VU Research Portal

Changes in Quality of Life During Training for the HandbikeBattle and Associations With Cardiorespiratory Fitness

Kouwijzer, I.; de Groot, S.; van Leeuwen, C.M.; Valent, L.J.; van Koppenhagen, C.F.; van der Woude, L.H.; Post, M.W.

published in

Archives of Physical Medicine and Rehabilitation
2020

DOI (link to publisher)

[10.1016/j.apmr.2019.12.015](https://doi.org/10.1016/j.apmr.2019.12.015)
[10.1016/j.apmr.2019.12.015](https://doi.org/10.1016/j.apmr.2019.12.015)

document version

Publisher's PDF, also known as Version of record

document license

Article 25fa Dutch Copyright Act

[Link to publication in VU Research Portal](#)

citation for published version (APA)

Kouwijzer, I., de Groot, S., van Leeuwen, C. M., Valent, L. J., van Koppenhagen, C. F., van der Woude, L. H., & Post, M. W. (2020). Changes in Quality of Life During Training for the HandbikeBattle and Associations With Cardiorespiratory Fitness. *Archives of Physical Medicine and Rehabilitation*, 101(6), 1017-1024. <https://doi.org/10.1016/j.apmr.2019.12.015>, <https://doi.org/10.1016/j.apmr.2019.12.015>

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal ?

Take down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

E-mail address:

vuresearchportal.ub@vu.nl

ORIGINAL RESEARCH

Changes in Quality of Life During Training for the HandbikeBattle and Associations With Cardiorespiratory Fitness

Ingrid Kouwijzer, MD, MSc,^{a,b,c} Sonja de Groot, PhD,^{b,c} Christel M. van Leeuwen, PhD,^d Linda J. Valent, OT, PhD,^a Casper F. van Koppenhagen, MD, PhD,^e HandbikeBattle Group, Lucas H. van der Woude, PhD,^{b,f} Marcel W. Post, PhD^{d,f}

From the ^aResearch and Development, Heliomare Rehabilitation Center, Wijk aan Zee; ^bUniversity of Groningen, University Medical Center Groningen, Center for Human Movement Sciences, Groningen; ^cAmsterdam Rehabilitation Research Center Reade, Amsterdam; ^dCenter of Excellence for Rehabilitation Medicine, University Medical Center Utrecht Brain Center, University Medical Center Utrecht and De Hoogstraat Rehabilitation, Utrecht; ^eDepartment of Rehabilitation, Physical Therapy Science and Sports, University Medical Center Utrecht Brain Center, University Medical Center Utrecht, Utrecht; and the ^fUniversity of Groningen, University Medical Center Groningen, Center for Rehabilitation, Groningen, the Netherlands.

Abstract

Objective: To investigate (1) changes in life satisfaction and mental health during 5 months of training for the HandbikeBattle and 4 months of follow-up; (2) associations between changes in handcycling cardiorespiratory fitness and changes in life satisfaction and mental health during the training period.

Design: This is a multicenter prospective cohort study with the following measurements: the start of the training (T1), after the 5-month training period, before the event (T2), and after 4 months of follow-up (T3). At T1, T2, and T3, questionnaires were filled out. At T1 and T2, a graded exercise test was performed to measure cardiorespiratory fitness (peak oxygen consumption [VO₂peak] and peak power output [POpeak]).

Setting: Ten Dutch rehabilitation centers training for the HandbikeBattle event.

Participants: Patients with a rehabilitation history (N = 136) and health conditions such as spinal cord injury, amputation, or multiple trauma history.

Interventions: Not applicable.

Main Outcome Measure: Life satisfaction as the sum score of 2 questions (range, 2-13) and the Mental Health subscale of the 36-item Short Form Health Survey (range, 0-100).

Results: Multilevel regression analyses showed that life satisfaction increased during the training period and did not significantly change during follow-up (mean ± SD, T1: 8.2±2.2; T2: 8.6±2.3; T3: 8.5±2.4). Mental health showed no change over time (T1: 77.7±14.5; T2: 77.8±14.5; T3: 75.7±16.5). An improvement in cardiorespiratory fitness was associated with an increase in life satisfaction (POpeak, β=0.014, P=.046; VO₂peak, β=1.068, P=.04). There were no associations between improvement in cardiorespiratory fitness and an increase in mental health (POpeak, P=.66; VO₂peak, P=.33).

Conclusions: This study shows a positive course of life satisfaction during training for the HandbikeBattle. An improvement in cardiorespiratory fitness was longitudinally associated with an increase in life satisfaction. Mental health showed no changes over time.

Archives of Physical Medicine and Rehabilitation 2020;101:1017-24

© 2020 by the American Congress of Rehabilitation Medicine

Supported by HandicapNL (project no. R2015028), Stichting Mitalto, Stichting Beatrixoord Noord-Nederland (project no. 210.175), University Medical Center Groningen, Heliomare Rehabilitation Center, and Stichting Handbike Events.

Disclosures: none.

