Heart rate recovery after the 10-meter incremental shuttle walking test in older adults with intellectual disabilities

Running head: Heart rate recovery older adults with ID

Authors: Alyt Oppewal[a], Thessa I.M. Hilgenkamp[a,b],

Ruud van Wijck[c], Heleen M. Evenhuis[a]

[a] Intellectual Disability Medicine, Department of General Practice, Erasmus MC, University Medical Center Rotterdam, P.O. Box 2040, 3000 CA Rotterdam, The Netherlands

[b] Abrona, Amersfoortseweg 56, 3712 BE Huis ter Heide, The Netherlands

[c] Center for Human Movement Sciences, University of Groningen, University Medical Center Groningen, A. Deusinglaan 1, 9713 AV Groningen, The Netherlands

Corresponding author:

Alyt Oppewal at Erasmus MC, University Medical Center Rotterdam, Department of General Practice, Intellectual Disability Medicine, P.O. Box 2040, 3000 CA Rotterdam, The Netherlands.

Tel.: +31 107032118

E-mail address: a.oppewal@erasmusmc.nl (A. Oppewal).

Abstract

Heart rate recovery (HRR) after exercise is an independent predictor for cardiovascular and all-cause mortality. To investigate the usefulness of HRR in cardiorespiratory exercise testing in older adults with intellectual disabilities (ID), the aims of this study were (a) to assess HRR in older adults with ID after the 10-meter incremental shuttle walking test (ISWT) and (b) its association with personal characteristics (gender, age, distance walked on the ISWT, level of ID, genetic syndrome causing ID, autism, behavioural problems, and peak heart rate [HRpeak]). HRR was assessed after the 10-meter incremental shuttle walking test in 300 older adults (> 50 years) with borderline to profound ID. HRR was defined as the change from HRpeak during the ISWT to heart rate measured after 1, 2, 3, 4, and 5 minutes of passive recovery. The largest decrease in heart rate was in the first minute of recovery leveling off towards the fifth minute of recovery. An abnormal HHR (≤ 12 bpm) was seen in 36.1% of the participants with Down syndrome (DS) and in 30.7% of the participants with ID by other causes. After the fifth minute the heart rates of 69.4% of the participants with DS and of 61.4% of the participants with ID by other causes returned to resting levels. HRpeak and distance walked on de the ISWT were positively related to all HRR measures. More severe ID was negatively related and having DS positively related to HRR after 3 to 5 minutes of recovery. The other characteristics were not significantly associated to HRR. HRR is a potentially useful outcome measure in cardiorespiratory fitness testing of older adults with ID with a direct, objective, and non-invasive measurement. Further research is needed to identify the relation between HRR and adverse health outcomes in this population.

Keywords: Heart rate recovery, cardiorespiratory fitness testing, intellectual disabilities, older adults

1. Introduction

After exercise, heart rate returns to resting levels due to the combination of parasympathetic reactivation and sympathetic withdrawal, and therefore reflects the activity of the autonomic nervous system (Pierpont, Adabag, & Yannopoulos, 2013). A delayed heart rate recovery (HRR) after exercise is an independent predictor for cardiovascular events and all-cause mortality in healthy adults and those with cardiovascular diseases and systemic disorders, such as diabetes mellitus and hypertension (Cahalin et al., 2013; Johnson & Goldberger, 2012; Messinger-Rapport, Pothier Snader, Blackstone, Yu, & Lauer, 2003; Okutucu, Karakulak, Aytemir, & Oto, 2011; Sharma, Kohli, & Gulati, 2012). Because increasing age is a risk factor for cardiovascular diseases, assessment of HRR in older adults is an important outcome measure in cardiorespiratory fitness testing of older adults (American College of Sports Medicine [ACSM], 2013; Kligfield & Lauer, 2006; Shetler et al., 2001; World Health Organization [WHO], 2007).

Despite of its clinical importance, HRR is little used in cardiorespiratory fitness evaluations of individuals with intellectual disabilities (ID). The few studies of HRR in adults with DS showed that individuals with DS had lower peak heart rates and lower HRR than controls with normal intelligence (Figueroa et al., 2005; Mendonca & Pereira, 2010; Mendonca, Pereira, & Fernhall, 2013). However, most studies regarding cardiorespiratory fitness of individuals with ID have focused on heart rate response during exercise and maximal oxygen uptake ($\dot{V}O_2max$). These studies show that individuals with ID have poor cardiorespiratory fitness and low peak heart rates (HRpeak), especially individuals with Down syndrome (DS) (Fernhall & Pitetti, 2001; Mendonca, Pereira, & Fernhall, 2010; Oppewal, Hilgenkamp, van Wijck, & Evenhuis, 2013). This may be because of an altered autonomic control (Acampa et al., 2008; Dipla et al., 2013; Guideri et al., 2004; Mendonca et al., 2010).

HRR may therefore be an interesting outcome measure in cardiorespiratory fitness testing of individuals with ID.

