longitudinal studies.

Knee adduction moment

About 70% of the medial-to-lateral forces during gait act on the medial tibiofemoral compartment, causing an external knee adduction moment (Schipplein and Andriacchi 1991). During weight-bearing activities, like gait or stair climbing, the adduction moment compresses the medial compartment of the knee, and causes a lateral “gapping”, which is prevented by active and passive soft tissues (Schipplein and Andriacchi 1991) (Figure 3). The size of the knee adduction moment is determined by the ground reaction force, acting through the foot and medial to the knee joint, and the perpendicular distance from ground reaction force to the axis of the knee joint ab- and adduction movement (Andriacchi 1994).

The shape of the bone ends and articular surfaces in the knee does not provide a stable position in itself. Thus stability of the knee is totally dependent on ligaments and muscle function, producing an internal abduction moment of equal size as the external moment acting on the knee (Andriacchi 1994; Jackson et al. 2004). Passive soft tissues can only act as stabilizers and produce a force when they are stretched. Knee joint laxity, caused by lax ligaments, is more common in patients with knee osteoarthritis than in healthy knees (Sharma et al. 1999b), increasing the risk of lateral joint opening and transferring of the entire joint load to the medial compartment (Schipplein and Andriacchi 1991). The external knee adduction moment is used as an approximate measurement of the net internal load acting on the medial knee joint compartment (Andriacchi 1994). The internal moment is determined by multiple muscles and ligaments acting simultaneously in multi-dimensional directions. Invasive measurement techniques are required to assess the specific internal moments which is not easily applicable in humans.

Treatment guidelines

Guidelines suggest a combination of pharmacological and non-pharmacological interventions as optimal treatment of mild to moderate knee osteoarthritis (Altman et al. 2000; Felson et al. 2000b; Jordan et al. 2003; Läkemedelsverket 2004) (Figure 3). The external knee adduction moment (m) is a rotating force, trying to adduct the medial compartment of the knee. The magnitude of the adduction moment is determined by the magnitude of the ground reaction force (F) and the perpendicular distance (d) from the ground reaction force to the axis of knee movements in the frontal plane.

Figure 3. The external knee adduction moment (m) is a rotating force, trying to adduct the medial compartment of the knee. The magnitude of the adduction moment is determined by the magnitude of the ground reaction force (F) and the perpendicular distance (d) from the ground reaction force to the axis of knee movements in the frontal plane.
4). Information, exercise and weight reduction can be regarded as active treatments, requiring participation from the patient and/or processing and transforming new knowledge into behavioural changes or change in attitude. Active treatments are advantageous since they are non-invasive, the side effects are small compared to pharmacological treatments (Jordan et al. 2003), and patients are less dependent on accessibility to health professionals. Severe disease, requiring surgical interventions, will only occur in a small proportion of all patients with osteoarthritis, and an English study estimated that about 10% of all patients with knee pain will ever be considered for knee osteoarthritis surgery (Peat et al. 2001).

**Exercise as osteoarthritis treatment**

Exercise is the most cost-effective treatment achievable for knee osteoarthritis, according to an Australian study evaluating the cost-benefit relationship for different osteoarthritis treatments (Segal et al. 2004). Treatment utility was determined by time lived in particular health states, described in previous studies of osteoarthritis. Exercise had the lowest costs, about 5000$ per quality-adjusted life-year, compared to total knee replacement, which also is a cost-effective treatment (10 000$ per quality-adjusted life-year). Exercise is as effective as pharmacological treatment in pain relief (Fransen et al. 2003; Jordan et al. 2003; Pendleton et al. 2000), and is recommended as one of the most important parts of knee osteoarthritis treatment in American, European, and Swedish guidelines (Altman et al. 2000; Jordan et al. 2003; Läkemedelsverket 2004). Both aerobic and strengthening exercises have positive effects on pain and function (Ettinger et al. 1997). A randomized controlled trial comparing high and low intensity ergometer cycling for 10 weeks showed improvement in gait-speed, chair-rising and pain in both groups (Mangione et al. 1999). A study comparing the effect of dynamic strengthening exercises with static strengthening exercises on pain and time to ascend and descend a flight of stairs showed similar positive results in both groups compared to the control group (Topp et al. 2002). This latter finding is in contrast to findings from dynamic versus static exercises in patients with rheumatoid arthritis, where dynamic strengthening exercises had greater benefits (Ek Dahl et al. 1990).

The optimal dose or type of exercise in knee osteoarthritis is yet to be determined (Brosseau et al. 2003; Fransen et al. 2003; O’Reilly and Doherty 2001). At least 30 minutes of accumulated moderate physical activity on most days of the week is recommended to prevent obesity and development of inactivity related diseases, such as cardiovascular disease, diabetes and colon cancer (Pate et al. 1995; WHO 2003). In the absence of specific exercise guidelines for knee osteoarthritis, these general recommendations should be implemented in patients with mild to moderate knee osteoarthritis as well.

Patients who are physically active have better self-efficacy for exercise than inactive patients (Hopman-Rock and Westhoff 2000; Rejeski et al. 1998). Self-efficacy also improves the likelihood of compliance with exercise and thus maintained physical function (Gecht et al. 1996; Sharma et al. 2003a). Besides self-efficacy, positive effects of exercise have been shown on depressive symptoms, anxiety and health related quality of life (Fransen et al. 2001; Minor et al. 1989).

**Moderate exercise do not contribute to overload**

Moderate exercise is not associated with risk of osteoarthritis development or progression (Conaghan 2002; Hannan et al. 1993; Hootman et al. 2003; Sutton et al. 2001). A recent review of the clinical literature showed that there has been a shift in the view upon exercise in knee osteoarthritis, from exercise as additive ‘wear and tear’ to exercise as a means of osteoarthritis treatment (Shrier 2004). The risk of osteoarthritis due to exercise is
related to repetitive high joint load activities and the risk of knee injury (Conaghan 2002; Lohmander et al. 2004; Roos et al. 1995; Roos et al. 1998c; Von Porat et al. 2004). The risk-benefit relationship in exercise is non-linear. With higher levels of activity the risks increase dramatically while the benefits stay the same (Figure 5) (Powell and Paffenbarger 1985).

**Barriers to exercise as treatment**

Perceived barriers to exercise are common in the general population. It has been estimated that 25–30% of the adult men and 10–15% of the adult women in Sweden are not physically active at all (www.fysisktaktiv.nu, accessed March 24, 2005). Of all Swedish adults, 44% are physically active at least two times per weeks (www.scb.se, accessed March 24, 2005). Patients with osteoarthritis should be offered information about the possible benefits of exercise and weight reduction on pain and function, as well as interventions targeting physical functioning and overweight (Jordan et al. 2003). Of the US adults with arthritis 40% meet the recommendations of regular physical activity (Fontaine et al. 2004; Keefe et al. 2000). Physical therapists have specific knowledge about exercise at different stages of disability, but physiotherapy is underused, and only 10% of patients with osteoarthritis have ever been to a physical therapist or tried to loose weight (Fontaine et al. 2004; Hsieh and Dominick 2003; Jordan et al. 2004). This could be related to contrasting perspectives of doctor and patient, influencing the agreement in treatment planning (Carr and Donovan 1998; Donovan 1991). Longitudinal studies report a decrease in compliance to exercise over time (Ettinger et al. 1997; Sullivan et al. 1998). In exercise as well as in any intervention, compliance is a prerequisite for optimal treatment effect (Carr 2001; Ettinger et al. 1997; Kettunen and Kujala 2004; Thomas et al. 2002; van Baar et al. 2001). Non-compliance is usually based on rational and logical decisions, based on the patient’s knowledge and convictions (Campbell et al. 2001; Donovan 1991). Another barrier to exercise as osteoarthritis treatment is that osteoarthritis often has been thought of as a result of “wear and tear”, an irreversible end-stage not possible to influence (Campbell et al. 2001; Okma-Keulen and Hopman-Rock 2001).
Aims of the study

General
The overall purpose of this thesis was to explore the impact of exercise and functional performance on development and treatment of knee osteoarthritis in the middle-aged.

Specific
• To determine whether, in a population-based cohort of middle-aged subjects with chronic knee pain at baseline, reduced functional performance in the lower extremity predicted development of radiographic knee osteoarthritis five years later.

• To study the effect of exercise on knee adduction moment during one-leg rise and gait in middle-aged patients with mild knee osteoarthritis.

• To study the effects of a short-term, high-intensity exercise program in middle-aged subjects with symptomatic and moderate to severe radiographic knee osteoarthritis on self-reported pain, function and quality of life.

• To describe conceptions, as registered by a semi-structured interview, of exercise as treatment among sixteen middle-aged patients with moderate to severe knee osteoarthritis.
Subjects and methods

Subjects

209 patients from two different cohorts were included in the studies (Figure 6). They were all younger than 65 years at inclusion and 44% were women. Patient characteristics are shown in Table 2. The two populations differed according to severity of radiographic features and symptoms (Table 3 and Table 6).

The Spenshult cohort (paper I and II)

Patients from a population based cohort, with chronic knee pain at inclusion, were included in paper I and II (Petersson et al. 1997). Two thousand people aged between 35–54 (963 women and 1 037 men) were randomly selected from a district in the south-west of Sweden. This mixed urban and rural population, received a postal questionnaire in 1990 concerning prevalence of chronic knee pain. Chronic knee pain was defined as “pain in either of your knees on most days during the last three months”. One thousand eight hundred and fifty-three persons (93%) answered the questionnaire, of whom 279 (15%) persons reported chronic knee pain.

Those who had chronic knee pain were offered radiographic and clinical examination (Petersson et al. 1997) and 204 agreed to participate. One hundred and fifty two subjects were available for follow-up five years later. As the aim was to determine risk factors for development of radiographic features, four patients with radiographic regression in one knee and radiographic progression in the other knee at follow-up were excluded. Thus 148 subjects constituted the cohort for paper I. Fifty four patients had radiographic changes corresponding to Kellgren & Lawrence grade I or more (minor osteophytes), and 94 patients had no radiographic features of osteoarthritis.

The Exercise cohort

Inclusion

Figure 6. Description of study populations and the time disposal for recruitment and interventions in paper I–IV. For paper I and II patients were recruited from the Spenshult cohort. For paper III and IV patients were recruited from the Exercise cohort.
Table 2. Patient characteristics of the 209 patients included in paper I–IV. Pain is derived from the KOOS pain subscale (Roos et al. 1998), 0–100, worst to best scale.

<table>
<thead>
<tr>
<th>Cohort</th>
<th>Paper</th>
<th>N</th>
<th>K&amp;L grade</th>
<th>Age mean (range)</th>
<th>Sex % women</th>
<th>BMI mean (range)</th>
<th>KOOS pain score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spenshult cohort</td>
<td>I, II</td>
<td>148</td>
<td>0–3</td>
<td>53.1 (35–54)</td>
<td>42%</td>
<td>25.8 (18.3–37.5)</td>
<td>97</td>
</tr>
<tr>
<td>Exercise cohort</td>
<td>III, IV</td>
<td>61</td>
<td>3–4</td>
<td>56.1 (36–64)</td>
<td>51%</td>
<td>29.5 (22.5–49.7)</td>
<td>61</td>
</tr>
</tbody>
</table>

Table 3. Clinical criteria of knee osteoarthritis in the Spenshult cohort and Exercise cohort according to ACR (Altman et al. 1986). Values are number (%)

<table>
<thead>
<tr>
<th></th>
<th>The Spenshult cohort</th>
<th>The Exercise cohort</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Paper I, N=148</td>
<td>Paper II, N=13</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Paper III, N=61</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Paper IV, N=16</td>
</tr>
<tr>
<td>Knee pain on most days last month</td>
<td>148 (100)</td>
<td>4 (31)</td>
</tr>
<tr>
<td>Morning stiffness</td>
<td>45 (30)</td>
<td>2 (15)</td>
</tr>
<tr>
<td>Grinding</td>
<td>78 (53)</td>
<td>8 (62)</td>
</tr>
<tr>
<td>Age &gt; 38</td>
<td>128 (86)</td>
<td>13 (100)</td>
</tr>
<tr>
<td>OA according to ACR criteria</td>
<td>24 (16)</td>
<td>1 (8)</td>
</tr>
</tbody>
</table>

In paper II, patients from the same cohort with radiographic signs of knee osteoarthritis, corresponding to Kellgren & Lawrence grade I (minor osteophytes) in 1995, and aged < 65 years at inclusion in 2003 were included. Forty patients fulfilled the inclusion criteria, and were contacted by telephone. Patients with dysfunction in the back or lower extremity (n=10), inflammatory joint disease (n=3), previous knee injury (n=2), chronic widespread pain (n=4) or depressive symptoms (n=1) were excluded. Seven patients declined to participate due to lack of time, leaving 13 eligible patients.

The Exercise cohort (paper III and IV)
The second cohort was recruited at the department of radiography at the Halmstad County Hospital in the south-west of Sweden. Radiologists and orthopedic surgeons as well as general practitioners within the catchments area of this hospital, were informed about the study (paper III) and were asked to list patients with radiographic knee osteoarthritis on a “patients eligible for research” list. Between October 1998 and October 2001 121 patients, referred by their general practitioner to radiographic examination because of knee pain, were listed. Ninety-seven fulfilled the inclusion criteria: age range 35–65, diagnosis of radiographic osteoarthritis of Kellgren and Lawrence grade III or more, i.e. definite osteophytes and joint space narrowing, and living in the defined geographic area. Twenty-eight patients declined participation for various reasons, the most common reason being lack of time and interest. To ensure only those patients with symptoms due to knee osteoarthritis and who were eligible for exercise intervention were included, the following exclusion criteria were applied: inflammatory joint disease, medical record of anterior cruciate ligament injury, symptomatic meniscal injury, hip symptoms more aggravating than the knee symptoms, about to have knee replacement surgery within 6 months, and co-morbidities not allowing exercise. Four patients were wrongly randomized, and thus 61/97 patients were included in paper III. In paper IV, 16 patients, aged 39–64, randomized to exercise intervention in paper III, were interviewed. They were strategically chosen so as to obtain a variation in variables that might influence their conceptions of exercise as treatment. In this study different ages, genders, levels of education, occupations, previous exercise habits, disease durations, and different outcomes of the exercise trial with regard to pain were considered as factors of importance to conceptions of exercise as treatment (Table 4).
Table 4. Subjects in paper IV were purposively chosen from the exercise group in paper III, to obtain a variation of variables that could affect their conceptions of exercise.

<table>
<thead>
<tr>
<th>Variable/Category</th>
<th>Categories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age range</td>
<td>39–64</td>
</tr>
<tr>
<td>Male/female (number)</td>
<td>10/6</td>
</tr>
<tr>
<td>Highest level of education (number)</td>
<td></td>
</tr>
<tr>
<td>University</td>
<td>2</td>
</tr>
<tr>
<td>Continuation of the 9-year compulsory school</td>
<td>4</td>
</tr>
<tr>
<td>Compulsory school</td>
<td>10</td>
</tr>
<tr>
<td>Joint load in occupation (number)</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>7</td>
</tr>
<tr>
<td>Low</td>
<td>8</td>
</tr>
<tr>
<td>Retired</td>
<td>1</td>
</tr>
<tr>
<td>Previous experience from exercise (number)</td>
<td></td>
</tr>
<tr>
<td>Regularly exercised</td>
<td>10</td>
</tr>
<tr>
<td>Never exercised regularly</td>
<td>6</td>
</tr>
<tr>
<td>Pain duration (years)</td>
<td>0.25–30</td>
</tr>
<tr>
<td>Change in pain from exercise intervention (number)</td>
<td></td>
</tr>
<tr>
<td>Improved</td>
<td>8</td>
</tr>
<tr>
<td>No change</td>
<td>2</td>
</tr>
<tr>
<td>Worsened</td>
<td>6</td>
</tr>
</tbody>
</table>

Interventions

Supervised group exercises, performed at stations, and with an intensity of ≥ 60% of maximum heart rate were used in both interventions (paper II and III). Exercises comprised postural control and lower extremity strength and endurance. Intensity was individually adjusted, and patients were encouraged to exercise at their most vigorous intensity possible, without losing quality in performance or severely exacerbating pain. Pain during exercise was not regarded an obstacle if the patient perceived it as “acceptable” and no increased symptoms persisted after 24 hours (Thomee 1997). If pain exceeded this level, exercise intensity was reduced occasionally, until the “acceptable” level was found. Intensity was gradually and individually increased. The aim of the exercise intervention was to increase muscle function and functional performance in the lower extremity. The effects on maximum number of one-leg rises and knee adduction moment was assessed in paper II. In paper III, the main outcome was self-estimated pain, function and quality of life.

After discussion with a panel of clinically experienced physical therapists, the exercises in paper II were chosen to fit younger patients with knee osteoarthritis. After warming up the program consisted of rebounder exercises, sit-ups, pulley exercises, step-ups, sit-to-stand, hip-abduction, and hip-extension. Exercises were conducted for eight weeks, twice a week at four stations, with three exercises per station, performed 3 x 15 times or 3 x 60 seconds (rebounder). Patients were told to align the knee over the toes throughout all exercises by using the hip external or internal rotators (Figure 7). Slide-board and soft-balls were used to challenge the postural control. Intensity was increased by using longer lever arms, dumbbells, bar-bells or medicine balls. A prerequisite to increase intensity was that exercises could be performed with full muscle control, i.e. constant speed and knee aligned with the toes.

Exercises in paper III followed the concept of a previously described study comprising patients with rheumatoid arthritis, with 6 weeks of one hour sessions twice a week (Ekdahl et al. 1990). Intensity was modified to fit patients with less physical impairment, by increased lever arms or performance on one leg instead of two. Types of exercises were similar to paper II, but with less demanding starting-positions and less frequent use of external weights. Exercises were carried out at three stations, with two to four exercises per station. 15 repetitions were performed before changing to next task.
Table 5. Outcome measures used in papers I–IV.

<table>
<thead>
<tr>
<th></th>
<th>Paper I</th>
<th>Paper II</th>
<th>Paper III</th>
<th>Paper IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knee radiographs</td>
<td>•</td>
<td>•</td>
<td></td>
<td>•</td>
</tr>
<tr>
<td>HKA</td>
<td>•</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>One-leg rise</td>
<td>•</td>
<td></td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>KOOS</td>
<td></td>
<td>•</td>
<td></td>
<td>•</td>
</tr>
<tr>
<td>SF-36</td>
<td></td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Interviews</td>
<td>•</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gait analysis</td>
<td></td>
<td></td>
<td></td>
<td>•</td>
</tr>
</tbody>
</table>

Outcomes

Radiographic examination (paper I, II and III)

A summary of outcomes used in paper I–IV is shown in Table 5.

In paper I, posteroanterior radiographs of both tibiofemoral joints were obtained at baseline, with straight legs in weight-bearing position and with the weight equally distributed on both legs. The medial aspects of the feet were aimed to be parallel to each other. The central x-ray beam was horizontal and aimed at the level of the centre of the popliteal fossa and the right and left knees were reproduced by the same exposure.

Five years later, in 1995–1996 (paper I and II), posteroanterior radiographs of both tibiofemoral joints were obtained in weight bearing under fluoroscopic control. The patients stood with almost the entire weight on the examined leg, with the knee flexed 30–50°, and with the patella and the big toe touching the table of the fluoroscopy unit. The medial aspect of the foot was parallel to the central X-ray beam and the beam was adjusted to be tangential to the anterior and posterior aspect of the medial tibial condyle.

