# Effect of a 7-week low intensity synchronous handcycling training program on physical capacity in abled-bodied women

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## Abstract

This study evaluated the effect of a low-intensity norm duration synchronous handcycle wheelchair training in untrained able-bodied women. The training group (n = 9) received 7-weeks of low-intensity upper body training in an instrumented handcycle on a motor driven treadmill (MDT), 3 × 30 min/week at 30% heart rate reserve. The control group (n = 10) received no training. Incremental handcycle tests on the MDT were used to determine peak values for oxygen uptake ($VO_{2peak}$), power output ($PO_{peak}$), heart rate ($HR_{peak}$), minute ventilation ($V_{Epeak}$), and respiratory exchange ratio ($RER_{peak}$), submaximal values for heart rate (HR), oxygen uptake ($VO_2$) and gross efficiency (GE) before and after training. Local perceived discomfort and rate of perceived exertion (RPE) were also assessed. Training significantly improved $PO_{peak}$ (+20%), $HR_{peak}$ (+3%), $RER_{peak}$ (+5%), submaximal GE (+21%), $VO_2$ (-20%), $V_E$ (-33%), HR (-12%) and RPE was low (7.1 ± 0.5) ($p<0.05$). No effects were found in $VO_{2peak}$ and $V_{Epeak}$ ($p>0.05$). Though $VO_{2peak}$ did not improve, low-intensity norm duration handcycling training improved handcycling $PO_{peak}$, while RPE was low. Also, GE increased, suggesting a motor control improvement. Handcycle training seems to be an appropriate exercise mode to improve physical capacity, and prevent early fatigue and overuse in untrained individuals.

Keywords: Rehabilitation, recreational adapted sports, handbiking, treadmill training, physical capacity, local perceived discomfort

## Introduction

Approximately 65 million people worldwide are reliant on a wheelchair in their day-to-day lives (1,2). Deconditioned and vulnerable people (the frail aged people or those with a chronic disease or disability) such as people with stroke, cerebral palsy, multiple sclerosis, spinal cord dysfunction, brain injury and lower limb amputation rely on their wheelchair for mobility and participation (1). Being largely dependent on the upper extremities for daily activities, wheelchair users are susceptible to overuse injuries and pain at the shoulders, elbows, and wrists which compromises their ability to perform necessary daily activities such as making transfers, upper-body lifting and wheelchair propulsion (1,3).

To cope adequately with the strain of daily activities and to prevent long-term secondary health problems, wheelchair users will require an upper body exercise mode involving wheelchair treadmill exercise, wheelchair ergometry and arm-crank ergometry to improve their physical capacity (4-12). The goal of upper body training is to increase active muscle mass and strength, maximize overall strength for functional independence, and improve efficiency of wheelchair propulsion (13-15). Research data provide evidence that upper-body endurance and resistance exercise improved physical capacity, quality of life and mood state, reduced risk for secondary health problems such as obesity, diabetes and cardiovascular disease, and reduced risk for mortality (13-15).

Despite growing efforts to improve physical capacity through exercise interventions in deconditioned and vulnerable people, studies investigating the effect of exercise interventions report a high number of dropouts, and identified that participants struggle to continue engaging in physical activity post-exercise program (16). Conversely, research shows that overuse complaints of wheelchair users are an important predictor for participation in physical activity and exercise during and after rehabilitation (17). Thus, high straining activities may induce over use complaints in wheelchair users and consequently lead to reduced physical activity participation. Therefore, to maintain a long-term physically active lifestyle and/or rehabilitation aftercare of wheelchair users, it is important to explore ways to prevent overuse complaints.

A low intensity training could be central to the adoption and maintenance of physical activity behaviour in de-conditioned and vulnerable people, and can provide the platform to engage in graduated activity or higher intensity exercises (18-21). Exercising at a lower intensity is accompanied with greater safety, would be perceived as achievable, reduces the risk of overuse complaints and can improve motivation to remain active (17). However, the potential of low intensity training to improve physical capacity have not been fully explored.

Only two studies were found that investigated the effects of low intensity training (30% HRR for 30-70 min) using hand-rim wheelchair on physical capacity (17,18). These studies showed improvements in peak power output, sprint power, mechanical efficiency, metabolic cost, and submaximal heart rate and oxygen uptake. Conversely, different studies showed that hand-rim wheelchairs have a low mechanical efficiency and are straining for the upper extremities (22,23). Hence, the use of hand-rim wheelchairs may lead to overuse complaints in the upper extremities and subsequent disengagement in physical activity and exercise over time.

Handcycling could be an alternate promising exercise mode, as it is less straining and more mechanically efficient than hand-rim wheelchair propulsion (23-25) and could optimize rehabilitation and increase long term adoption of engagement in exercise and physical activity among wheelchair users. The task load during handcycling is spread over time and muscle groups are alternatingly active (front and back) through the full circular movement of handcycling, and no high peak loads occur (26). Consequently, higher physical capacity can be reached with handcycling compared to hand-rim wheelchair (17). Yet, the effects of low intensity handcycle training on maximal and submaximal exercise capacity are yet unknown.