An additional advantage of HRR could be that it may not be necessary for participants to perform maximal or close to maximal exercise, which is required for measurement of $\dot{V}O_2max$. This may be especially useful for older adults with ID, because in the ‘Healthy ageing and intellectual disabilities’ (HA-ID) study we found that 61% of the participants did not achieve 85% of their estimated maximal heart rate (HRmax) during the 10-meter incremental shuttle walking test (ISWT) (Hilgenkamp, van Wijck, & Evenhuis, 2012b) which was a criterion to validly estimate $\dot{V}O_2max$ (Singh, Morgan, Hardman, Rowe, & Bardsley, 1994). Another problem with estimating $\dot{V}O_2max$ is that the available equations are problematic for use in individuals with ID (Oppewal et al., 2013). Although exercise intensity has been mentioned as a factor influencing HRR (Bosquet, Gamelin, & Berthoin, 2008; Lamberts, Maskell, Borresen, & Lambert, 2011; Morshedi-Meibodi, Larson, Levy, O'Donnell, & Vasan, 2002), HRR after 1 minute has been found equal after exercise at 65% and 85% of HRmax (Arduini, Gomez-Cabrera, & Romagnoli, 2011). However, HRR after 2 and 3 minutes of recovery did differ (Arduini et al., 2011). The prognostic value of HRR for cardiovascular events and all-cause mortality has also been found to not depend upon maximal effort (Cahalin et al., 2013; Cole, Blackstone, Pashkow, Snader, & Lauer, 1999; Cole, Foody, Blackstone, & Lauer, 2000). In addition, Mendonca & Pereira (2010) suggested that the attenuated HRR of individuals with DS was independent of their low HRpeak, supporting the idea that HRpeak achieved during the test may be less important for HRR than it is for $\dot{V}O_2max$.

Therefore, to investigate the usefulness of HRR in cardiorespiratory exercise testing in older adults with ID, the aims of this study were to assess (a) HRR in older adults with ID after the 10-meter incremental shuttle walking test and (b) its association with personal characteristics that are known in the general population to influence HRR (age, gender, cardiorespiratory fitness [expressed as distance walked on the ISWT]) (Okutucu et al., 2011), specific characteristics of the ID population that may influence HRR because of a possible influence on the autonomic nervous system (level of ID (Keary et al., 2012), genetic syndrome causing ID (Heilman, Harden, Zageris, Berry-Kravis, & Porges, 2011; Mendonca et al., 2010; Oppewal et al., 2013), autism spectrum disorder (Cheshire, 2012), behavioural problems (Boyce et al., 2001)), and HRpeak.

2. Methods

2.1 Study design and participants

This study was part of the large Dutch cross-sectional 'Healthy ageing and intellectual disabilities' study (HA-ID) conducted by a consort consisting of three ID care-provider services in collaboration with two university departments (Intellectual Disability Medicine, Erasmus MC, University Medical Center Rotterdam and the Center for Human Movement Sciences, University of Groningen, University Medical Center Groningen). All 2150 older clients with ID (≥ 50 years) were invited to participate, resulting in a near-representative sample of 1050 clients. Details about design, recruitment, and representativeness of the sample have been presented elsewhere (Hilgenkamp et al., 2011). Of the HA-ID study sample, 654 older adults performed the cardiorespiratory fitness measurements. Older adults (70 – 79 years) and participants with more severe ID and mobility impairments were underrepresented with respect to the total HA-ID sample (*n* = 1050) (Hilgenkamp, van Wijck, et al., 2012b), limiting the generalizability to these groups.

For the current study, individuals who had medical conditions and/or used medication that may alter heart rates, and/or in whom information about the presence of Down syndrome (DS) was missing –which is necessary to calculate HRmax– were omitted from the analyses.

Ethical approval was provided by the Medical Ethical Committee at Erasmus Medical Center (MEC 2008-234) and by the ethical committees of the participating ID care-provider services. Informed consent was obtained from all participants or their legal representatives; however, unusual resistance was a reason for aborting measurements at all times. This study followed the guidelines of the Declaration of Helsinki (Helsinki, 2008).

2.2 Measurements

2.2.1 Personal characteristics

Gender and age were collected from the administrative systems of the ID care-provider services. Level of ID was categorized by behavioral therapists or psychologists as borderline (IQ=70-84), mild (IQ=50-69), moderate (IQ=35-49), severe (IQ=20-34), or profound (IQ<20) (WHO, 1996). The presence of a genetic syndrome, autistic spectrum disorder, and behavioral problems were obtained from medical and behavioral therapists' records.

To describe the study population in detail, the following information was collected. Professional caregivers gave information about mobility (independent, with walking aid, or wheelchair-bound). Height and weight was measured by trained medical assistants during physical examination. Height was measured with a stadiometer (Seca type 214) with the participant wearing no shoes. Weight was measured with a digital floor scale (Seca robusta type 813) with participants wearing light clothes and no shoes. Body mass index (BMI) was calculated by weight divided by squared height (WHO, 1995). Physical activity was measured with a pedometer (NL-1000 pedometer, New Lifestyles, Missouri, USA) and a minimum of

7500 steps per day was classified as sufficient. Detailed methods have been described elsewhere (Hilgenkamp, Reis, van Wijck, & Evenhuis, 2012).

2.2.2 Exclusion criteria

To exclude participants with medical conditions and/or using medications that may alter heart rates, information about relevant medical conditions (arrhythmias, pacemaker, thyroid dysfunction), use of medication (beta blocking agents, digitalis glycosides, vasodilators, calcium channel blockers, thyroid therapy drugs, anti-Parkinson drugs, obstructive airway therapy drugs, and antihypertensives) were retrieved from medical files.

2.2.3 Cardiorespiratory fitness

Cardiorespiratory fitness was measured with the 10-meter incremental shuttle walking test (ISWT) (Singh, Morgan, Scott, Walters, & Hardman, 1992). Participants had to repeatedly walk up and down a 10m course at increasing pace. An instructor accompanied the participant and set the pace. The starting speed was 0.50 m/s. Every minute, the instructor increased walking speed by 0.17 m/s, according to the test protocol. The test ended when either the participant was too breathless to maintain the required pace or failed to complete a 10m shuttle within the time allowed (Singh et al., 1992). The distance covered was the test result. The ISWT results are reproducible ($r \geq 0.98$) in patients with chronic airway construction (Singh et al., 1992) and in patients attending cardiac rehabilitation (ICC = 0.94) (Jolly, Taylor, Lip, Singh, & Committee, 2008). Validity has been confirmed in patients with chronic airway construction with the relation between the distance walked on the ISWT and $\dot{V}O_2max$ during maximal treadmill exercise ($r = 0.88$) and increasing oxygen consumption was found in response to increasing intensity of the ISWT (Singh et al., 1994). The ISWT is feasible in older adults with ID, except for individuals with profound ID and, obviously, wheelchair users (Hilgenkamp, van Wijck, & Evenhuis, 2013). Also, test-retest reliability was good (ICC of 0.90 [same day interval] and 0.76 [two-week interval]) (Hilgenkamp, van Wijck, & Evenhuis, 2012a).

