Thesis summary

The general aim of this thesis was to investigate effects of medial hamstring lengthening in children with spastic paresis (SP) on knee joint mechanics, morphological characteristics of the semitendinosus (ST) muscle and gait and, thereby, to identify factors that may contribute to a favourable or unfavourable outcome of the surgery.

In Chapter 2, we presented a modified dynamometer approach to measure knee joint mechanics. We aimed (1) to test the standard errors of measurement (SEM) and the smallest detectable differences (SDD) of knee joint mechanics in repeated measurements, (2) to determine the correlation between knee angle measurements at 4 Nm knee flexion moment by instrumented hand-held dynamometry and popliteal angle and (3) to compare knee joint mechanics between children with SP to typically developing (TD) children. We showed with instrumented hand-held dynamometry it is possible to measure knee moment-angle curves between days with a SEM of about 5º and SDD of below 14º at knee angles corresponding to 1-4 Nm net knee flexion moments. In children with SP, the knee angle measured at a standardized knee moment (i.e. 4 Nm) did not correlate with popliteal angle. The knee moment-angle curve of children with SP was not shifted compared to the curve of TD children, while the slope of the knee-moment angle curve at 4 Nm was steeper in children with SP compared to TD children (i.e. knee angles did not differ between groups at low net knee moments). In conclusion, we have shown that the presented method to measure knee joint mechanics can be used to assess clinically relevant changes in knee moment-angle characteristics.

The aims in Chapter 3 were (1) to present a newly developed analysing protocol for measuring muscle morphology of ST muscle by freehand three-dimensional ultrasound (3D US) and (2) to compare morphological characteristics of ST determined by 3D US with those measured on dissected cadaveric muscles. Mean differences between morphological characteristics (e.g. muscle belly length, muscle fascicle length and muscle volume) measured by 3D US and after dissection were smaller than 10%. Intra-class correlation coefficients (ICCs) were higher than 0.75 for all variables except for the length of proximal fascicles (ICC=0.58). We concluded that the presented 3D US method allows for reasonably accurate measurements of key morphological characteristics of ST muscle.

In Chapter 4, we aimed to determine how knee joint mechanics and ST morphology differ between children with SP selected for medial hamstring lengthening and TD, as well as to assess how knee joint mechanics and ST morphology are related. At net knee flexion moments above 0.5 Nm, more flexed knee angles at equal knee moments were found for SP compared to TD children (Figure 6.1). The mean slope of the knee-moment angle curve was increased in children with SP, indicating an increased stiffness of the structures spanning the knee joint. This increased stiffness around the knee joint suggests an increased muscle-tendon unit (MTU) stiffness of the hamstring muscles. Muscle volume, physiological cross-sectional area (PCSA), and fascicle length of ST normalized to femur length were smaller
in SP compared to those in TD children (62%, 48%, and 18%, respectively). Tendon length normalized to femur length did not differ between groups. The shorter fascicle length shown in children with SP partly explains the knee angle reached at 4 Nm knee moment and, hence, a more flexed knee joint in children with SP. Other factors that might have contributed to limited knee extension in children with SP are altered tissue composition of fascicles due to increased collagen content, alterations in morphology of other knee flexor muscles and/or increased stiffness of other structures around the knee (i.e. articular capsule, ligaments, nerves, blood vessels and connective tissues).

In Chapter 5, the aim was to evaluate longitudinal effects of medial hamstring lengthening on knee joint characteristics (i.e. knee moment-angle characteristics, popliteal angle and minimal knee angle towards extension with the hip extended), ST muscle morphology and gait kinematics. At short-term follow-up (i.e. 11-20 weeks after surgery), the mean slope of the knee moment-angle curve was decreased, suggesting a decrease in stiffness of the structures spanning the knee joint. However, this was only temporary. At medium-term follow-up (i.e. about one year after medial hamstring lengthening), there was no difference in slope compared to the pre-surgical slope of the knee moment-angle curve. The observed recurrence of the steepness of the knee moment-angle curve between short-term and medium-term follow-up could not be explained by changes in ST morphology. At medium-term follow-up, in most subjects a shift of the knee-moment angle curve towards more knee extension was observed (Figure 6.1), as well as an increase in maximum knee extension during static knee angle measurements (i.e. popliteal angle and minimal knee angle towards extension with the hip extended) as well as during gait, but also pelvic anterior tilt increased. About a year after medial hamstring lengthening ST belly length was more than 28% decreased and tendon length more than 77% increased. These results show that in most subjects, lengthening of ST tendon contributed to an increased knee extension during gait.

Combining the results of the studies on muscle morphology and knee joint mechanics of chapter 4 and 5, shows that after medial hamstring lengthening, muscle belly length and muscle volume of children with SP differ to a larger extent from those of TD children compared to the pre-surgical situation (i.e. shorter length and smaller volume), while the knee angle corresponding to 4 Nm is shifted towards more knee extension and was more comparable to that of TD children. However, after medial hamstring lengthening at medium-term follow-up the slope of the knee-moment angle curve (i.e. the range of knee angles between 0 and 4 Nm) remained unchanged in children with SP (Figure 6.1). This implies that the more extended knee angle at 4 Nm in most subjects was reached by a shift of the whole curve. Due to this shift the 0 Nm measured for children with SP knee angle was also shifted towards a more extended angle compared to TD children and to the pre-surgical situation. This shift of knee angle at 0 Nm may negatively affect the movement towards knee flexion after surgery.
In summary, the surgery results to a change in knee angle at 4 Nm comparable to knee angles shown for TD children, while the knee angle at 0 Nm was more extended compared to TD children. As a consequence, the range of knee joint angles between 0 and 4 Nm was not increased, but knee angles at measured moment were shifted towards more knee extension. These changes resulted in more knee extension during gait in the majority of children, which is most likely a functional advantage during walking.