The influence of walking aids on the recovery of gait function and balance following stroke

Summary

Chapter 1. In the general introduction, the prevalence of stroke, resulting disability and global burden of disease are discussed in order to highlight the need for effective and affordable treatment interventions. The requirement of a clear understanding of neurophysiological processes as a basis for the development of effective treatments is debated. These thoughts are considered both in the context of the International Classification of Function (ICF) and in relation to the historical development of many physiotherapeutic, rehabilitative interventions. Current research into walking aids is summarized, indicating that the majority of experimental studies are cross-sectional, testing the immediate, biomechanical effects of assistive devices. It is shown that prospective, experimental studies which consider the neurophysiological impact of walking-aids are lacking. Finally, the aims of the thesis are described.

Chapter 2. In this chapter we reviewed the structure and function of spinal interneuronal networks and Central Pattern Generators with respect to walking in healthy and post-stroke patients. The influence of afferent inputs (essential for proper gait) on these structures was discussed. Recent evidence demonstrating spinal post-stroke plasticity was presented and its relevance for gait recovery and the possible influence of walking aids on these mechanisms were considered. The aim of this review was to relate, as far as we are aware for the first time, knowledge from basic neuroscience and clinical research done with other patient groups (primarily spinal cord injury patients) to stroke rehabilitation. We discussed recent studies which indicate that changes in spinal cord circuitry post-stroke contribute to functional recovery. We presented evidence which suggests that peripheral inputs such as joint and muscle loading and muscle activity during gait can influence spinal plasticity and therefore impact motor recovery. We suggest that peripheral afferent information should be as similar as possible to input during healthy gait in order to positively impact spinal plasticity and functional recovery. We concluded that assistive walking devices should allow normal joint loading, not reduce muscle activity or length during walking and not require the use of hands. We show that canes and rollators negatively impact all of these afferent inputs whereas an orthosis TheraTogs, allows normal joint and muscle loading, increases muscle activity and does not require the use of hands. TheraTogs and similar orthoses may therefore be more effective in gait rehabilitation. This extrapolation of knowledge was an attempt to improve the understanding of neural, neuromuscular and pathophysiological processes which occur when walking with different devices following stroke. This may help to optimize prescription and use of walking aids in rehabilitation.

Chapter 3. In this chapter we reviewed aspects of cortical control of gait and movement, and focused on muscle synergies, as a way of translating cortical commands into specific muscle activity and as an efficient means of reducing neural and musculoskeletal redundancy. We presented evidence which suggests that four to five muscle synergies are responsible for the normal control of walking and running in all conditions and are stored in the spinal cord as Central Pattern Generators. We summarized evidence showing that post-stroke these synergies appear initially to remain intact at spinal-cord level, but that the ability to selectively recruit and combine them in flexible ways to serve the motor task, is lost. It appears that this selective recruitment is primarily under supra-spinal and cortical control but also influenced by peripheral inputs. As spinal plasticity occurs post-stroke and is activity dependent, the repeated recruitment of combined muscle synergies may lead to a permanent loss of selective and adaptable gait control. We suggest that normalizing peripheral input during gait may facilitate the selective recruitment of spinal Central Pattern Generators (gait muscle synergies), potentially compensating for abnormal cortical inputs and helping to maintain or restore selective recruitment. The need for walking aids to allow normal afferent information from the periphery, as discussed in chapter 2 was therefore re-emphasized. The disadvantages of canes and rollators and the advantages of TheraTogs were again debated. This chapter was a further attempt to improve and broaden the understanding of neurophysiological and pathophysiological processes which occur following stroke in the control of walking and how these processes are relevant for the optimal prescription and use of walking aids in rehabilitation.

Chapter 4. In this cross-sectional study in post-stroke individuals, we investigated the immediate effect of walking with canes, tape and an orthotic garment TheraTogs on hip abductor muscle activity on the hemiplegic side and on tempero-spatial gait parameters, compared to walking with no aids. We found that walking with canes in the hemiplegic hand significantly reduced muscle activity on the hemiplegic side compared to walking with no aids. Walking with tape and TheraTogs significantly increased hemiplegic muscle activity compared to walking with no aids. Increases in muscle activity were greatest with TheraTogs. No significant changes in tempero-spatial gait parameters between conditions were found. As other studies have indicated that increasing muscle activity on the hemiplegic side increases ipsilesional cortical plasticity, which correlates to better function, these findings were potentially important when considering how walking aids should be prescribed post-stroke to optimally influence recovery. We generated the hypotheses that canes which reduce hemiplegic muscle activity, may reduce ipsilesional cortical plasticity and therefore function. TheraTogs which increase hemiplegic muscle activity during walking, may increase ipsilesional cortical plasticity and therefore function. These hypotheses provided the basis for the development of prospective study designs in acute and chronic stroke patients (chapters 7 & 8).

