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Walking-adaptability assessment and training: steps towards clinical implementation

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Summary

The overarching aim of this thesis was to examine the reliability, validity, efficacy and feasibility of walking-adaptability assessment and training with gait-dependent augmented reality (using the C-Mill and the IWW) as a step towards a large-scale implementation of assessment and training of walking adaptability in clinical practice. The studies reported in **Chapters 2 to 6** all contributed to this aim.

Chapter 2 focused on gaitography, that is, gait analysis based on the center-of-pressure trajectories measured while walking on an instrumented treadmill. Gaitography may be useful for prosthetic gait analyses, as the trajectories in question can be rapidly and unobtrusively collected over multiple gait cycles without constraining foot placement. Moreover, the gait characteristics derived from these trajectories may be used to determine features of gait-dependent environmental context (i.e., obstacles presented at the location where one would place one's foot without adjusting gait). The aim of this study was to assess the within-method test-retest repeatability and between-methods agreement (instrumented treadmill vs. pressure-insoles system) for temporal gait events (foot contact, foot off) and gait characteristics (e.g., step times, single-support duration). Ten male proficient prosthetic walkers with a unilateral trans-femoral or trans-tibial amputation were equipped with a pressure-insole system and invited to walk on two separate days on an instrumented treadmill (the C-Mill). Better between-methods reproducibility than within-method repeatability was found for temporal gait characteristics. Step times, stride times and foot-contact events matched well between the two methods. In contrast, insole-based foot-off events were detected one or two samples earlier. A similar bias was observed for temporal gait characteristics that incorporated foot-off events. Small systematic biases notwithstanding, the good between-methods agreement indicated that temporal gait characteristics may be determined interchangeably with gaitograms and insoles in persons with a prosthesis.

To underpin the relevance of walking-adaptability assessment and training, **Chapter 3** evaluated cognitive-motor interference and task prioritization in dual-task walking in different walking environments in people after stroke. Increased cognitive-motor interference and improper task prioritization may contribute to the risk of falling in people with stroke. Using a repeated-measures design, cognitive-motor interference and

task prioritization were assessed in thirty stroke survivors while walking in a plain environment and in two challenging environments enriched with either stationary physical context (10MWT with environmental context) or suddenly appearing projector-generated context (the IWW). All three walking-environment conditions were performed with and without a concurrent serial-3 subtraction task. Stronger cognitive-motor interference was found for the two challenging environments than for the plain walking environment. Cognitive-motor interference did not differ between challenging walking environments, whereas task prioritization did: motor performance was prioritized more in the environment with physical context than in the environment with projector-generated context, and vice versa for cognitive-task performance. In conclusion, walking environment strongly influenced cognitive-motor interference and task prioritization during dual-task walking in people after stroke.

To evaluate the efficacy of walking-adaptability training with gait-dependent augmented reality, **Chapter 4** reported the design of a randomized controlled trial comparing the efficacy of two interventions for improving walking speed and walking adaptability: treadmill-based C-Mill therapy (therapy with gait-dependent augmented reality) and the overground FALLS program (a conventional therapy program) in people after stroke. It was hypothesized that C-Mill therapy would result in better outcomes than the FALLS program, owing to its expected greater amount of walking practice (number of steps taken per session). To test this hypothesis, a single-center parallel group randomized controlled trial with pre-intervention, post-intervention, retention, and follow-up tests was proposed. The protocol recommended to include thirty persons after stroke (at least three months) with deficits in walking or balance and to randomly allocate them to either C-Mill therapy or the overground FALLS program for five weeks. Both interventions incorporated practice of walking adaptability and were matched in terms of frequency, duration, and therapist attention. The proposed main outcomes were walking speed and walking adaptability, using 10 Meter Walking Tests with or without physical context and a novel Interactive Walkway assessment with gait-dependent projected context. All three assessments were performed with and without a cognitive dual-task to determine the cognitive dual-task performance and cognitive-motor interference. Furthermore, the protocol recommended a complementary set of walking-related assessments to determine walking ability, walking independence, balance and

balance confidence. Finally, the study proposed to assess participants' attitude towards the intervention using a purpose-designed evaluation questionnaire and the amount of walking practice were scored using the treadmill's inbuilt step counter (C-Mill therapy) and video recordings (FALLS program).

Chapter 5 presented the results of this randomized controlled trial in people after stroke. No significant improvements in walking speed as assessed with the 10MWT as the primary outcome measure were found. However, both interventions resulted in significant improvements in walking speed, walking adaptability and cognitive dual-task performance when walking in context-enriched environments. Moreover, C-Mill therapy led to greater improvement in walking speed as assessed with the 10MWT with context compared to the FALLS program. However, those results were no longer significant at retention and one-year follow-up. Both interventions were well received, with C-Mill therapy scoring higher on recommendation to peers, fun and perceived increased fitness. Moreover, C-Mill training allowed for about twice as many steps compared to the FALLS program (with similar therapy time). The superior outcomes of the C-Mill therapy might be explained by this greater amount of walking practice next to the difference in design of the intervention.

An important step towards large-scale introduction of walking-adaptability assessment and training with gait-dependent augmented reality in clinical practice was presented in **Chapter 6**. We developed a standardized, automatized and patient-tailored progressive walking-adaptability training protocol, called C-Gait. C-Gait consists of a baseline walking-adaptability assessment involving seven putatively distinct walking-adaptability tasks and a decision-algorithm to automatically adapt training content and execution parameters to (changes in) patients' performance and perceived challenge. The aim of the study was to evaluate the content and construct validity of the baseline assessment, and to examine the feasibility, acceptability and clinical potential of C-Gait training. Twenty-four healthy adults, twelve healthy elderly and twenty-eight patients with gait and/or balance deficits (GD) performed the baseline assessment; the GD group received ten C-Gait training sessions over a 5-week period and also performed post-training and retention tests (baseline assessment and walking-related clinical measures). The content and construct validity of the baseline assessment involving

supposedly distinct walking-adaptability tasks were evidenced by significant differences over groups and difficulty levels, no-to-moderate correlations with walking-related clinical measures, and limited correlations between walking-adaptability tasks. C-Gait training exhibited significant progression in training content and execution, with considerable between-patient variation and minimal overruling by therapists. C-Gait training was well accepted by the GD group, which showed improvements in walking adaptability and general walking ability, which prevailed at retention, indicating clinical potential. C-Gait appeared valid for walking-adaptability assessments and offers automatized, standardized and patient-tailored walking-adaptability training, and was feasible and well accepted, with good potential for improving both task-specific and generic measures of walking.