The aim of the present study was to investigate whether a 7-weeks low intensity (30% heart rate reserve; HRR) handcycle training with a norm duration (30 min/session) can induce favorable effects in physical capacity of able-bodied untrained female subjects, thus simulating to some extent training effects in wheelchair users in early rehabilitation (27,28). Based on the results of previous studies (17,18), we hypothesized that a low-intensity (30% HRR) norm duration handcycle training program would improve mobility related parameters such as peak power output and submaximal efficiency. Physical capacity is reflected by the maximal performance [peak values of oxygen uptake ($VO_{2Peak}$), power output ($PO_{peak}$), heart rate ($HR_{peak}$), minute ventilation ($V_{Epeak}$) and respiratory exchange ratio ($RER_{peak}$)], submaximal performance [oxygen uptake ($VO_2$), respiratory exchange ratio (RER), minute ventilation ($V_E$) and heart rate (HR)] and gross efficiency (GE).

## Materials and methods

*Participants*

Twenty-two able-bodied women initially volunteered to take part in the study. During an initial visit, study details and participation requirements were explained, and after screening with the Physical Activity Readiness Questionnaire (PAR-Q) (29) written informed consent was obtained. One participant was no longer willing to participate in the study. The remaining participants (n = 21) were randomly assigned to two groups; a training group (TG: n = 11) and a control group (CG: n = 10). Criteria for inclusion of this study were: female, no experience in handcycling, no recent activity in (upper body) endurance sports, no change in activity level during the study and no medical contraindications. Participants were instructed not to alter other training activities outside those of the study protocol. The study received approval from the local Ethics Committee of the Center for Human Movement Sciences of University Medical Center Groningen and was conducted in accordance with the Declaration of Helsinki.

At their first visit to the laboratory, participants familiarized to the experimental set-up with three 6-minutes familiarization trials in the instrumented synchronous handcycle on a cycle trainer (Sirius T1435, Tacx BV, The Netherlands). Thus, participants could become acquainted to the synchronous hand cycle propulsion technique. Subsequently, a fourth trial was presented on a handcycle on the motor-driven treadmill to get used to the propulsion and steering mechanism.

*Design*

All training sessions and incremental tests were performed on an instrumented handcycle mounted on a motor driven treadmill (Enraf Nonius, The Netherlands). The instrumented handcycle consisted of an add-on system (Tracker Challenger, Alois Praschberger, Austria) coupled to a regular standard wheelchair (Double Performance, RGK, RGK Wheelchairs Inc., England) fixed at the lightest gear. To measure power output, it was equipped with an instrumented wheel hub in the front wheel (Powertap SL, CycleOps, USA; 1.5% accuracy, sample frequency 1Hz). Tire pressure was fixed on 6.0 bar and was measured before all tests and training sessions.

An incremental exercise test was performed to obtain peak cardiovascular and physiological variables and to evaluate handcycling performance before and after a 7-week training or no training program. The test protocols for the pre- and post-test were standardized in terms of handcycle settings (gear, tire pressure, velocity and resistance). The training group (TG) received a 7-week hand cycling training program with a frequency of three times a week with a duration of 30min conform to the ACSM guidelines (8). The average training intensity was 30% heart rate reserve (HRR) using two different training forms, which are described further in training. The control group (CG) did not receive any training and was asked to maintain their activity level similar during the experimental period.

Training

All training sessions were performed on a motor driven treadmill (Enraf Nonius, Delft, Netherlands) in a climate controlled work lab. The training sessions were executed 3 times per week for half an hour on a motor driven treadmill (Enraf–Nonius, Delft, Netherlands) at an average power output corresponding with 30% HRR. Resting heart rate ($HR_{rest}$) and peak heart rate ($HR_{peak}$) were measured before training (Polar Accurex Plus; Polar Electro, OY, Finland) to calculate HRR. To measure $HR_{rest}$, subjects sat quietly in the handcycle for 10min in a quiet laboratory, before commencement of the warm-up preceding the incremental test. The final minute was used as $HR_{rest}$. $HR_{peak}$ was measured during the final stage of the incremental handcycle pre-test as described in “incremental testing”.

The training sessions were performed at 30% HRR, determined conform (30). The required workload, which elicited an intensity of 30% HRR, was determined by the linear relation between HR and PO, measured during the maximal incremental test pre-training. Two different types of training: resistance training and velocity training were used, on alternate days. In the resistance training, the work load was increased when necessary to reach a mean exercise intensity of 30% HRR by adding work load through a pulley system as described in Dallmeijer et al. (31), while the velocity was kept constant at $1.11 m \cdot s^{-1}$ as done in van der Woude et al. (32). During the velocity training, the resistance was kept constant at a workload corresponding to the workload required to handcycle at 30% HRR only now the velocity was increased when necessary to reach a mean exercise intensity of 30 % HRR.

Training sessions were monitored by heart rate (Polar Electro, Finland) and power output (PowerTap SL, CycleOps, Saris Sycling Group Inc., United States). During the last three minutes of each training session rating of perceived exertion (33) and local perceived discomfort (LPD) of the upper body were obtained (34). Participant completed 21 (11 resistance, 10 velocity) training sessions.