Because earlier studies suggested the need for a practice session to obtain valid results (Jolly et al., 2008; Rintala, McCubbin, & Dunn, 1995; Singh et al., 1992), the ISWT was performed twice. The ISWT test with the best effort, i.e. in which the participant reached the highest heart rate (HRpeak), was defined as the best test; heart-rate data of this test was used in the analyses.

2.2.4 Heart rates and heart rate recovery

Heart rates were monitored with wireless heart-rate monitors (Suunto T6c) directly before the test (HRrest), continuously during the ISWT, and during a 5-minute passive recovery period in which participants sat quietly.

Heart rate recovery (HRR) after exercise was defined as the change from peak heart rate (HRpeak) during the ISWT to that measured after 1, 2, 3, 4 and 5 minutes of recovery; $HRR1 = HRpeak – HR_{1\text{-min recovery}}$ and $HRR2 = HRpeak – HR_{2\text{-min recovery}}$ etcetera. A decrease in heart rate equal to or less than 12 beats per minute (bpm) during the first minute of recovery was considered abnormal (ACSM, 2013; Cole et al., 1999; Lauer, Froelicher, Williams, & Kligfield, 2005).

The exercise intensity of the ISWT was assessed with peak heart rate and the percentage of age-predicted HRmax (%HRmax) achieved during the ISWT. HRmax was calculated with the population-specific formula: HRmax = 210 – (0.56 * age) – (15.5 * DS), with non-DS coded as 1 and DS coded as 2 (Fernhall et al., 2001). The percentage of HRmax achieved was calculated with the following formula: %HRmax = (maximal heart rate during the ISWT / HRmax) * 100%).

2.3 Procedure

Data collection was part of an extensive physical fitness assessment that was conducted at locations familiar or close to participants: a large room within their home, a familiar daycare center, or a gym. Assessments were guided by instructors, who all were physiotherapists, occupational therapists, or physical activity instructors with experience with individuals with ID. All received an instruction manual and followed two days of training on conducting the fitness tests. To avoid undesirable influences of consecutive ISWT tests, both ISWTs were conducted with at least one hour in between.

The standardized encouragement provided by test instructions for testing individuals with normal intellectual capabilities is unsuitable for individuals with ID. To keep this motivational aspect as equal as possible, we prescribed ‘maximal motivation’ to the test instructors for all tests. In some cases, this meant that participants were motivated to engage in the assessments by constant verbal encouragement and verbal rewarding. In other cases the test instructor had to remain very calm and quiet to motivate the client as much as possible and to prevent stress or anxiety. The specific background, knowledge, and experience of the test instructors were important conditions for ensuring the most suitable ‘maximal motivation’ for every participant, while regarding safety as well.

To assure safety during testing, the Revised Physical Activity Readiness Questionnaire (rPAR-Q) was administered by professional caregivers in advance of participation (Cardinal, Esters, & Cardinal, 1996; Thomas, Reading, & Shephard, 1992). If any of the questions were answered with ‘yes’ or ‘unknown’, the medical physician was consulted to determine whether it was safe for the participant to perform the ISWT. If not, the participant was excluded.

2.4 Statistical analyses

Differences in personal characteristics between individuals omitted from the study due to the exclusion criteria, and participants remaining in the study were checked with independent t-tests and Pearson's chi-square test.

If categories of categorical variables contained $\leq$ 5% of the study sample, these categories were compared with remaining categories, using independent *t* tests and Pearson's chi-square tests, to determine if they could be grouped together.

Characteristics of the remaining participants were described for participants with DS and participants with ID by other causes separately, because of established differences in cardiorespiratory fitness and exercise response (Fernhall et al., 2001; Mendonca et al., 2010). Descriptive statistics were calculated for distance walked, duration of the ISWT, HRrest, HRpeak, %HRmax, heart rates during the recovery period, and HRR1 to HRR5. The number of participants with an abnormal HRR1 (≤12 bpm) was calculated. Differences between participants with DS and ID by other causes were analyzed with independent *t* tests and Pearson's chi-square tests.

To check whether the heart rates of participants returned to their resting heart rates after exercise, the difference between resting heart rates and heart rates during recovery was analyzed. When differences were smaller than 5 bpm, participants were considered to have returned to resting heart rates.

A multiple linear regression model was used to determine the association of personal characteristics with HRR. Categorical variables with more than two categories were recoded into dummy variables. HRR1 to HRR5 were used as dependent variables. Independent variables known to be relevant were entered in the first block (age [in years], gender [male = 0, female = 1], and distance walked on the ISWT [in meters]). Other independent variables were placed in the second block with the forward method (level of ID [borderline-mild, moderate, severe-profound], DS [no = 0, yes = 1], autism spectrum disorder [no = 0, yes = 1], behavioural problems [no = 0, yes = 1], and HRpeak [in bpm]), resulting in a model with only variables that contribute significantly to the predictive power of the model. Multicollinearity was checked with the Variance Inflation Factor (VIF), which had to be below 10 for all independent variables (Field, 2005). Results are presented as the unstandardized coefficients (*B),* representing the strength of the relation between each independent variable and the outcome in units of the independent variable; its standard error (SE *B*), the standardized beta (β), representing the strength of the relation between each independent variable and the outcome in standardized units; and the explained variance (adjusted R^2).