All radiographs were read by an experienced radiologist. The intra-observer agreement for rereading the radiographs from baseline has been evaluated previously, showing high agreement (κ 0.88) (Petersson et al. 1997). The inter- and intra-observer agreement for minimum joint space and osteophytes in the semi-flexed position used in 1995-96 ranged from κ 0.72-0.98 (Boegard et al. 1998; Boegard et al. 1997).

Radiographic features were classified using the Kellgren and Lawrence index (Kellgren and Lawrence 1957) (paper I, II and III, Table 6). We defined Kellgren and Lawrence grade one as prevalent osteoarthritis (paper I and II) (Boegard et al. 1998; Hart and Spector 2003). A change of one grade or more according to Kellgren and Lawrence was defined as progression (paper I) (Hart and Spector 2003; Spector et al. 1992).

The hip-knee-ankle (HKA) angle was assessed in a standing anteroposterior radiograph of the lower limb (paper II). The patient was barefoot and stood with equal weight on both legs and with 15° of knee flexion. The X-ray beam was centred on the knee at a distance of 2.2 m. The frontal projection was perpendicular to a lateral view of the knee, which was achieved by superimposing the dorsal aspects of the femoral condyles. The landmarks used were the centre of the femoral head, the centre of the tibial spines, and the centre of the talus. The HKA angle was defined as the lateral angle between the lines from the centre of the tibial spines to the centre of the femoral head and the talus respectively (Figure 8). An angle of more than 180° denotes a varus alignment (Odenbring et al. 1993). All radiographs were read by the same experienced radiologist.

Table 6. Definition of Kellgren and Lawrence grade (Kellgren and Lawrence 1957) and number of patients within each category in paper I–IV.

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Normal radiographs</td>
<td>94</td>
<td>1</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>1</td>
<td>Minute osteophytes, doubtful significance</td>
<td>36</td>
<td>3</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>2</td>
<td>Definite osteophyte, unimpaired joint space</td>
<td>9</td>
<td>8</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>3</td>
<td>Moderate diminution of joint space</td>
<td>9</td>
<td>1</td>
<td>42</td>
<td>9</td>
</tr>
<tr>
<td>4</td>
<td>Joint space greatly impaired, sclerosis of subchondral bone</td>
<td>–</td>
<td>–</td>
<td>19</td>
<td>7</td>
</tr>
</tbody>
</table>
Tests of functional performance

The maximum number of one-leg rises from a stool (48 cm) was assessed (paper I and II). Patients were allowed to try out the best foot-stool-position before the trial, by rising up and sitting down a couple of times. They were asked to perform as many one-leg rises as possible, with arms hanging along the body, and without putting the other foot on the floor (Figure 9). The test should be performed with full muscle control, i.e. the sitting down phase should be performed with constant speed and the rising up phase without adding any arm or trunk movement. The foot position was not to be changed during the test, and body-weight had to be kept on the supporting leg and foot during the entire sitting-down phase. The numbers of adequately performed rises were counted. To avoid influence of aerobic capacity on test performance, a pause was held before the testing second leg. The length of the pause was decided by the patient.

Time spent walking 300 m indoor was assessed (paper I). Patients were told to walk as fast as they could without running, 150 m and pass a line on the floor, before turning around and walking back. Another line on the floor marked start and stop. Patients were told to keep up the speed past the stop-line. Time was measured in minutes and seconds using an analogue stopwatch.

Timed standing on one leg with simultaneous, rapid repeated neck rotations, with eyes open and arms hanging along the body was assessed (paper I). One attempt was allowed before the time was measured using an analogue stopwatch. When the lifted foot touched the floor, when support was needed, or after 30 seconds, which was considered “normal”, the test was interrupted.

To assure the effectiveness of the exercise interventions used in paper II and III, five tests of functional performance and ergometer cycling were used.

2. Rising on one leg, from sitting on lowest possible height (Paper III) (Ostenberg et al. 1998; Roos et al. 2001).
5. One-leg semi squatting; maximum number during 30 seconds (paper III) (Roos et al. 2001).
6. Heel-raises on one leg; maximum number during 20 seconds (paper III) (Kaikkonen et al. 1994; Roos et al. 2001).

Self-reported measures of pain, function, quality of life, and health status

The Knee injury and Osteoarthritis Outcome Score (KOOS) (paper II, III and IV) is a disease-specific self-administered questionnaire with 42 questions in five subscales; pain, other symptoms, activities of daily living (ADL), function in sport and recreation (sport/rec) and quality of life (QOL), and takes about 10 minutes to complete (Roos et al. 1998a; Roos et al. 1998b). The KOOS is scored from 0...
to 100, separately for each subscale, 0 indicating extreme problems and 100 indicating no problems. The mean KOOS scores in the Spenshult cohort and the Exercise cohort at inclusion are shown in Figure 10. A change of 10 points or more is considered a clinically significant change (Roos and Lohmander 2003). If 50% or more of the answers within the KOOS subscale quality of life and 2 of the 4 additional scales were answered with at least a one-step decrease from the best response, patients were categorized as having symptomatic knee osteoarthritis (Englund et al. 2004). This cut-off was chosen to identify individuals likely to seek medical care. The questionnaire and scoring manual can be found at www.koos.nu.

The Western Ontario and McMaster Osteoarthritis Index (WOMAC) (Bellamy et al. 1988) is included in the KOOS, and WOMAC scores can also be calculated.

The Short Form-36 item (SF-36) (paper III) is a generic, widely used measure of general health status, which comprises eight subscales: Physical Functioning, Role-Physical, Bodily Pain, General Health, Vitality, Social Functioning, Role-Emotional and Mental Health (Ware and Sherbourne 1992). The SF-36 is self-explanatory and takes about 10 minutes to complete. The SF-36 is scored from 0 to 100, 0 indicating extreme problems and 100 indicating no problems. To avoid significant results by chance (type 1 error), the Physical Component Summary scale (PCS) and the Mental Component Summary scale (MCS) were calculated from the eight subscales (Ware and Kosinski 2004). These scores are normalized with mean of 50 and standard deviation of 10, using U.S. general population norms from 1998. A score above 50 indicate health above average, while a score below 50 indicate health below average (Ware and Kosinski 2004).

Gait analysis (paper II)

Vicon 612 (OMG, Oxford, UK) was used to assess kinetics and kinematics of the knee joint (paper II). This is a system consisting of six 100 Hz cameras with infrared strobes, one AMTI force-plate (Advanced Mechanical Technology, Inc., USA), one data-station and one PC, where the information was gathered and processed in Plug-In Gait software.

Special markers, reflecting the infrared light from the cameras, were attached by a physical therapist with specific knowledge and experience within the area of motion analysis, over standardised landmarks (anterior superior iliac spine, lower lateral third of the thigh, lateral epicondyle of femur, lower lateral third of the calf, lateral malleolus of fibula and over the second metatarsal head, on
Step 2. Identifying statements

C. How does it feel when you put your foot down on the ground? Is it normal for you?

L. Yes, it is normal for me.

C. What feeling do you experience around the knee joint, and the perpendicular distance from the ground reaction force to the axis of the knee joint? And adduction movement.

Resistance

Support

Motivation

Gain health

Step 3. Content related conceptions

Jn, do you think it’s normal that you feel it now?

L. Yes, it is normal.

Jn, do you think it’s normal that you feel it now?

C. What does it feel like?

L. It feels normal.

Step 4. Descriptive categories

Figure 12. Illustration of the 4 step analysis process in phenomenography. Example is authentic (Swedish), and only to be considered as an illustration of the process.

The peak knee adduction moment during one-leg rise and gait was used as the main outcome. Knee adduction moment was computed by Vicon software, and approximates the product of the ground reaction force, acting through the foot and medial to the knee joint, and the perpendicular distance from the ground reaction force to the axis of the knee joint ab- and adduction movement (Andricacchi 1994).

Phenomenographic approach (paper IV)

Phenomenography is one out of several qualitative methods. It is an exploratory approach, developed in educational research and first described by Marton (Marton 1981), and the method has been used in nursing and health care research (Barnard et al. 1999; Sjostrom and Dahlgren 2002). This research approach is usually based on interviews or observations, and aims at identifying and describing different ways of experiencing phenomena in the world that surrounds us. In phenomenography, it is not the reality or how something really is that is interesting, but how different people experience a phenomenon (Marton 1981).

Procedure: A strategically chosen sample of patients from the exercise intervention study in paper III was interviewed. The interviews were performed in a conversational style, audio-taped and verbatim transcribed. Six open-ended questions served as a guide of the conversation. These questions were constructed in consultation with a researcher with broad experience from phenomenography, and aimed at catching the conceptions of exercise as treatment of knee osteoarthritis. The questions were:

- What does exercise mean to you?
- What does osteoarthritis of the knee mean to you?
• How does exercise affect you?
• How does exercise affect osteoarthritis of the knee?
• How do you conceive the importance of exercise as a form of treatment?
• How has your conception of exercise changed over time?

Each interview lasted between 20 and 90 minutes, and was conducted at a place preferred by the patient.

Data analysis The transcribed interviews were analysed in four steps (Figure 12) (Dahlgren and Fallsberg 1991). In step one, the transcribed interviews were carefully read while listening to the tape recording, in order to correct errors in the transcript and to become familiar with the material. The next step was to identify the statements, which corresponded to the aim of the study. Thereafter the statements were assigned to content-related categories; conceptions. In this phase the number of conceptions was large. In the fourth step similarities and differences between conceptions were observed, and conceptions that had the same theme were grouped together and further assigned to a more general category; a descriptive category. A revision of the conceptions decided upon in a previous step was necessary on a few occasions in order to continue. The fourth step continued until descriptive categories emerged, which were different in content and meaning, and corresponded to the context. The final descriptive categories were illustrated with carefully selected quotations from the interview statements.

Statistics

Due to rather small study samples (paper I, II, III) data were analyzed using nonparametric tests. P-values of less than or equal to 0.05 were considered to be statistically significant, and all tests were two-tailed. To compare groups, Mann-Whitney U-test was used (paper I, II and III). Spearman’s test was used to determine correlations (paper I and II). Friedman’s test was used for repeated measures analysis of variance (paper III). Wilcoxon signed rank test was performed to study paired analysis of variance (paper II and III). Logistic regression was used to determine the odds ratio (95% confidence interval) of progression of radiographic features (paper I). Analyses were performed using SPSS for Windows.
Results

Functional performance and risk of incident knee osteoarthritis (Paper I)

Incident osteoarthritis developed after five years in 41/94 subjects (44%) without radiographic features of osteoarthritis at baseline. The test of maximum number of one-leg rises from sitting significantly predicted development of incident knee osteoarthritis five years later (median 17 vs. 25 times, OR 2.6, 95% CI 1.1–6.0). Age, sex, body mass index and baseline pain did not predict incident radiographic osteoarthritis. The number of subjects did not allow for multiple regression analyses, however, the impact of fewer one-leg rises on the development of incident osteoarthritis at follow-up remained significant even when controlling for age, sex, body mass index and baseline pain one by one. The number of adequately performed one-leg rises was not significantly associated with baseline pain.

A cut-off between 20 and 24 one-leg rises could best discriminate between no radiographic changes and incident knee osteoarthritis (Figure 13) (data not shown in paper I).

Progression in radiographic status was seen in 29/54 subjects (54%) with radiographic features of osteoarthritis at baseline. None of the variables analysed could explain the radiographic progression, although those who progressed tended to have higher body mass index, perform fewer one-leg rises, and manage a shorter time standing on one leg.

Regression with regard to radiographic features was seen in 11/54 patients at follow-up. A comparison of characteristics between them and the remaining cohort showed that they had a lower body mass index (23.4 vs. 25.5 kg/m$^2$, p=0.05).

The effect from exercise on knee joint load (paper II)

Results are presented as mean (SD), if nothing else is stated.

Change in peak adduction moment during one-leg rise

The individual peak adduction moment at baseline ranged from 0.41 to 0.86 for the index knee, and for the opposite knee from 0.37 to 0.79 Nm/kg.

For the index knee (‘the worst knee’) peak adduction moment during one-leg rise was reduced from 0.57 (0.14) Nm/kg to 0.51 (0.13) Nm/kg (p=0.04, Figure 14). For the opposite knee there was no significant change in peak adduction moment from baseline to follow-up. No significant changes were seen for the index knee or the opposite knee in peak adduction moment during gait. In most cases, the exercise-induced changes in knee adduction moment were larger during one-leg rises than during gait (Figure 14).

Relationship between peak adduction moment and maximum number of one-leg rises

Higher peak adduction moment was correlated to reduced functional performance, measured as
maximum number of one-leg rises. The correlation for the index knee was $r_s = -0.35$ at baseline and -0.65 at the 8 week follow up ($p=0.24$ and 0.03 respectively). For the opposite knee the correlation was $r_s = -0.47$ at baseline and 0.13 at follow-up. To determine the number of one-leg rises best predicting a higher than median peak adduction moment, a ROC curve was calculated (Figure 15). For the 26 knees included at baseline, 23 to 29 one-leg rises best separated a higher than median from a lower than median peak adduction moment.

**The effect from exercise on pain and function (paper III)**

There were no significant differences in pain, self-estimated function or quality of life between the exercise group and the control group. In the exercise group, significant improvement was seen in the KOOS subscale Quality of Life at the six week follow up (45 vs. 40, $p=0.04$, Figure 16). This improvement persisted at six months (46 vs. 40, $p=0.05$). The individual changes over time ranged from clinically significant improvement to clinically significant deterioration in all KOOS subscales in both the exercise and control groups.

Significant improvement compared to baseline was found in the exercise group at six weeks with regard to the SF-36 Physical Component Summary scale (PCS) (45.7 vs. 42.5, $p=0.02$). This improvement persisted over time. Within the control group no significant improvement was found.
According to the tests of functional performance, the exercise program improved aerobic capacity and endurance in the lower extremity; The number of knee bendings and lateral step ups in 30 seconds increased from baseline to 6 weeks, and the results persisted over time (p<0.05).

Patients’ experiences from exercise as osteoarthritis treatment (paper IV)

Four descriptive categories emerged from the analysis of the transcribed interviews: To gain health, to become motivated, to experience the need for support, and to experience resistance. These four descriptive categories together included 13 conceptions (paper IV).

Conceptions were labelled as positive, but could hold a range of statements from positive to negative.

**Descriptive category – To gain health**

This category contained conceptions about experienced or known health related effects of exercise and consisted of five conceptions: to experience coherence, to experience well-being, to be in control, to experience improved physical functioning, and to experience symptom relief.

Patients related their knowledge about osteoarthritis to knowledge and experiences of exercise. They were satisfied and convinced of the effectiveness of exercise for health.

The moments immediately following the exercise sessions were associated with mental and physical relaxation, satisfaction and well being.

Several patients had experienced how exercise could improve their ability to handle their daily situation, and cope with the problems related to knee osteoarthritis. Some were able to regain functional performance or performing daily recreational activities more easily after the exercise intervention. However, the effects of exercise on pain and other symptoms were described within a range from total pain relief to a worsening of symptoms.

**Descriptive category – To become motivated**

This category contained three conceptions dealing with the informants’ desire to exercise: To experience inspiration, to be prepared to persevere, and to experience the need to exercise. Despite pain, the informants talked about exercise with varying degrees of enthusiasm and a sense of duty.

They experienced a wide range in motivation to exercise, from a desire to exercise regularly to having no motivation to exercise at all. Most of them were exercising despite pain and discomfort,
because of the known benefits on health related aspects. The definition of exercise needed varied greatly. Some felt that daily living demands movement was enough exercise, while others thought of regularly exercise sessions as important to maintain physical functioning.

**Descriptive category – To experience the need for support**

This category described conceptions of conditions necessary for wanting to exercise. Three conceptions emerged: To have structure, to receive guidance, and to devote time.

Accessibility was described as a prerequisite for exercise, and exercise should be of high quality, concerning the individual performance as well as the purpose with and type of exercise. All patients expressed a perceived need for moral support, encouragement and instructions on how to exercise. They were worried about doing something wrong and felt need for support to comply with exercise.

Different aspects of time were mentioned as essential for the effectiveness of the exercise. It concerned the most appropriate time point during the disease course to start exercise, and also how to find adequate time to exercise.

**Descriptive category – To experience resistance**

This category described the reasons for not exercising and comprised two conceptions: To hesitate and to deprecate.

Patients felt doubts about the benefits of exercise. Experiencing pain while exercising made it difficult to decide whether exercise was beneficial or counterproductive. They were worried that exercise could cause harm. Some considered other treatments to be more effective, and thought of exercise as unnecessary.

**Conceptions of knee osteoarthritis**

Some patients described their view of why they had knee osteoarthritis; hard work (n=2), injury from traffic accident (n=1) and heredity (n=1).

Patients talked about the limited physical performance due to knee osteoarthritis (n=13), avoidance of activities causing pain (n=9), and altered movement pattern (n=5). Osteoarthritis was described as painful by 14/16 patients. Five patients described discouragement from knee osteoarthritis; frustration (n=3), depression (n=3) and fear or anxiety (n=3). (Results not described in paper IV).
General discussion

Main message

Based on the results from the papers included in this thesis, I suggest that sufficient lower extremity muscle function reduces the risk of incident knee osteoarthritis (paper I), and that exercise has the potential to alter joint load (paper II). Exercise should be performed at an early stage of the disease, and preferably during periods of less pain (paper II, III, IV). Some patients with more severe disease benefit from exercise, but the prescription of exercise should be individual, based on patients’ preferences and previous experiences (paper III, IV). Continuous support, guidance and encouragement are essential components to avoid anxiety about exercising with knee osteoarthritis (paper IV).

Incidence of osteoarthritis

The incident rate of osteoarthritis after five years, defined as Kellgren and Lawrence grade one or more, in the Spenshult cohort was 44% (paper I). Applying the method used by Hart et al. (Hart et al. 1999) and Cooper et al. (Cooper et al. 2000) the yearly incident rate was 8.8% per year which is high compared to other studies. The comparison of incidence rates between different studies is complicated by several factors, such as different age-groups, previous joint injury, percentage of women, presence of knee pain like in the Spenshult cohort, patellofemoral involvement, and also by the fact that different radiographic atlases and different cut off points for ‘no osteoarthritis’ and ‘incident osteoarthritis’ are used (Cicuttini et al. 1996; Cooper et al. 2000; Felson et al. 1997; Gelber et al. 2000; Hart et al. 1999; Spector et al. 1994). The incident rate in a Bristol population, aged 55 years or older, was 3.3% per year (Cooper et al. 2000), and in the Chingford study, which comprised middle-aged women, the incidence rate was 5.8% per year (Hart et al. 1999).

Modifiable risk factors

Muscle weakness

Knee osteoarthritis is associated with muscle weakness (Hurley et al. 1997; Lewek et al. 2004; Pap et al. 2004; Toda et al. 2000). Whether the muscle weakness is a cause or consequence of knee osteoarthritis has been a topic for discussion (Hurley 1999; Roos 2005; Shrier 2004).

