The feasibility of supramaximal verification of peak oxygen uptake of a graded maximal treadmill test in adults with Intellectual Disability

Masterthesis

Physiotherapy Science

Program in Clinical Health Sciences

Utrecht University

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“ONDERGETEKENDE

Stijn Weterings,

bevestigt hierbij dat de onderhavige verhandeling mag worden geraadpleegd en vrij mag worden gefotokopieerd. Bij het citeren moet steeds de titel en de auteur van de verhandeling worden vermeld.”

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Masterthesis, Physical Therapy Sciences, Program in Clinical Health Sciences, Utrecht University, Utrecht, 2015

SAMENVATTING

Introductie: *Er is onder therapeuten en onderzoekers een grote behoefte aan een valide manier om het uithoudingsvermogen van volwassenen met een verstandelijke beperking (VB) te kunnen meten, om zo gezondheidsrisico's te kunnen inschatten en therapieën te evalueren. De gouden standaard om uithoudingsvermogen te meten is door de maximale zuurstofopname (VO_{2max}) te meten tijdens een maximale inspanningstest, zoals bij een getrapte maximale loopband test (GXTT). Het is echter niet zeker dat de gemeten piek in de zuurstofopname (VO_{2piek}) tijdens een maximale inspanningstest ook echt de VO_{2max} is. Een supramaximale inspanningstest (SET) kan gebruikt worden om te verifiëren of de gemeten VO_{2piek} van de GXTT ook een echte VO_{2max} is. Het is tot op heden echter niet bekend of volwassen met een VB de GXTT gevolgd door een SET kunnen en willen uitvoeren.*

Doel: *Het onderzoeken van drie aspecten van de haalbaarheid (het voltooien van de test; de overeenstemming van de gemeten VO_{2piek} scores en de acceptatie van de meetprocedure) van een oefen sessie, een maximale loopbandtest gecombineerd met een supramaximale inspanningstest bij volwassenen (18 tot 50 jaar) met een VB.*

Methode: *Er is een cross-sectioneel observationeel design gebruikt. Voor de haalbaarheid werd gekeken naar het volbrengen van de test (met behulp van de Rowland-criteria voor maximale inspanning), en naar de overeenkomst tussen de VO_{2piek} scores (met behulp van de $ICC_{agreement}$). Met een specifiek voor dit onderzoek opgestelde vragenlijst werd gekeken of de deelnemers de test acceptabel vonden.*

Resultaten: *Twaalf deelnemers hebben meegedaan aan het onderzoek. 75% van de deelnemers heeft de test goed volbracht, met een $ICC_{agreement}$ van 0,99 ($p<0,000$). De vragenlijst maakte duidelijk dat de deelnemers de test acceptabel vonden.*

Conclusie: *Dit onderzoek toont aan dat het haalbaar lijkt te zijn om een maximale loopbandtest gevolgd door een supramaximale inspanningstest uit te voeren bij volwassenen met VB.*

ABSTRACT

Background: *Currently used cardiorespiratory fitness tests for adults with an intellectual disability (ID) have not been studied for validity within this group for measuring the cardiorespiratory fitness. There is a need for a valid cardiorespiratory fitness test, for determining health risk factors and evaluating therapy in clinical practice. The gold standard of measuring cardiorespiratory fitness is a maximal exercise test, measuring the maximal oxygen uptake (VO_{2max}). It is not clear if the peak oxygen uptake (VO_{2peak}) of a maximal cardiorespiratory exercise test, like a graded maximal treadmill test (GXTT), represents the true maximal oxygen uptake in adults with ID. A supramaximal exercise test (SET) can be used to verify, if the measured VO_{2peak} reflects a true VO_{2max}. To date it is not known if adults with ID are able and willing to perform both the GXTT and the SET until exhaustion.*

Aim: *To examine three aspects (completion rate, agreement and acceptability) of feasibility of a graded maximal treadmill test combined with a supramaximal exercise test in adults (18-50 years) with ID.*

Methods: *A cross sectional observational design was used, which consisted of 2 sessions. Prior to testing, a 3-step familiarization process was performed (session 1), after which the VO_{2peak} of the GXTT ($VO_{2peakGXTT}$) and the SET ($VO_{2peakSET}$) were measured (session 2). The feasibility parameters used in this study were completion rate (through the Rowland criteria of maximal effort), agreement (through intraclass-correlation-coefficient ($ICC_{agreement}$)) and acceptability (through a custom-made questionnaire).*