Statistical significance was set at $p < 0.05$. Bonferroni correction was used to correct for the inflated familywise error rate of multiple testing. Analyses were performed with the Statistical Package for Social Sciences (SPSS) version 20.0 (IBM Corporation, New York).

3. Results

3.1 Participants

Out of 654 older adults with ID who successfully participated in the ISWT measurements (study population is described elsewhere (Hilgenkamp, van Wijck, et al., 2012b)), 354 were omitted from the analysis because of medical conditions (arrhythmias [*n* = 12], pacemaker [*n* = 3], and thyroid dysfunction [*n* = 73], medication use (beta blocking agents [*n* = 44], vasodilators [*n* = 5], calcium channel blockers [*n* = 18], thyroid therapy drugs [*n* = 71], anti-Parkinson drugs [*n* = 24], obstructive airway therapy drugs [*n* = 37], and antihypertensives [*n* = 1]), and missing or inconsistent information regarding the presence of such medical conditions (*n* = 102) or DS (*n* = 113). Finally, 63 individuals were omitted because of problems with the heart rate registration. The omitted individuals had a higher BMI (*t*(573) =

3.90, $p < 0.001$) and less often autism spectrum disorder (χ^2 [1, n = 591] = 8.831, p = 0.003) than the 300 participants remaining in the further analyses.

Six participants had Fragile X syndrome, which was less than 5%. This group was not significantly different from the other participants with ID, therefore they were taken together in the analyses. The groups of participants with borderline (n = 12) and profound (n = 15) ID were also small and not significantly different from the groups mild and severe ID, respectively. Therefore, the borderline and mild ID groups and severe and profound ID groups were combined as well.

The characteristics of the remaining 300 participants are shown in table 1. Participants with DS were significantly younger (t(54.31) = 4.39, $p < 0.001$), shorter (t(293) = 6.22, $p < 0.001$), and weighed less (t(292) = 4.29, $p < 0.001$) than participants with ID by other causes (Table 1). The other characteristics did not differ significantly.

Table 1. Characteristics of participants with intellectual disabilities by other causes than Down syndrome and participants with Down syndrome.

Characteristics	***n* (%)**	**ID**	**DS**
Total		264	36
Age	Years (*m* ± *sd*)	60.5 ± 7.3*	56.1 ± 5.4*
Gender	Female	118 (44.7)	11 (30.6)
	Male	146 (55.3)	25 (69.4)
Height	cm (*m* ± *sd*)	165.4 ± 10.3*	153.7 ± 9.4*
Weight	kg (*m* ± *sd*)	72.4 ± 14.6*	61.2 ± 8.6*
BMI	kg/m^2 (*m* ± *sd*)	26.5 ± 4.9	26.0 ± 3.7
Level of ID	Borderline - mild	70 (26.5)	2 (5.6)
	Moderate	132 (50)	22 (61.1)
	Severe - profound	56 (21.2)	12 (33.3)
	Unknown	6 (2.3)	0
Autism spectrum disorder	Yes	65 (24.6)	3 (8.3)

	No	181 (68.6)	33 (91.7)
	Unknown	18 (6.8)	0
Behavioral problems	Yes	78 (29.5)	5 (13.9)
	No	166 (62.9)	29 (80.6)
	Unknown	20 (7.6)	2 (5.6)
Mobility	Independent	221 (83.7)	34 (94.4)
	Walking aid	37 (14.0)	2 (5.6)
	Unknown	6 (2.3)	0
Physical activity	> 7500 steps/day	40 (15.2)	1 (2.8)
	< 7500 steps/day	61 (23.1)	7 (19.4)
	Unknown	163 (61.7)	28 (77.8)

m = mean; *sd* = standard deviation; *n* = number of participants; ID = intellectual disability by other causes than Down syndrome; DS = Down syndrome; BMI = Body mass index.

[Insert figure 1 here]

3.2 Heart rates and heart rate recovery

The range of the percentage of HRmax achieved (%HRmax) during the ISWT was wide (Figure 1). Participants exerted themselves from 42.7% to 108.8% of their age-predicted HRmax.

The heart rates and heart rate recovery results are shown in Table 2 and Figure 2. Participants with DS had significantly lower resting heart rates ($t(296) = 3.05$, $p = 0.002$) and lower heart rates after 4 and 5 minutes of recovery ($t(272) = 2.62$, $p = 0.009$ and ($t(270) = 2.81$, $p = 0.005$) than those with ID by other causes. The other heart rate variables did not differ significantly. The largest decrease in heart rate was in the first minute of recovery, leveling off towards the fifth minute of recovery (Table 2 and Figure 1). An abnormal HHR after 1 minute (≤ 12 bpm) was seen in 36.1% of the participants with DS and in 30.7% of the participants with ID by other causes (no significant difference).

After the first minute of recovery, the heart rates of 19.4% of the participants with DS and of 27.3% of the participants with ID by other causes were returned to resting levels. After the second minute this was 48.5% and 38.9%, after the third minute 55.3% and 52.8%, after the fourth minute 57.6% and 58.3%, and after the fifth minute the heart rates of 61.4% of the participants with ID by other causes than DS and 69.4% of the participants with DS were returned to resting levels.

Table 2. Heart rate and heart rate recovery results of participants with intellectual disabilities by other causes than Down syndrome and those with Down syndrome, presented as means with 95% confidence intervals.