For assessment of muscular strength isokinetic or isometric muscle forces have most commonly been determined. These apparatuses however, are not readily available in clinical practice. Isokinetic and isometric assessments are laboratory tests, assessing dynamic lower extremity strength for one group of muscles at a time, using constant speed or constant force in open chain movements. In activities of daily living the conditions are more complex. It has been suggested that assessing different aspects of physical function might be more informative about overall functional performance (Hurley et al. 1997). The maximum number of one-leg rise test is such a test and is easily applied in clinical practice, and could be used to screen patients at increased risk of developing knee osteoarthritis.
We found reduced muscle function to be a risk factor for incident knee osteoarthritis five years later, controlling for known confounding factors like age, gender, body mass index and pain (paper I). These results support the suggestion by Slemenda et al. that reduced quadriceps strength in relation to body weight is a risk factor of knee osteoarthritis in women (Slemenda et al. 1998). Muscle function can be improved through exercise (Deyle et al. 2000; Ettinger et al. 1997; O’Reilly et al. 1999; Petrella and Bartha 2000; Thomas et al. 2002), and it is possible that the risk of osteoarthritis development thereby could be reduced. In retrospective studies, moderate exercise has been associated with reduced risk of incident osteoarthritis (Sutton et al. 2001) and osteoarthritis requiring joint replacement (Manninen et al. 2001).

**Joint load**

In a knee with neutral alignment, the lever arm between the quadriceps tendon and the medial joint contact surface – the axis of the adduction moment – is longer than in the varus knee. The quadriceps then acts, lateral to the axis of the adduction moment, as a stabilizer against lateral gapping, together with the passive lateral soft tissues (Figure 17) (Schipplein and Andriacchi 1991). Weak muscles put a greater demand on the passive lateral soft tissues. Insufficient tension of the lateral passive soft tissues contributes to a lateral gapping of the knee joint, and a shift in the local joint load (Andriacchi et al. 2004; Schipplein and Andriacchi 1991).

It seems possible to reduce peak adduction moment with exercise (paper II), indicating the role of the muscles as dynamic stabilisers of the knee joint. Previously, high tibial osteotomy has been shown to reduce the peak adduction moment, by reducing the varus alignment (Prodromos et al. 1985). Valgus braces intended to reduce the adduction moment have been studied with various results (Hewett et al. 1998; Pollo et al. 2002; Self et al. 2000). In future studies it would be interesting to explore the effect on joint load of combined treatments in knee osteoarthritis.

**Exercise as osteoarthritis treatment**

**Effect of exercise**

Most studies of the effects of exercise in knee osteoarthritis have included elderly subjects and have higher proportions of women than the populations included in paper II and III (Figure 18).

The mean changes in pain score and self-reported function in paper III were small and not significant (ranging from 2 to 4 points), however, some patients reported more than 10 KOOS points improvement in pain or function, while others reported similar deteriorations. The diverging results in our study are not unique (Fransen et al. 2001; Minor et al. 1989). It is a challenge to health care professionals to determine who will improve from exercise and who will not. Knee joint laxity or malalignment were not assessed in the population included in paper III, thus it is possible that local biomechanical factors contributed to the lack of improvement in pain and self-reported function (Sharma et al. 1999b). Sharma et al. (Sharma et al. 1999a; Sharma et al. 2003a) suggested that muscle strengthening exercise cannot contribute to increased functional performance, unless the dynamic alignment is normalized, and a cross-sectional relationship has been reported between strong quadriceps in knees with static malalignment and increased risk of progression of radiographic changes (Sharma et al. 2003b).

Patients in paper II and the exercise group in paper III were told not to exercise with more
than ‘acceptable pain’, but it might be difficult to decide how much pain is ‘acceptable’. There is a risk that they might have had neglected or distracted pain during exercise. Patients have different coping strategies, and neglecting or distracting pain in knee osteoarthritis has been demonstrated to increase pain 6 months later (Steultjens et al. 2001). The study by Steultjens et al. concluded that if patients pretend the pain is not there or is less severe, they might neglect pain as a warning signal of overuse. It has been suggested that pain reduction results in increased knee joint load (Hurwitz et al. 2000), and that the pain in fact might be protective in that it prevents from further joint load on the affected cartilage (Hurwitz et al. 1999).

Figure 18. The mean age of subjects, and proportion of women included in paper II and III compared to other exercise interventions in patients with knee osteoarthritis.
It is also possible that some of the variation could be related to unknown factors that might interfere with the severity and course of disease. Knowledge about the natural course of osteoarthritis is limited, but indicates that patients with osteoarthritis show great variability over time in self-reported pain and function (Dieppe et al. 2000; Paradowski et al. 2004).

**Type of exercise**

The exercise intensity in paper II and III was moderate/intensive, and patients exercised at the most vigorous intensity possible, without exacerbating pain. One of the problems with randomized controlled trials using exercise interventions is that the intervention is assumed to be uniform to all patients. No significant difference in effect on group level has been demonstrated between different types of exercise interventions (Brosseau et al. 2003; Ettinger et al. 1997; Fransen et al. 2003; Mangione et al. 1999; O’Reilly et al. 1999; Topp et al. 2002). However, the individual experience may vary between patients, even within the same exercise program (paper IV). This could affect the outcomes, especially self-estimated pain and function.

The intervention length of 6 weeks, used in paper III, was short (Ettinger et al. 1997; Minor et al. 1989; O’Reilly et al. 1999; Petrella and Bartha 2000; van Baar et al. 2001), however we found improvements in aerobic capacity and lower extremity endurance at six weeks which were maintained at 6 months. Hurley and Scott demonstrated positive effects on quadriceps strength, voluntary activation and functional performance after five weeks of exercise, in patients with knee osteoarthritis according to the ACR criteria (Altman et al. 1987), and data from 25 of the 60 (42%) patients who completed the exercise intervention in that study indicated that the results persisted over time (Hurley and Scott 1998).

**Compliance with exercise**

Patients have doubts about exercising, even when they have perceived benefit from exercise (paper IV). The hesitation can be related to fear of worsening the osteoarthritis or to the uncertainty about how to exercise, but also to more practical problems, like access to gyms, available time or transport to the exercise class (paper IV). Compliance to exercise is probably related to factors other than benefit of exercise (Campbell et al. 2001; Hsieh and Dominick 2003). Lack of time was mentioned as a reason not to exercise in paper IV, and it has been shown to be the most common reason not to exercise among younger and middle-aged women (Anderson 2003).

Another obstacle to compliance with exercise is the discrepancy between treatment recommendations and treatment preferences among patients with knee osteoarthritis (Fontaine et al. 2004; Jordan et al. 2004; Tallon et al. 2000). Results from paper IV showed that some patients prefer passive treatments, like pills or injections, and therefore think of exercise as unnecessary.

Supervised exercises seem to have better compliance, and thus better effects than home exercises (Fransen et al. 2003; Kettunen and Kujala 2004). The exercises in paper II and III were supervised and combined with home exercises. Home exercises combined with initial instructions and supervision have been shown to be more effective than home exercises alone or telephone advice (McCarthy et al. 2004; Thomas et al. 2002). To get the highest possible compliance, patients’ preferences should be recognized and wishes about certain conditions should be met, without losing the intention of treatment.

**Pain and exercise in knee osteoarthritis**

The lack of improvement in pain and function from exercise in patients with moderate to severe knee osteoarthritis in paper III coincides with the theory by Fransen et al. suggesting the effect from exercise being negatively correlated to grade of radiographic changes (Fransen et al. 2001). Interviews with 16/30 patients from the exercise group (paper IV) demonstrated that patients would prefer exercise at an earlier stage of the disease. Exercising at an early stage of the disease is less likely to induce severe pain, since pain becomes more intense and frequent with increasing radiographic severity (Cooper et al. 2000; Felson et al. 1987). Experiencing pain from exercise contributed to difficulties for the patients to determine the degree of benefit or damage related to exercise, and thus caused feelings of anxiety and helplessness (paper IV). Pain also seems to interfere with the possibil-
ity to achieve increased functional performance (paper II, III, IV). Thus, it is desirable to initially combine exercise with analgesics or acupuncture.

**Motivational factors for exercise**

Information, continuous support, encouragement and patience are important to achieve a change in behaviour among patients with osteoarthritis (paper IV). The results from paper IV indicated that the motivation to exercise varied. One factor suggested to interact with motivation to exercise is coping with the disease. Patients with rheumatoid arthritis who thought of the disease as possible to influence and were motivated to exercise were prepared to comply with exercise and physical activities despite the disease, while those who had accepted the disease but thought of it as impossible to influence were less eager to be physically active (Eurenius et al. 2003). It seems as if coping with the disease is of similar importance in knee osteoarthritis (paper IV). Patients who use passive strategies, like rest, to cope with osteoarthritis pain are at higher risk of developing physical disability over time (Steultjens et al. 2001). Patients with mild disease participate more frequently in exercise and have a stronger belief in exercise than patients with moderate to severe knee osteoarthritis (Gecht et al. 1996).

**Strengths and limitations**

**Outcomes**

I suggest that muscle function is more appropriately assessed using functional performance tests than isokinetic or isokinetic muscle strength testing. The maximum number of one-leg rises assesses a combination of muscle function, i.e. strength, endurance and proprioception, balance, and motivational factors. Sit to stand is performed several times per day in activities of daily living, and perceived difficulties are described by patients with knee osteoarthritis. The difficulty with rising from sitting is evaluated in WOMAC (Bellamy et al. 1988) and KOOS (Roos et al. 1998a; Roos et al. 1998b), both questionnaires frequently used in patients with knee osteoarthritis. 50/61 (82%) of the patients in the exercise cohort in this thesis described at least some difficulty with the task. This makes the test relevant in this population. The reliability of maximum number of one-leg rises is yet to be determined.

Three-dimensional gait analysis, or analysis of other activities of daily living is widely used to describe kinetics and kinematics in healthy subjects as well as in patients with lower extremity dysfunction (Al-Zahrani and Bakheit 2002; Amin et al. 2004; Chmielewski et al. 2001; Draganich and Kuo 2004; Herzog et al. 1989; Hinman et al. 2002; Kaufman et al. 2001; Mikesky et al. 2000). Three-dimensional motion analysis provides the researcher with rich information about limb position, degrees of motion, speed, frequencies, and external forces across several joints, in the frontal, coronal and sagittal planes simultaneously 100 times per second (100 Hz). Beforehand decisions have to be made about variables of interest. These decisions are guided by previous research and clinical questions. The anatomical landmarks for the reflective markers are clearly defined (Davis et al. 1991b; Kadaba et al. 1990), and correct placement is crucial for the reliability. In the current study we have not assessed the reliability of the procedures, which of course could bias the results. A second source of unreliability was introduced since peak adduction moment was obtained from graphs. To minimize bias the graph reader was blinded to subject, knee, and if data was obtained before or after the intervention. Other concerns are the small number of patients included, and the lack of knowledge about peak adduction moment during tests of functional performance, and the lack of control group. Previous studies comprising 18–19 patients have shown significant differences on gait parameters over time (Schnitzer et al. 1993; Shrader et al. 2004). Our study should be considered as a pilot study within the field, and the clinical importance of the significant changes in paper II should be determined in future studies.

**Qualitative research methodology**

Life-style, knowledge, and previous experiences are factors that influence people’s acting and beliefs. The characteristics and effect of these factors are often not explored within quantitative research. The variation in responses to questions in a questionnaire is often predetermined by fix alternatives, like in a Likkert Scale. In quantitative
studies individual answers are grouped together, and useful information might be lost, or the results may indicate ‘no difference’ on group level (paper III). Qualitative studies can contribute to a deeper understanding, by taking the individual responses and perspectives into account. Based on the participants’ conceptions individual differences can be illuminated and provide a deeper perspective on the results (Malterud 2001). Qualitative research is based on data not able to describe or analyze with statistical methods. Paper IV was undertaken to elucidate such a situation, where there were no change at group level but a wide variation in individual outcomes after an exercise intervention (paper III). A recent study has shown that there is a lack of agreement between pain assessed by questionnaires and by interviews (Campbell et al. 2003). In paper IV however, the range of statements obtained by means of interviews concerning symptom relief clearly correlated with the divergent outcome derived from paper III. I found that the patients with moderate to severe knee osteoarthritis were worried about the pain they had felt during exercise. All the informants in paper IV expressed doubts and concerns about exercise as a form of treatment, even though they did believe in general health benefits from exercise, and some of them had experienced pain relief from exercise.

I used phenomenography to analyze the data in paper IV. The method is descriptive and results are presented on group level. The methodological objective was to remain close to empirical data in order to gain a better understanding of how patients with knee osteoarthritis experience exercise as treatment, and since this was the objective, it was considered logical and appropriate to use phenomenographic approach. The possibility to formulate and test new hypothesis within phenomenography is restricted compared to other qualitative methods, which limits the interpretation of the results into a wider context. The results could however be applied in clinical practice and taken into account in planning of future exercise trials.

Clinical implications
Incorporating the results from paper I and II in clinical practice, would suggest that if a patient with knee pain (and no radiographic features of knee osteoarthritis) perform more than 29 one-leg rises, the risk of having a high peak adduction moment during one-leg rise is low. If the patient performs less than 20 one-leg rises, the risk of developing radiographic knee osteoarthritis is increased (Figures 13 and 15).

Muscle weakness is associated with increased or altered joint loads (Andriacchi et al. 2004; Mikesky et al. 2000). The results from paper II indicated that also reduced functional performance, i.e. fewer one-leg rises, was associated with increased peak adduction moment. In future studies it would be of interest to explore if maximum number of one-leg rises could be used to screen patients for joint load in large scale studies and clinical practice.

Pain during exercise is related to feelings of hesitation about if exercise might cause further harm (paper IV). By initially combining exercise with analgesics, acupuncture or pain coping strategies compliance could be enhanced. The choice of exercise should be based on patient’s preferences and previous experiences. Structured exercises and continuous feedback and encouragement should be provided.
Conclusions

- Reduced functional performance, assessed by maximum number of one-leg rises, predicted development of incident knee osteoarthritis in middle-aged subjects with knee pain.
- Exercise has the potential to reduce peak adduction moment in mild to moderate knee osteoarthritis.
- Increased peak adduction moment was correlated to a lower number of one-leg rises.
- Six weeks of high-intensity supervised group exercise in patients with moderate to severe knee osteoarthritis had no effect on pain and self-reported function, however the quality of life improved.
- Among patients with moderate to severe knee osteoarthritis the individual changes in pain and function after 6 weeks of exercise ranged from clinically significant improvement to clinically significant worsening.
- Middle-aged patients with moderate to severe knee osteoarthritis and knee pain had doubts about exercise as osteoarthritis treatment, despite known and perceived benefits from exercise on health aspects and symptoms related to osteoarthritis.
- Patients with moderate to severe knee osteoarthritis expressed that exercise as treatment for osteoarthritis should be supervised, and that continuous encouragement and support is crucial to compliance.
Knee osteoarthritis is one of the ten most disabling diseases in adults older than 30. Previous knee injury increases the risk of developing knee osteoarthritis already in middle-age. It can be estimated that approximately 5% in the age group 35-54 have radiographic features of knee osteoarthritis. Of these, 2/3 have a previous knee injury and 1/3 have knee pain without known previous knee injury. Muscle weakness is associated with increased joint loads. Increased or altered joint loads will finally result in osteoarthritis. It is not clear whether muscle weakness is a cause or consequence of osteoarthritis. Exercise reduces pain and improves function in knee osteoarthritis and is recommended as the first line treatment in international guidelines.

In this thesis, I have studied a population based cohort of middle-aged subjects (35–54 years, 42% women) with chronic knee pain at baseline, to evaluate the longitudinal effect of muscle weakness on knee osteoarthritis development, the relationship between muscle function and joint load and the effects of exercise on joint load. I have also studied the effect of exercise on pain and function in another middle-aged cohort (36–65 years, 51% women) with moderate to severe knee osteoarthritis, and explored their conceptions of exercise as treatment.

In the first study, 148 subjects with chronic knee pain underwent radiographic examination and tests of functional performance at baseline. 94 of them had no radiographic signs of knee osteoarthritis. Five years later they had new radiographs taken and 41/94 (44 %) had developed incident knee osteoarthritis. I found that reduced functional performance, assessed by maximum number of one-leg rises from a stool, predicted knee osteoarthritis development. The result was controlled for the previously known risk factors of age, BMI and pain.

In the second study, I used three-dimensional motion analysis to explore the possibility of altering joint load by exercise. The medial compartment joint load (peak adduction moment) during maximum number of one-leg rises was assessed in 13 subjects with early radiographic signs of knee osteoarthritis from the cohort in study one, before and after 8 weeks of exercise. Two subjects were lost to follow up for reasons not related to the knee. The peak adduction moment could be reduced by exercise, and a high maximum number of one-leg rises was associated with lower levels of peak adduction moment.

The third study included 61 subjects with moderate to severe radiographic knee osteoarthritis. They were randomized to 6 weeks of intensive exercise or to a control group. The effects of exercise were assessed using questionnaires. No effects were seen on pain or self estimated function, however, the quality of life improved. The individual response to exercise ranged from clinically significant improvement to clinically significant worsening.

As an attempt to understand this large inter individual response to exercise, I designed the fourth study, where I interviewed 16 of the 30 patients in the exercise group about their conceptions of exercise as treatment. The interviews were analysed using qualitative methodology, and it was revealed that all patients were aware of the general health benefits of exercise, but had doubts about exercise as treatment of osteoarthritis even if they had perceived pain relief and improvement in physical function from the exercise intervention. The pain experienced during exercise caused the patients to believe that exercise was harmful to their knees, and some of them would prefer not to exercise at all. They thought that exercise should be introduced early during the course of the disease, and all of them expressed the need of continuous encouragement and support to adhere to exercise.

From this thesis I conclude that reduced muscle function is a risk factor of knee osteoarthritis development among middle aged subjects with knee pain. Reduced muscle function is associated with increased joint load, which seem to be modifiable by exercise. Initial pain when starting exercise, or occasional pain from exercise, should be treated by combining exercise with pain relief such
as analgesics or acupuncture. Pain contributes to the difficulty patients have determining the degree of benefit or damage related to exercise, and thus causes feelings of anxiety and helplessness (paper IV). Pain also seems to interfere with the possibility of achieving increased functional performance (paper II, III, IV).
Sammanfattning på svenska


Artros är en sjukdom som drabbar hela leden, men där effekterna märks främst på ledbrosk och ben. Ledbrosket blir skört och tunnas ut, det bildas bennabbar på ledytans kanter och benvävnaden under ledbrosket förtätas. Ett tidigt och mycket vanligt symptom vid artros är att det blir svårt att belasta leden. En skada av knäleden ökar risken för artros på lång sikt, men även utan tidigare skada är det ungefär 1.5% av befolkningen som drabbar. Alltför stor belastning på leden medför ökad risk för artrosutveckling. Svaga lårmuskler är vanligt vid knäartros och det har diskuterats om det är en riskfaktor eller en konsekvens av artros. Träning rekommenderas ofta som behandling och har i studier av äldre personer med knäartros visats kunna minska smärta och förbättra muskelfunktionen.

I min första studie undersökte muskelfunktion i benen hos ca 150 medelålders personer, som alla hade knäsmärta. Bland annat fick de att testa att sätta sig så många gånger en gång som de kunde på ett ben från sittande. Deras knäleder röntgades och ungefär 1/3 hade förändringar som vid artros medan resten var "knäfriska" enligt röntgen. Fem år senare togs nya röntgenbilder och då hade 44% av de tidigare "knäfriska" utvecklat artros. Jag fann att de som hade sämre förmåga att resa sig på ett ben från sittande i större utsträckning hade utvecklat artros, även om hänsyn togs till övrigt, ålder och kön. Det betyder att nedsatt muskelfunktion i benen ökar risken för att utveckla knäartros.