Incremental testing

Before the training commenced, but after the initial handcycle familiarization sessions and a 10 minute resting period, an incremental handcycling test was performed on the handcycle on the motor-driven treadmill. After 7 weeks of training or no training (CT), the incremental test was repeated at the same time of day on the same day of the week in an identical test protocol and set-up. Participants were asked to refrain from consuming alcohol, caffeine and engaging in strenuous exercise for at least 2-h prior to testing. The test started with a 5-min submaximal steady state warm-up at 30W.

The protocol of the handcycling stepwise (1min) incremental maximal test was based on a handcycling protocol designed for males (31). This protocol was modified for females based on pilot testing, so that the incremental exercise test would last about 8–12 min (35). The initial power output (PO) of the maximal test was set at 20W, and increased with 7W every minute until voluntary exhaustion. PO was increased by adding or reducing weight to a pulley system attached to the rear end of the handcycle (32), and was determined by the additional force ($F_{add}$), the drag force ($F_{drag}$) and the velocity (v), as described by Eq. (1):

$$\text{Power output (PO)} = (F_{add} + F_{drag}) \times v. \qquad (1)$$

The velocity of the treadmill was kept at the same speed at $1.11 m \cdot s^{-1}$. Drag force was determined by riding with no additional force at $1.11\ m \cdot s^{-1}$.

Respiratory parameters were measured breath by breath, using open circuit spirometry (Oxycon Delta, Germany). The gas analyzer was calibrated prior to each test using room air, a Jaeger 3-1 syringe and a calibration gas (16.0% $O_2$, 5.0% $CO_2$). Peak values for power output ($PO_{peak}$), oxygen uptake ($VO_{2peak}$), heart rate ($HR_{peak}$), minute ventilation ($V_{Epeak}$) and the respiratory exchange ratio ($RER_{peak}$) were calculated between the 20th and 50th second of every completed minute.

RPE scores were obtained using a 15-point (6–20) Borg scale (33). During the last 10 s of each stage, the experimenter moved his finger along an enlarged, printed RPE list. Participants were informed to nod when the experimenter was pointing to their RPE, so that speech would not interfere with the collected respiratory data. When voluntary exhaustion was reached or when participants could not keep speed constant at $1.11 m \cdot s^{-1}$ the test was ended. Directly after each test, Local Perceived Discomfort (LPD) scores (34) were obtained. The participants had to score discomfort in hands, lower arms, upper arms and shoulders, lower back and upper back, and the neck. A scale from 0 (no discomfort) to 10 (maximal discomfort) was used. Total score on the perceived local discomfort was the sum of all parts, which means that the maximal possible score was 50 and minimum score was zero points.

Additionally, HR, $VO_2$ ($ml \cdot min^{-1}$), VE ($L \cdot min^{-1}$), RER and RPE of the $2^{nd}$, $4^{th}$ and $6^{th}$ stages of the incremental test (PO of 27 W, 41 W and 65 W respectively) were evaluated for submaximal performance during handcycle. These stages.

Gross-efficiency (GE) was calculated for the submaximal steady state (PO = 30 W) by dividing the measured mechanical PO by the metabolic power input ($P_{met}$):

$$GE = PO / P_{met} * 100\%$$

$P_{met}$ was calculated in the last minute (from second 20 to 50) by multiplying oxygen consumption with the oxygen equivalent: $P_{met} = VO_2 * ((4940 * RER + 16040)/60)$ (36). For all measured parameters, means and standard deviations were calculated.

## Statistics

All data were analyzed and calculated using SPSS 17.0 (SPSS Inc., USA) and Matlab 2013 (The Mathworks, USA) and are presented as mean ± SD. An independent t test was used to determine baseline differences in personal characteristics (age, length, body mass) and the pre-test peak and submaximal values ($VO_2$, $V_E$, HR, RER, PO, RPE and LPD) between the training and control group. The effect of the training on peak and staged submaximal values between the two groups was evaluated with a 2 factor repeated measures ANOVA. The difference between pre- and post-test was used as within-subject factor and group as between-subjects factor. The significance level was set at $p < 0.05$ for all tests.

## Results

### Participants

In total nine participants of the training group completed the 7 week training program. Two participants were excluded during the training program (week 3 and week 6), because of injuries unrelated to the training program. The flow of participants through the study and reasons for exclusions and withdrawals are displayed in Figure 1. Participant characteristics are presented in Table 1. At baseline, there were no statistical differences between training group and control group with regard to age, height (stature), body mass, body mass index, and performance or cardiorespiratory variables ($p > 0.05$) (see Table 1).

[Insert figure 1 near here]

[Insert table 1 near here]

### Training sessions

In the training group, training was performed at an average intensity of 30.3 ± 1.94% HRR. The average heart frequency was 105 ± 4.8 beats per minute for all participants. Participant completed 21 (11 resistance, 10 velocity) training sessions. The average power output (PO) during resistance training session was 25.6 ± 3.4W and significantly increased ($p = 0.001$) between the first four training sessions (23.0 ± 2.9W) and the last four training sessions (29.1 ± 4.2W). The average speed during the velocity training sessions was 1.47 ± 0.06 $m \cdot s^{-1}$. No significant differences were found between the first four (1.41 ± 0.13$m \cdot s^{-1}$) and last four (1.46 ± 0.12$m \cdot s^{-1}$) velocity training sessions ($p = 0.308$). Some participants could not perform the required three training sessions every week and were then allowed to perform extra sessions in other weeks. The training group indicated some discomfort in the hands and the lower back during training, indicated by an average local perceived discomfort (LDP) score of 3.4 ± 1.6. The total score of LDP decreased significantly ($p = 0.004$) from 5.3 ± 2.4 in the first four training sessions to 2.5 ± 2.0 in the last four training sessions. The training was perceived “very very light”, with an average session rate of perceived exertion (RPE) of 7.1 ± 0.5.