HandbikeBattle Group: Paul Grandjean Perrenod Comtesse, Adelante Zorggroep, Hoensbroek, the Netherlands; Eric Helmantel, University Medical Center Groningen, Center for Rehabilitation Beatrixoord, Groningen, the Netherlands; Mark van de Mijll Dekker, Heliomare Rehabilitation Center, Wijk aan Zee, the Netherlands; Marenka Zwinkels, Rehabilitation Center De Hoogstraat, Utrecht, the Netherlands; Misha Metsaars, Libra Rehabilitation and Audiology, Eindhoven, the Netherlands; Lise Wilders, Sint Maartenskliniek, Nijmegen, the Netherlands; Linda van Vliet, Amsterdam Rehabilitation Research Center Reade, Amsterdam, the Netherlands; Karin Postma, Rijndam Rehabilitation Center, Rotterdam, the Netherlands; Bram van Gemeren, Roessingh Rehabilitation Center, Enschede, the Netherlands; Alinda Gjaltema, Vogellanden, Zwolle, the Netherlands.

0003-9993/20/\$36 - see front matter © 2020 by the American Congress of Rehabilitation Medicine

<https://doi.org/10.1016/j.apmr.2019.12.015>

Handcycling is a popular mode of daily transportation and exercise in wheelchair users with, for example, a spinal cord injury (SCI), leg amputation, or muscular disease.¹ Compared with wheelchair propulsion, handcycling has a higher efficiency² and lower mechanical strain,³ which possibly reduces the risks of upper-body overuse injuries. Moreover, with handcycling, it is easier to cover large distances at higher speed than with wheelchair propulsion. Therefore, handcycling has been introduced as an exercise mode to increase cardiorespiratory fitness during and after rehabilitation.^{4,5} An increase in cardiorespiratory fitness is necessary for most wheelchair users, as their fitness is generally low.⁶⁻⁸ Low cardiorespiratory fitness is associated with a high prevalence of cardiometabolic disease, which is the leading cause of mortality in this population.^{9,10}

In addition to the potential of reducing cardiometabolic risk factors, it has been shown that improvements in cardiorespiratory fitness are associated with increased quality of life (QoL).^{11,12} Moreover, it has been shown that in people with SCI, life satisfaction (LS) is reduced and mental health problems are more common than in the general population.¹³⁻¹⁵ Therefore, interventions to increase QoL are important.

Participating in exercise and sports might be such an intervention.¹⁶ Several studies showed positive associations between participation in sports and QoL in individuals with physical disabilities, such as SCI, amputation, cerebral palsy, and neuromuscular disease^{12,17-24}; they reported less stress, depressive symptoms, pain, and a higher satisfaction with physical functioning.¹² For example, a lifestyle intervention in adults with cerebral palsy resulted in an increase in health-related QoL (mental health domain) compared with the control group, with cardiorespiratory fitness (peak oxygen consumption [$\text{VO}_{2\text{peak}}$]) explaining 22.6% of this increase.²⁴ Most studies investigated cross-sectional associations, and longitudinal studies are, unfortunately, scarce. A previous longitudinal study showed that an increase in cardiorespiratory fitness was associated with an increase in LS in individuals with SCI.¹¹ Possible mechanisms to explain these longitudinal associations are intermediate effects such as a decrease in pain^{12,21} and increase in self-efficacy,²¹ social integration,^{12,21} and functional independence.^{19,25}

Recognizing the importance of cardiorespiratory fitness and considering the potential positive effects of handcycling, since 2013, the HandbikeBattle is organized to promote handcycling among Dutch patients with a history of rehabilitation.²⁶ The HandbikeBattle is an annual uphill handcycling race in the mountains of Austria among teams of rehabilitation centers. The event was created to initiate an active lifestyle by means of handcycling with peers and to push the participant's physical and mental boundaries. A previous publication showed positive effects of training for the HandbikeBattle on cardiorespiratory fitness and health.⁵ However, longitudinal changes in QoL (LS and mental health¹³) and the associations with cardiorespiratory fitness are

unknown. Therefore, the purpose of this study was to examine: (1) changes in LS and mental health during 5 months of training prior to the HandbikeBattle and at 4 months of follow-up and (2) the associations among changes in handcycling cardiorespiratory fitness and changes in LS and mental health during the training period. It was hypothesized that LS and mental health would increase over time and that this increase would be associated with an increase in cardiorespiratory fitness.

Methods

The HandbikeBattle project

The HandbikeBattle event is a serious challenge (20.2-km length and 863-m elevation gain). At the start of the training period, most participants are relatively untrained handcyclists. Guidance during the training period is provided by therapists from the respective rehabilitation centers, but otherwise the training period is free-living, that is, no specific training program is provided by the researchers. Connected to, but not part of, the HandbikeBattle is an observational cohort study that was initiated to monitor effects of participation in the training period and the event.

Participants

Inclusion criteria for the HandbikeBattle event were (1) being a former rehabilitation patient from 1 of the 10 rehabilitation centers; (2) impairment of the lower extremities (eg, SCI, amputation, cerebral palsy, or spina bifida); and (3) commitment to the HandbikeBattle challenge. The exclusion criterion included any contraindication to participate in the HandbikeBattle as diagnosed during the medical screening. Additional inclusion criteria for the HandbikeBattle study were first time of participation in the HandbikeBattle event and sufficient knowledge of the Dutch language to understand the instructions. In the present study, data were used from participants of the HandbikeBattle 2013-2016 cohorts. In total, 187 individuals started training for the event in this period. Twenty-one individuals dropped out due to motivational problems ($n=9$), medical reasons ($n=5$), overuse injuries ($n=2$), or unknown reasons ($n=5$). Thirty further individuals did not fill out questionnaires at any time point ($n=10$), or only at 1 time point ($n=20$). Hence, data from 136 participants were used in the present study.