Den tredje studien inkluderade drygt 60 personer som alla hade knäsmärta och måttliga till svåra artrosförändringar enligt röntgen. De lottades hälften till 6 veckors intensiv träning och hälften till en kontrollgrupp som levde som vanligt. Jag mätte effekten av träningen med frågeformulär och resultaten visade att träning inte påverkade vare sig smärta eller funktion i träningsgruppen, men att livskvaliteten förbättrades jämfört med kontrollgruppen. Resultatet på individnivå varierade från tydlig förbättring till tydlig försämring.

För att försöka förstå dessa variationer mellan individer genomförde jag i min fjärde studie intervjuer med hälften av de personer som varit med i träningsgruppen. Jag ville undersöka hur de såg på träning som behandling av artros. Resultaten visade att alla var medvetna om de positiva effekter som träning har på hälsan, men tvivlade på om träning var bra för artros även om de själva hade upplevt förbättring av träning. Att det gjorde om att träna medförde att de kände sig osäkra på om träning kunde skada leden ytterligare och vissa av dem ville helst inte träna överhuvudtaget. Många ansåg att träning bör introduceras tidigt i sjukdomsförloppet och alla uttryckte att det krävs kontinuerligt
stöd och uppmuntran för att fortsätta träna.
Baserat på resultaten av studierna drar jag följande slutsatser:

• Nedsatt muskelfunktion medför ökad ledbelastning och är en riskfaktor för att utveckla artros hos medelålders med knäsmärtor.
• Träning kan förbättra lärmuskelfunktionen och tycks minska ledbelastningen i knäna och kan således kanske minska risken för såväl utveckling som progress av röntgenverifierad knäledsartros.
• Träning bör introduceras i ett så tidigt skede som möjligt innan smärtan har hunnit bli för svår, för att få bästa effekt på muskelfunktionen och minska oron hos patienterna.
• Träning kan i vissa fall minska smärtan och förbättra funktion även vid måttlig till svår artros, men hänsyn bör tas till individuella önskemål och kontinuerligt stöd och vägledning bör erbjudas under träningen.
Acknowledgements

This thesis has been brought out with the contribution from many people. I would like to express my sincere gratitude to you all, with special thanks to:

All patients, for your participation in the studies and your contribution to my knowledge of osteoarthritis by sharing your experiences from life.

My supervisor Ewa Roos, for sharing your knowledge, guiding me into science, for your belief in me and your intelligent, straight forward comments. They have always taken me to new horizons, sometimes through excitement and sometimes through despair. However, you were always there for support and advice when I got stuck. You have served as my model.

Ingemar Petersson, my co-advisor, boss and problem-solver. If it wasn’t for you, I would never have thought about research. You knew I was going to write this thesis before I did. I am grateful to you, but how could you be so sure? I am still impressed by your many skills, in rheumatology as well as in negotiation and in life experiences.

Lennart Jacobsson, my co-advisor. Thank you for helping me out with epidemiology, for your bright comments on my first paper, and your interest in and contributions to my process. I appreciate your combination of sharp intelligence and relaxed humility.

Tore Saxne, my co-advisor and head of the Department of Rheumatology, for accepting me as a doctoral student at your department, without hesitation. Thanks to you, this journey became much easier.

Barbro Arvidsson, my co-author and qualitative advisor, for taking me into the world of qualitative research. That was a challenge for all of us, but an experience that I am very grateful for. I believe we both have introduced an upstart in our research network.

Charlotte Ekdahl, my co-author, for involving me in the exercise intervention plans in 1996 and for your patience through-out the years when recruitment went slow.

Torsten Boegård, my co-author, for your skilful reading of all radiographs in the separate studies.

Marketta Henriksson, Catharina Sjödahl, my co-authors for sharing your knowledge about kinetics and kinematics.

Anette von Porat, my co-author, colleague and friend, for sharing your experience and my frustration during data extraction in Vicon, for your company on our first visit at an international congress, in San Francisco 2001, and for support and good talks in between.

Ann Bremander, my room-mate, colleague and friend, for fruitful discussions and sharing tears and laughs and Riesens, throughout the years in the “terrarium”.

Maria Andersson, my colleague and friend, for all your help with technical, practical and mental issues, and for all big laughs.

Stefan Bergman, for statistical advices and lunch talks about research and life. I appreciate the times you are passing by to say hello or to chat.

Pia Andersson, Annika Flink-Persson and Karina Turesson, for your assistance in every way, and for your company and laughter during essential breaks.

The physical therapists at Laholm Primary Care Center, for letting me and my patients in to use your gym.

Louise Mattsson, for practical matters during the movement analyses.

To my friends and colleagues in the Ph.D. student network, for many fruitful discussions, experiences from misfortunes, as well as champagne and celebrations.

Members of the osteoarthritis network, for interdisciplinary discussions and exchange of knowledge about osteoarthritis.

Bodil Jönsson, for giving me good advice and thoughts I never had thought of.

Klas Sjöberg, for your never ending passion for computers. I wish I wouldn’t have needed your help, but thank you for your efforts and encouraging comments, even in the middle of the night,
when I was desperate during the last intensive months of writing.

*Alan Crozier, Gullvi Nilsson, Margaret Byron, Clare Kelly and Ingela Roos* for making my written words clearer.

*All friends and colleagues at Spenshult Hospital for Rheumatic Diseases*, especially at the department of physical therapy, and at the R&D-centre, for your help and friendship.

*Patrik Appelquist*, for taking the challenge to illustrate my ideas.

*Maja*, you are my greatest fan. I believe you and *Per* introduced me to the world of literature and language, some 35 years ago.

My large family; parents, brothers, and family-in-law. Thank you for your help when I was out of time.

*Jerker*, my husband, for keeping up the “real work” with house and children, while I’ve been physically or mentally absent. How could you ever understand what this means to me?

To my children, *Pontus, Måns and Mårten*, for your lovely drawings and big warm hugs waiting for me, no matter when I come home or how long I’ve been gone. You are the meaning of my life!

References


EXERCISE AND FUNCTIONAL PERFORMANCE IN KNEE OSTEOARTHRITIS


EXERCISE AND FUNCTIONAL PERFORMANCE IN KNEE OSTEOARTHRITIS


He wakes up the next morning and he has a fresh new world to work with, but he has something else too. He has his yesterday.

From “The five people you meet in heaven” by Mitch Albom
Reduced functional performance in the lower extremity predicted radiographic knee osteoarthritis five years later

C A Thorstensson, I F Petersson, L T H Jacobsson, T L Boegård, E M Roos


Background: Reduced quadriceps strength is an early finding in subjects with knee osteoarthritis, but it is not clear whether it is a cause or a consequence of knee osteoarthritis.

Objective: To determine whether reduced functional performance in the lower extremity predicts the incidence or progression of radiographic knee osteoarthritis.

Design: Prospective, epidemiological, population based cohort study.

Patients: 148 subjects (62 women), aged 35–54 (mean 44.8), with chronic knee pain from a population based cohort.

Measurements: Predictors analysed were age, sex, body mass index, baseline knee pain, and three tests of lower extremity functional performance: maximum number of one-leg rises from sitting, time spent walking 300 m, and timed standing on one leg. Weightbearing tibiofemoral knee radiographs were obtained at baseline and after 5 years (median 5.1, range 4.2–6.1), and classified according to Kellgren and Lawrence as no osteoarthritis (Kellgren and Lawrence = 0, n = 94) or prevalent osteoarthritis (Kellgren and Lawrence ≥1, n = 54).

Results: Fewer one-leg rises (median 17 v 25) predicted incident radiographic osteoarthritis five years later (OR 2.6, 95% CI 1.1 to 6.0). The association remained significant after controlling for age, sex, body mass index, and pain. No significant predictor of radiographic progression in the group with prevalent osteoarthritis was found.

Conclusion: Reduced functional performance in the lower extremity predicted development of radiographic knee osteoarthritis 5 years later among people aged 35–55 with chronic knee pain and normal radiographs at baseline. These findings suggest that a test of one-leg rises may be useful, and interventions aimed at improving functional performance may be protective against development of knee osteoarthritis.

METHODS

Subjects

In 1990 a questionnaire was sent to 2000 randomly selected people aged 35–54 (963 women and 1037 men) in a district in the south west of Sweden, with a mixed urban and rural population, to estimate the prevalence of chronic knee pain. Chronic knee pain was defined as “pain in either of your knees practically daily for the past three months”. One thousand eight hundred and fifty three people (93%) answered the questionnaire, of whom 279 (15%) reported chronic knee pain. Those who had chronic knee pain were offered a radiographic and a clinical examination, and 204 agreed to participate. One hundred and fifty two subjects were available for follow up five years later (fig 1). Because this study concerns the development of radiographic knee osteoarthritis, we decided to exclude four patients owing to diverging radiographic features in the right and left knee at follow up. These four patients each had one knee that had become worse and one that had become better. This made it difficult to determine whether they had progressed or not. Thus 148 subjects constituted the cohort of the present study. Table 1 describes the patient characteristics.

Ethical approval was obtained from the ethics committee, Medical Faculty, Lund University.
by putting a mark on a visual analogue scale (VAS) just before and straight after the test of time spent walking.

- **Timed standing on one leg** with simultaneous, rapid repeated neck rotations, with eyes open and arms hanging along the body (modification of the test used by Ekdahl et al\(^\text{15}\)). Time spent on one leg, without any support, was measured in seconds using an analogue stopwatch. When the lifted foot touched the floor, when support was needed, or after 30 seconds, which was considered “normal”, the test was interrupted. One attempt was allowed.

### Radiographic and clinical examination

Posteroanterior radiographs of both tibiofemoral joints were obtained with straight knees in the weightbearing position and with the weight equally distributed on both legs. The medial aspects of the feet were aimed to be parallel with each other. The central x ray beam was horizontal and aimed at the level of the centre of the popliteal fossa, and the right and left knees were reproduced by the same exposure.

The medical history was obtained and a rheumatologist made a clinical examination. Height and weight were recorded, and body mass index was calculated as kg/m\(^2\). Patients with disorders, other than osteoarthritis, known to cause knee pain were identified and excluded from further analysis (fig 1).

### Follow up

#### Radiographic examination

After 5 years (median 5.1, range 4.2–6.1) posteroanterior radiographs of both tibiofemoral joints were obtained in weight bearing in a fluoroscopy unit. The patients stood with almost the entire weight on the examined leg, with the knee flexed 30–50\(^\circ\), and with the patella and the big toe touching the table of the fluoroscopy unit. The medial aspect of the foot was parallel to the central x ray beam, and the beam was adjusted to be tangential to the anterior and posterior aspect of the medial tibial condyle.

The baseline radiographs and the radiographs at the follow up were classified according to Kellgren and Lawrence\(^\text{6}\) by an experienced radiologist (TLB). The baseline radiographs and the radiographs at the follow up were evaluated on different occasions and the reader was unaware of the name and the age of the patient and the results from other examinations and tests. The intraobserver agreement for re-reading the baseline radiographs has been evaluated previously,\(^\text{9}\) showing high agreement (\(k = 0.88\)). The inter- and intraobserver variation for minimum joint space and osteophytes in the semiflexed position varied from 0.72 to 0.98.\(^\text{17,18}\) Kellgren and Lawrence grade 1 was defined as prevalent osteoarthritis.\(^\text{20}\) A change of one grade or more according to Kellgren and Lawrence was defined as progression.\(^\text{20}\) The index knee was set as the knee with radiographic signs of progression at follow up for those who had radiographic changes in only one knee. If two knees were affected to different grades, the knee with the worst progression at follow up became the index knee, and for those who had no radiographic changes (Kellgren and Lawrence = 0), or equal changes in both knees, the right or left knee was randomly assigned as the index knee.

#### Statistics

 Statistical testing was performed using SPSS 10.0 for Windows. Analyses were conducted using non-parametric tests.\(^\text{20}\) Calculations were made using data from the index knee only. Because progression was influenced by increased grade of radiographic changes at baseline, as determined by the Kruskal-Wallis test (\(p = 0.05\)), we decided to analyse two
groups separately: those with no radiographic changes at baseline and those with prevalent knee osteoarthritis at baseline (Table 1). Firstly, the risk of developing incident radiographic knee osteoarthritis or progression of already existing knee osteoarthritis was determined for the two groups separately. The median value of each predictor was used to dichotomise the predictor variable into a category variable, with values above or below the median. Logistic regression was used to determine the odds ratio of progression of radiographic features 5 years later. To determine whether those whose radiographic changes had regressed differed from the remaining cohort, the Mann-Whitney U test was used. Spearman’s test was used to determine covariation between predictors.

**Role of the funding source**

The study sponsors had no role in the study design, in the collection, analysis, or interpretation of the data, or in the writing and publication of the report.

**RESULTS**

**No osteoarthritis at baseline (Table 1)**

Forty one of 94 patients (44%) developed incident osteoarthritis. The test of the maximum number of one-leg rises from sitting at baseline significantly predicted development of incident knee osteoarthritis 5 years later (median 17 v 25 times, table 2). Age, sex, body mass index, and baseline pain did not predict incident osteoarthritis. The impact of fewer one-leg rises on the development of incident osteoarthritis at follow up remained significant even when controlling for age, sex, body mass index, and baseline pain one by one (table 3). The number of adequately performed one-leg rises, time spent walking, and timed standing on one leg were not significantly associated with baseline pain.

**Prevalent osteoarthritis at baseline (Table 1)**

The radiographic status progressed in 29/54 (54%) patients. None of the variables analysed could explain the radiographic progression of already existing knee osteoarthritis, although where progression occurred patients tended to have higher body mass index, perform fewer one-leg rises, and manage a shorter time standing on one leg (table 4). Controlling the three tests of lower extremity functional performance for age, sex, body mass index, and pain did not change the results (data not shown). Radiographic features of 11 patients had regressed at follow up (table 1). A comparison of characteristics between them and the remaining cohort showed that they had a lower body mass index (23.4 v 25.5 kg/m², p = 0.05).

**DISCUSSION**

**Main message**

This study supports the hypothesis that limitations in lower extremity functional performance can predict radiographic progression of knee osteoarthritis. In this study cohort of subjects reporting knee pain before baseline examination we found that reduced functional performance in the lower extremities is an early sign of knee osteoarthritis, detectable before radiographic changes appear, and that reduced functional performance may in fact even be causative. Pain intensity in the knee on the day of examination did not affect functional performance, as measured with the tests in this study. The maximum number of one-leg rises from sitting, the test that significantly predicted radiographic osteoarthritis, may be of importance in the early identification of subjects who have poor prognosis. By directing preventive treatments, it might be possible to delay, or perhaps prevent, the development and the consequences of osteoarthritis.

**Comparison with other studies**

Our results suggest that tests of lower extremity functional performance are valuable in predicting incident osteoarthritis. None of the factors analysed in this study could explain progression, and it has been suggested that different risk factors might influence the incidence and progression of osteoarthritis. Incidence in this study is chiefly defined as development of osteophytes, while progression is chiefly defined by joint space narrowing. Our decision to perform separate analyses of prevalent and incident cases was based on the fact that progression is influenced by increased radiographic changes at baseline. Recent studies have shown that existing radiographic changes due to osteoarthritis are strong predictors of progression, which supports our decision. It has previously been shown that quadriceps strength did affect the incidence of knee osteoarthritis, but not the progression of radiographic changes in elderly subjects with existing knee osteoarthritis. Our findings pointed in the expected direction. In the group with prevalent osteoarthritis, there was a trend towards worse functional performance and higher body mass index among those with radiographic progression. It is well known that being overweight is a risk factor for developing incident knee osteoarthritis, but in the present study, body mass index was not associated with the development of osteoarthritis in the group with normal radiographs at baseline. Possible explanations for this include chance or that the majority of cases analysed developed osteophytes and not joint space narrowing. Further follow up may be needed to show how many of these go on to develop joint space narrowing, for which body mass index may be a stronger predictor. The median body mass index (25.2 kg/m²) in the group developing incident knee osteoarthritis in the present study was just above what is considered normal. However, in our study those whose radiographic changes regressed turned out to have a lower body mass index than those who had stable or progressive radiographic changes. Also worth noticing is the fact that the median age of this cohort was about 10 years younger than, for instance, the women in the Chingford study.

---

**Table 1** Group characteristics for the total study cohort and the two subgroups with (a) no radiographic signs of osteoarthritis at baseline (no OA) and (b) prevalent OA at baseline (OA)

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>Age† (years)</th>
<th>Female No (%)</th>
<th>BMI (kg/m²)</th>
<th>Progression§ No (%)</th>
<th>Kellgren and Lawrence grade</th>
<th>Follow up</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>148</td>
<td>45 (35–54)</td>
<td>42 (42)</td>
<td>25.3 (18–37.5)</td>
<td>70 (47)</td>
<td>0/1/2/3/4 (n)</td>
<td>0/1/2/3/4</td>
</tr>
<tr>
<td>No OA</td>
<td>94</td>
<td>45 (35–54)</td>
<td>41 (41)</td>
<td>25.3 (18–30.0)</td>
<td>41 (44)</td>
<td>94/0/0/0/0 (n)</td>
<td>53/33/4/3/1</td>
</tr>
<tr>
<td>OA</td>
<td>54</td>
<td>45.5 (35–54)</td>
<td>23 (43)</td>
<td>26.5 (20–37.5)</td>
<td>29 (54)</td>
<td>0/36/9/9/0 (n)</td>
<td>8/13/12/12/9</td>
</tr>
</tbody>
</table>

*Number of patients included; †age at baseline, median (range); §number (%) women of total selection; BMI mass index at baseline, median (range); ¶number (%) of patients with progression of radiographic changes at follow up (Kellgren and Lawrence ≥1 grade).
Reduced functional performance predicts knee OA

It has been suggested that knee pain affects quadriceps strength. In our study cohort all had chronic knee pain at inclusion, but lower extremity functional performance was not associated with baseline pain. This result is in accordance with previous findings by Slemenda et al. Furthermore, there was no association in this study between pain at baseline and development of radiographic osteoarthritis.

Critical assessments

The strengths of the present study are primarily the population based, prospective design, together with the younger age of the cohort. To our knowledge this is the first study of the role of functional performance in developing knee osteoarthritis in young or middle aged subjects. Osteoarthritis treatment today is symptomatic. If we could identify risk factors for osteoarthritis in younger patients, we might have a chance to intervene and influence the development of the disease.

One concern is the validity of the functional tests used. At baseline, in 1990, validated tests of functional performance in osteoarthritis of the lower extremity were lacking. The tests in this study were chosen because of their applicability to clinical situations; they were easy to perform, required no special equipment, and they tested functional performance used in daily situations. In an effort to validate the test of maximum number of one-leg rises, strength was measured on a small number of patients with a hand held dynamometer in knee extension (n = 47) and knee flexion (n = 46) (p = 0.0001 and p = 0.01 (unpublished data)).

Another possible concern is the difference in radiographic technique at baseline and follow up. At baseline, radiographs were taken with straight knees, and at follow up a semiflexed position was considered a more reliable radiographic technique, which has later been corroborated. Hence, radiographs could not be read “blinded” for their time sequence, although the baseline and follow up radiographs were read at different occasions, and the reader was unaware of all other clinical information. These methodological differences may have affected the occurrence and disappearance of radiographic findings, such as osteophytes. Such misclassification would, however, be non-differential in relation to evaluated predictors and would therefore not bias the results, although it may explain the high incidence of osteoarthritis in this cohort. The relevance of Kellgren and Lawrence grade 1 (minute osteophytes) could also be questioned, but the technique for reading and its relation to other features of osteoarthritis, both on plain radiographs and on magnetic resonance imaging, is well documented. The validity of our finding of regression of radiographic changes is also supported by other studies and by the association between radiographic regression and lower body mass index. The high

Table 2: In the group with no radiographic changes at baseline, less endurance in one-leg rise from sitting predicted incident osteoarthritis (OA) 5 years later. Variables dichotomised by the median value. Univariate odds ratio (OR) with 95% confidence intervals (CI).

