Summary/ Samenvatting
Chapter 1: Introduction

Many people over the age of 40 years suffer from knee osteoarthritis. Knee osteoarthritis is a degenerative disorder of the articular cartilage in the knee, evident as joint space narrowing on X-rays, leading to pain and functional limitations. In severe cases, patients may be recommended to undergo knee arthroplasty, which is becoming more and more popular. After the operation, pain usually decreases, but may remain present. Functional recovery often occurs later than the patients expect, may remain limited, and after a while, there is a risk of functional decline. The present thesis focuses on functional problems in knee osteoarthritis before and after knee arthroplasty. The emphasis is on walking, which is a fundamental activity of daily life, known to be affected by knee osteoarthritis. We performed five studies reported in the five chapters that form the core of this thesis. In the General Discussion, the studies are summarized and further questions are proposed.

Chapter 2: Walking speed in knee osteoarthritis

Knee osteoarthritis patients tend to walk slower than healthy controls. The question of this chapter was if the literature would reveal this effect to be systematic, and significant, and which factors could be found that co-determine walking speed in knee osteoarthritis. We performed a meta-analysis of 26 published comparisons of the walking speed of patients and of controls. On average, patients walked about 0.5 km/h slower than controls, which was significant, but different studies gave very different results. There are many factors that could potentially affect walking speed, but in our study, meta-regression analysis only revealed older age, more severe knee osteoarthritis, and co-morbidity to be factors that slowed down walking in the studies analysed. Of the variance of effect-sizes, 52% remained unexplained.

Chapter 3: Walking speed effects of knee arthroplasty

Our next question was if walking speed improved systematically, and significantly, after knee arthroplasty, and which factors could be found that co-determine (the pattern of) walking speed recovery after knee arthroplasty. We
performed a meta-analysis of 16 studies of walking speed before and after arthroplasty. Until six months after the operation, very different changes in walking speed were reported, and no valid conclusion about the walking speed effects of knee arthroplasty could be reached. From six to 12 months post-operatively, patients’ comfortable walking speed was about 0.8 km/h faster than pre-operatively, which was significant, and probably enough for a return to the walking speed of healthy peers. From 13 to 60 months after the operation, some signs of post-operative decline could be seen. In meta-regression analysis, the only factor that could be identified as co-determining walking speed was time, both linear and squared. There was insufficient systematic information to decide which factors help to speed-up recovery, or which factors lead to recovery that lasts.

Chapter 4: Long term reliability / stability in monitoring patients after knee arthroplasty
Health professionals who monitor functional recovery after knee arthroplasty should be able to discriminate between systematic changes over time, the normal ups and downs of human health, and sudden deterioration in variables that normally are stable, which would require further attention. Our main question was if we could identify variables with sufficient long-term reliability / stability to pinpoint relevant sudden changes. We followed initially 16 and finally 10 patients before knee arthroplasty, and 6 weeks, 6 months, 1 year, and 2.5 years post-operatively, using four different performance tests and three questionnaires, while pain was also measured. Linear mixed models were used to assess systematic changes over time, and to estimate long-term reliability / stability. After 6 weeks, some deterioration could be observed in performance tests, while the questionnaires already revealed improvement. All scores improved from 6 weeks post-operatively onwards, with a peak at 1 year post-operatively. Comfortable walking speed was perturbed after the operation, but then returned to its original pattern of inter-individual differences, with high long-term reliability / stability. Pain settled on a new, stable pattern post-
operatively. WOMAC Function had moderate long-term reliability between subsequent measurement points, which declined over longer periods of relative time. Also maximum walking speed, maximum knee extension moment, and SF-36 function had moderate or high long-term reliability / stability, at least at some time points. Practical considerations led us to recommend the routine use of comfortable walking speed (with a dip in reliability at 6 weeks post-operatively), post-operative pain, WOMAC Function (relying on comparisons between subsequent measurement points only), and, if possible, the maximum knee extension moment, to monitor functional recovery after knee arthroplasty.