### Training evaluation

Table 2 shows the peak physiological and performance capacity of both training group and the non-training control group before (pre) and after (post) the experimental period. Due to mechanical problems with the heart rate monitor in the posttest, heart rate could not be measured in three control subjects.

Training resulted in a 20% increase in peak power output ($PO_{peak}$), 5% increase in peak respiratory exchange rate ($RER_{peak}$) and 3% increase in peak heart rate ($HR_{peak}$). Comparisons of peak values obtained during maximal incremental tests before and after training are presented in Table 2. Significant group × time interactions were found for $PO_{peak}$ (W), $PO_{peak}$ ($W \cdot kg^{-1}$), $RER_{peak}$ and $HR_{peak}$ with greater increases occurring in the training group for each variable. Significant main effects of time (increases) were found in $PO_{peak}$ (W), $PO_{peak}$ ($W \cdot kg^{-1}$), $RER_{peak}$ and $HR_{peak}$. No significant interactions or main effects of time were detected in $VO_{2peak}$ ($L \cdot min^{-1}$), $VO_{2peak}$ ($ml \cdot min^{-1} \cdot kg^{-1}$), $V_E$ ($L \cdot min^{-1}$), LPD and RPE.

[Insert table 2 near here]

To examine submaximal performance during handbiking, the 2nd, 4th and 6th stages of the incremental test were evaluated. In table 3 the mean values and differences for the submaximal stages 2nd, 4th and 6th are presented for the variables HR, $VO_2$ ($ml \cdot min^{-1}$), $V_E$ ($L \cdot min^{-1}$), RER and RPE for both groups. These stages corresponds with a power output of 27 W, 41 W and 65 W.

Significant group x time interactions were found for $V_E$ ($L \cdot min^{-1}$) and RPE, and stage 2 $VO_2$ ($ml \cdot min^{-1}$) with greater increases occurring in TG for each variable. Significant main effects of time (decreases) were found in HR, $VO_2$ ($ml \cdot min^{-1}$), $V_E$ ($L \cdot min^{-1}$) and RPE in the training group. The greatest differences were found for ventilation ($V_E$), where participants inhaled on average 31% (38 ± 6 $l \cdot min^{-1}$ to 28 ± 5 $l \cdot min^{-1}$) less air per minute. $VO_2$ decreased by 20% (1148 ± 117 $ml \cdot kg^{-1} \cdot min^{-1}$ to 955 ± 133 $ml \cdot kg^{-1} \cdot min^{-1}$) and HR by 12% (152 ± 17 $beats \cdot min^{-1}$ to 136 ± 12 $beats \cdot min^{-1}$). A significant main effect of time (-7%) was found for stage 6 $VO_2$ ($ml \cdot min^{-1}$) in the control group. No significant interactions or main effects of time were detected in RER.

[Insert table 3 near here]

[Insert figure 2 near here]

Comparisons of GE during the steady submaximal warm-up (PO = 30W) and the 4th stage of the maximal incremental test (PO = 41W), before and after intervention is presented in Figure 2. For the 4th stage, GE was determined for only 10 participants (5 training, 5 control), as RER-values in the other participants were greater than 1.0. Significant main time effects were found showing increases in GE at submaximal warm-up phase (11.2 to 13.6%, $p = 0.001$) and 4th stage of incremental test (12.7 to 16.6%, $p = 0.019$) in the training groups, compared to no improvement (11.2 to 10.7%; warm up, and 13.7 to 13.6%; 4th stage) in the control group.

## Discussion

This study is the first to evaluate the effect of a 7-week low intensity (30% HRR) handcycle training program on the physical capacity of able-bodied women, and revealed the design effectively increased gross efficiency; GE (+2.4-3.9%), peak heart rate; $HR_{peak}$ (+3.0%), peak power output; $PO_{peak}$ (+20.1%), and peak respiratory exchange ratio; $RER_{peak}$ (+5.0%) without any signals of muscle soreness and physical strain. This study provides insight into the potential use of handcycling for rehabilitation of wheelchair users, who might struggle with higher intensities, particularly in the early stages of rehabilitation. Training resulted in lower values on ventilation, oxygen uptake and rate of perceived exertion at different submaximal stages (27 W, 41 W & 65 W). Furthermore, the training was perceived as low straining and was easily achieved as shown by the low values of LPD (3.4 ± 1.6) and RPE (7.1 ± 0.5) scores.