Procedure

The study has a prospective design. Measurements are performed at the start of the training period (January, T1); after the training period, prior to the event (June, T2); and at follow-up, 4 months after the event (October, T3; [fig 1](#)). At T1, T2, and T3, participants were asked to fill out questionnaires on LS and mental health. At T1 and T2, participants were asked to fill out a questionnaire about musculoskeletal pain. The questionnaires were part of a set of questionnaires which took participants 30-45 minutes to complete in total. Participants were invited by e-mail with a link and could fill out the questionnaires in their own time at home. At T1, a medical screening was performed by a rehabilitation physician or sports physician at the rehabilitation center. The screening was comprised of a medical anamnesis, physical examination, and a handcycling or arm crank graded exercise test (GXT). At T2, the

List of abbreviations:

GXT	graded exercise test
LS	life satisfaction
MHI-5	Mental Health Inventory
PO	power output
POpeak	peak power output
QoL	quality of life
SCI	spinal cord injury
VO _{2peak}	peak oxygen consumption

Fig 1 Study design. Measurements are performed at the start of the training period (January, T1); after the training period, prior to the event (June, T2); and follow-up, 4 months after the event (October, T3). ; Abbreviations: HBB, HandbikeBattle event; MH, mental health.

GXT was repeated with the same protocol and equipment. All participants voluntarily signed an informed consent form. The study was approved by the local ethics committee of the Center for Human Movement Sciences, University Medical Center Groningen, the Netherlands (ECB/2012_12.04_1_rev/MI).

Measurement instruments

General participant information was collected at T1 and included age (y), sex (male or female), and impairment type (SCI, amputation, multiple traumas, spina bifida, or other).

Outcome measures

LS was assessed with the 2LS, consisting of 2 questions.^{27,28} Question 1 stated satisfaction with life as a whole at the moment (LS Now, 1=very unsatisfying, 6=very satisfying). Question 2 stated satisfaction with life now compared with life before the onset of the condition (LS Comparison, 1=much worse, 7=much better). The sum score (LS) ranges from 2-13. LS was only calculated for participants with an acquired impairment, as, LS Comparison was not collected from individuals with a congenital impairment. The validity of the LS questions was supported.²⁸

Mental health was assessed with the Mental Health Inventory (MHI-5) of the 36-item Short Form Health Survey.^{29,30} The MHI-5 consists of 5 items concerning nervousness, sadness, peacefulness, mood, and happiness on a 6-point scale, a sum score was calculated ranging from 0 (lowest mental health) to 100 (highest mental health).²⁹ A cutoff point of ≤ 72 refers to mental health problems, and a cutoff point of ≤ 60 refers to severe mental health problems.^{31,32} Mental health showed a non-normal distribution (skewness, -0.76; SE 0.13). Therefore, logarithmically transformed scores were used in the statistical analyses. The MHI-5 showed reliability and validity in persons with SCI.³⁰

Determinants

Cardiorespiratory fitness was measured during an incremental handcycling or arm crank GXT to volitional exhaustion at T1 and T2, organized in and conducted by the staff of each of the participating rehabilitation centers. Details on equipment and testing protocols have been described in a previous study.³³ Either a 1-minute step protocol or continuous ramp protocol was used,

and was individualized for each participant. The set-up and protocol choice were dependent on the available equipment in the rehabilitation centers, but were consistent within participants over time. Power output (PO) in Watts and oxygen consumption in liters per minute were measured during the test. For the 1-minute protocol, POpeak was defined as the highest PO that was maintained for at least 30 seconds. For the ramp protocol, the highest PO achieved during the test was considered POpeak. Peak Vo_2 was defined as the highest 30-second average for oxygen consumption.

Possible confounding variables

Possible confounding variables were age, sex, musculoskeletal pain, and handcycling classification. Musculoskeletal pain comprised 7 locations: the left and right hand and wrist, the left and right elbow, the left and right shoulder, and the neck. The pain was graded on a range from 1=no pain to 6=very severe pain. Having moderate-severe pain was defined as ≥ 4 (moderate pain) at ≥ 1 locations.

Handcycling classification was used as a proxy for severity of impairment and determined by an Union Cycliste Internationale certified paracycling classifier, following the Union Cycliste Internationale Para-cycling Regulations. The classification resulted in 5 different classes, ranging from H1 (most impaired) to H5 (least impaired).³⁴ H1 and H2 handcyclists have limitations in arm-hand function, whereas H3, H4, and H5 handcyclists have intact arm-hand function and limitations in the trunk or lower extremities only. For the analyses in the present study, participants were divided in 2 large groups: (1) H1-H3 and (2) H4 and H5.