Results: *12 Participants performed the measurement procedure. The completion rate was 75% and the $ICC_{agreement}$ was 0.99 ($p<0.000$). The questionnaire showed the measuring procedure was acceptable for the participants.*

Conclusion: *This study showed it seems feasible to perform a maximal treadmill test (GXTT) followed by a supramaximal exercise test for adults with ID.*

Keywords: adults, intellectual disability, maximal cardiopulmonary exercise test, supramaximal exercise test, and feasibility

INTRODUCTION

An intellectual disability (ID) is characterized by significant limitations in both intellectual functioning and adaptive behavior, covering many everyday social and practical skills and originates before the age of 18 (1). The prevalence of ID ranges between 1% and 1.25% of the world's population (2).

Research on the physical fitness of adults with ID shows lower physical fitness in this population(3-6). Their physical fitness can be compared to the physical fitness of a normal population 20 years older (3). Physical fitness is important for independence, well-being and health (7, 8). Research in adults with ID has identified that cardiorespiratory capacity, one component of physical fitness, is a major indicator for one's overall fitness (9, 10). However, hard evidence is lacking, because little research has been done regarding the validity of maximal and submaximal cardiorespiratory exercise tests in adults with ID (11). Current used submaximal tests have not been studied sufficiently for measuring cardiorespiratory fitness of adults with ID (3, 12). There is a need for a valid submaximal test to measure the cardiorespiratory fitness of adults with ID, for determining health risk factors and evaluating therapy in clinical practice. A graded maximal treadmill test (GXTT) is maximal cardiorespiratory exercise test, and has been used in younger people with ID (13, 14), but because of a number of limitations, the findings cannot be generalized to adults with ID (11).

First, the studies into cardiorespiratory fitness of people with ID using maximal cardiorespiratory exercise tests mainly focused on children and adolescents with Down syndrome (9, 14, 15). However, people with Down syndrome could significantly differ in cardiorespiratory fitness compared to adults with ID in general, because of chronotropic incompetence, joint laxity and muscle hypotonia (16), thereby limiting the generalizability of the findings to adults with ID (11).

Second, the available research shows different GXTT protocols have been used, although they all refer to the same articles for the feasibility and reliability (14, 17). The measurement procedure almost always includes a familiarization phase to optimize maximal testing results, but protocols differ in using a fixed starting speed to an individual based treadmill speed or using different inclinations in different timeframes (8, 17-22). This raises questions whether the feasibility of the measurement procedure is still applicable.

Third, these studies used mostly Respiratory Exchange Ratio (RER) and maximal or peak heart rate (HR_{max}) criteria; to check if the peak oxygen uptake measured during a test (VO_{2peak}) was a true VO_{2max} measurement. There has been much debate, whether or not these criteria are valid ways to confirm true VO_{2max} (23, 24). So for adults with ID, it is also debatable if the results of a maximal cardiorespiratory exercise test reflect their true maximal capacity.

A better way to determine whether the attained VO_{2peak} during a test is indeed the true VO_{2max}, is to use a supramaximal exercise test (SET) after the graded exercise protocol (23). Supramaximal means a workload above the peak workload attained during a GXTT. A feasible and safe supramaximal exercise protocol consists of performing at least at a 110% workload of the maximum workload of the GXTT. The SET test has a duration of about 3-5 minutes (23), whereas GXTT will take on average 10 to 15 minutes. If consistent VO_{2peak} values are found in both exercise tests, the true VO_{2max} score has been verified. A recent study by Astorino et al.(2009) found supramaximal testing suited for sedentary adults in the general population (25), which is promising considering most adults with ID

lead a sedentary lifestyle (3). The SET provides opportunities to verify the scores of GXTT protocol in adults with ID, establishing true VO_{2max}-scores as a more valid gold standard for adults with ID. This would be a solid starting point for the much-needed research into the validity of submaximal exercise tests for adults with ID. To this date it is not known if adults with ID are able and willing to perform both the GXTT and the SET until exhaustion.