Chapter 5. In this cross-sectional study in healthy subjects we investigated the immediate effect of walking with a four-wheeled-walker (rollator) on lower-limb muscle activity and trunk-sway, compared to walking with no aids. We found that during rollator use, muscle activity in all muscle groups was reduced in both lower limbs and that increasing the push on the walker through the arms, resulted in further reductions. This increased push replicates the situation in patients who require more support and therefore push more on the rollator. Despite reductions in the hip abductor and extensor muscle activity, which are partly responsible for maintaining a stable pelvis during gait, trunk sway did not increase. It would be expected that pelvic instability caused by reduced activity in the stabilizing musculature, would result in increased trunk sway. As this did not occur, other mechanisms must have been responsible for maintaining stability. We postulated that increased activity at the arms when pushing on the rollator frame, compensated for reduced activity at the lower extremities. Rollator walking may therefore cause reduced muscle activity in the lower extremities and abnormal balance reactions as stability is gained via compensatory activity at the arms. These findings need to be investigated further in patient groups and long term consequences should be studied. Rollator walking may be beneficial in patients who would otherwise not walk at all, but possibly is deleterious in patients who are able to walk without or with other aids.

Chapter 6. In this case report, a patient with delayed healing of a conservatively treated avulsion fracture of the greater trochanter 12 weeks previously and with a 14-year history of total hip arthroplasty was presented. We systematically documented the effect of walking with crutches, an orthotic garment TheraTogs, and no walking aids over three 4-week periods on walking speed, trunk sway, and muscle activity measured with EMG. We found that walking speed improved at a faster rate in the TheraTogs phase than in the crutches phase and that walking speed reduced in no-walking-aids phase. Trunk sway increased in the crutch and no-aids phases, and became more stable in the TheraTogs phase. In this patient, function and recovery rate of all measured parameters increased more in the TheraTogs phase than when walking with crutches or during the no-aids phase. We postulated that this may have been because crutch walking unloaded the affected hip and the recovering structures, thereby enabling walking, but without facilitating muscle activity in the affected structures. TheraTogs on the other hand facilitated muscle activity, thereby enabling active support of recovering structures. No walking aids provided no support, so that affected structures became inflamed and walking was painful. This case report provided insight into the prospective, on-going influence of walking aids on muscle activity and function during rehabilitation in a patient with an intact nervous system.

Chapter 7. In this chapter we described the study protocol for a multi-centered randomized control trial in acute stroke patients, in which the effect of early gait rehabilitation with two different walking aids, canes and an orthotic garment TheraTogs, on the recovery of gait function and balance would be compared. This was the first protocol that we were aware of to investigate the long-term influence of walking aids in rehabilitation in post-stroke patients. It was also the first study on walking aids in which the hypotheses were based on an understanding of mechanisms influencing neuroplasticity, motor learning and functional recovery post-stroke.

Chapter 8. In this multiple single case study with four cane using, chronic stroke patients we experimentally investigated the long-term effect of reducing cane use as much as possible and replacing it with the orthosis TheraTogs, on gait function and balance. During a baseline period subjects walked with canes as usual. Gait function and trunk sway were measured weekly. During intervention periods of varying and randomized time spans, cane use was reduced as much as possible and the orthotic garment TheraTogs was worn daily from morning to evening. Subjects continued to be measured weekly. In a follow-up period subjects either returned to cane use, continued to use TheraTogs or walked with no aids, depending on their functional abilities and personal preferences. All patients improved in gait function, two showed improvements larger than a Clinically Important Minimal Difference, one of whom became an independent walker without walking aids. Trunk sway also improved but changes were not statistically significant. These results indicated that walking-aids decisively impact gait and balance ability. Walking-aids which increase muscle activity, allow normal joint-loading and do not require hands may be more effective than canes for gait rehabilitation. Further research is needed to confirm these results, to identify which patients benefit and to optimize further aspects of intervention (e.g. duration).

Chapter 9. In this chapter a general discussion of the overall findings was presented. Implications for clinical practice, the formulation of clinical practice guidelines and future research were examined. Insights gained throughout the research process, which were not defined as aims at the outset, such as the influence of study design on results and the optimal designs for rehabilitation research, were also discussed.