The improvements in physical capacity found in this study were similar to those found after wheelchair ergometry training in persons with lower limb amputation, stroke and spinal cord injuries (37,38). Specifically, the improvement in GE, $HR_{peak}$, $PO_{peak}$ and $RER_{peak}$ are in accordance with handcycle studies in able-bodied individuals, persons with spinal cord injury and wheelchair users (4-7, 14), and comparable to low intensity training studies using hand-rim wheelchair (17,18). The improvement in $PO_{peak}$ (+20.1%) found in this study was comparable to that reported by Van de Berg [18] in their study to simulate the effect of low-intensity exercise in early rehabilitation using hand-rim wheelchair (+34%) (18). The improvement in GE (+2.4-3.9%) found in this study was higher than that reported by De Groot et al., [17] in their study evaluating the effect of low intensity training using hand-rim wheelchair (+1.3-1.9%). This is conform expectations that a higher physical capacity can be reached with handcycling compared to using a hand-rim wheelchair. It is worth mentioning that in this current study, GE was determined for only 10 participants (5 out of 9 participants in the training group, and 5 out of 10 participants from the control group respectively), as RER-values in the other participants were greater than 1. The difference with previous literature may be due to the different sample population. Participants in previous studies (17,18,31) had clinical conditions and experience using a manual wheelchair, compared with novice able-bodied participants who were recruited in the present study.

The improvement in $PO_{peak}$ and GE is an important finding, as performance of many daily activities, particularly mobility lean on strength and efficiency, and thus improvement in $PO_{peak}$ and GE leads to more mobility and participation in daily activities at lower physical strain (39). However, $VO_{2peak}$ did not increase significantly over the training program. This is in accordance with previous work [18] (30% HRR training) using hand-rim wheelchair which did not show significant improvements on $VO_{2peak}$ either, but contrary to those of handcycling studies exploring higher exercise intensities (40,41) and wheelchair ergometer training studies in people with spinal cord injury, stroke and lower limb amputation (37) that found improvements in $VO_{2peak}$.

The improvement in $PO_{peak}$ and non-significant improvement in $VO_{2peak}$ found in this study may indicate an improvement in handcycle GE, the ratio between external power output and metabolic power input, after the training program (35). Studies indicate that the $PO_{peak}$ is positively associated with improvements in GE (40,42), which increased significantly over the training period in this study. Conversely, the improvement in GE suggests a motor control improvement or motor learning optimization and may explain the lower submaximal physiological values found, as $V_E$ decreased by 30%, $VO_2$ by 18% and HR by 10%. Our findings of lower physiological values and a higher efficiency in submaximal stages are in accordance with previous works (17,18) and support the notion that low intensity training program could have greater beneficial effects on performance compared with control as wheelchair users perform most activities of daily life at submaximal levels (39).

The current study findings indicate that training at low intensities improves physical capacity, leads to motor skills optimization, and consequently improves participation and mobility. The limited data available on low intensity upper body training makes it difficult to conclude whether exercising at a low intensity is always beneficial. It remains uncertain whether the improvement in GE is due to physiological advantages, such as oxygen utilization in the working muscles, or from mechanical/propulsion advantages such as user-interface optimization. That notwithstanding, the improvements in mobility parameters; $PO_{peak}$ and GE found in this study indicates that handcycling at lower intensities is an appropriate approach to stimulate an active lifestyle and subsequently prevent or reduce disability and sedentary lifestyle and thereby reduce the risk for cardiovascular problems in persons with disabilities and or chronic conditions such as wheelchair-dependent people (24).

The training was perceived as “very very light”, with low physical strain as evident in the average RPE and LPD scores. The scores on local perceived discomfort indicates that the physical strain was low at the beginning of the training and further decreased after training. This finding supports the notion that handcycling is an appropriate alternative for training wheelchair users and reduces the risk of overuse injuries in the shoulder joint (26,32). Incorporating this study design in rehabilitation program will improve motivation to stay active and to participate in different leisure time activities after rehabilitation. Thus the low straining nature of the current training makes it applicable for the early phase of rehabilitation of novice wheelchair users, and makes adoption and maintenance of physical activity behaviour more likely (13,14), and can provide the platform to engage in graduated activity or higher intensity exercises.

Previous studies have explored the effect of upper body handcycle on physical capacity and wheelchair performance using resistance training, moderate intensity continuous training and/or high intensity interval training (4-7). The uniqueness of this study, is that deliberately low intensity (30% HRR) was chosen to induce favourable effects in physical capacity, as low intensity exercise is accompanied by greater safety, reduces the risk of overuse complaints and can stimulate participation and long-term adoption and adherence to physically active lifestyle among novice wheelchair users. Variables related to mobility and adherence were positively influenced in the current study, which indicate that low intensity handcycle training may be appropriate in novice wheelchair users at the start of their rehabilitation, to prevent early fatigue and overuse and enhance participation, motivation and adherence.

There is a strong rationale for generalization of the study findings to wheelchair-dependent people with spinal cord injury, stroke, multiple sclerosis, cerebral palsy and lower limb amputation. First, the study sample: able-bodied women, respond relatively homogenous to handcycle exercise (32). Second, able-bodied women have a comparable physical capacity with paraplegic SCI patients (27,28). Third, participants in this study had no prior experience in upper body exercise, which is comparable to inexperienced wheelchair dependent persons early in rehabilitation (43). Lastly, studies have shown that similar trends are seen in physiological outcomes in both able-bodied subjects and wheelchair users (25). Thus, this study gives valuable insight on effects of low intensity handcycling training in people with a SCI who are novice wheelchair users in early rehabilitation. However, future low intensities training programs should include people with a SCI to allow firm conclusion to be drawn. Future studies should evaluate the effect of low intensity handcycling training on wheelchair capacity, as was done in Chaikhot et al [6] for concurrent training. In their study, they found a decrease in push frequency at speed typical of everyday functional propulsion (comfortable speed and at 125% of comfortable) following a combined resistance and high intensity training.