	ID	**DS**	***p***
Distance walked (m)	264.4 [241.6, 287.2]	196.1 [151.4, 240.8]	0.008
Duration ISWT (min:s)	5:16 [4:59, 5:34]	4:27 [3:50, 5:05]	0.046
HRrest (bpm)	82.4 [80.7, 84.2]	74.6 [69.2, 80.0]	0.002*
HRpeak (bpm)	118.5 [115.8, 121.2]	109.6 [102.8, 116.3]	0.022
%HRmax	73.7 [72.1, 75.3]	74.3 [69.6, 79.0]	0.808
HRR1 (bpm)	20.2 [18.4, 21.9]	16.0 [12.1, 19.8]	0.110
HRR2 (bpm)	28.4 [26.3, 30.4]	25.2 [20.8, 29.7]	0.294
HRR3 (bpm)	31.0 [28.8, 33.1]	29.9 [24.7, 35.2]	0.742
HRR4 (bpm)	32.3 [30.1, 34.4]	31.8 [26.9, 36.7]	0.876
HRR5 (bpm)	33.0 [30.7, 35.4]	33.0 [28.2, 37.8]	0.988

ID = intellectual disability by other causes than Down syndrome; DS = Down syndrome; ISWT = 10-meter incremental shuttle walking test; HRrest = heart rate prior to the ISWT; HRpeak = peak heart rate achieved during the ISWT; %HRmax = percentage of age-predicted maximal heart rate reached during the ISWT; HRR1 = heart rate recovery at 1 minute after exercise; HRR2 = heart rate recovery at 2 minutes after exercise; HRR3 = heart rate recovery at 3 minutes after exercise; HRR4 = heart rate recovery at 4 minutes after exercise; HRR5 = heart rate recovery at 5 minutes after exercise; bpm = beats per minute.

* significant difference between DS and ID, $p < 0.005$ (Bonferroni correction 0.05/10).

[Insert figure 2 here]

3.3 Multiple regression analysis

The results of the multiple regression analysis for HHR1 to HRR5 are presented in Table 3. The explained variance ranges from 28.6% (HRR1) to 60.6% (HRR4).

Participants who walked a larger distance and participants with a higher HRpeak during the ISWT had a higher HRR. For HRR3 to HRR5, participants with a more severe ID had a lower HRR, and participants with DS had a higher HRR.

Table 3. Results of the multiple regression analysis for heart rate recovery after each minute of recovery.

		B	**SE *B***	***β***	**adjusted R^2**
HRR1 (*n* = 244)					0.281
	Age	0.056	0.113	0.028	
	Female	-0.475	1.600	-0.017	
	Distance walked	0.015	0.005	0.200*	
	HRpeak	0.253	0.042	0.4206*	
HRR2 (*n* = 237)					0.436
	Age	0.074	0.113	0.033	
	Female	1.110	1.642	0.035	
	Distance walked	0.021	0.005	0.255**	
	HRpeak	0.351	0.042	0.497**	
HRR3 (*n* = 241)					0.519
	Age	0.180	0.116	0.075	
	Female	1.198	1.598	0.036	
	Distance walked	0.019	0.005	0.216**	
	HRpeak	0.431	0.042	0.576**	

	More severe ID	-4.553	1.839	-0.114*	
	Down syndrome	5.696	2.298	0.115*	
HRR4 (*n* = 241)					0.596
	Age	0.158	0.105	0.066	
	Female	0.948	1.479	0.028	
	Distance walked	0.022	0.005	0.249**	
	HRpeak	0.459	0.039	0.607**	
	More severe ID	-4.019	1.704	-0.099*	
	Down syndrome	6.126	2.102	0.124**	
HRR5 (*n* = 239)					0.589
	Age	0.198	0.108	0.082	
	Female	2.055	1.534	0.060	
	Distance walked	0.021	0.005	0.235**	
	HRpeak	0.474	0.040	0.615**	
	More severe ID	-4.712	1.745	-0.115**	
	Down syndrome	7.480	2.139	0.151**	

n = number of participants; HRR = Heart rate recovery; HRpeak = peak heart rate achieved during the ISWT; ID = intellectual disability; HRR1 = heart rate recovery at 1 minute after exercise; HRR2 = heart rate recovery at 2 minutes after exercise; HRR3 = heart rate recovery at 3 minutes after exercise; HRR4 = heart rate recovery at 4 minutes after exercise; HRR5 = heart rate recovery at 5 minutes after exercise; bpm = beats per minute.

Age (in years), gender (male = 0, female = 1), distance walked (in meters), level of ID (borderline-mild = 0, moderate =1, severe-profound = 1), DS (no = 0, yes = 1), autism (no = 0, yes = 1), behavioural problems (no = 0, yes = 1), and HRpeak (in bpm).

* $p < 0.05$

** $p < 0.01$

4. Discussion

This study was the first to assess heart rate recovery (HRR) in a large sample of older adults with intellectual disabilities (ID) using the 10-meter incremental shuttle walking test (ISWT). At first glance, the trajectory of HRR in older adults with ID does not seem to differ much from the general population, with the largest decrease in heart rate during the first minutes of recovery (Okutucu et al., 2011). One third of the older adults with ID had an abnormal HRR after 1 minute (≤ 12 bpm). This is comparable to the general adult population (Cole et al., 1999; Cole et al., 2000; Messinger-Rapport et al., 2003). However, this result is dependent on the cut-off score used, and different cut-off scores for an abnormal HRR are reported in literature (Cole et al., 1999; Cole et al., 2000; Shetler et al., 2001; Watanabe, Thamilarasan, Blackstone, Thomas, & Lauer, 2001). Together with the lack of normative data and different recovery protocols (passive versus active, sitting, lying) used across studies affecting HRR results (Bosquet et al., 2008), this hampers the interpretation of our results.