Statistical analysis

The analyses were performed using SPSS software version 20^a and MLwiN version 2.02.^{35,b} Descriptive statistics were calculated for outcome measures and determinants. Data were tested for normality with the Kolmogorov-Smirnov test with Lilliefors significance correction and the Shapiro-Wilk test, combined with z scores for skewness and kurtosis. To ascertain possible response bias, characteristics of included participants in the present study ($N=136$) were compared with nonparticipants ($n=51$) using t tests, Mann-Whitney U tests, and chi-square tests.

Three-level multilevel models were created with observations within participants as first level, participant as second level, and

Table 1 Characteristics and outcomes at T1 for participants and nonparticipants

Characteristics	n	Participants	n	Nonparticipants
Sex (male/female), n (%)	136	109/27 (80/20)	51	40/11 (78/22)
Mean age (y) $\pm$ SD	136	41 $\pm$ 13	49	35 $\pm$ 12*
Impairment type, n (%)	136		44	
Spinal cord injury		96 (71)		31 (71)
Tetraplegia		10 (8)		8*
Paraplegia		86 (63)		23*
Amputation		17 (13)		3 (7)
Multiple trauma		2 (1)		2 (4)
Spina bifida		6 (4)		2 (4)
Other		15 (11)		6 (14)
Mean LS $\pm$ SD	110	8.2 $\pm$ 2.2	20	7.7 $\pm$ 2.4
T1 (range, 2-13)				
Mean mental health $\pm$ SD	122	77.7 $\pm$ 14.5	20	68.2 $\pm$ 18.1*
T1 (range, 0-100)				
Mean POpeak (W) $\pm$ SD T1	107	126 $\pm$ 37	32	113 $\pm$ 32
Mean VO ₂ peak (L/min) $\pm$ SD T1	123	2.01 $\pm$ 0.57	36	1.85 $\pm$ 0.40
Musculoskeletal pain (no-mild/moderate-severe), n (%) T1	121	74/47 (61/39)	20	9/11 (45/55)
Handcycling classification (H1-H3/H4-H5), n (%)	136	60/76 (44/56)	33	15/18 (46/54)

NOTE. Data are represented as n (%) or mean $\pm$ SD. Musculoskeletal pain has 2 categories: (1) no or mild pain and (2) moderate or severe pain. Handcycling classification has 2 categories: (1) H1-H3 and (2) H4 and H5.

* Significant difference with $P < .05$ between participants and nonparticipants.

rehabilitation center as third level to make adjustments for the dependency of the observations within participants and participants within centers.³⁶

To answer the first research question on the longitudinal trajectory of LS and mental health over time, 2 models were created: one with LS and one with mental health as dependent variable. Time (T1, T2, T3) was included as a categorical variable with 2 dummies and T2 as reference category.

To answer the second research question on the longitudinal associations, 4 models were created, one for each of the combinations of POpeak or VO₂peak as independent variables and LS or mental health as dependent variables (T1, T2). To be able to distinguish between the between-subject component and the within-subject component, the 4 models were created as hybrid models.³⁷ The between-subject component reflects the cross-sectional association between 2 variables. The within-subject component reflects the longitudinal association; for example, an increase in cardiorespiratory fitness is associated with an increase

in LS. In a standard longitudinal model, there is one regression coefficient that reflects both components of the association, whereas in the present study we are mostly interested in the within-subject component. A hybrid model accounts for this by providing separate regression coefficients with standard errors for each component.³⁷ Possible confounding variables including age, sex (reference: male), musculoskeletal pain (reference: no or mild), and handcycling classification (reference: H1-H3) were added separately to each model first. A variable was included as confounder in the final model if its inclusion changed the regression coefficient with more than 10%.³⁶

Results

Participants were on average older, had a paraplegia more often, and had higher scores for mental health, than nonparticipants (table 1). Descriptive data of the outcome measures and

Table 2 Descriptive data and outcome measures of participants at all time points

Variables	n	T1	n	T2	n	T3
LS	110	8.2 $\pm$ 2.2	110	8.6 $\pm$ 2.3	100	8.5 $\pm$ 2.4
Mental health	122	77.7 $\pm$ 14.5	124	77.8 $\pm$ 14.5	109	75.7 $\pm$ 16.5
POpeak (W)	107	126 $\pm$ 37	105	141 $\pm$ 46		
VO ₂ peak (L/min)	123	2.01 $\pm$ 0.57	112	2.13 $\pm$ 0.63		
Musculoskeletal pain (no-mild/moderate-severe), n (%)	121	74/47 (61/39)	124	88/36 (71/29)		

NOTE. Data are represented as n (%) or mean $\pm$ SD. Musculoskeletal pain has 2 categories: (1) no or mild pain and (2) moderate or severe pain. T1 represents the start of the training period. T2 represents after the training period, prior to the HandbikeBattle event. T3 represents the follow-up measurement, 4 months after training.

Table 3 Longitudinal trajectory of LS and mental health

Independent Variable	LS (n=124)			Mental Health (n=133)			Mental Health Subgroup (n=38)		
	Regression Coefficient	SE	P Value	Regression Coefficient	SE	P Value	Regression Coefficient	SE	P Value
Constant (reference T2)	8.610	0.206		1.116	0.024		0.920	0.029	
Δ T2-T1	-0.502	0.146	<.01*	-0.018	0.020	.37	-0.099	0.028	<.01*
Δ T2-T3	-0.169	0.183	.36	-0.023	0.027	.39	-0.032	0.032	.32

NOTE. T1 represents the start of the training period. T2 represents after the training period, prior to the HandbikeBattle event. T3 represents the follow-up measurement, 4 months after training.