## Conclusion

Low intensity handcycling training was perceived as achievable and accomplished without any discomfort, and improves gross efficiency and peak power output. This indicates that improvements in performance can be found for low training intensity. The study training design provides an alternate for people who cannot or are not motivated to train at high intensity such as novice wheelchair-dependent persons. Training at low intensities, individuals can improve their physical capacity, which subsequently can improve their social participation and mobility. This study also supports the idea that handcycling is an appropriate exercise training during rehabilitation to maintain physical capacity and lower risk of developing overuse complaints. The study findings suggest motor adaptation in the form of improved task skill in combination with physiological adaptations at submaximal activity levels. Further studies employing this study design in a sample of wheelchair-dependent people in rehabilitation setting is warranted.

**Disclosure of interest**

The authors report no conflict of interest.

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**Table 1: Participant characteristics for training and control group**

| | Training (N = 9) Mean ± SD | Control (N = 10) Mean ± SD | p-value |
|---|---|---|---|
| Age (years) | 20.8 ± 1.69 | 20.9 ± 1.83 | 0.91 |
| Height (meters) | 1.69 ± 5,4 | 1.69 ± 8.1 | 0.95 |
| Body mass (kg) | 62. 8 ± 6.8 | 61.9 ± 9,3 | 0.80 |
| Body mass index ($kg{\cdot}m^{-2}$) | 22.0 ± 1.6 | 21.7 ± 3.1 | 0.80 |
| $HR_{peak}$ (beats · $min^{-1}$) | 182 ± 11 | 182 ± 9 | 0.97 |
| $PO_{peak}$ (W) | 81.1 ± 11.2 | 88.2 ± 18.9 | 0.34 |
| $PO_{peak}$ ($W{\cdot}kg^{-1}$) | 1.33 ± 0.19 | 1.41 ± 0.28 | 0.47 |
| VE ($L{\cdot}min^{-1}$) | 69.2 ± 14.4 | 73.0 ± 20.1 | 0.65 |
| $VO_{2peak}$ ($L{\cdot}min^{-1}$) | 1.60 ± 0.20 | 1.78 ± 0.42 | 0.27 |
| $VO_{2peak}$ ($ml{\cdot}min^{-1}{\cdot}kg^{-1}$) | 26.4 ± 4.6 | 28.5 ± 7,1 | 0.46 |
| RER | 1.21 ± 0.08 | 1.21 ± 0.04 | 0.93 |
| RPE | 19.4 ± 1.3 | 19.2 ± 1.0 | 0.66 |
| LPD | 16 ± 5 | 15 ± 3 | 0.49 |

**Table 2: Changes in physiological capacity and handcycling performance using handcycling incremental maximal test from pre- to post-training period for two groups.**

| | Training group (N=9) | | Control group (N=10) | | Interaction (group x time) | | | |
|---|---|---|---|---|---|---|---|---|
| | Pre-test | Post-test | Pre-test | Post-test | p-value | F | Partial Eta square ($\eta^2$) | Observed Power |
| HRpeak (beats·min$^{-1}$) | 182 ± 11 | 188 ± 11[a]* | 182 ± 9 | 183 ± 5 | 0.02[§] | 6.83 | 0.33 | 0.83 |
| $PO_{peak}$ (W) | 81.1 ± 11.2 | 97.4 ± 11.3* | 88.2 ± 18.9 | 91.3 ± 20.7 | 0.00[§§] | 28.88 | 0.59 | 1.00 |
| $PO_{peak}$ (W·kg$^{-1}$) | 1.33 ± 0.19 | 1.59 ± 0.22* | 1.41 ± 0.28 | 1.47 ± 0.30 | 0.00[§§] | 24.03 | 0.74 | 1.00 |
| $RER_{peak}$ | 1.21 ± 0.08 | 1.27 ± 0.07* | 1.21 ± 0.04 | 1.21 ± 0.04 | 0.04[§] | 4.81 | 0.22 | 0.54 |
| $V_{Epeak}$ (L·min$^{-1}$) | 69.2 ± 14.4 | 79.1 ± 17.5 | 73.0 ± 20.1 | 75.7 ± 25.5 | 0.40 | 0.75 | 0.04 | 0.13 |
| $VO_{2peak}$ (L·min$^{-1}$) | 1.60 ± 0.20 | 1.68 ± 0.24 | 1.78 ± 0.42 | 1.81 ± 0.47 | 0.73 | 0.11 | 0.01 | 0.06 |
| $VO_{2peak}$ (ml·min$^{-1}$·kg$^{-1}$) | 26.4 ± 4.6 | 27.5 ± 3.8 | 28.5 ± 7.1 | 29.0 ± 7.4 | 0.74 | 0.10 | 0.01 | 0.06 |
| LPD | 16 ± 5 | 16 ± 8 | 15 ± 3 | 12 ± 4 | 0.26 | 1.01 | 0.06 | 0.16 |
| RPE | 19.4 ± 1.3 | 19.8 ± 0.4 | 19.2 ± 1.0 | 19.6 ± 0.5 | 0.92 | 0.01 | 0.00 | 0.05 |

Data are reported as mean ± SD.