In addition, cut-off scores for an abnormal HRR have been based on the predictive value of HRR for cardiovascular and all-cause mortality in the general population. The mechanism behind the association between HRR and mortality may be an altered autonomic modulation (Lahiri, Kannankeril, & Goldberger, 2008; Laing et al., 2011). There are reasons to suppose that autonomic control is different in individuals with ID, which might imply a different relationship of HRR and health in this group. Blunted parasympathetic withdrawal and reduced sympathetic activation during exercise have been found in individuals with DS (Mendonca et al., 2010) and a parasympathetic / sympathetic imbalance during rest has been found in females with Rett syndrome (Acampa et al., 2008; Guideri et al., 2004). A diminished vagal withdrawal during isometric hand grip exercise has also been found in individuals with ID without specific genetic syndromes (Dipla et al., 2013). It seems that an altered autonomic control may be associated with the intellectual disability. This is supported by our finding that the level of ID and the presence of DS were related to HRR, and gender and age were not, in contrary to the general population (Okutucu et al., 2011). Different cut-off score may therefore be needed for the ID population underscoring the necessity of specific studies of predictive validity of HRR.

In this study, the mean HRR of participants with DS after the first minute of recovery (16.0 bpm, 95% CI [12.1, 19.8]) and after the second minute of recovery (25.2 bpm, 95% CI [20.8, 29.7]) were around 9 and 13 bpm lower than those found in previous studies with individuals with DS (Mendonca & Pereira, 2010; Mendonca et al., 2013). This may be caused by differences in age of the study samples and differences in exercise and recovery protocols (Mendonca & Pereira, 2010; Mendonca et al., 2013). Standardization of assessment of HRR in future studies will improve comparison across studies.

Four characteristics were significantly associated with HRR. Firstly, HRpeak had the strongest positive association with HRR, indicating that HRR may be underestimated if participants do not exert themselves fully. Therefore, using HRR as an outcome measure for cardiorespiratory fitness does not solve the problem of low numbers of participation due to too little exertion (Hilgenkamp, van Wijck, et al., 2012b). Full exertion is difficult for (older) adults with ID, due to little experience with exercise and low physical activity levels (Hilgenkamp, Reis, et al., 2012). It is therefore important to implement exercise and physical activity in their daily life, allowing them to become familiar with the signs of exercise, hopefully resulting in better fitness and participation in cardiorespiratory fitness testing. Secondly, the distance walked was positively related to HRR. Since the distance walked during the ISWT is a measure of cardiorespiratory fitness (Singh et al., 1994), this result provides convergent validity for HRR as an indirect measure of cardiorespiratory fitness of older adults with ID. Thirdly, having DS was positively related to HRR in the third, fourth, and fifth minute of recovery. This was unexpected because it is consistently seen that individuals with DS have poorer cardiorespiratory fitness than individuals with ID by other causes (Fernhall & Pitetti, 2001; Mendonca et al., 2010; Oppewal et al., 2013). We do not have an explanation for this finding and further research is needed to see if this finding is consistent and what the possible mechanisms might be. Finally, having more severe ID was negatively associated with HRR during the last three minutes of recovery, suggesting that HRR is influenced by the intellectual disability. This is in line with the findings of Keary et al. (2012) that HRR was related to poorer cognitive function. However, the underlying mechanisms are currently unknown, so further research is necessary in this area as well.

A limitation of this study was that we did not have the actual maximal heart rates of the participants and used population-specific age-predicted HRmax to get insight in the intensity of the ISWT. However, the formula we used to calculate HRmax may not be adequate for older adults with ID, because we found actual HRpeak to be higher than calculated age-predicted HRmax in twelve participants. This formula was developed with a study sample of individuals with ID ranging from 9 to 46 years, so no older adults were included in this study and the formula may therefore be not suitable for this group (Fernhall et al., 2001). In addition, the formula predicted only 32.5% of the variance in HR (Fernhall et al., 2001). Unfortunately, a better alternative is lacking. Further research is needed to provide a more adequate formula for older adults with ID.

The participants only differed in BMI and prevalence of autism spectrum disorder in comparison to those omitted from the analyses, and these characteristics did not influence HRR (Mendonca & Pereira, 2010; Mendonca et al., 2013). Therefore, the results of this study are likely to be representative for the sample of 654 participants that performed cardiorespiratory fitness testing in the HA-ID study (Hilgenkamp, van Wijck, et al., 2012b).

Although using HRR as an outcome measure does still require participants to perform maximal or close to maximal exercise, and reference data and standardized protocols are lacking, HRR is a direct, objective measurement that can be assessed during field cardiorespiratory fitness testing. HRR also provides information about autonomic control without invasive measurement. Therefore, HRR is a potentially relevant outcome in cardiorespiratory fitness testing in older adults with ID, but more research is needed to identify the relation between HRR and adverse outcomes and the reliability of HRR measurements.

Acknowledgements

The authors thank the management and professionals of the care provider services, Abrona at Huis ter Heide, Amarant at Tilburg and Ipse de Bruggen at Zwammerdam, involved in the HA-ID consort for their collaboration and support. We also thank all participants, their family members and caregivers for their collaboration. This study was carried out with the financial support of ZonMw (No. 57000003).

Conflict of interest

None

References

Acampa, M., Guideri, F., Hayek, J., Blardi, P., De Lalla, A., Zappella, M., & Auteri, A. (2008). Sympathetic overactivity and plasma leptin levels in Rett syndrome. *Neuroscience letters*, *432*(1), 69-72.

American College of Sports Medicine [ACSM]. (2013). ACSM's guidelines for exercise testing and prescription (9th ed.). Philadelphia: Lippincott Williams & Wilkins.