<table>
<thead>
<tr>
<th>Predictor variable (values from baseline)*</th>
<th>Incident OA at follow up (n = 41)</th>
<th>No OA at follow up (n = 53)</th>
<th>OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>94</td>
<td>44</td>
<td>1.58 (0.69 to 3.60)</td>
</tr>
<tr>
<td>Sex (women/men)</td>
<td>94</td>
<td>44</td>
<td>1.58 (0.69 to 3.60)</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>94</td>
<td>44</td>
<td>1.58 (0.69 to 3.60)</td>
</tr>
<tr>
<td>Pain VAS (0–100)‡</td>
<td>94</td>
<td>44</td>
<td>1.58 (0.69 to 3.60)</td>
</tr>
<tr>
<td>Maximum number of one-leg rises†</td>
<td>94</td>
<td>44</td>
<td>1.58 (0.69 to 3.60)</td>
</tr>
<tr>
<td>Time spent walking 300 m (min)‡</td>
<td>94</td>
<td>44</td>
<td>1.58 (0.69 to 3.60)</td>
</tr>
<tr>
<td>Timed standing on one leg (s)‡</td>
<td>94</td>
<td>44</td>
<td>1.58 (0.69 to 3.60)</td>
</tr>
</tbody>
</table>

*Variable expressed as median (range), except for sex where numbers are presented; †numbers of patients included in analysis; ‡lower value indicates better result; ‡higher value indicates better result.
Table 4  There was no significant predictor of radiographic progression 5 years later among those with prevalent knee osteoarthritis (OA) at baseline. Variables dichotomised by the median value. Univariate odds ratio (OR) with 95% confidence intervals (CI).

<table>
<thead>
<tr>
<th>Predictor variable (values from baseline)*</th>
<th>n†</th>
<th>Progress at follow up (n = 29)</th>
<th>No progress at follow up (n = 25)</th>
<th>OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>54</td>
<td>46 (36–53)</td>
<td>44 (35–54)</td>
<td>1.57 (0.53 to 4.60)</td>
</tr>
<tr>
<td>Sex (women/men)</td>
<td>23/31</td>
<td>11/18</td>
<td>12/13</td>
<td>1.51 (0.51 to 4.47)</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>54</td>
<td>26.8 (21.6–37.5)</td>
<td>24.5 (20.2–31)</td>
<td>1.87 (0.62 to 5.63)</td>
</tr>
<tr>
<td>Pain VAS (0–100)‡</td>
<td>53</td>
<td>5 (0–50)</td>
<td>0 (0–20)</td>
<td>2.23 (0.66 to 6.80)</td>
</tr>
<tr>
<td>Maximum number of one-leg rises§</td>
<td>54</td>
<td>17 (10–140)</td>
<td>22 (1–213)</td>
<td>1.33 (0.46 to 3.90)</td>
</tr>
<tr>
<td>Time spent walking 300 m (min)¶</td>
<td>53</td>
<td>2.45 (1.74–4.29)</td>
<td>2.48 (2.12–3.33)</td>
<td>0.98 (0.32 to 3.02)</td>
</tr>
<tr>
<td>Timed standing on one leg (s)</td>
<td>54</td>
<td>12 (2.6–31)</td>
<td>31 (2.8–31)</td>
<td>1.56 (0.53 to 4.60)</td>
</tr>
</tbody>
</table>

*Variable expressed as median (range), except for sex where numbers are presented; †numbers of patients included; ‡lower value indicates better result; §higher value indicates better result.

CONCLUSION

Reduced functional performance in the lower extremity predicted the development of radiographic knee osteoarthritis, mainly osteophytes, five years later in middle aged subjects with chronic knee pain at inclusion, even when controlled for age, sex, body mass index, and pain intensity. This result suggests that functional performance is of importance for the development of knee osteoarthritis. The test of the maximum number of one-leg rises is potentially useful to screen which patients with knee pain are at risk for developing knee osteoarthritis.

ACKNOWLEDGEMENTS

Grants were received from the Swedish Rheumatism Association in Stockholm, the Swedish Rheumatism Association in Gothenburg, the Department of Research and Development at Spenshult Hospital for Rheumatic Diseases, Halmstad, Sweden, and the Zöga Foundation of Medical Research.

REFERENCES


www.annrheumdis.com
Rapid ELISA for PR3- and MPO-ANCA is a reliable emergency screen for small vessel vasculitis

A rapid test for serological markers of small vessel vasculitis developed for urgent assessment is as reliable as recommended tests, according to an audit in a regional immunology laboratory in the UK. The rapid enzyme linked immunosorbent assays (ELISAs) for proteinase 3 (PR3) and myeloperoxidase (MPO) antineutrophil cytoplasmic antibodies (ANCA) are therefore suitable for emergency testing in suspected small vessel vasculitis in acute renal failure, pulmonary renal syndrome, and mononeuritis multiplex.

Good agreement was observed between the rapid (qualitative) PR3/MPO-ANCA ELISA and the international standard indirect immunofluorescence (IIF) test, with a reported sensitivity of 82%, specificity 97%, positive predictive value 92%, and negative predictive value 93%. Similar results were obtained between rapid PR3-ANCA ELISA and its standard quantitative ELISA counterpart (sensitivity 87%, specificity 93%, positive predictive value 93%, negative predictive value 88%), and complete correlation occurred between the rapid and quantitative MPO-ANCA ELISAs. Positive results in rapid and quantitative ELISAs correlated with small vessel vasculitis in all cases for which biopsy specimens were available (14 PR3-ANCA, 8 MPO-ANCA).

The audit screened serum from 103 consecutive patients over 12 months with rapid PR3- and MPO-ANCA ELISA and further tested positive samples with standard IIF and ELISA tests for ANCA. Clinical records were available for 31 of 34 patients with positive results on any test and biopsy specimens for 22.

Rapid PR3- and MPO-ANCA ELISAs are widely used in diagnostic laboratories to determine vasculitis in urgent situations but have not before been formally tested against the recommended standardised IIF and quantitative ELISA.

▲ Journal of Clinical Pathology 2003;56:775–777.
Eight weeks of exercise reduced knee adduction moment during one-leg rise in patients with early knee osteoarthritis

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Abstract

Background Reduced functional performance is a risk factor for development of knee osteoarthritis, and peak knee adduction moment is associated with radiographic progression. Knee adduction moment can be reduced by high tibial osteotomy. The effect of dynamic stabilization through increased muscle performance is not known.

Aims To study the effect from exercise on external peak knee adduction moment during one-leg rise, and the relationship between peak knee adduction moment during one-leg rise and maximum number of one-leg rise.

Methods 13 patients, aged 48–63, with mild to moderate knee osteoarthritis underwent 8 weeks of supervised exercise, aiming at increasing neuromuscular control and lower extremity strength. The maximum number of one-leg rise from a stool (48 cm), 3-dimensional gait analysis and self-estimated knee symptoms were assessed before and after exercise intervention. Peak external knee adduction moment during one-leg rise and gait was calculated using a Vicon system. The Knee injury and Osteoarthritis Outcome Score (KOOS) was used as assessment of knee symptoms. Patients defined their most symptomatic knee as index knee.

Results Peak knee adduction moment during one-leg rise was reduced for the index knee from 0.57 Nm/kg at baseline to 0.51 after 8 weeks of exercise (p=0.04). The change for the opposite knee was not significant (from 0.58 to 0.56 Nm/kg, p=0.23). No significant changes were seen for index or opposite knees in peak adduction moment during gait (p>0.40). A higher maximum number of one-leg rise was correlated to a lower peak adduction moment for the index knee at baseline (rs = -0.35, p=0.24) and follow up (rs = -0.65, p=0.03). For the opposite knee the correlation was similar at baseline (rs = -0.47, p=0.10), and no correlation was seen at follow-up (rs = 0.13, p=0.70). Correlations for change over time were poor (-0.43 to -0.03) and not significant (p>0.20).

Patients with symptomatic knee osteoarthritis had higher peak adduction moment in their opposite knee, than patients without symptoms at baseline (0.72 (0.09) vs. 0.50 (0.11), p=0.01) and follow-up (0.66 (0.14) vs. 0.51 (0.07), p=0.04). The differences for the index knee pointed in the same direction, however not significant (p>0.28).

Conclusion Peak knee adduction moment in the most symptomatic knee of middle-aged patients with early signs of knee osteoarthritis can be reduced by exercise. Improved muscular performance might reduce the risk of radiographic progression of knee osteoarthritis. It seem of importance to reduce pain prior to starting exercising. A lower maximum number of one-leg rise is associated with higher peak knee adduction moment and has the potential to serve as a surrogate in studies where 3-dimensional analysis is not feasible.
Background

Moderate exercise is known as an important treatment of knee osteoarthritis, with positive effects on pain and function [1]. The positive effects seen might arise through different pathways including local mechanical factors, acting at the knee joint. Reduced muscle function contributes to an increased dynamic joint-load in the medial compartment of the knee [2], shown to be associated with radiographic progression of knee osteoarthritis [3]. The risk of incident knee osteoarthritis is associated with reduced functional performance [4], suggesting that biomechanical factors influence not only progression, but also development of knee osteoarthritis. The external knee adduction moment is used as an approximate measurement of the load acting on the medial knee joint compartment [5]. The peak adduction moment in knee osteoarthritis can be reduced by high tibial osteotomy, altering the joint load from medial towards the lateral compartment [6]. The effect of dynamic stabilization, through increased muscle performance, on medial compartment joint load is not known. To determine knee adduction moment 3-dimensional assessment, usually performed at a movement laboratory, is performed. It would be beneficial to find other tests correlated to knee adduction moment which could be used in epidemiological studies.

The aims of this study were twofold: 1) to study the effect of moderate exercise on knee adduction moment during one-leg rise and gait, and 2) to study the relationship of knee adduction moment during one-leg rise and the maximum number of one-leg rise in patients with mild knee osteoarthritis.

Methods

Patients

Patients, younger than 65 years, with radiographic signs of knee osteoarthritis corresponding to Kellgren and Lawrence grade I (minute osteophytes), were recruited from a previously described population based cohort, with chronic knee pain at inclusion in 1990 [7]. Radiographic inclusion criteria were based on a previous examination conducted in 1995. Since our aim was to study subjects with early OA, we did not include subjects with Kellgren and Lawrence grade II or more in 1995 which might have progressed radiographically during the 7 years from examination to study start in 2002. One-hundred and fifty-six patients were examined in 1995, six patients had moved from the geographic area or were not able to reach. Forty patients fulfilled the inclusion criteria, and were contacted by telephone. Patients with dysfunction in back or lower extremity (n=10), inflammatory joint disease (n=3), previous knee injury (n=2), chronic widespread pain (n=4) and depressive symptoms (n=1) were excluded. Seven patients declined to participate due to lack of time. Thirteen patients were included after oral and written informed consent (Figure 1).

Exercise intervention

Patients participated in supervised exercise classes, two times per week for 8 weeks. The exercise classes were held at an out-patient clinic, and the physical therapist (CT) reserved three hours per occasion, when the patients could decide what start time was the most appropriate from time to time. Thus, patients exercised together, but individually, and with different tasks. The exercise program was performed at a self-selected speed. Intensity was gradually and individually increased by the physical therapist, when exercises could be performed with sustained neuromuscular quality. Patients were told to align the knee over the toes throughout all exercises, by using muscles acting as hip rotators.

After a warming up session, exercises aiming at improving neuromuscular control of the knee and lower extremity strength were performed at four stations. Each station consisted of three exercises, which were performed 3 x 15 times or 3 x 60 seconds (rebounder).

- 10 minutes of ergometer cycling or walking on treadmill (warm-up).
- Station 1
  a. Lying supine with one foot on a twinball. The other knee held against the trunk. Lifting and lowering the pelvis.
  b. Sit-ups
  c. Lunging forward
- Station 2
a. Lying prone on a traverse board, with head 136 cm above the floor. A soft-ball, 34 cm, under the belly, and one foot lifted. Bending and stretching the knee of the supporting limb, with knee kept in line with the toes.
b. Standing in front of a stool. Knee bending until buttocks touches the stool.
c. Rebounder. Straddle-legged tramping or jumping, with knees bent and hips externally rotated.

• Station 3
  a. Slide board. Knee flexion with simultaneous abduction or extension of opposite limb.
  b. Stepping up and down on a step board.
  c. Straddle-legged deep knee bending. Explosive extension up on one leg stance or jump, on right and left leg alternately.

• Station 4 – Pulley exercises, supporting limb slightly flexed.
  a. Pulling leg in extension and internal rotation
  b. Pulling leg in abduction
  c. Pulling leg in flexion, with simultaneous hip flexion.

Finally, stretching exercises for Mm triceps surae, Mm quadriceps, Mm hamstrings, and Mm iliopsoas were performed.

Intensity was increased by using longer lever arms, dumbbells, bar-bells or medicine balls. A prerequisite to increase intensity was that exercises could be performed with full muscle control, i.e. constant speed and knee aligned with the toes. Pain was not considered an obstacle as long as it did not exceed what patient judged as acceptable pain, and no increased symptoms were persistent after 24 hours [8]. If so, intensity was lowered until the level of pain was acceptable.

Patients were encouraged to perform some kind of weight bearing submaximal activity, such as walking, for at least 30 minutes or two times 15 minutes every day.

**Treatment efficacy**
We expected the intervention to improve functional performance and aerobic capacity. Three tests of functional performance were used to assess the effectiveness of the intervention; lateral step-up in 30 seconds [9], one-leg hop [10] and one-leg rise from lowest possible height [10, 11]. Aerobic capacity was assessed by bicycle ergometer test [12].

**Radiographic and clinical examination**
Current radiographic status was obtained by posteroanterior radiographs of both tibiofemoral joints in weight-bearing position in a fluoroscopy unit. The patients stood with almost the entire weight on the examined leg, with the knee flexed 30–50°, and with the patella and the big toe touching the table of the fluoroscopy unit. The medial aspect of the foot was parallel to the central X-ray beam and the
beam was adjusted to be tangential to the anterior and posterior aspect of the medial tibial condyle. The hip-knee-ankle (HKA) angle was assessed in a standing anteroposterior radiograph of the lower limb. The patient was barefoot and stood with equal weight on both legs and with 15° of knee flexion. The X-ray beam was centred on the knee at a distance of 2.2 m. The frontal projection was perpendicular to a lateral view of the knee, which was achieved by superimposing the dorsal aspects of the femoral condyles.

The landmarks used were the centre of the femoral head, the centre of the tibial spines, and the centre of the talus. The HKA angle was defined as the lateral angle between the lines from the centre of the tibial spines to the centre of the femoral head and the talus respectively. An angle of more than 180° denotes a varus alignment [13]. All radiographs were read by the same experienced radiologist, and classified according to the Kellgren and Lawrence system [14].

Range of movement in hip, knee and ankle was assessed using goniometer. Height and weight was measured, and body mass index (BMI) was calculated. Prior to the baseline examination of functional performance, patients were asked to identify their most symptomatic knee as their index knee.

Outcome measurements

Primary outcome was peak external knee adduction moment during one-leg rise.

The maximum number of one-leg rise test

Functional performance was assessed before and after the exercise intervention by maximum number of one-leg rise from a stool (48 cm). Patients were allowed to try out the best foot-stool-position before the trial, by rising and sitting down a couple of times. They were asked to perform as many one-leg rises as possible, with arms hanging along the body, and without putting the other foot on the floor. The test should be performed with full muscle control i.e. the sitting down phase should be performed with constant speed and the up rise phase without adding arm or trunk movement. The number of adequately performed rises was counted. Patients decided on the length of pause before the test of the second leg. The maximum number of one-leg rise was adjusted for leg length.

Knee adduction moment assessment

External knee adduction moment was assessed by use of Vicon 612 (OMG, Oxford, UK) before and after eight weeks of exercise. This is a system consisting of six 100 Hz cameras with infrared strobes, one AMTI force-plate (Advanced Mechanical Technology, Inc., USA), one data-station and one PC, where the information was gathered and processed in Plug-In Gait software.

Special markers, reflecting the infrared light from the cameras, were attached by a physical therapist with specific knowledge and experience within the area of motion analysis, over standardised landmarks (anterior superior iliac spine, lower lateral third of the thigh, lateral epicondyle of femur, lower lateral third of the calf, lateral malleolus of fibula and over the second metatarsal head, on the posterior calcaneus at the same distance from ground level as the forefoot marker and one marker between the posterior superior iliac spines) according to the biomechanical model of Kadaba et al., (1990) [15] and Davis et al. (1991) [16].

The main outcome variable, external knee adduction moment, was calculated by Vicon software, and corresponds to the product of the ground reaction force, acting through the foot and medial to the knee joint, and the perpendicular distance from the ground reaction force to the axis of knee joint ab- and adduction movement.

Knee adduction moment during one-leg rise

Before the assessment of one-leg rise, patients were sitting with feet above the force-plate, and on a given command they put down the foot and started to rise and sit-down. The foot position was not to be changed during the test, and some body-weight had to be kept on the supporting leg and foot during the entire sitting-down phase. The order of legs tested was decided by the patient. Knee adduction moment was assessed during the first 30 seconds of the maximum number of one-leg rise test. It was previously decided that the first rise in the series should be considered as synchronization of position. To avoid influence of fatigue on functional performance, and to have comparable data independently of how many rise a person could perform, the second rise was used as data source (Figure 2).
Knee adduction moment during gait
Knee adduction moment was assessed in the shock absorption phase during gait [17], which occurs at approximately 10% of the gait cycle. Gait was performed on a 10-m walkway in the gait laboratory, and patients were told to walk in a rapid but comfortable speed. The force plate, built-in at floor level, was placed in the middle of the walkway. Three trials with satisfying force plate data were collected on each leg. The mean peak adduction moment from the three trials was calculated (Figure 3).

Assessment of knee symptoms
The Knee injury and Osteoarthritis Outcome Score (KOOS) was used at baseline and follow-up to assess patients’ rating of knee symptoms. KOOS is a disease-specific self-administered questionnaire with 42 questions in five subscales; pain, other symptoms, activities of daily living (ADL), function in sport and recreation (sport/rec) and quality of life (QOL), and takes about 10 minutes to complete [18, 19]. The KOOS is scored from 0 to 100, separately for each subscale, 0 indicating extreme problems and 100 indicating no problems. A change of 10 points or more is considered a clinically significant change [20]. The questionnaire and scoring manual can be found at www.koos.nu.
The Western Ontario and McMaster Osteoarthritis Index (WOMAC) [21] is included in the KOOS, and WOMAC scores can also be calculated. A previously described definition of a symptomatic knee was used [22]. The cut-off is created from the patient’s self-report from the KOOS, and aimed at identifying individuals symptomatic enough to possibly seek medical care. Patients were categorized as symptomatic or asymptomatic, giving the same label for both index and opposite knee in each patient.

Data handling and statistics
The data was obtained by manual readings from Vicon-graphs, cleared of identity information and time of evaluation. Each knee had a separate graph. To avoid bias, each graph was given a number from a random number list by the last author (ER). The code was not available to the graph reader until all graphs were read and the data was entered into a PC.