[a]N = 7.

No significant differences were found in baseline values between the training group and the non-training control group.

*Significant different from pre-test ($p < 0.05$).

[§]Significant interaction of group*time ($p < 0.05$).

[§§]Significant interaction of group*time ($p < 0.001$).

**Table 3: Changes in physiological capacity and handcycling performance using submaximal stages 2, 4 & 6 from pre- to post-training period for the two groups**

| | | Training Group | | Control Group | | Difference (%) | | Interaction (group x time) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Pre-test (Mean ± SD) | Post-test (Mean ± SD) | Pre-test (Mean ± SD) | Post-test (Mean ± SD) | Training Pre-Post | Control Pre-Post | P-value | F | Partial Eta square ($\eta^2$) | Observed Power |
| HR (bpm) | Stage 2 | 135 ± 18 | 121 ± 10 | 131 ± 23 | 128 ± 15[a] | -11.6* | -2.3 | 0.07 | 2.52 | 0.14 | 0.32 |
| | Stage 4 | 152 ± 17 | 136 ± 12 | 146 ± 22 | 141 ± 19[a] | -11.8* | -3.4 | 0.26 | 2.27 | 0.14 | 0.29 |
| | Stage 6 | 163 ± 15 | 154 ± 12 | 160 ± 18 | 155 ± 15[a] | -5.8* | -3.1 | 0.24 | 2.04 | 0.13 | 0.27 |
| $VO_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$) | Stage 2 | 690 ± 76 | 589 ± 101 | 744 ± 94 | 703 ± 111 | -17.1* | -5.51 | 0.02[§] | 1.38 | 0.08 | 0.20 |
| | Stage 4 | 958 ± 110 | 803 ± 92 | 921 ± 98 | 894 ± 158 | -19.3* | -2.93 | 0.07 | 3.81 | 0.18 | 0.45 |
| | Stage 6 | 1148 ± 117 | 955 ± 133 | 1151 ± 137 | 1067 ± 159 | -20.2* | -7.30* | 0.15 | 2.30 | 0.12 | 0.30 |
| $V_E$ ($l \cdot min^{-1}$) | Stage 2 | 21.4 ± 3.6 | 16.3 ± 3.1 | 21.8 ± 2.2 | 20.8 ± 2.4 | -31.3* | -4.59 | 0.03[§] | 5.65 | 0.25 | 0.61 |
| | Stage 4 | 28.4 ± 4.1 | 21.7 ± 3.5 | 27.7 ± 4.6 | 26.9 ± 4.0 | -30.9* | -2.89 | 0.03[§] | 5.86 | 0.27 | 0.63 |
| | Stage 6 | 37.6 ± 6.1 | 28.3 ± 4.5 | 36.1 ± 5.5 | 34.1 ± 5.0 | -32.9* | -5.54 | 0.02[§] | 6.18 | 0.27 | 0.65 |
| RER | Stage 2 | 0.97 ± 0.11 | 0.92 ± 0.08 | 0.92 ± 0.06 | 0.92 ± 0.07 | -5.4 | 0.00 | 0.35 | 0.92 | 0.05 | 0.15 |
| | Stage 4 | 0.97 ± 0.08 | 0.95 ± 0.06 | 0.98 ± 0.07 | 0.98 ± 0.06 | -2.1 | 0.00 | 0.27 | 0.34 | 0.02 | 0.09 |
| | Stage 6 | 1.06 ± 0.07 | 1,06 ± 0.05 | 1.04 ± 0.05 | 1.06 ± 0.06 | 0 | 1.92 | 0.28 | 1.25 | 0.07 | 0.18 |
| RPE | Stage 2 | 8.6 ± 1.2 | 6.3 ± 0.5 | 7.4 ± 1.6 | 7.6 ± 1.2 | -36.5* | 2.70 | 0.00[§§] | 7.27 | 0.30 | 1.00 |
| | Stage 4 | 11.7 ± 1.7 | 8.3 ± 1.3 | 10.5 ± 2.9 | 11.0 ± 2.9 | -41.0* | 4.76 | 0.00[§§] | 7.00 | 0.29 | 1.00 |
| | Stage 6 | 14.8 ± 2.4 | 11.0 ± 3.2 | 13.8 ± 3.5 | 14.3 ± 3.2 | -34.5* | 3.62 | 0.00[§§] | 12.77 | 0.43 | 1.00 |

Data are reported as mean ± SD.

[a]N = 7

No significant differences were found in baseline values between the training group and the non-training control group.

*Significant different from pre-test ($p < 0.05$).

[§]Significant interaction of group*time ($p < 0.05$).

[§§]Significant interaction of group*time ($p < 0.001$).

