Summary
To ultimately reduce fall incidence in stroke survivors, we first need to know who is at increased risk for falls. Therefore, the first aim of this thesis was to study the ability of a variety of gait assessments to predict fall risk in ambulatory chronic stroke survivors. The second aim was to explore whether we can improve gait stability in fall-prone stroke survivors.

Assessing gait in daily life provides insight in the amount, frequency and quality of gait in stroke survivors. Quantification of gait activity in daily life by accelerometry may be more challenging in stroke survivors as compared to healthy older adults, due to the reduced gait speed and consequent smaller amplitudes of the acceleration time series during gait. In chapter 2, we investigated criterion validity and test-retest reliability of several basic quantitative gait characteristics like number of steps and walking distance. Thirty-three chronic stroke survivors participated during the first test for criterion validity, twenty-seven participants performed a second test to obtain test-retest reliability. The gait assessment was performed on a treadmill to determine the number of steps and distance at comfortable walking speed and at 15% below and above comfortable walking speed. Furthermore, over ground gait was detected by performing a six-minute walk test on a twenty meter pathway. The results indicated that the amount of gait can be quantified validly and reliably by using accelerometers located at the lower back.

Over the past few years, fall risk assessment based on gait characteristics has mainly focused on healthy older adults. To determine whether fall prediction models developed for older adults can also be applied to stroke survivors, chapter 3 explored whether the same gait characteristics are associated with fall risk in stroke survivors as in older adults, or whether modifications are needed in either the cut-off value and/or regression coefficients of fall risk prediction models. A total of 106 participants were recruited, including 31 non-fall-prone stroke survivors, 25 fall-prone stroke survivors, 25 fall-prone older adults and 25 non-fall-prone older adults. All participants wore the accelerometer at the lower back during seven consecutive days. From the acceleration time series, quantitative and qualitative gait characteristics were determined. We created a binary logistic regression model to assess the ability to predict falls for each gait characteristic. We included health status and the interaction between health status (stroke survivors versus older adults) and gait characteristics in the model. Four interactions of gait characteristics with health status were found, suggesting that gait characteristics are differently associated with falls in stroke survivors as compared to healthy older adults. Given the interactions found, we concluded that specific fall
prediction models are needed to predict fall risk in community dwelling chronic stroke survivors based on daily-life gait characteristics.

In chapter 4, we determined to what extent clinical physical therapy assessments, daily-life gait characteristics, steady-state gait characteristics and a combination of both types of gait characteristics are able to predict fall risk in chronic stroke survivors. In a group of forty stroke survivors, six physical and psychological assessments were administered. Subsequently, gait data were collected in daily life and in a laboratory setting. From this data, the most promising gait characteristics were determined. A fall calendar and monthly phone calls registered fall events over a six-months period. A total of 15 participants reported at least one fall. Univariate logistic regressions indicated that only one out of six clinical assessments was significantly associated with falls. Furthermore, several gait characteristics derived from both steady-state and daily-life gait revealed a significant association with falls. After data reduction through principal component analysis, the predictive ability of each method was determined by logistic regression. Results indicated that both gait assessment methods were able to predict fall risk, while clinical assessments showed a limited ability to predict fall risk. A combination of both gait assessment methods revealed no improvement in predicting fall risk. Clinicians might enhance currently used fall risk assessments in ambulatory chronic stroke survivors by applying one of either tested gait assessments.

Larger perturbations in gait arise from external sources like unexpected hard wind, slippery roads or for instance from other people walking in the same area. Whether people will actually fall due to such perturbations ultimately comes down to how adequate their response to the perturbation is. It may be that fall prone stroke survivors respond less adequately to unexpected gait perturbations, which could result in a increased risk of falls. In chapter 5, we addressed this hypothesis by assessing how stroke survivors respond to six types of gait perturbations. Thirty-eight chronic stroke survivors participated; fifteen experienced at least one fall during a six month follow up period. All participants performed multiple walking trials while medio-lateral belt translations and trips were applied at a fixed moment in the gait cycle. Base of support (BoS) gait characteristics, step time and margins of stability (MoS) were calculated during the first six steps after the gait perturbation. Results revealed that all types of gait perturbations resulted in significantly deviating BoS gait characteristics compared to steady-state gait characteristics. The deviating BoS gait characteristics resulted in similar MoS values compared to steady-state values. Gait characteristics did not differ between fall-prone and non-fall-prone stroke survivors. Thus, as MoS values did not differ and gait characteristics after perturbing gait were similar in the fall-prone and non-fall-prone groups, it seems that at least for the applied gait perturbations, fall-prone stroke survivors have a preserved ability to respond to
external gait perturbations.

Falls may also be caused by unsuccessful negotiation of expected gait perturbations like obstacles. To walk safely in more complex environments like walking inside a home, adequate obstacle crossing is needed. In chapter 6, we explored whether obstacle crossing characteristics can be used as a diagnostic and evaluation tool for gait training, by determining associations of obstacle crossing characteristics with falls and by determining test-retest reliability. Twenty-nine stroke survivors participated in the experiment; twelve stroke survivors experienced at least one fall during the six-months follow up period. Five virtual, two dimensional, obstacles of increasing width needed to be crossed. After a break, the test was repeated to obtain test-retest reliability. The test-retest reliability was poor for most of the obstacle crossing characteristics, but reliability increased with increased obstacle width. No differences in crossing characteristics between fall-prone and non-fall-prone stroke survivors were found, indicating no diagnostic value for obstacle crossing characteristics. It is worth to further explore the reliability of crossing characteristics and their association to fall risk in a set up with more challenging obstacles than used in our experiment, as more challenging obstacles perturb gait more, and subsequently may improve reliability.

Fall prevention programs generally aim to improve physical activity and thereby physical functioning. Although fall-prone stroke survivors are perhaps able to improve physical function to some extent, this might be outweighed by the increased exposure to fall hazards and this could explain the ineffectiveness of current fall prevention programs. Therefore, in chapter 7 we addressed the question, whether we can improve gait stability in fall-prone stroke survivors. We developed a perturbation based gait training intervention (PBT) using the GRAIL system. Ten fall-prone stroke survivors were recruited and followed a five-weeks training protocol with two training sessions each week. The PBT contained three parts: steady-state gait training, gait training with a great variety of unexpected gait perturbations and gait training with several expected gait perturbations like obstacle crossing tasks. Finally, the perturbations were combined with a visual Stroop task in order to make the training more challenging. Prior to, and after the PBT, gait stability was assessed using the fall prediction models developed in chapter 4. Steady-state gait characteristics were improved in nine out of ten participants and consequently predicted fall risk reduced. However, daily-life gait characteristics showed no clear improvements, and thus predicted fall risk remained similar after the PBT. Gait quantity, expressed as the number of walking bouts was increased after PBT. In conclusion, it seems that a PBT intervention improves gait stability in steady-state gait, yet it does not transfer to daily-life gait. These latter results, however, could be affected by confounding effects like changes in gait behavior, like for instance performing more small walking bouts inside home which may have
lower gait quality.