It was decided a priori that index knee and opposite knee should be analyzed separately. Data were analyzed using nonparametric tests. P-values of less than or equal to 0.05 were considered to be significant, and all tests were two-tailed. To compare groups, the Mann-Whitney U-test was used. The Wilcoxon signed rank test was performed to study changes from baseline to eight weeks. Correlations were calculated using the Spearman rank correlation test. Analyses were performed using SPSS 13.0 for Windows [23].

A formal power analysis was not performed a priori, since previous data on knee adduction moment during one leg rise is missing. However, previous studies on gait analysis in patients with knee osteoarthritis, comprising 13–20 patients, have shown significant differences in knee adduction moments compared to a control group [24-26] and in changes over time [27, 28].

The study was approved by the Research Ethics Committee at Lund University, Sweden (LU 600-02), and is in compliance with the Helsinki Declaration.

Results
Results are presented as mean (SD) if nothing else is stated.

Subjects
Mean age of the included patients was 54.5 (5.5) years. Baseline characteristics of the group and of individual subjects are shown in Table 1. None of the patients had a leg length discrepancy of more than 1.5 cm. Three of 26 knees had an extension limitation (5° n=2, 10° n=1). No other important mobility limitations were noted. The peak knee flexion during the one-leg rise test was 85° (7°)

### Table 1. Baseline characteristics

<table>
<thead>
<tr>
<th>ID</th>
<th>Age (years)</th>
<th>BMI (kg/m²)</th>
<th>Gender</th>
<th>Length (m)</th>
<th>Index knee KOOS ♠</th>
<th>Kellgren and Lawrence grade</th>
<th>HKA index opposite</th>
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<td></td>
<td>Median</td>
<td>53</td>
<td>25.5</td>
<td>54% F</td>
<td>1.71</td>
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<td>F</td>
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<td>1 -5 -4</td>
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<td>4 3</td>
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<td>2 6 5</td>
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<tr>
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<td>1 -2 -1</td>
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<td>30.3</td>
<td>M</td>
<td>1.94</td>
<td>left</td>
<td>64 1</td>
<td>2 9 6</td>
</tr>
</tbody>
</table>

♠ Knee injury and Osteoarthritis Outcome Score, 0–100 worst to best scale [18, 19]
for the index knee and 86° (8°) for the opposite knee. Medial joint space width for the index knee was 4.4 (1.2) and for the opposite 4.4 (1.0) mm. According to Kellgren and Lawrence, 1 knee had improved in radiographic status since 1995, from Kellgren and Lawrence grade 1 (minute osteophytes) to no radiographic changes, 12 were indifferent, 11 had progressed to grade 2 (definite osteophytes) and 2 had progressed to grade 3 (osteophytes and joint space narrowing) since the examination 7 years earlier. The hip-knee-ankle angle ranged from 5° valgus to 9° varus for the index knee, and from 4° valgus to 6° varus for the opposite knee (Table 1).

Effect from exercise on functional performance, kinematics and self-reported variables

The average number of exercise occasions performed was 13 (range 10–16) out of 16 possible. The intervention was effective in improving functional performance in the index leg (p=0.04–0.06). For the opposite leg, the improvement in functional performance was not significant (p=0.09–0.37). The aerobic capacity increased from 33.2 (9.1) to 36.6 (7.3) ml O₂/kg × min (p=0.12). Gait speed at baseline was on average 1.36 (0.16) m/s, and mean step length was 0.69 (0.07) m. These parameters did not change after exercise (p=0.24 and 0.11, respectively). Six subjects improved at least 10 KOOS points in self-reported pain, function or quality of life, representing a clinical significant difference. The KOOS changes were not statistically significant (p>0.19).

Knee adduction moment during one-leg rise

For the index knee, peak knee adduction moment during one-leg rise was reduced after 8 weeks of exercise (p=0.04, Table 2). For the opposite knee, no significant change in peak adduction moment from baseline to follow-up in one-leg rise was seen.

During gait, no significant changes were seen for the index knee or the opposite knee in peak adduction moment (Table 2).

The individual knee adduction moment at baseline ranged from 0.41 to 0.86 and in the opposite knee from 0.37 to 0.79 Nm/kg. The individual changes in peak adduction moment for both legs during one leg rise and gait are given in Figure 4.

Table 2. Peak adduction moment (Nm/kg) during one-leg rise and gait

<table>
<thead>
<tr>
<th>Peak adduction moment Mean ± SD, Nm/kg</th>
<th>Index knee</th>
<th>Opposite knee</th>
<th>p-value for change</th>
<th>p-value for change</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>One-leg rise</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Baseline</td>
<td>0.57 ± 0.14</td>
<td>0.58 ± 0.15</td>
<td>0.04</td>
<td>0.23</td>
</tr>
<tr>
<td>8 weeks</td>
<td>0.51 ± 0.13</td>
<td>0.56 ± 0.12</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Gait</strong></td>
<td>0.52 ± 0.11</td>
<td>0.55 ± 0.14</td>
<td>0.45</td>
<td>0.50</td>
</tr>
<tr>
<td>8 weeks</td>
<td>0.54 ± 0.13</td>
<td>0.54 ± 0.10</td>
<td></td>
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</tr>
</tbody>
</table>

Figure 4. Change over time in peak adduction moment during one-leg rise (A and B) and during gait (C and D) in index and opposite knees.
Generally, the exercise-induced changes in knee adduction moment were larger during one-leg rise than during gait. Peak adduction moment vs. maximum number of one-leg rise

Better functional performance, measured as maximum number of one-leg rise, was correlated to a lower peak adduction moment (Table 3). The correlation for the index knee was \( r_s = -0.35 \) at baseline and \(-0.65\) at 8 weeks follow up. The correlation at follow-up is shown in Figure 5. For the opposite knee the correlation was \( r_s = -0.47 \) at baseline and \(0.13\) at follow-up (Table 3). Correlations for change over time were poor (-0.43 to -0.03) and not significant (p>0.20, Table 4).

Knee symptoms as confounding factor

At baseline, eight patients were categorized as having no symptoms and five were symptomatic. Patients with symptomatic knee osteoarthritis according to KOOS had higher peak adduction moment in their opposite knee, (‘the best knee’) than patients without symptoms at baseline (0.72 (0.09) vs. 0.50 (0.11), p=0.01) and follow-up (0.66 (0.14) vs. 0.51 (0.07), p=0.04). For the index knee the differences pointed in the same direction, with higher peak adduction moments for patients with symptoms at baseline and follow-up, however not significant (p>0.28).

Patients who were categorized as symptomatic at baseline did not improve in functional performance as assessed by maximum number of one-leg rise. In the index knee, patients categorized as non-symptomatic increased the maximum number of one-leg rise by 10 (9), while patients categorized as symptomatic showed a reduction of 7 (11) (p=0.04). The corresponding numbers for the opposite knee was an increase of 21(17) vs. a reduction of 3(7) (p=0.01).
Discussion

Main message
Our study supports the hypothesis that knee adduction moment can be reduced by improved muscular performance, and suggests that a higher maximum number of one-leg rise represents a lower peak knee adduction moment.

Knee adduction moment during one-leg rise
The reduction of peak adduction moment during one-leg rise in the index knee of 0.08 Nm/kg corresponds to the changes in previous studies after 2 weeks use of a valgus brace [29, 30]. However, a prospective study of 9 weeks use of a valgus brace showed no differences in peak adduction moment during gait [31], indicating that exercise might have a more lasting effect. The clinical importance of these changes is yet to be determined.

Knee adduction moment during gait
The peak adduction moment during gait was not significantly reduced from exercise. Previous studies have shown that patients with knee osteoarthritis have higher peak adduction moment during gait than normal subjects [32, 33]. However, the peak adduction moment in this study sample did not exceed 0.86 Nm/kg, or 1.53 mean percent body weight times height, which is low compared to other osteoarthritis populations studied [17, 26-28, 34]. This probably affected the possibility to significantly reduce the peak adduction moment during gait in the present population. Our hypothesis that peak adduction moment during one-leg rise was more sensitive than peak knee adduction during gait in this population of younger patients with early knee osteoarthritis was confirmed (Figure 4).

Correlation between knee adduction moment and maximum number of one-leg rise
The maximum number of one-leg rise explained 42% of the variation in peak adduction moment for the index knee at follow-up. It has previously been suggested that a high knee adduction moment predicts osteoarthritis progression [3], and that a low number of one-leg rise predicts incident radiographic knee osteoarthritis [4]. The results from the present study are in agreement with those findings, suggesting that low functional performance, assessed by maximum number of one-leg rise, is associated with a high peak adduction moment. The relationship between peak adduction moment during gait and the maximum number of one-leg rise pointed in the same direction, however not significant.

To test the possibility that the one-leg rise test could discriminate between high and low peak adduction moment, a post-hoc analysis was performed on the data from the 13 patients (26 knees) at baseline. Adduction moment was split by median 0.56, and values exceeding median were regarded as high adduction moment. The cut off value of one-leg rise that best separated high from low knee adduction moment was chosen. Eleven knees were identified performing 30 one-leg rise or more. Of these 11 knees, 8 (73%) had a low peak adduction moment. Ten of the 15 (67%) knees performing fewer than 30 one-leg rise had a high peak adduction moment. Thus, performing 30 one-leg rise or more is likely to be associated with a low knee adduction moment (sensitivity = 0.77, specificity = 0.62).

Limitations
The primary concern of this study is the small number of patients and the lack of control group. This limits the possibilities of interpreting the results and controlling for possible confounders. Previous data on joint kinetics during one-leg rise are lacking and this study should be considered a pilot-study.

Knee symptoms as confounding factor
Knee symptoms seemed to interfere with knee adduction moment and the possibility to gain increased functional performance from exercise, and thus knee symptoms could be a reason to the lack of correlation between changes over time in knee adduction moment and one-leg rise. O’Reilly et al have demonstrated that patients with knee pain have reduced quadriceps strength compared to a control group without pain [35]. Pain reduction has proved to increase the maximum voluntary contraction of quadriceps in patients with knee osteoarthritis, supporting the association found in the present study [36]. It has also been suggested that pain interfere with knee adduction moment during gait. Previous studies, however,
have shown that pain reduction is associated with higher knee adduction moment [17, 27, 37], which is contradictory to the findings from the present study. A possible explanation could be related to disease severity, since this study population have mild knee osteoarthritis compared to the previous studies. Another possibility could be that a high knee adduction moment might precede knee joint pain. The cause and consequence of pain and knee adduction moment is not clear.

Other factors that have been proposed to affect knee adduction moment are toe-out angle [26, 38], gait speed [34, 39], stride length [5] static hip-knee-ankle alignment [17, 38, 40], joint space width [33], and BMI [41]. The small sample included in this study did not allow for multiple regression analysis.

It has been suggested that one-leg stance would diminish the influence of toe-out angle, stride-length and gait speed on peak knee adduction moment, but still allow assessment of knee adduction moment [42]. In the present study, peak adduction moment was assessed during one-leg rise, and the foot position was not changed during the test. However, it is possible that patients could have rotated their lower limb during the performance test, by internal hip rotation, causing a shorter lever arm of the ground reaction force, the same mechanical compensation as with the toe-out angle [5].

**Conclusion**

Exercise, aiming at increasing the neuromuscular control and lower extremity strength, reduced peak knee adduction moment during one-leg rise in the most symptomatic knee of middle-aged patients with early signs of knee osteoarthritis. Improved muscular performance might reduce the risk of radiographic progression of knee osteoarthritis. It seems to be of importance to reduce pain prior to starting exercising.

Reduced functional performance, assessed by maximum number of one-leg rise, is associated with higher peak knee adduction moment and has the potential to serve as a surrogate in studies where 3-dimensional analysis is not feasible.

**References**


Six-week high-intensity exercise program for middle-aged patients with knee osteoarthritis
A prospective, randomized, and controlled study

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Abstract

**Background**  Studies on exercise in knee osteoarthritis (OA) have focused on elderly subjects. The aim of this study was to study the effects of a short-term, high-intensity exercise program in middle-aged subjects with symptomatic and definite radiographic knee osteoarthritis on self-reported pain, function and quality of life.

**Methods**  Patients aged 36–65, referred to radiographic examination due to knee pain and no history of major knee injury, with OA grade III (Kellgren & Lawrence), were included. They were randomized to supervised exercise intervention for one hour, twice a week for 6 weeks, or to a non-intervention control group. Exercise was performed at ≥60% of HR max. Primary outcome measure at 6 and 26 week follow-ups was the Knee injury and Osteoarthritis Outcome Score (KOOS). Measures of aerobic capacity and lower extremity functional performance were used to ensure the effectiveness of the intervention.

**Results**  Sixty-one subjects (mean age 56, 51 % women, mean BMI 29.5) were randomly assigned to intervention (n=30) or control group (n=31). Improvements were seen for the KOOS subscale quality of life in the exercise group at 6 weeks compared to baseline (mean change 5.0, p=0.04) which persisted at 6 months (p=0.05). No significant differences were seen in the KOOS subscales assessing pain, other symptoms, or function in daily life of in sport and recreation. Compared to baseline, aerobic capacity was significantly increased in the exercise group at 6 and 26 weeks.

**Conclusion**  A six-week high-intensive exercise program had some effect on quality of life but no effect on pain and function in middle-aged with moderate to severe radiographic knee OA. It was however possible for some individuals, despite moderate to severe radiographic knee OA, to benefit from the program.

**Background**  Exercise is considered one of the most important treatments for patients with mild to moderate knee osteoarthritis, concerning both effect on pain and function, and cost-effectiveness [1-3]. The effect size from exercise on pain is similar to pharmacological treatment, and the side effects are mostly positive, including reduced risk of inactivity-related disorders, such as cardiovascular disease and diabetes [1, 4, 5]. Moderate levels of physical activity are not associated with radiographic progression, but activities including risk of severe knee injury are closely related to increased risk of developing radiographic knee osteoarthritis [6-10]. The dose-response relationship of exercise on symptoms and function is not clear and exercise recommendations in osteoarthritis guidelines are based on studies.
including mostly elderly people [2, 11-14]. It is not clear whether exercise has a similar effect on pain and function in middle-aged patients as in elderly patients. The effects of short-term, high-intensity, supervised exercises on pain and function in knee osteoarthritis have previously not been determined. The aim of this study was to examine the effects of a short-term, high-intensity exercise program in middle-aged subjects with definite radiographic knee osteoarthritis on self-reported pain, function, and quality of life.

Methods

Subjects

A flow chart of the recruitment process is given in Figure 1. Radiologists and orthopedic surgeons at the Halmstad County Hospital, in the south-west of Sweden, and general practitioners within the catchments area of this hospital, were informed about the study and asked to list patients with radiographic knee osteoarthritis on a “patients eligible for research” list. Between October 1998 and October 2001, 121 patients, referred by their general practitioner to radiographic examination because of long standing knee pain, were listed. Ninety-seven fulfilled the inclusion criteria: age 35–65, living in the defined geographic area, and
diagnosis of radiographic osteoarthritis of Kellgren and Lawrence grade III or more, i.e. definite osteophytes and joint space narrowing. All listed patients received written information about the study. One week after the information was sent, patients were contacted by telephone, and invited to participate in the study. Twenty-eight patients declined participation for various reasons, the most common reason being lack of time and interest. To ensure only patients with symptoms due to knee osteoarthritis and eligible for exercise intervention were included, the following exclusion criteria were used: inflammatory joint disease, anterior cruciate ligament injury, known symptomatic injury to the menisci, hip symptoms more aggravating than the knee symptoms, about to have knee replacement surgery within 6 months, and co-morbidities not allowing exercise (Figure 1).

When eight or more patients fulfilled the inclusion criteria they were invited to baseline interview and examination for determination of exclusion criteria. Randomization was performed after the baseline examination. All patients were informed that they could be randomly allocated to either the exercise or the control group. After written informed consent, sixty-five subjects were randomized. Randomization was performed by the patient drawing a sealed envelope containing a piece of folded paper with either the word “exercise” or “control” written on it. Four persons were falsely randomized (one was too old at inclusion, one had severe hip osteoarthritis, one had fibromyalgia, and one had only joint space narrowing and no significant osteophytes), and thus 61 subjects entered the study. Thirty persons were allocated to the exercise group and 31 to the control group. Patients in the control group were offered exercise classes after the six-month follow-up period.

Exercise group
The number of participants exercising together varied from two to nine. There were eight intervention groups in all. One-hour exercise sessions, twice a week for six weeks, were supervised by a physical therapist (CT). The program consisted of weight-bearing exercises aimed at increasing postural control and endurance and strength in the lower extremity (see additional file). Exercises were performed at five stations at submaximal intensity (minimum 60% of $HR_{max}$). Exercises were (in sequential order):
1) 10 minutes ergometer cycling
2) 5 minutes rebounder exercises; tramping/walking
3) 5 minutes step-board exercises, 15 times per leg repetitive; step up/step down
4) 15 minutes floor exercises, 15 times repetitive; lying supine lifting and lowering the pelvis sit-ups side-lying hip abduction one-leg rise and sit on lowest possible height
5) 10 minutes pulley exercises, 15 times per leg repetitive; straight leg flexion, abduction, extension and adduction of the hip and lunging forward
6) 15 minutes stretching; mm triceps surae, mm quadriceps, mm hamstrings, mm iliopsoas.

Intensity was gradually and individually increased during the six weeks by increased lever arms or range of motion (see additional file 1 for the complete exercise program). Patients were encouraged to exercise at their most vigorous intensity possible, without losing quality in performance or severely exacerbating pain. Pain during exercise was not concerned as an obstacle if the patient perceived it as “acceptable” and no increased symptoms were persistent after 24 hours [15]. If pain exceeded this level, exercise intensity was reduced occasionally, until the “acceptable” level was found.

On every occasion, the heart rate of two random participants was estimated at each station using Polar pulsimeters (Polar® Accurex Plus, Polar, Sweden). The other patients had their heart rate measured by the physical therapist or themselves, palpating their arteria carotis. Notes were taken by the supervising physical therapist, on every occasion and on all patients, about exercise intensity, heart rate, and perceived exertion according to Borg’s Rate of Perceived Exertion scale (RPE) at each station [16]. These data were used to give the physical therapist a view of exercise intensity and to assure the preservation or increase of intensity from time to time. Patients were encouraged to keep up and increase intensity whenever possible throughout the six weeks.
Patients received a rubber band to perform daily pulley exercises at home. In addition, three exercises, which were considered as the most challenging to the individual, were chosen as daily home exercises. Patients were recommended to perform some kind of weight bearing submaximal activity, such as walking or their home exercises, for at least 30 minutes or two times 15 minutes every day.

**Control group**
The controls were told not to make any lifestyle changes. They met the physical therapist (CT) for one hour at three times; baseline, follow-ups at 6 weeks and 6 months. After six months they were offered exercise classes or instructions and a home-exercise program.

**Outcome measures**

**Primary outcome**
The primary outcome measure was the disease-specific Knee injury and Osteoarthritis Outcome Score (KOOS) [17, 18]. The KOOS assesses the patients' self-report of pain, other symptoms, activities of daily living, sport and recreation function, and knee-related quality of life, in 42 questions which take about 10 minutes to complete. The KOOS is scored from 0 to 100, separately for each subscale, 0 indicating extreme problems and 100 indicating no problems. A change of 10 points or more is considered a clinically significant change [19]. The questionnaire and scoring manual can be found at www.koos.nu. The Western Ontario and McMaster Osteoarthritis Index (WOMAC) [20] is included in the KOOS, and WOMAC scores can also be calculated.