Arduini, A., Gomez-Cabrera, M. C., & Romagnoli, M. (2011). Reliability of different models to assess heart rate recovery after submaximal bicycle exercise. *Journal of Science and Medicine in Sport*, *14*(4), 352-357.

Bosquet, L., Gamelin, F. X., & Berthoin, S. (2008). Reliability of postexercise heart rate recovery. *International Journal of Sports Medicine*, *29*(3), 238-243.

Boyce, W. T., Quas, J., Alkon, A., Smider, N. A., Essex, M. J., Kupfer, D. J., MacArthur Assessment Battery Working Group of the MacArthur Foundation Research Netwrok on, P., & Development. (2001). Autonomic reactivity and psychopathology in middle childhood. *The British Journal of Psychiatry*, *179*, 144-150.

Cahalin, L. P., Forman, D. E., Chase, P., Guazzi, M., Myers, J., Bensimhon, D., Peberdy, M. A., Ashley, E., West, E., & Arena, R. (2013). The prognostic significance of heart rate recovery is not dependent upon maximal effort in patients with heart failure. *International Journal of Cardiology*.

Cardinal, B. J., Esters, J., & Cardinal, M. K. (1996). Evaluation of the revised physical activity readiness questionnaire in older adults. *Medicine and Science in Sports and Exercise, 28*(4), 468-472.

Cheshire, W. P. (2012). Highlights in clinical autonomic neuroscience: new insights into autonomic dysfunction in autism. *Autonomic Neuroscience: Basic & Clinical., 171*(1-2), 4-7.

Cole, C. R., Blackstone, E. H., Pashkow, F. J., Snader, C. E., & Lauer, M. S. (1999). Heart-rate recovery immediately after exercise as a predictor of mortality. *The New England Journal of Medicine, 341*(18), 1351-1357.

Cole, C. R., Foody, J. M., Blackstone, E. H., & Lauer, M. S. (2000). Heart rate recovery after submaximal exercise testing as a predictor of mortality in a cardiovascularly healthy cohort. *Annals of Internal Medicine, 132*(7), 552-555.

Dipla, K., Zafeiridis, A., Papadopoulos, S., Koskolou, M., Geladas, N., & Vrabas, I. S. (2013). Reduced metaboreflex control of blood pressure during exercise in individuals with intellectual disability: a possible contributor to exercise intolerance. *Research in Developmental Disabilities, 34*(1), 335-343.

Fernhall, B., McCubbin, J. A., Pitetti, K. H., Rintala, P., Rimmer, J. H., Millar, A. L., & De Silva, A. (2001). Prediction of maximal heart rate in individuals with mental retardation. *Medicine and Science in Sports and Exercise, 33*(10), 1655-1660.

Fernhall, B., & Pitetti, K. H. (2001). Limitations to physical work capacity in individuals with mental retardation. *Clinical Exercise Physiology, 3*, 176-185.

Field, A. (2005). Discovering statistics using SPSS (2nd ed.). London: SAGE Publications Ltd.

Figueroa, A., Collier, S. R., Baynard, T., Giannopoulou, I., Goulopoulou, S., & Fernhall, B. (2005). Impaired vagal modulation of heart rate in individuals with Down syndrome. *Clinical Autonomic Research, 15*(1), 45-50.

Guideri, F., Acampa, M., Blardi, P., de Lalla, A., Zappella, M., & Hayek, Y. (2004). Cardiac dysautonomia and serotonin plasma levels in Rett syndrome. *Neuropediatrics, 35*(1), 36-38.

Heilman, K. J., Harden, E. R., Zageris, D. M., Berry-Kravis, E., & Porges, S. W. (2011). Autonomic regulation in fragile X syndrome. *Developmental Psychobiology, 53*(8), 785-795.

Helsinki. (2008). World Medical Association Declaration of Helsinki, Ethical Principles for Medical Research Involving Human Subjects. Retrieved from http://www.wma.net/en/30publications/10policies/b3/

Hilgenkamp, T. I., Bastiaanse, L. P., Hermans, H., Penning, C., van Wijck, R., & Evenhuis, H. M. (2011). Study healthy ageing and intellectual disabilities: Recruitment and design. *Research in Developmental Disabilities, 32*(3), 1097-1106.

Hilgenkamp, T. I., Reis, D., van Wijck, R., & Evenhuis, H. M. (2012). Physical activity levels in older adults with intellectual disabilities are extremely low. *Research in Developmental Disabilities, 33*(2), 477-483.

Hilgenkamp, T. I., van Wijck, R., & Evenhuis, H. M. (2012a). Feasibility and reliability of physical fitness tests in older adults with intellectual disability: A pilot study. *Journal of Intellectual & Developmental Disability, 37*(2), 158-162.

Hilgenkamp, T. I., van Wijck, R., & Evenhuis, H. M. (2012b). Low physical fitness levels in older adults with ID: Results of the HA-ID study. *Research in Developmental Disabilities, 33*(4), 1048-1058.

Hilgenkamp, T. I., van Wijck, R., & Evenhuis, H. M. (2013). Feasibility of eight physical fitness tests in 1,050 older adults with intellectual disability: results of the healthy ageing with intellectual disabilities study. *Intellectual and Developmental Disabilities, 51*(1), 33-47.

Johnson, N. P., & Goldberger, J. J. (2012). Prognostic value of late heart rate recovery after treadmill exercise. *The American Journal of Cardiology, 110*(1), 45-49.

Jolly, K., Taylor, R. S., Lip, G. Y., Singh, S., & Committee, B. S. (2008). Reproducibility and safety of the incremental shuttle walking test for cardiac rehabilitation. *International Journal of Cardiology, 125*(1), 144-145.