The transformed value of mental health was used for analysis. Mental health subgroup represents participants with score ≤72 at T1. The Δ T2-T1 = a negative regression coefficient representing an improvement of the dependent variable over time. The Δ T2-T3 = a negative regression coefficient representing a deterioration of the dependent variable over time.

* Significance with $P < .05$.

determinants over time are depicted in table 2. Participants were classified with the following distribution: H1, n=7; H2, n=4; H3, n=49; H4, n=57; and H5, n=19.

Longitudinal trajectory of LS and mental health

LS showed a significant increase between T1 (start of training) and T2 (after training), and did not significantly change between T2 and T3 (follow-up) (table 3). When the model was recalculated with T1 as reference category, there was still a significant increase between T1 and T2, but no significant change between T1 and T3 (regression coefficient, 0.333; SE, 0.183; $P = .07$).

Mental health showed no significant change over time (see table 3). When the model was recalculated with T1 as reference category, there were no changes over time. However, a subgroup analysis with participants with mental health problems at T1 (score ≤72; n=38) showed a significant increase between T1 and T2, and no significant change between T2 and T3 (see table 3). In addition, there was a significant increase between T1 and T3 (regression coefficient, 0.069; SE, 0.028; $P = .01$). The mean scores ± SD were as follows: T1: 60.0±10.1; T2: 67.1±14.7; T3: 63.4±15.0.

Longitudinal associations between cardiorespiratory fitness and LS

Peak PO as well as VO_{2peak} showed a significant within-subject component association with LS (table 4). After adding

confounders to the model with POpeak, the within-subject component association between POpeak and LS remained significant (table 5). After adding confounders to the model with VO_{2peak} , both the within-subject and between-subject component associations between VO_{2peak} and LS were significant (see table 5).

Longitudinal associations between cardiorespiratory fitness and mental health

POpeak showed no significant association with mental health (see table 4). Peak VO_2 showed a significant between-subject, but no within-subject component association with mental health (see table 4). After adding confounders to the models, there were no significant associations among cardiorespiratory fitness and mental health (see table 5). However, a subgroup analysis with participants with mental health problems at T1 (score ≤72; n=38) showed that POpeak had a significant between-subject and within-subject component association with mental health (see table 5). Peak VO_2 showed only a significant within-subject component association (see table 5).

Discussion

The present study showed that LS increased during 5 months of training for the HandbikeBattle and did not significantly change during follow-up. LS at follow-up was, however, not significantly

Table 4 Basic models without confounders: longitudinal and cross-sectional associations between cardiorespiratory fitness and QoL (T1, T2)

Independent Variable	LS			Mental Health			Mental Health Subgroup		
	Regression Coefficient	SE	P Value	Regression Coefficient	SE	P Value	Regression Coefficient	SE	P Value
POpeak (W)	(n=84)			(n=87)			(n=25)		
Constant	8.409	0.851		0.954	0.088		0.690	0.095	
Between-subject	0.000	0.006	>.99	0.001	0.001	.10	0.001	0.001	.06
Within-subject	0.017	0.007	.02*	0.001	0.001	.37	0.005	0.002	<.01*
VO_{2peak} (L/min)	(n=97)			(n=99)			(n=31)		
Constant	6.869	0.819		0.864	0.093		0.750	0.088	
Between-subject	0.741	0.385	.05	0.103	0.044	.02*	0.054	0.043	.21
Within-subject	1.315	0.507	<.01*	0.091	0.061	.14	0.240	0.113	.03*

Note. The transformed value of mental health was used for analysis. Mental health subgroup represents participants with score ≤72 at T1.

* Significance with $P < .05$.

Table 5 Final models with confounders: longitudinal and cross-sectional associations between cardiorespiratory fitness and QoL (T1, T2)

Independent Variable	LS			Mental Health			Mental Health Subgroup		
	Regression Coefficient	SE	P Value	Regression Coefficient	SE	P Value	Regression Coefficient	SE	P Value
POpeak (W)	(n = 84)			(n = 87)			(n = 25)		
Constant	7.788	0.961		0.926	0.127		0.721	0.092	
Between-subject	0.004	0.007	.57	0.001	0.001	.32	0.001	0.001	.03*
Within-subject	0.014	0.007	.046*	0.000	0.001	.66	0.004	0.002	.01*
Confounders									
Age	-	-		0.003	0.002	.14	-	-	
Sex	0.886	0.735	.23	-0.043	0.069	.54	-	-	
Musculoskeletal pain	-0.669	0.381	.08	-0.098	0.040	.01	-0.095	0.050	.06
Classification	0.472	0.481	.33	-	-		-	-	
Vo ₂ peak (L/min)	(n = 97)			(n = 99)			(n = 31)		
Constant	6.644	0.904		0.974	0.107		0.750	0.088	
Between-subject	0.904	0.406	.03*	0.073	0.047	.12	0.054	0.043	.21
Within-subject	1.068	0.516	.04*	0.060	0.062	.33	0.240	0.113	.03*
Confounders									
Age	-	-		-	-		-	-	
Sex	0.807	0.630	.20	-0.071	0.068	.29	-	-	
Musculoskeletal pain	-0.708	0.332	.03	-0.101	0.038	<.01	-	-	
Classification	-	-		-	-		-	-	

NOTE. The transformed value of mental health was used for analysis. Mental health subgroup represents participants with score ≤ 72 at T1. Sex: reference male. Musculoskeletal pain has 2 categories: (1) no or mild pain and (2) moderate or severe pain (reference: no or mild). Handcycling classification has 2 categories: (1) H1-H3 and (2) H4 and H5 (reference: H1-H3). A variable was included as confounder if the regression coefficient of POpeak or Vo₂peak changed more than 10%.