Chapter 5: Stability and variability of knee movements during gait in knee osteoarthritis

Knee osteoarthritis patients fall relatively often, which may be related to buckling of the knee. The question of this study was which aspects of knee kinematics during gait revealed instability or were a risk factor for falling. We studied stability and variability of sagittal plane knee movements during treadmill walking at different speeds, before and 1 year after knee replacement surgery in 16 knee osteoarthritis patients, and compared the patients to healthy peers. Patients reported how often they had fallen during the preceding period. Kinematic registration was performed opto-electronically. “Stability” was calculated as the short-term Lyapunov exponent of the angular velocity of sagittal plane knee movements, variability as the standard-deviation of these movements in the first 10% after heel contact. Patients’ maximum walking speed was reduced, possibly in order to walk more carefully. Pre-operatively, patients’ knee movements were less variable, particularly at the affected side. After the operation, variability had reduced even more. Variability was positively related to number of falls, and patients may have reduced variability to avoid falling. Pre-operatively, the sagittal plane knee movements of the patients had less local dynamic stability, especially at the unaffected side, which suggests that they relied on their unaffected leg to compensate for affected side problems. Post-operatively, stability normalized.
Chapter 6: The control of frontal plane balance during gait in knee osteoarthritis

Frontal plane trunk movements are a major risk factor for falling in the elderly. This last study attempted to identify kinematic aspects of trunk movements during gait that possibly contributed to balance problems and fall risk in knee osteoarthritis patients, and to establish which strategies patients used to control balance. We studied gait kinematics in 16 knee osteoarthritis patients, waitlisted for knee arthroplasty, compared to 12 healthy elderly, and 15 young healthy controls. As a general indicator of muscle weakness, we included the maximum knee extension moment. Patients reported the number of falls in the preceding year. Frontal plane trunk movements were more variable in the patients, and local dynamic stability was decreased, but neither factor significantly predicted the number of falls. Patients used shorter stride time and larger step width, which are known strategies to reduce balance problems. Patients had a larger safety margin of their trunk movements, which suggested that their strategies were successful, at least in part. Still, both strategies were positively correlated with the number of falls. Patients’ maximum knee extension moment was reduced, and they reached their maximum trunk excursion closer to foot placement, possibly because of hip abductor weakness. Maximum knee extension moment and the relative timing of foot placement were both predictors of falling. The timing of foot placement close to the maximum of trunk movement may be a risk factor because it reduces the patients’ ability to reverse the ongoing lateral movement of the trunk at the time of foot placement.

Chapter 7: General discussion

In the General Discussion, we elaborated on some debates that are presently of relevance to understand walking with knee osteoarthritis. First, it is important to be aware of the fact that knee osteoarthritis has both local and systemic aspects. It is difficult to disentangle the two, particularly since some factors, such as leptin, appear to be involved in local as well as systemic processes in
knee osteoarthritis. Future research into walking with knee osteoarthritis should at least include serum concentrations of inflammation mediators, and an extensive specification of co-morbidities.

Second, there is no doubt that reduced walking speed is an important symptom of knee osteoarthritis, and that increasing walking speed again is an important goal of treatment. The literature gives some indication of the lowest walking speed at which patients can still be self-sustaining, i.e., 2.2 km/h. When comfortable walking speed is really high, 4.9 km/h, this can be taken as a sign of general health. Most knee osteoarthritis patients are between these two extremes. The results of our study of the walking speed effects of knee arthroplasty may be used to inform the patients on what to expect. Our analysis of long-term reliability/stability suggested that early functional improvement also leads to higher peak levels, which emphasizes the importance of rapid recovery. Walking speed has gained importance in recent literature, because it is a predictor of general health. Our data suggest that also WOMAC Function, post-operative pain, and the knee extension moment can be used as potential warning signals for functional decline.

Third, we discussed the importance of fall risk in studying knee osteoarthritis. In our own studies, we found a patient strategy that appeared to be successful, i.e., reducing the kinematic variability of sagittal plane knee movements, and two strategies to improve frontal plane balance, i.e., decreasing stride time, and increasing step width, which may have been successful, in that patients’ trunk movements had a larger margin of safety, but still predicted falling. Perhaps, the most surprising results of stability and balance during walking with knee osteoarthritis, was the changed timing relationship between the peak of trunk movements and foot placement. The two almost coincided in the patients, which appears to be a risk factor, a clear direction for further research.

Finally, we summarized our studies, and indicated specific directions for future research.