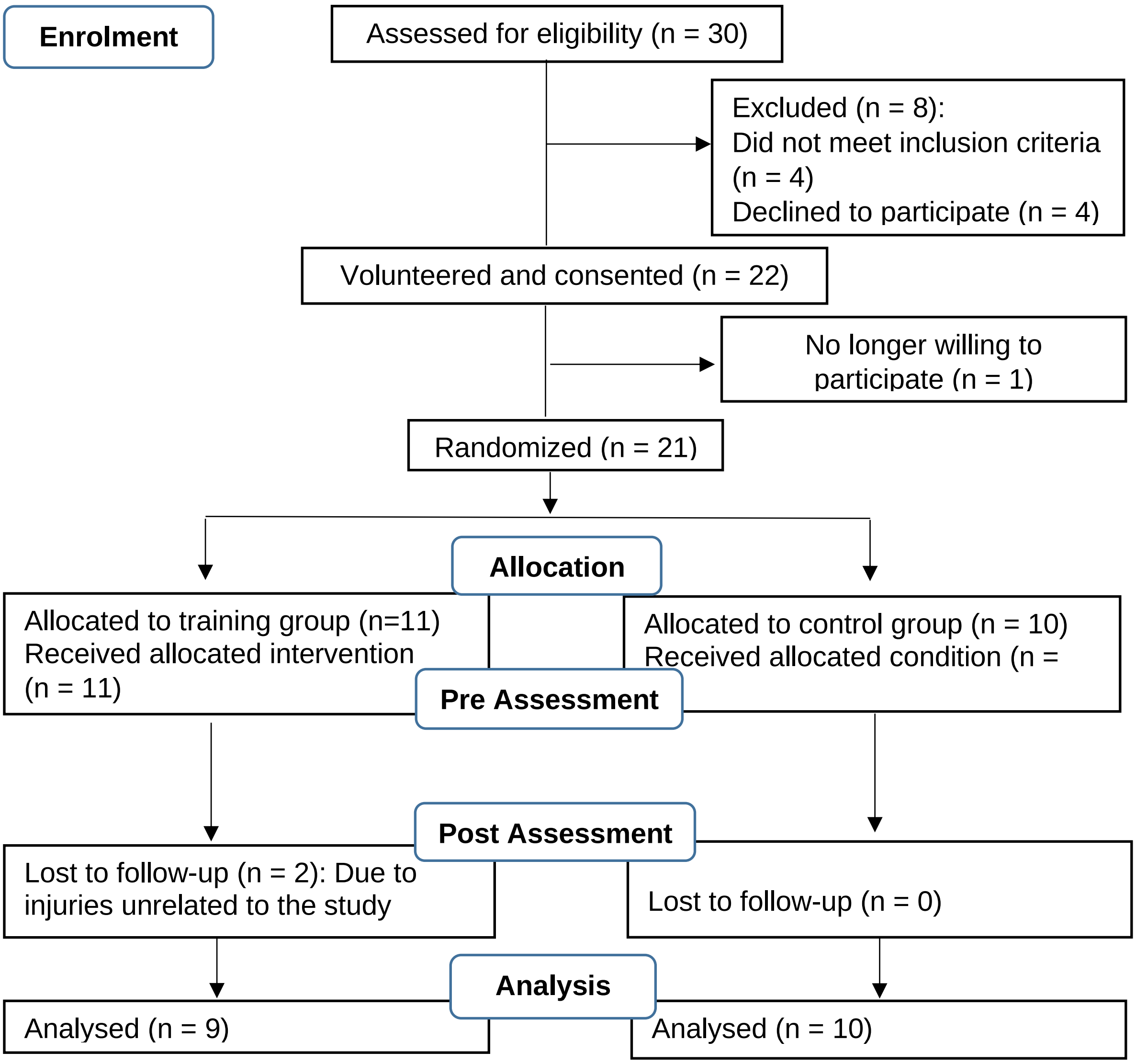


Figure 1 Flowchart of the study

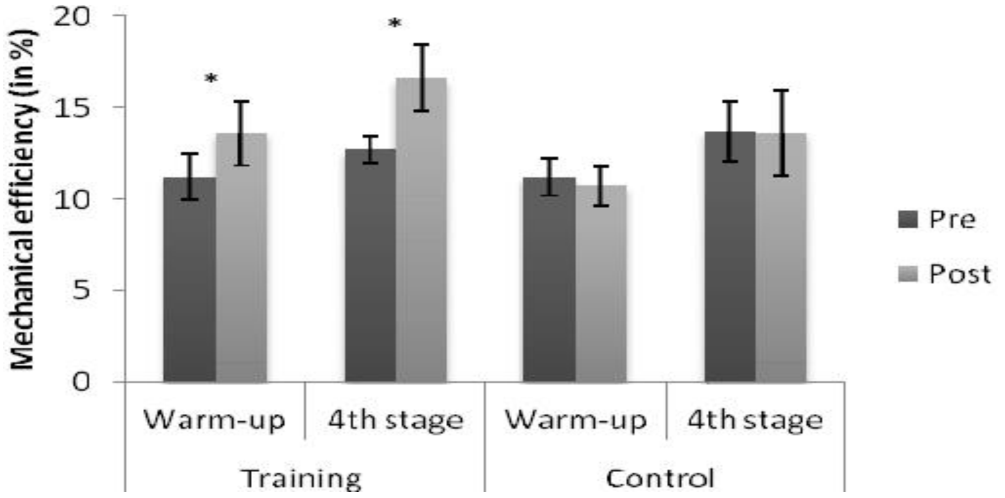


Figure 2: The gross efficiency (GE) (in percentage) at warm up (PO = 30 W) and the 4th stage (PO = 41 W).