* Significance with $P < .05$.

higher than LS at the start of the training period. Mental health showed no significant change over time for the total group. The results of this study further showed that, over time, an improvement in cardiorespiratory fitness was associated with an increase in LS. There were no associations between improvement in cardiorespiratory fitness and increase in mental health for the total group, however, those with low mental health showed a positive longitudinal association.

The results with respect to LS are in line with a previous longitudinal study in which a positive association was found between cardiorespiratory fitness and LS measured from the start of active rehabilitation until 5 years after discharge in individuals with an SCI.¹¹ Previously mentioned underlying mechanisms for the association between cardiorespiratory fitness and QoL include enhanced feelings of self-worth, self-efficacy and personal control, increased social interaction, reduced pain, and increased production of neurotransmitters regulating emotions.²⁰ Other intermediate effects might be the positive effect of an increase in cardiorespiratory fitness on functional independence and activities of daily living,^{19,27,38,39} or body image and satisfaction.^{40,41}

In contrast to previous studies,^{12,20,24} mental health did not significantly change over time. A possible explanation for this lack of change is that mental health scores were already high at baseline, the average of 77.7 is even above the mean score of 76.8 in the general Dutch population.⁴² A similar mean score of 77.2 was found among Dutch individuals with an SCI 5 years after discharge from initial inpatient rehabilitation.^{30,43} Although there was no ceiling effect in the present study, this high baseline score might be less susceptible to change. In addition, mental health was not significantly associated with cardiorespiratory fitness. It might

be that mental health is less susceptible to changes in cardiorespiratory fitness and physical functioning than LS. In previous studies, LS was positively associated with functional independence,^{27,39} whereas mental health was not.^{43,44} Psychological factors such as self-efficacy, mastery, acceptance, and purpose in life might be more important determinants to improve mental health.⁴⁴⁻⁴⁶

Nevertheless, a subgroup analysis of participants with a mental health score ≤ 72 at T1 showed that there was an improvement over time and that this improvement was associated with an increase in cardiorespiratory fitness. Although it is a small group and regression to the mean could have played a role, these findings suggest that an increase in cardiorespiratory fitness might have a positive effect on mental health in individuals with lower mental health scores at baseline. There seems to be only a thin line, as nonparticipants also had a low mental health score. More intensive (mental health) guidance might be warranted for individuals with low mental health; this may prevent them from dropping out during the training period.

Implications and future studies

The present study is one of few studies that examined longitudinal associations between cardiorespiratory fitness and QoL. Unique aspects are that the training is free-living with peers and that participants are training toward a goal. In future studies, it would be interesting to examine which training regimes led to these improvements in cardiorespiratory fitness and to provide long term follow-up results on the association between cardiorespiratory fitness and QoL in individuals participating in the

HandbikeBattle. In addition, it would be interesting to unravel in more detail for which individuals in or after rehabilitation an increase in cardiorespiratory fitness would be most effective in increasing QoL and by which underlying mechanisms this could be achieved. Moreover, other determinants that could potentially affect QoL, such as peer support or psychological factors, should be investigated. The use of questionnaires or interviews would be valuable to gain knowledge about benefits (and adverse effects) of participating in and training for such an event.

Study limitations

There might be a selection bias, as individuals who dropped out before or during the training period were not included in the analyses. Therefore, individuals with a very low cardiorespiratory fitness might be less prominent in the present study. In addition, it might be possible that individuals with a very low mental health or LS score are not willing to participate in an event like the HandbikeBattle. It is, however, important to mention that the event was created to push physical and mental boundaries for individuals who might need this and that participants were not professional athletes. Lastly, only the association between cardiorespiratory fitness and QoL was investigated. Other possible determinants of QoL should be addressed in future studies.

Conclusions

LS increased during the training period and did not significantly change during follow-up. Mental health showed no change over time for the total group of participants. The present study showed that cardiorespiratory fitness and LS are longitudinally associated, that is, an improvement in cardiorespiratory fitness was associated with an increase in LS.

Suppliers

- a. SPSS version 20; IBM Corp.
- b. MLwiN version 2.02; University of Bristol.

Keywords

Exercise; Longitudinal study; Quality of life; Rehabilitation

Corresponding author

Ingrid Kouwijzer, MD, MSc, Research and Development, Heliomare Rehabilitation Center, Relweg 51, 1949 EC Wijk aan Zee, the Netherlands. *E-mail address:* i.kouwijzer@heliomare.nl.