**Secondary outcome**
Secondary outcome measure was the Short Form-36 item (SF-36). The SF-36 is a generic, widely used measure of general health status, which comprises eight subscales: Physical Functioning (PF), Role-Physical (RP), Bodily Pain (BP), General Health (GH), Vitality (VT), Social Functioning (SF), Role-Emotional (RE) and Mental Health (MH) [21]. The SF-36 is self-explanatory and takes about 10 minutes to complete. The SF-36 is scored from 0 to 100, 0 indicating extreme problems and 100 indicating no problems. The subscales assessing mainly physical components (PF, RP, BP, GH) were summarized to a physical component summary score (PCS), and the mental subscales (VT, SF, RE, MH) to a mental component summary score (MCS) [22]. Questionnaires were distributed prior to randomization at baseline, after 6 weeks, and 6 months.

To assess compliance the number of exercise occasions attended was noted. To ensure the effectiveness of the intervention, a bicycle ergometer test and five tests of functional performance were used (Figure 2).
1. Åstrand’s bicycle-ergometer test [23] (Figure 2A).
2. Rising on one leg, from sitting on lowest possible height [24, 25](Figure 2B).
3. One-leg hop [24] (Figure 2C).
4. Lateral step-up [26](Figure 2D).
5. One-leg semi squatting; maximum number during 30 seconds [25] (Figure 2E).
6. Heel-raising on one leg; maximum number during 20 seconds [25](Figure 2F).

Tests of functional performance were recorded on three occasions; prior to randomization at baseline, after 6 weeks, and at 6 months.

**Statistics**
Post-hoc, a power analysis was performed to estimate the number of patients needed to show a clinically significant difference between groups. Estimating the least clinical significant difference to be 11±15 KOOS points, a total of 30 subjects in each group were needed to detect a difference with 80% power, p=0.05.

Data were analyzed using nonparametric tests. P-values of less than or equal to 0.05 were considered to be significant, and all tests were two-tailed. To compare groups, Mann-Whitney U-test was used. Friedman’s test was used for repeated measures analysis of variance. Six weeks was considered as the time-point of primary interest, and 6 months as follow-ups. Wilcoxon signed rank test was performed to study changes from baseline to six weeks and 6 months respectively. Analyses were performed using SPSS 12.0.1 for Windows [27].

The study was approved by the Research Ethics Committee at Lund University, Sweden (LU 99-98), and is in compliance with the Helsinki Declaration.
Results

Subjects
The mean age of the 61 included subjects was 56 ± 6 years, and the mean BMI was 29.5 ± 4.8 kg/m². Patient characteristics are shown in Table 1. Twenty-eight patients in each group were available for follow-up. The reasons for dropout were lack of time, reorganization at work, sudden illness, and increased knee symptoms (Figure 1). There were no clinically significant differences in baseline characteristics between the groups. Patient characteristics are shown in Table 1.

Between-group differences
No between-group differences were seen in primary outcome measures at neither 6 week nor 6 month follow ups.

Within-group differences
Primary outcome
At six weeks a significant improvement was seen in the KOOS subscale Quality of Life (mean score change 4, p=0.04). This improvement persisted at six months (p=0.05, Table 2). The individual differences ranged from clinically significant improvement of at least 10 points to clinically significant deterioration in all KOOS subscales and in both the exercise and control group (Figure 3).

Secondary outcomes
Significant improvement compared to baseline
was found in the exercise group at six weeks with regard to the SF-36 Physical Component Summary scale (PCS) (45.7 vs. 42.5, p=0.02, Table 3). This improvement persisted over time. Within the control group no significant improvement was found.

**Compliance and effectiveness of exercise program**

The total number of performed supervised exercise sessions by the 28 patients available for follow-up in the intervention group was 302/336 (89.9%). Patients participated on average in 11 out of 12 possible exercise classes (12 classes (n=11), 11 (n=9), 10 (n=6), 9 (n=1), 2 (n=1)). The most common reason for absence was illness not related to knee osteoarthritis, and work-related lack of time.

The six-week exercise program was effective in improving aerobic capacity and lower extremity endurance (Table 4). If patients were unable to perform or gave up trying any test of functional performance due to knee problems, they were given the worst score achieved among performers. Other reasons (foot-, hip-, or back-related) were treated as dropouts within protocol. The results persisted over time (Table 4).

**Discussion**

**Main message**

Six weeks of intensive exercise improved knee-related quality of life in middle-aged patients with knee osteoarthritis.
symptomatic and moderate-severe radiographic knee osteoarthritis, and the improvement persisted over 6 months. There was no change in pain or self-reported function.

Comparison with other studies

Quite opposite to previously published studies on exercise in knee osteoarthritis we found no improvement in pain or function. Possible reasons for this include our study group having moderate to severe osteoarthritis compared to mild to moderate in most previous studies, being younger than previously studied groups and the intervention being of comparably short duration and high intensity.

It has been suggested that the responsiveness to exercise is modified by the loss of joint space width [28]. The homogeneity of this study population, with regard to radiographic changes, provided us the possibility to study the effects of exercise on patients with moderate to severe radiographic knee osteoarthritis. Can significant improvements of pain or self-reported function be expected in patients with radiographic knee osteoarthritis corresponding to Kellgren and Lawrence grade 3 or more? The present study suggests that some individuals with severe knee osteoarthritis benefit from exercise (Figure 3). In clinical practice, patients with severe knee osteoarthritis should have treat-
ments based on individual preferences and different stages of motivation [29].

Severe knee osteoarthritis is associated with a hip-knee-ankle malalignment and an increase in varus-valgus laxity compared to healthy knees [30]. It is suggested that the different degrees of varus-valgus laxity should be taken into account in exercise interventions, to enhance the functional outcome [31, 32]. Malalignment may cause increased joint loads, and greater quadriceps strength might further increase joint load by the muscles compressing the articular surfaces [33]. An increase in pain from too intensive exercises may restrain patients from further joint loading, which otherwise could cause further cartilage damage [34]. It is thus possible that varus-valgus laxity mediated the effect of exercise on pain since all patients had radiographic changes corresponding to Kellgren and Lawrence grade III or more.

Our study population was younger (<65 years) and comprised more men (49%) than most other populations with knee osteoarthritis described in randomized controlled trials of exercise [11-14, 35]. Younger patients are usually more physically active than elderly [36], which might affect the demands of and satisfaction with physical function and physical performance at work or leisure time.

Six weeks is a short time for an exercise intervention to achieve long-lasting changes. However, the improvements seen in functional performance at six weeks were maintained at six months (Table 4). Even though the intensity of each exercise was individually adopted, all individuals exercised at a minimum of 60% of HRmax, and it can be argued that the intensity was too high for this group with moderate to severe knee osteoarthritis.

This study showed no significant differences on pain and self-reported function neither between nor within groups. A post-hoc analysis was performed to study the possibility that the benefit from exercise was larger in subjects with worse pain at baseline. Fifteen patients in the exercise group were

### Table 4. Change in physical function from baseline to 6 weeks and 6 months

<table>
<thead>
<tr>
<th>Test of physical function</th>
<th>Exercise group</th>
<th>Control group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>mean ± SD</td>
</tr>
<tr>
<td>One-leg jump, cm baseline</td>
<td>29</td>
<td>54 ± 31</td>
</tr>
<tr>
<td>6 w</td>
<td>27</td>
<td>56 ± 37</td>
</tr>
<tr>
<td>6 m</td>
<td>28</td>
<td>57 ± 34</td>
</tr>
<tr>
<td>Knee bendings/30 sec baseline</td>
<td>29</td>
<td>22 ± 7</td>
</tr>
<tr>
<td>6 w</td>
<td>27</td>
<td>25 ± 8</td>
</tr>
<tr>
<td>6 m</td>
<td>28</td>
<td>27 ± 8</td>
</tr>
<tr>
<td>Toe raises/20 sec baseline</td>
<td>29</td>
<td>17 ± 5</td>
</tr>
<tr>
<td>6 w</td>
<td>27</td>
<td>18 ± 4</td>
</tr>
<tr>
<td>6 m</td>
<td>27</td>
<td>18 ± 6</td>
</tr>
<tr>
<td>Lateral step-ups/30 sec baseline</td>
<td>29</td>
<td>14 ± 5</td>
</tr>
<tr>
<td>6 w</td>
<td>27</td>
<td>16 ± 5</td>
</tr>
<tr>
<td>6 m</td>
<td>28</td>
<td>16 ± 4</td>
</tr>
<tr>
<td>One-leg rise, cm baseline</td>
<td>30</td>
<td>44 ± 8</td>
</tr>
<tr>
<td>6 w</td>
<td>27</td>
<td>42 ± 7</td>
</tr>
<tr>
<td>6 m</td>
<td>28</td>
<td>43 ± 8</td>
</tr>
<tr>
<td>Aerobic capacity mL O2/kg x min</td>
<td>27</td>
<td>25.9 ± 6.4</td>
</tr>
<tr>
<td>baseline</td>
<td>26</td>
<td>27.9 ± 4.7</td>
</tr>
<tr>
<td>6 w</td>
<td>27</td>
<td>27.9 ± 5.7</td>
</tr>
<tr>
<td>6 m</td>
<td>27</td>
<td>27.9 ± 5.7</td>
</tr>
</tbody>
</table>

*a* Mean of left and right leg  
*b* Change from baseline, Wilcoxon signed rank test  
*n.s* = Friedman’s test not significant
compared to 13 from the control group who had worse than total group median pain score (KOOS Pain 58 on a 0–100, worst to best scale) at baseline. The groups had comparable patient characteristics. The changes seen in these subgroups were however not different from the changes seen in the total groups.

A possible limitation could be lack of power. A post-hoc analysis was performed to estimate the number of patients needed to show a clinically significant difference of 11±15 KOOS-points [19]. The standard deviation of 15 is supported by results from randomized controlled trials of glucosamine supplementation [37] and a nutritional supplement [38] for knee osteoarthritis, where significant group differences were found in KOOS pain and ADL subscales. The number of subjects in each treatment arm in these RCT:s ranged from 15 to 27. The standard deviations in KOOS subscales have not previously been determined in exercise interventions.

Only one of the five KOOS subscales showed a significant improvement, and it can not be excluded that this result could be due to chance. However, the improvement of the KOOS subscale Quality Of Life in the exercise group persisted over time, and is in accordance with previous findings of impact from exercise on mental health aspects in patients with knee osteoarthritis [28, 39, 40]. Group dynamics, support, or attention received may possibly have influenced the quality of life more than the exercise itself in the present study. Psychosocial factors are important determinants of physical function [41], and our results suggest that supervised exercises and follow-up are important, and that quality of life should be evaluated in osteoarthritis interventions.

The long recruitment period, from 1998 to 2001, could have biased the results. During this time the awareness of both the importance of physical activity in maintaining health, and the importance of exercise as treatment of knee osteoarthritis increased in the general population through the coverage in the media [5, 42, 43]. It is also possible that taking part as control in an exercise intervention study inspire patients to an increase in physical activity level, as shown in a randomized controlled trial of primary-care-based physical activity advice [44]. Possible indication of bias were the significant increase in aerobic capacity in the control group noted at six months and the fact that 14/30 patients from the control group either joined exercise classes or received exercise information and a home after the six-month follw up. However, the change seen in aerobic capacity at six weeks was not time dependent, indicating that the influence of increasing knowledge of benefits of exercise over time was negligible. A limitation is that no exercise or physical activity diary was kept by the controls.

Conclusion

A six-week high-intensive exercise program had some effect on quality of life but no effect on pain and function in middle-aged with moderate to severe radiographic knee osteoarthritis. It was however possible for some individuals, despite moderate to severe radiographic knee osteoarthritis, to benefit from the exercise intervention.

Competing interests

The authors declare that there are no competing interests involved in any part of this study.

Authors’ contributions

CT participated in design, exercise intervention, assessments and follow-ups, statistical analyses and writing. ER participated in design, analysis and interpretation of the data, and critically revised the article. IP participated in design and interpretation of the data and critically revised the article. CE initiated and obtained necessary permissions for the study, arranged the initial funding, and participated in the analyses, interpretation and revision of the manuscript. All authors read and approved the final manuscript.

Acknowledgments

Grants were received from The Vårdal Foundation, Sweden, The Swedish Rheumatism Association in Stockholm, The Swedish Rheumatism Association in Gothenburg, The Swedish Research Council, The Department of Research and Development at Spenshult Hospital for Rheumatic Diseases, Halmstad, Sweden.
References


High-intensity exercises for patients with knee osteoarthritis

The program consisted of weight-bearing exercises for the lower extremities. They were performed in five stations at submaximal intensity.

Exercises aimed at increasing endurance and strength in proximal muscles and lower extremities.

**Intensity:** at least 60% of HRmax

**Timewaste:** 45 minutes + stretching.

Exercises were supervised and performed twice a week for six weeks. Furthermore patients were recommended to exercise at least 30 minutes a day in some kind of weight-bearing, submaximal activity, such as walking.

Pain during exercise was not considered an obstacle as long as it was below 5 on a Visual Analog Scale (VAS), or considered “acceptable” by the patient, and had disappeared within 24 hours after exercise. If pain was experienced as more than 5 on VAS, exercise intensity was reduced occasionally, until pain was experienced as “acceptable”.

The load of each exercise was chosen by the patient, but they were encouraged to exercise at the most vigorous intensity possible without losing quality in performance or severely exacerbating pain.

1. **Ergometer cycling – 10 minutes**

   **Intensity:** 50–60 revs per minute.
   **Load:** self-chosen.

2. **Trampoline – 5 minutes**

   One of the following exercises, or a combination was chosen:
   - tramping/walking,
   - walk with high knee lifting,
   - jogging,
   - jumping – feet together or jogging with high knee lifting.

3. **Step-board – 5 minutes**

   One of the following alternatives was chosen and repeated 15 times per leg:
   - step up and down,
   - standing with one foot on the board. The other foot touched the floor with heel in front of the board and with toe behind the board alternately.

   The height of the step-board was used to increase intensity.

4. **Floor exercises – 15 min**

   Each stage (A–D) was performed 15 times per leg at a time.

   **A) Hip lifting**

   Lying supine, one leg placed on a *square pillow*. The other leg flexed, with knee held against belly. Pelvis was lifted and lowered with maintained muscle control. One of the following positions was chosen:
   - calf-muscle rested on pillow,
   - foot placed on the center of pillow,
   - foot placed on the edge of pillow.

   **B) Sit-ups**

   Lying supine, knees flexed and feet on the floor. The most demanding exercise that could be performed with full muscle control was chosen:
   - raising the shoulders, with hands reaching the knees/thighs,
   - raising the shoulders, with arms kept on the chest,
   - raising the shoulders, with hands held at the ears and elbows pointing laterally,
   - raising the shoulders, with arms held over the head along the bodyline.

   **C) Hip abduction**

   Lying on side.
   One of the following exercises was chosen:
– single straight leg rise (hip abduction); hip extended and internal rotated,
– standing on elbow and knee; pelvis and upper leg were raised at the same time,
– standing on hand and foot; pelvis and upper leg were raised at the same time.

**D) One-leg rise from sitting**

Sitting on a bench with adjustable height.

The lowest possible height from which both rising and descending could be performed with full muscle control was chosen. Weight was to be kept on foot during the entire movement. If one-leg rise was impossible, using both legs was allowed.

**5. Pulley – 10 minutes**

Straight leg flexions, abductions, extensions and adductions of the hip, and lunging forward.

All five moments performed with 15 repetitions before changing leg.

Standing knee should be flexed about 10 degrees.

Loading was self-chosen. Maintaining performance quality throughout all stages was essential.

**6. Strech – 10–15 minutes**

– Mm triceps surae
– Mm quadriceps
– Mm hamstrings
– Mm iliopsoas
– ….

Patients were given a rubber-band to perform pulley exercises at home. Furthermore three of the most demanding exercises were chosen as daily individual home exercises. Patients were recommended to exercise at least 30 minutes, or two times 15 minutes, per day with these exercises and/or walking.
How do middle-aged patients conceive exercise as a form of treatment for knee osteoarthritis?

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Running head: Conceptions of exercise as OA-treatment

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Accepted for publication 2005-03-09 in Disability and Rehabilitation

ABSTRACT

Purpose To describe conceptions, as registered by a semi-structured interview, of exercise as treatment among sixteen middle-aged patients with moderate to severe knee osteoarthritis.

Method Sixteen patients (aged 39–64) with symptomatic, radiographic knee osteoarthritis and previous participants in an exercise intervention, were interviewed. The qualitative data obtained were analysed using phenomenographic approach.

Results Four descriptive categories containing 13 conceptions emerged: Category 1) To gain health included five conceptions; to experience coherence, to experience well-being, to be in control, to experience improved physical functioning, to experience symptom relief; 2) To become motivated included three conceptions; to experience inspiration, to be prepared to persevere, to experience the need to exercise; 3) To experience the need for support included three conceptions; to have structure, to receive guidance, to devote time; 4) To experience resistance included two conceptions; to hesitate, to deprecate.

Conclusion Patients with knee osteoarthritis and knee pain, previously participating in exercise intervention, are aware of the health benefits of exercise, but have many doubts and concerns about exercise as treatment. These aspects should be considered when designing patient information and treatment programmes. Furthermore, a hesitant and resistive perception of exercise as a concept could have major influences on the implementation of health programmes.

Keywords: Knee osteoarthritis, exercise, patient perspective, perception, qualitative research.

INTRODUCTION

Knee osteoarthritis is common and causes pain and disability among elderly and middle-aged people. Guidelines concerning the optimal management of knee osteoarthritis include both pharmacological and non-pharmacological treatments; exercise, weight reduction and information [1]. Exercise is effective in increasing function and decreasing pain in knee osteoarthritis [2-4], and the positive effects of exercise on knee osteoarthritis is described on group level in a number of studies, comprising mostly elderly patients [3-7]. There is however uncertainty about which type and dose is preferable [2, 8]. Exercise is also important for improvement and preservation of function in patients with other chronic diseases such as rheumatoid arthritis and inflammatory myositis [1, 9-11]. Exercise can be defined as a part of physical activity: “Physical activity is defined as any bodily movement produced by skeletal muscles that result in energy expenditure. Exercise is a subset of physical activ-
EXERCISE AND FUNCTIONAL PERFORMANCE IN KNEE OSTEOARTHRITIS

ity that is planned, structured, and repetitive and has as a final or an intermediate objective the improvement or maintenance of physical fitness” [12]. The effect size from exercise on pain and function in knee osteoarthritis is moderate [2], however based on individual responses, the effect is diverging, from worsening or indifferent to improvement [13, 14]. It is likely that both adherence to and the results of exercise programmes are influenced by patients’ engagement and conceptions. This qualitative study was designed to better understand the underlying processes, leading to response or non response to exercise as a treatment especially in middle aged individuals. Furthermore, there is a need to better understand why motivation to exercise is low and exercise as self-management is under-used [15-17]. The aim of the present study was to describe how middle-aged patients conceive exercise as a treatment for knee osteoarthritis.

MATERIALS AND METHODS

Phenomenography

The study design is descriptive, and qualitative, with a phenomenographic approach. Phenomenography was developed in educational research and first described by Marton [18]. This research approach is usually based on interviews or observations, and aims at identifying and describing different ways of experiencing phenomena in the world that surrounds us. In phenomenography, it is not the reality or how something really is that is interesting, but how different people experience a phenomenon [18]. Life-style, knowledge, and previous experiences are factors that influence and are reflected in peoples’ experiences of a certain phenomenon, and, thus, result in different acting and beliefs.