Keary, T. A., Galioto, R., Hughes, J., Waechter, D., Spitznagel, M. B., Rosneck, J., Josephson, R., & Gunstad, J. (2012). Reduced heart rate recovery is associated with poorer cognitive function in older adults with cardiovascular disease. *Cardiovascular Psychiatry and Neurology, 2012*, 392490.

Kligfield, P., & Lauer, M. S. (2006). Exercise electrocardiogram testing: beyond the ST segment. *Circulation, 114*(19), 2070-2082.

Lahiri, M. K., Kannankeril, P. J., & Goldberger, J. J. (2008). Assessment of autonomic function in cardiovascular disease: physiological basis and prognostic implications. *Journal of the American College of Cardiology, 51*(18), 1725-1733.

Laing, S. T., Gluckman, T. J., Weinberg, K. M., Lahiri, M. K., Ng, J., & Goldberger, J. J. (2011). Autonomic effects of exercise-based cardiac rehabilitation. *Journal of Cardiopulmonary Rehabilitation and Prevention, 31*(2), 87-91.

Lamberts, R. P., Maskell, S., Borresen, J., & Lambert, M. I. (2011). Adapting workload improves the measurement of heart rate recovery. *International Journal of Sports Medicine, 32*(9), 698-702.

Lauer, M., Froelicher, E. S., Williams, M., & Kligfield, P. (2005). Exercise testing in asymptomatic adults: a statement for professionals from the American Heart Association Council on Clinical Cardiology, Subcommittee on Exercise, Cardiac Rehabilitation, and Prevention. *Circulation*, *112*(5), 771-776.

Mendonca, G. V., & Pereira, F. D. (2010). Heart rate recovery after exercise in adults with the Down syndrome. *The American Journal of Cardiology, 105*(10), 1470-1473.

Mendonca, G. V., Pereira, F. D., & Fernhall, B. (2010). Reduced exercise capacity in persons with Down syndrome: cause, effect, and management. *Therapeutics and Clinical Risk Management, 6*, 601-610.

Mendonca, G. V., Pereira, F. D., & Fernhall, B. (2013). Heart rate recovery and variability following combined aerobic and resistance exercise training in adults with and without Down syndrome. *Research in Developmental Disabilities, 34*(1), 353-361.

Messinger-Rapport, B., Pothier Snader, C. E., Blackstone, E. H., Yu, D., & Lauer, M. S. (2003). Value of exercise capacity and heart rate recovery in older people. *Journal of the American Geriatrics Society, 51*(1), 63-68.

Morshedi-Meibodi, A., Larson, M. G., Levy, D., O'Donnell, C. J., & Vasan, R. S. (2002). Heart rate recovery after treadmill exercise testing and risk of cardiovascular disease events (The Framingham Heart Study). *The American Journal of Cardiology, 90*(8), 848-852.

Okutucu, S., Karakulak, U. N., Aytemir, K., & Oto, A. (2011). Heart rate recovery: a practical clinical indicator of abnormal cardiac autonomic function. *Expert Review of Cardiovascular Therapy, 9*(11), 1417-1430.

Oppewal, A., Hilgenkamp, T. I., van Wijck, R., & Evenhuis, H. M. (2013). Cardiorespiratory fitness in individuals with intellectual disabilities—A review. *Research in Developmental Disabilities, 34*(10), 3301-3316.

Pierpont, G. L., Adabag, S., & Yannopoulos, D. (2013). Pathophysiology of exercise heart rate recovery: a comprehensive analysis. *Annals of Noninvasive Electrocardiology, 18*(2), 107-117.

Rintala, P., McCubbin, J. A., & Dunn, J. M. (1995). Familiarization process in cardiorespiratory fitness testing for persons with mental retardation. [doi: 10.1080/15438629509512032]. *Sports Medicine, Training and Rehabilitation, 6*(1), 15-27.

Sharma, K., Kohli, P., & Gulati, M. (2012). An update on exercise stress testing. *Current Problems in Cardiology, 37*(5), 177-202.

Shetler, K., Marcus, R., Froelicher, V. F., Vora, S., Kalisetti, D., Prakash, M., Do, D., & Myers, J. (2001). Heart rate recovery: validation and methodologic issues. *Journal of the American College of Cardiology, 38*(7), 1980-1987.

Singh, S. J., Morgan, M. D., Hardman, A. E., Rowe, C., & Bardsley, P. A. (1994). Comparison of oxygen uptake during a conventional treadmill test and the shuttle walking test in chronic airflow limitation. *The European Respiratory Journal, 7*(11), 2016-2020.

Singh, S. J., Morgan, M. D., Scott, S., Walters, D., & Hardman, A. E. (1992). Development of a shuttle walking test of disability in patients with chronic airways obstruction. *Thorax, 47*(12), 1019-1024.

Thomas, S., Reading, J., & Shephard, R. J. (1992). Revision of the Physical Activity Readiness Questionnaire (PAR-Q). *Canadian Journal of Sport Sciences, 17*(4), 338-345.

Watanabe, J., Thamilarasan, M., Blackstone, E. H., Thomas, J. D., & Lauer, M. S. (2001). Heart rate recovery immediately after treadmill exercise and left ventricular systolic dysfunction as predictors of mortality: the case of stress echocardiography. *Circulation, 104*(16), 1911-1916.

World Health Organization [WHO]. (1995). *Physical status: The use and interpretation of anthropometry. WHP Technical Report Series 854.* Geneva. Switzerland: World Health Organization.

World Health Organization [WHO]. (1996). *ICD-10 Guide for Mental Retardation*. Geneva, Switzerland: World Health Organization.

World Health Organization [WHO]. (2007). *Prevention of cardiovascular disease: guidelines for assessment and management of total cardiovascular risk.* Geneva, Switzerland: World Health Organitazion.