Acknowledgments

We thank Jos Twisk, PhD, Department of Epidemiology and Biostatistics, University Medical Center Amsterdam, Amsterdam, the Netherlands, for his support with the study statistics, and Sjoerd Jansman, MSc, University of Groningen, University Medical Center Groningen, Center for Human Movement

Sciences, Groningen, the Netherlands, for his support with data processing.

References

1. Abel T, Vanlandewijck Y, Verellen J. Handcycling. In: Goosey-Tolfrey V, ed. *Wheelchair sport*. Champaign: Human Kinetics; 2010. p 187-97.
2. Dallmeijer AJ, Zentgraaff ID, Zijp NI, Van Der Woude LH. Submaximal physical strain and peak performance in handcycling versus handrim wheelchair propulsion. *Spinal Cord* 2004; 42:91-8.
3. Arnet U, Van Drongelen S, Scheel-Sailer A, Van Der Woude LH, Veeger DH. Shoulder load during synchronous handcycling and handrim wheelchair propulsion in persons with paraplegia. *J Rehabil Med* 2012;44:222-8.
4. Valent LJ, Dallmeijer AJ, Houdijk H, et al. Effects of hand cycle training on physical capacity in individuals with tetraplegia: a clinical trial. *Phys Ther* 2009;89:1051-60.
5. Hoekstra S, Valent L, Gobets D, van der Woude L, de Groot S. Effects of four-month handbike training under free-living conditions on physical fitness and health in wheelchair users. *Disabil Rehabil* 2017; 39:1581-8.
6. van den Berg-Emons RJ, Bussmann JB, Haisma JA, et al. A prospective study on physical activity levels after spinal cord injury during inpatient rehabilitation and the year after discharge. *Arch Phys Med Rehabil* 2008;89:2094-101.
7. Haisma JA, Van Der Woude LH, Stam HJ, Bergen MP, Sluis TA, Bussmann JB. Physical capacity in wheelchair-dependent persons with a spinal cord injury: a critical review of the literature. *Spinal Cord* 2006;44:642-52.
8. Jacobs PL, Nash MS. Exercise recommendations for individuals with spinal cord injury. *Sports Med* 2004;34:727-51.
9. Garshick E, Kelley A, Cohen SA, et al. A prospective assessment of mortality in chronic spinal cord injury. *Spinal Cord* 2005;43: 408-16.
10. Nightingale TE, Metcalfe RS, Vollaard NB, Bilzon JL. Exercise guidelines to promote cardiometabolic health in spinal cord injured humans: time to raise the intensity? *Arch Phys Med Rehabil* 2017;98: 1693-704.
11. van Koppenhagen CF, Post M, de Groot S, et al. Longitudinal relationship between wheelchair exercise capacity and life satisfaction in patients with spinal cord injury: a cohort study in the Netherlands. *J Spinal Cord Med* 2014;37:328-37.
12. Hicks AL, Martin KA, Ditor DS, et al. Long-term exercise training in persons with spinal cord injury: effects on strength, arm ergometry performance and psychological well-being. *Spinal Cord* 2003;41:34-43.
13. Post MW, van Leeuwen CM. Psychosocial issues in spinal cord injury: a review. *Spinal Cord* 2012;50:382-9.
14. van Koppenhagen CF, Post MW, van der Woude LH, et al. Changes and determinants of life satisfaction after spinal cord injury: a cohort study in The Netherlands. *Arch Phys Med Rehabil* 2008;89: 1733-40.
15. Dijkers MP. Quality of life of individuals with spinal cord injury: a review of conceptualization, measurement, and research findings. *J Rehabil Res Dev* 2005;42:87-110.
16. Chekroud SR, Gueorguieva R, Zheutlin AB, et al. Association between physical exercise and mental health in 1.2 million individuals in the USA between 2011 and 2015: a cross-sectional study. *Lancet Psychiatry* 2018;5:739-46.
17. Anneken V, Hanssen-Dooze A, Hirschfeld S, Scheuer T, Thietje R. Influence of physical exercise on quality of life in individuals with spinal cord injury. *Spinal Cord* 2010;48:393-9.
18. Ditor DS, Latimer AE, Ginis KA, Arbour KP, McCartney N, Hicks AL. Maintenance of exercise participation in individuals with

