

Summary

Summary

Following spinal cord injury (SCI), the loss of motor (sensory and autonomic) function leads to a reduced physical work capacity and may hinder physical activity or exercise at an adequate level in order to maintain fitness and health in daily life. Moreover, persons with SCI are prone to secondary health complications. Especially for those with tetraplegia, who essentially have an extremely low active muscle mass and a (partly) disturbed blood circulation due to paralysis and autonomic dysfunction, it is difficult to engage in physical activity. Not many easy accessible, not too strenuous exercise modes are available or can be performed independently by persons with high lesions or those with recent spinal cord injury. In the current thesis the focus was on the synchronous¹ hand cycle add-on unit, as exercise mode. This type of hand cycle unit can be attached to the own hand rim wheelchair with slight adaptations. Hand cycling is assumed to offer an adequate alternative exercise mode for persons with SCI to improve physical capacity during and after clinical rehabilitation.

The introductory Chapter 1 describes SCI and the consequences for health and physical capacity. Physical capacity is defined as the joint ability of muscles and respiratory and cardiovascular systems to attain a peak level of activity. The relation between physical capacity, functioning, participation and quality of life is outlined. The hand cycle is described as well as its use as exercise and mobility mode around the world. The interface characteristics and mechanical efficiency of hand cycling are compared with hand rim wheelchair propulsion and conventional arm cranking. The favourable characteristics of hand cycling, especially for persons with tetraplegia, are described. Chapter 1 concludes with an outline of this thesis. Chapter 2 describes a systematic review of the international literature of the effects of upper body exercise and training on physical capacity in persons with SCI. The gains on the main outcomes PO_{peak} and VO_{2peak} are compared between arm crank exercise, wheelchair exercise and alternative modes such as resistance training and quad rugby. Due to the relatively low number of studies and the limited methodological quality (the lack

¹Although also used in current thesis, the commonly used definitions 'synchronous' and asynchronous are less appropriate. Synchronous refers to the correct definition in-phase (phase-angle of 0°), whereas asynchronous refers to out-of-phase (angle of 180°).

Summary

of randomised controlled trials), it was not possible to draw definitive conclusions on training effects for different lesion groups or training modes. Average relative gains on PO_{peak} and VO_{2peak} were found to be between 10-30% in studies with predominantly pre-post-training design. Most studies were performed in persons with paraplegia, while gains in the few studies on persons with tetraplegia were mostly positive but not uniform. The results of the relatively few studies with an acceptable quality seem to support the view that upper-body exercise may increase the physical capacity of people with SCI. None of the studies however focussed on the effects of hand cycle training.

In the past decade, hand cycling as an exercise therapy has become part of the rehabilitation program in The Netherlands. In Chapter 3, an epidemiological study is described in which the influence of hand cycle use on physical capacity during (and in the year after) clinical rehabilitation was studied. The outcomes of physical capacity between hand cycling and non-hand cycling individuals, after correction for baseline-values and confounders (lesion and personal characteristics) were compared. A significantly larger increment in VO_{2peak} , PO_{peak} and elbow extension strength was found in subjects with paraplegia who were hand cycling during clinical rehabilitation, compared to those who were not. The small and heterogeneous study groups may have hampered the finding of positive results of hand cycling in persons with tetraplegia. In the post-rehabilitation period, out of all outcome measures, only a positive effect on elbow extension strength was found and only in subjects with paraplegia.

The ACSM-training guidelines recommend heart rate as indicator of exercise intensity in persons with SCI. However in practise, some individuals with tetraplegia encounter problems when training according to heart rate due to a disturbed autonomic nervous system. A disturbed autonomic nervous system may influence the heart rate-oxygen uptake (HR- VO_2 -) relationship. The cross-sectional study in Chapter 4 addresses the question whether heart rate reflects the actual aerobic training intensity based on the assumed linear HR- VO_2 -relationship between the oxygen uptake and heart rate and whether training according to heart rate is appropriate in persons with tetraplegia. The heart rate-oxygen uptake relationship appeared linear in less than half of the subjects and an individual analysis of this relationship is necessary to determine whether heart rate can be used to quantify exercise intensity. In conclusion, the use of

Summary

heart rate to prescribe training intensity should be reconsidered in persons with tetraplegia. Suggested alternatives for exercise intensity monitoring - perceived exertion and ambulant power output readings - should be evaluated experimentally in near future.

Chapter 5 outlines the effects on physical capacity and health-related quality of life in subjects with tetraplegia following a structured hand cycle interval-training program. Pre- (t1) and post (t2) outcome measures on physical capacity and health-related quality of life were compared. In addition, double baseline data (t0, t1) were available for a subgroup. A significant improvement after the structured hand cycle training on physical capacity as reflected by PO_{peak} and VO_{2peak} was found. Except for shoulder abduction, no significant effects were found on muscle strength, pulmonary function or health-related quality of life. Despite dropouts and non-compliance (due to common health and practical problems), untrained subjects with tetraplegia were able to improve their physical capacity through regular hand cycle interval training.

In Chapter 3 hand cycling during clinical rehabilitation was studied with an observational analysis and thus without a controlled training protocol. Therefore, Chapter 6 addresses an experimental study on the effects of a structured hand cycle training program during rehabilitation of subjects with paraplegia or tetraplegia. The results are compared with matched control subjects from the cohort group receiving usual treatment described in Chapter 3. Tendencies for improvement were found in wheelchair capacity, reflected by PO_{peak} and oxygen pulse after additional hand cycle training. Significant effects on shoulder exo- and endo-rotation strength were found but no improvements on pulmonary function. Additional hand cycle training during clinical rehabilitation seems to show similar or slightly favourable results on fitness and muscle strength compared with usual treatment. The heterogeneous subject group and large variation in training period (and number of training sessions) may explain the lack of significant effects of additional hand cycle training on wheelchair capacity. Moreover, the contrast between hand cycling and regular treatment during clinical rehabilitation is relatively small.

Finally, in Chapter 7, the main findings and conclusions of this thesis are summarized and discussed. Practical implications for the design and prescription of hand cycle training- and rehabilitation programs for individuals

Summary

with SCI are discussed. Suggestions are given for future research in order to optimize physical training protocols for persons with SCI, and especially for persons with tetraplegia. The main conclusions of the current thesis were that structured hand cycle training leads to mainly significant improvements in physical capacity, reflected by improvements in PO_{peak} and to a lesser extent in VO_{2peak} , compared to usual care in persons with SCI during and after clinical rehabilitation. Some improvements in peak arm muscle strength were found compared to usual care and no consistent improvements in pulmonary function were found that could be attributed to hand cycling only. No over-use injuries as a consequence of hand cycle training were reported. In conclusion, hand cycling offers a safe exercise and mobility mode to maintain and train physical capacity in those with SCI, already in early rehabilitation.