Informants and ethical issues

The informants were strategically chosen from a group of 31 middle aged patients, who had taken part in an exercise intervention, so as to obtain a variation in variables that might influence their conceptions of exercise as a form of treatment. In this study the variables previously decided upon were sex, age, body mass index, level of education, disease duration, occupational joint load, previous exercise habits, and perceived change in pain from exercise (Table 1). Having given informed consent, 16 patients, aged 39–64, with symptomatic and radiographic knee osteoarthritis (Kellgren and Lawrence grade 3 or more, i.e. definitive osteophytes and joint space narrowing), were interviewed. The interviewer was familiar with the research method and interview technique.

Ethical approval was obtained from the Ethics Committee, Medical Faculty, Lund University (LU 176-02).

Table 1. Sociodemographic and clinical characteristics of the patients (N=16)

<table>
<thead>
<tr>
<th>Informant</th>
<th>Sex</th>
<th>Age</th>
<th>BMI (kg/m²)</th>
<th>Education</th>
<th>Disease duration (years)</th>
<th>Joint load in occupation</th>
<th>Previously experienced from exercise</th>
<th>Perceived change in knee pain from exercise</th>
</tr>
</thead>
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<tr>
<td>1</td>
<td>Female</td>
<td>63</td>
<td>33.7</td>
<td>Compulsory</td>
<td>21</td>
<td>Retired</td>
<td>Experienced</td>
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<tr>
<td>2</td>
<td>Male</td>
<td>64</td>
<td>24.6</td>
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<td>Experienced</td>
<td>Better</td>
</tr>
<tr>
<td>3</td>
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<td>59</td>
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<td>Better</td>
</tr>
<tr>
<td>4</td>
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<td>48</td>
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<td>University</td>
<td>30</td>
<td>Low</td>
<td>Experienced</td>
<td>Better</td>
</tr>
<tr>
<td>5</td>
<td>Female</td>
<td>39</td>
<td>36.7</td>
<td>Upper secondary</td>
<td>5</td>
<td>High</td>
<td>Experienced</td>
<td>Better</td>
</tr>
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<td>6</td>
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Data collection

All interviews were conducted by the main researcher (CT), at a place that was chosen by the informants, either in their homes (n=9), at their workplace (n=1), at the interviewers home (n=2) or at Spenshult hospital (n=4). Each interview lasted between 20 and 90 minutes and was audio-taped. Notes were taken during the interview, as a memory support. An interview guide consisting of six questions, constructed by the main researcher (CT) and co researcher (BA) together, was used:

• What does exercise mean to you?
• What does osteoarthritis of the knee mean to you?
• How does exercise affect you?
• How does exercise affect osteoarthritis of the knee?
• How do you conceive the importance of exercise as a form of treatment?
• How has your conception of exercise changed over time?

The interviews were performed in a conversational style. The sequence of the interview questions differed due to the fact that the answers could inspire new questions. It was important that the questions were open-ended in order to give as deep and comprehensive understanding as possible of the informants’ conceptions. Two test interviews were conducted in order to evaluate the interview plan. No revision was made, and the two test interviews were included in the analysis.

Data analysis

All 16 interviews were included in the analysis. The transcribed data were analysed in four steps with focus on the content of the separate statements in order to identify and describe different conceptions of exercise as a form of treatment for knee osteoarthritis [19].

1. The transcribed interviews were carefully read while listening to the tape recording, in order to correct errors in the transcript and to become familiar with the material.
2. The next step was to identify the statements, which corresponded to the aim of the study. Eight hundred and forty-nine statements were identified on the subject of exercise.
3. Thereafter the statements were assigned to content-related categories; conceptions. In this phase the number of conceptions was large.
4. In the fourth step, similarities and differences between conceptions were observed, and conceptions that had the same theme were grouped together and further assigned to a more general category; a descriptive category. A revision of the conceptions decided upon at a previous step was necessary on a few occasions in order to continue. The fourth step continued until descriptive categories emerged, which were different in content and meaning, and corresponded to the context.

The final descriptive categories consisted of 2-5 conceptions, which were illustrated with carefully selected quotations from the interview statements. Saturation, i.e. when all conceptions were represented by quotations and no further category emerged, was achieved after 6 interviews. During the process an experienced researcher (BA), who possessed extensive knowledge of the research method, served as a co-assessor in all steps in order to assure reliability of the results.

RESULTS

Four descriptive categories emerged: To gain health, to become motivated, to experience the need for support, and to experience resistance. These four descriptive categories together included 13 conceptions (Table 2).

Conceptions were labelled as positive, but could hold a range of statements from positive to negative.

TO GAIN HEALTH

This category contained conceptions about experienced or known health related effects of exercise and consisted of five conceptions: to experience coherence, to experience well-being, to be in control, to experience improved physical functioning, and to experience symptom relief.

Figures in brackets show in which interviews the conceptions were described, and the number of statements within each category (n).

To experience coherence

( Interviews 1–9, 13–16; n=78)

This conception contained statements about con-
EXERCISE AND FUNCTIONAL PERFORMANCE IN KNEE OSTEOARTHRITIS

Connecting knowledge about osteoarthritis with knowledge and experiences of exercise. The informants expressed satisfaction and were convinced of the effectiveness of exercise.

“It can’t have improved just like that. It [exercise] must have helped. So that’s why I’ve found it beneficial in all sorts of ways, and it has changed my attitude to this kind of exercise. It must have done it.” (Informant 1)

…”I now know that it is beneficial. I know that simply going for a walk every day is very good for me. In that way I have changed. Previously I was not even aware that it was necessary.” (Informant 16)

**To experience well-being**
(Interviews 1–10, 13–16; n=70)
In this conception the informants described experiences of mental and physical relaxation, satisfaction and well being connected to the moments immediately following the exercise sessions.

…”it has a beneficial effect on the whole body. It gives you a sense of well-being, not just because you have done it and feel good about it, but your muscles feel as if they have benefited too.” (Informant 13)

…”yes, I definitely feel better, apart from my knees that is, …I’m more alert. …Perhaps not immediately afterwards but I feel more alert after a shower. (Laughter).” (Informant 5)

**To be in control**
(Interviews 1, 3, 4, 6–10, 13–16; n=61)
This conception described the informants’ experiences of how exercise could improve their ability to handle their situation, and cope with the problems related to knee osteoarthritis.

“Well, I suppose to some extent it is up to yourself how much effort you wish to put into it, …If I don’t want to do anything then I don’t think I’ll benefit from any treatment. I suppose that, at the end of the day, the outcome of the treatment depends on no one but myself.” (Informant 9)

“I try to walk more and more, to walk in the correct way and to climb stairs in the correct way and not to wear myself out.” (Informant 4)

**To experience improved physical functioning**
(Interviews 1–3, 5–9, 13, 15; n=56)
This conception described thoughts about regaining functional performance or performing daily recreational activities more easily after the exercise intervention.

“Yes, what I can see is that the muscles around the knee have become stronger, which makes the knee more stable.” (Informant 8)
“… for example, walking longer distances, there are limits, but nevertheless longer walks without experiencing pain. It is a huge difference. So it was very positive. …it makes it possible to work more and you can do more enjoyable things too. …Go fishing and hunting, walking the dog. All those things, like simply going for a walk.” (Informant 7)

To experience symptom relief
(Interviews 1–3, 6–9, 11–13; n=38)
This conception contained experiences of the effects of exercise on pain and other symptoms. Statements ranged from total pain relief to a worsening of symptoms.

“… when I have been walking for a while, the pain goes away, which makes me happy.” (Informant 6)
“… exercise hurts. The pain was almost unbearable but I still carried on. Yes, it was very strenuous, but that’s how it is, the pain becomes increasingly worse, I think…it just becomes more and more painful.” (Informant 15)

TO BECOME MOTIVATED
This category contained three conceptions dealing with the informants’ desire to exercise: To experience inspiration, to be prepared to persevere, and to experience the need to exercise. Despite pain, the informants talked about exercise with varying degrees of enthusiasm and a sense of duty.

To experience inspiration
(Interviews 1–16; n=119)
This conception was about the wish to be active. The statements ranged from a desire to exercise regularly to having no motivation to exercise at all.

“Well, with respect to time, I try to be out for at least half an hour and then I try to go for a longer walk at the weekend, perhaps for up to an hour.” (Informant 4)
“… you need to have the will to do it. …when you are well you don’t do it, and when you need to do it, then it hurts and therefore you don’t do it (laughter).” (Informant 2)

To be prepared to persevere
(Interviews 1–6, 8–14, 16; n=80)
This conception described the experience of exercising despite pain and discomfort, because of the known benefits.

“… being able to go out into the garden, to work in the garden even if it is a strain and I feel that my knee hurts a little and then I have to sit down and I wobble a bit. I played 18 holes of golf and that is also quality of life. I refuse to sit at home and navel gaze, I just won’t.” (Informant 11)
“… if it hurts a bit, one should not give in but of course sometimes you can feel sore or aching joints afterwards, if it hurts when doing certain movements... of course it hurts, even when exercising.” (Informant 1)

To experience the need to exercise
(Interviews 1, 2, 4–7, 9, 10, 12–15; n=31)
In this conception, the informants described their need to exercise. The statements ranged from conceptions about the importance of exercise in order to maintain physical functioning, to the fact that daily living demands movement.

“Well, it is different now because, as I’ve already said, previously you exercised to maintain your level of fitness whereas now you exercise in order to regain your physical condition.” (Informant 13)
“I really don’t think that I need to take some exercise but I just tell myself that I am going shopping and things like that.” (Informant 12)

TO EXPERIENCE THE NEED FOR SUPPORT
This category described conceptions of conditions necessary for wanting to exercise. Three conceptions emerged: To have structure, to receive guidance, and to devote time.

To have structure
(Interviews 1–10, 12–16; n=80)
This conception contained statements about accessibility as a prerequisite for exercise, and the
importance of quality of exercise, concerning both purpose with and type of exercise.

“It has to be close at hand, one should not have to travel long distances. It would never work for me, if I had to travel to a rehabilitation centre every day. I don’t think so.” (Informant 13)

“But it [the exercise] should be done in an appropriate manner.” (Informant 2)

To receive guidance
(Interviews 1–16; n=75)
This conception concerned the perceived need for moral support, encouragement and instructions on how to exercise. The statements were about compliance and the anxiety of doing something wrong.

“It is something you notice when you give it up, since it [the exercise] was very difficult to do on your own... As there was nobody to supervise me it was easy to deteriorate again... Then there was nobody to urge you on.” (Informant 5)

“I think that [an instructor] is good because then you learn what to do so that you do not do it in the wrong way. Otherwise you might do certain movements incorrectly and put too much pressure on your knees.” (Informant 10)

To devote time
(Interviews 1–10, 12–15; n=71)
This conception included different aspects of time as essential for the effectiveness of the exercise. The statements concerned time as the most appropriate time point during disease course when first starting to exercise, and having adequate time to exercise.

“... exercise can help, I am convinced about that, although it did not work for me... the damage was too great when I started. It had gone too far. If one had started to exercise five or six years earlier, it might have helped.” (Informant 15)

“one is so occupied that it is very easy not to find time for exercise. Everything else takes precedence.” (Informant 14)

TO EXPERIENCE RESISTANCE
This category described the reasons for not exercising and comprised two conceptions: To hesitate and to deprecate

To hesitate
(Interviews 1–6, 8–16; n=57)
This conception contained doubts about the benefits of exercise. Experiencing pain while exercising made it difficult to decide whether it was beneficial or counterproductive.

“I do not know if exercise makes it better or worse. I have never been really sure. I do not know if exercise makes my condition worse, I just do not know.” (Informant 12)

“Well, I am worried, I sometimes think that if it hurts when I do something it will cause even more damage.” (Informant 14)

To deprecate
(Interviews 2, 3, 5, 7, 9, 11, 12, 14–16; n=33)
This conception described the belief that exercise could cause harm or be unnecessary in that the informants considered other treatments to be more effective.

“In my case ... the damage became worse, it only led to more pain instead of improvement.” (Informant 15)

“it [the exercise] was beneficial and it helped in the short term. However, had I not received injections I would never have been able to work for so long. It is thanks to them that I have been able to work for the past five or six years or since I got osteoarthritis. That is a fact.” (Informant 3)

DISCUSSION
Results discussion
Four descriptive categories emerged; to gain health, to become motivated, to experience the need for support, and to experience resistance.

To gain health
Exercise is obviously not the best treatment for everyone with osteoarthritis. All informants in
this study were well aware of the positive effects of exercise on health. The thoughts about benefits from exercise on knee osteoarthritis were, however, divergent. Some informants reported increased pain from exercise. This, of course, affects people’s motivation to exercise as well as their conception of exercise as a form of treatment. A perceived positive outcome of the exercise intervention is often a prerequisite for continued participation in exercise programmes [20]. Pain in osteoarthritis is more influenced by psychological factors than structural changes, which partly may explain the perceived increase in pain [21]. Lack of knowledge about the cause of osteoarthritis can contribute to a view of the disease as a non-reversible condition, in which exercise makes no difference [20]. Detailed information about the possible causes and treatments of osteoarthritis is essential, in order to avoid doubt and anxiety, which may lead to a passive lifestyle and increase the risk of inactivity-related diseases such as cardiovascular disease and diabetes. This highlights the importance of exercise as a treatment option in subjects with osteoarthritis [1, 22].

To become motivated
In this study some patients felt no need to exercise, others were planning to start but experienced several obstacles and some were exercising at present. These different stages of motivation can be described as in the trans-theoretical model of stages of change and correspond to findings from stages of change profiles among patients with arthritis [16, 23]. Most patients with arthritis are not sufficiently physically active, and many of them are not motivated to change their activity level [16, 17]. A study involving elderly people with chronic pain showed that the preferred strategies for coping with pain were informal cognitive coping strategies, massage, topical agents and home remedies. The least preferred strategies were prescribed treatments such as medications, physiotherapy and exercise [15]. It has been demonstrated that people who previously exercised regularly, who had positive experiences of exercise both recently and in early life, and people with positive beliefs about exercise are more motivated and adhere to exercise interventions to a greater extent [24-26]. In a study of healthy women, the most common obstacles for exercise were lack of time and lack of motivation, while the most common motives for exercise were improving physical appearance, to be fit and to experience a sense of well-being [27]. Patients with rheumatoid arthritis, to whom exercise is often recommended as a mean of increasing function and reducing pain, perceived exercise time-consuming, painful and boring to a great extent, and 37 % had...
a negative attitude towards exercise [24]. The basic motivation to exercise in this study population is probably determined mainly by such personal factors and not by knee osteoarthritis. This brings out the need for different approaches from health care providers towards subgroups of patients with various degrees of motivation and willingness to change the physical activity level.

To experience the need for support
All patients expressed a desire for advice and guidance, but in different ways, to exercise. This corresponds to results from previous studies, reporting a low level of participation in exercise at long-term follow-up [4, 20, 28]. Initial compliance with exercise intervention may, however, be high, partly because the patient would like to please the physiotherapist [20]. As exercise need to be performed continuously to be efficient [29], home-exercises are often prescribed. Previous studies have shown that supervised and scheduled exercises has a greater impact on symptoms and function compared to home exercises, which partly can be explained by patients’ conceived need for support [4, 30]. Health care providers need to support the patient in exercise performance, but also in the shift from reliance on others towards a more self-management approach, where social support from family and friends can be of importance [24].

To experience resistance
This study shows that middle-aged patients with knee osteoarthritis have many doubts and concerns about exercise as a form of treatment, even though they do believe that exercise is good for one’s health. All informants in this study experienced depreciation and/or hesitation about the benefits versus harm from exercise on knee osteoarthritis. Negative or hesitative conceptions are perhaps more common than we assume. Experience of pain is affected by often unconscious co-actions of cognition, feelings, behaviour and physical components [31]. If exercise is perceived as something destructive for the outcome of knee osteoarthritis, the consequence is likely to be inactivity. This demands us to listen to patients’ beliefs and be more careful about information about osteoarthritis and individual recommendations concerning exercise. Active listening and developing pain coping strategies are recommended strategies in sport medicine team care, and might be useful even in the management of patients with osteoarthritis [32].

Method discussion
Qualitative studies can contribute to a deeper understanding of quantitative research results. Based on the participants’ conceptions individual differences can be illuminated and provide a deeper perspective on the results [33]. The current study was undertaken to elucidate the often wide variation in individual outcomes after an exercise intervention.

Conclusions are based on 16 interviews, which could be considered as a small number of patients. A sufficient number of informants are necessary to cover every different conception in the population studied. On the other hand, too much information would be very time consuming, as the interviews are transcribed and read thoroughly several times in the analysis process. Too extensive material increases the risk of losing focus and accuracy in the analysis [34]. In this material saturation was achieved after 6 interviews, which indicates that the number of patients was sufficient for this purpose.

It can be argued that the researcher (CT) could have influenced both the informants’ statements and the interpretation of the answers. The researcher has to be aware of and leave his/her preconceptions out of account during the interview. However, a broad range of preconceptions from the area of interest can help understanding the meaning of the statements during analysis. This research method aims to capture the informants’ fundamental opinions that have not really been reflected upon prior to the interview. It is likely that these opinions are not easily influenced by a desire to please the investigator. The informants’ confidence in the interviewer could have influenced the interview in two directions, either the informants felt more comfortable and could be honest in their statements or they did not dare to speak their mind. It is reasonable to assume that negative opinions would not be revealed and that the patient’s desire to please leads to false positive results in research. However, all informants in the present study expressed depreciation and/or hesitation.

A recent study has shown that there is a lack of agreement between pain assessed by question-
naires and by interviews [35]. In this study, however, the range of statements obtained by means of interviews concerning symptom relief clearly correlated with the divergent outcome in perceived pain seen after exercise interventions [13, 14]. Since all interviews took place after an exercise intervention, all informants talked about their experience of exercise as a form of treatment. Their original conceptions of exercise are not known. It can be assumed that those who benefited from the intervention, irrespective of the reason for the improvement, were more positive and vice versa.

The topic of the present study, exercise and osteoarthritis, is multidimensional and, thus, other researchers might obtain different results, due to differing preconceptions and previous experience. This does not mean that the results lack reliability, but that there are several ways of viewing this phenomenon. Each researcher can contribute to a deeper understanding of the phenomenon [36].

**Perspective**

From the results of this study, we conclude that middle-aged people with knee osteoarthritis are aware of the health benefits from exercise, but experience various degrees of benefit from exercise, as well as motivation to exercise. They also experience doubts and resistance to the idea of exercise as a form of treatment, even when they have benefited from an exercise programme. Patients with knee osteoarthritis believe that supervision and continuous encouragement is a prerequisite for exercise.

Caregivers have to take the different conceptions and degrees of motivation among patients into account when planning patient information and in clinical practice. Different subgroups of patients should be treated with different approaches. Thorough information about the possible causes and consequences of osteoarthritis and discussion about the effects and benefits from exercise on knee osteoarthritis is essential in increasing compliance and results from exercise interventions.

Furthermore, a hesitative and resistive attitude against exercise as a concept could have major influences on the implementation of major health programmes for the western populations in other conditions than osteoarthritis, such as cardiovascular diseases and diabetes.

**ACKNOWLEDGEMENTS**

Grants were received from The Swedish Rheumatism Association in Stockholm, The Swedish Rheumatism Association in Gothenburg, The Department of Research and Development at Spenshult Hospital for Rheumatic Diseases, Halmstad, Sweden.

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