- spinal cord injury: effects on quality of life, stress and pain. *Spinal Cord* 2003;41:446-50.
19. Sweet SN, Ginis KA, Tomasone JR. Investigating intermediary variables in the physical activity and quality of life relationship in persons with spinal cord injury. *Health Psychology* 2013;32:877-85.
 20. Ginis KA, Jetha A, Mack DE, Hetz S. Physical activity and subjective well-being among people with spinal cord injury: a meta-analysis. *Spinal Cord* 2010;48:65-72.
 21. Motl RW, McAuley E. Pathways between physical activity and quality of life in adults with multiple sclerosis. *Health Psychol* 2009;28:682-9.
 22. Kroops LA, Jaarsma EA, Dijkstra PU, Geertzen JH, Dekker R. Health related quality of life in a Dutch rehabilitation population: reference values and the effect of physical activity. *PLoS One* 2017;12:e0169169.
 23. Bragaru M, Dekker R, Geertzen JH, Dijkstra PU. Amputees and sports. A systematic review. *Sports Med* 2011;41:721-40.
 24. Slaman J, van den Berg-Emons HJ, van Meeteren J, et al. A lifestyle intervention improves fatigue, mental health and social support among adolescents and young adults with cerebral palsy: focus on mediating effects. *Clin Rehabil* 2015;29:717-27.
 25. Haisma JA, Post MW, van der Woude LH, et al. Functional independence and health-related functional status following spinal cord injury: a prospective study of the association with physical capacity. *J Rehabil Med* 2008;40:812-8.
 26. de Groot S, Postma K, Van Vliet L, Timmermans R, Valent LJ. Mountain time trial in handcycling: Exercise intensity and predictors of race time in people with spinal cord injury. *Spinal Cord* 2014;52:455-61.
 27. van Koppenhagen CF, Post MW, van der Woude LH, et al. Recovery of life satisfaction in persons with spinal cord injury during inpatient rehabilitation. *Am J Phys Med Rehabil* 2009;88:887-95.
 28. Post MW, van Leeuwen CM, van Koppenhagen CF, de Groot S. Validity of the Life Satisfaction Questions, the Life Satisfaction Questionnaire, and the Satisfaction With Life Scale in persons with spinal cord injury. *Arch Phys Med Rehabil* 2012;93:1832-7.
 29. Ware JE, Snow KK, Kosinski M, Gandek B. Scoring the SF-36. In: *SF-36 Health Survey: manual and interpretation guide*. Boston: The Health Institute, New England Medical Center; 1993. p 1-22.
 30. van Leeuwen CM, van der Woude LH, Post MW. Validity of the mental health subscale of the SF-36 in persons with spinal cord injury. *Spinal Cord* 2012;50:707-10.
 31. Perenboom R, Oudshoorn K, van Herten L, Hoeymans N, Bijl R. Life expectancy in good mental health: establishing cut-offs for the MHI-5 and GHQ-12 [Dutch]. Leiden: TNO Publications; 2000.
 32. Hoeymans N, Garssen AA, Westert GP, Verhaak PF. Measuring mental health of the Dutch population: a comparison of the GHQ-12 and the MHI-5. *Health Qual Life Outcomes* 2004;2:23.
 33. Kouwijzer I, Valent L, Osterthun R, van der Woude LH, de Groot S; HandbikeBattle Group. Peak power output in handcycling of individuals with a chronic spinal cord injury: predictive modeling, validation and reference values. *Disabil Rehabil* 2020;42:400-9.
 34. Union Cycliste Internationale. Cycling regulations, part 16 para-cycling. Available at: https://www.uci.org/docs/default-source/rules-and-regulations/part-xvi-para-cycling.pdf?sfvrsn=47af1c56_34. Accessed November 25, 2018.
 35. Rasbash J, Charlton C, Browne W, et al. MLwiN version 2.02. Centre for multilevel modelling. Bristol (UK): University of Bristol; 2005.
 36. Twisk JW. Applied longitudinal data analysis for epidemiology. A practical guide. 4th ed. Cambridge (UK): Cambridge University Press; 2003.
 37. Twisk JW, De Vente W. Hybrid models were found to be very elegant to disentangle longitudinal within- and between-subject relationships. *J Clin Epidemiol* 2019;107:66-70.
 38. van Leeuwen CM, Post MW, Hoekstra T, et al. Trajectories in the course of life satisfaction after spinal cord injury: identification and predictors. *Arch Phys Med Rehabil* 2011;92:207-13.
 39. van Leeuwen CM, Post MW, van Asbeck FW, et al. Life satisfaction in people with spinal cord injury during the first five years after discharge from inpatient rehabilitation. *Disabil Rehabil* 2012;34:76-83.
 40. Bassett RL, Ginis KA, Buchholz AC; SHAPE SCI Research Group. A pilot study examining correlates of body image among women living with SCI. *Spinal Cord* 2009;47:496-8.
 41. Reboussin BA, Rejeski WJ, Martin KA, et al. Correlates of satisfaction with body function and body appearance in middle- and older aged adults: the activity counseling trial (ACT). *Psychol Health* 2000; 15:239-54.
 42. Aaronson NK, Muller M, Cohen PD, et al. Translation, validation, and norming of the Dutch language version of the SF-36 Health Survey in community and chronic disease populations. *J Clin Epidemiol* 1998; 51:1055-68.
 43. van Leeuwen CM, Hoekstra T, van Koppenhagen CF, de Groot S, Post MW. Trajectories and predictors of the course of mental health after spinal cord injury. *Arch Phys Med Rehabil* 2012;93:2170-6.
 44. van Leeuwen CM, Post MW, Westers P, et al. Relationships between activities, participation, personal factors, mental health, and life satisfaction in persons with spinal cord injury. *Arch Phys Med Rehabil* 2012;93:82-9.
 45. van Leeuwen CM, Kraaijeveld S, Lindeman E, Post MW. Associations between psychological factors and quality of life ratings in persons with spinal cord injury: a systematic review. *Spinal Cord* 2012;50:174-87.
 46. van Leeuwen CM, Edelaar-Peters Y, Peter C, Stiggelbout AM, Post MW. Psychological factors and mental health in persons with spinal cord injury: an exploration of change or stability. *J Rehabil Med* 2015;47:531-7.