This study explored three aspects (completion rate, agreement and acceptability) of feasibility of measuring VO_{2max} with a GXTT followed by a SET. Prior to testing there was a 3-step familiarization process for the participants to get acquainted with the test equipment and procedure (26). Therefore the aim of this study was to examine the feasibility of a graded maximal treadmill test, combined with a supramaximal exercise test in adults (18-50 years) with ID.

METHODS

Participants

A convenience sample was used for this study. All participants had to live and/or work in a residential setting for people with ID in the Utrecht region of the Netherlands. Participants were included when they were diagnosed with ID, between 18 and 50 years old, and able to follow test instructions. Participants were excluded when significant ambulatory problems inhibited treadmill walking or when there was no medical clearance given by the doctor. All participants and their legal representatives gave written informed consent. The medical ethics committee of the Erasmus Medical Centre at Rotterdam, the Netherlands, approved this study (MEC-2014-603).

Design

A cross sectional observational design was used, which consisted of 2 sessions. Before measuring VO_{2peak} of the GXTT ($VO_{2peakGXTT}$) and the SET ($VO_{2peakSET}$) (session 2), a familiarization process was followed (session 1). The test protocol (session 2) started with the GXTT, with a total duration of about 10-15 minutes, followed by a recovery period of at least 10 minutes or until the heart rate (HR) dropped below 120 beats/minute, before performing the SET, with a duration of about 3-5 minutes and a workload of at least a 110% of the GXTT had to be achieved (23). There were at least 24 hours between the 2 sessions, to prevent fatigue hampering the outcome of the test. In the first session overall physical fitness was tested with the "VB-fitscan" (ID-fitscan), which consists of measuring weight, length, waist circumference, 30-second chair stand (30sCS), 5-times-chair-stand (5tCS), grip strength, static balance and walking speed. All tests have been found feasible and reliable for people with ID (27, 28).

Outcome

Feasibility

The three feasibility parameters for this study were completion rate, agreement between VO_{2peak} scores of the GXTT and SET, and acceptance of the measurement procedure by the participants and the investigators (described in more detail below). The overall feasibility of the measurement procedure was interpreted as [1] feasible without adaptations necessary, [2] feasible with adaptations necessary or [3] not feasible *(see table 1 for detailed definitions)*(29).

***Table 1**: Definition of feasibility*

Feasible without adaptations necessary	Both the completion rate and the agreement between $VO_{2peakGXTT}$ and $VO_{2pekSET}$ were good to excellent and no major problems arose from the questionnaire.
Feasible with adaptations necessary	Completion rate or agreement scored less than good to excellent and/or a major problem arose from the questionnaire; the measurement procedure should be re-evaluated or adjusted.
Not feasible	Both completion rate and the agreement between $VO_{2peakGXTT}$ and $VO_{2pekSET}$ scored less than good and/or multiple major problems arose from the questionnaire.

Completion rate

Completion rate was defined by completion of both tests (GXTT and SET) and meeting the Rowland criteria of maximal effort for both tests (30). Completion will be recorded after each test as completed 'yes' or 'no'. The completion rate was characterised as low (<25%), moderate (>25% and <50%), good (>50% and <75%), and excellent (>75%)(27).

The Rowland criteria were used to define maximal effort (30). The Rowland criteria are divided in subjective and objective criteria *(see table 2)*. A participant had to meet at least 2 subjective and 1 objective criteria before the test was considered successfully completed. The predicted heart rate ($HR_{predicted}$) was calculated with the population specific formula: HRpredicted: 210 - (0.56 age) - (15.5 DS), with non-DS (Down syndrome) coded as 1 and DS coded as 2 (31).

***Table** 2: Rowland criteria of Maximal effort*

Subjective Criteria	Objective Criteria
Unsteady walking	HR_{peak} > 95% $HR_{predicted}$*
Sweating	RER_{peak} > 1.00(32)
Facial flushing	VO_2 plateau in the last minute
Clear unwillingness to continue despite encouragement	

HR=heart rate; RER= respiratory exchange ratio; $HR_{predicted}$: 210 - (0.56 age) - (15.5 DS) (31)

Agreement of VO_{2peak}

Only the scores of the participants who completed the test and met the Rowland criteria of maximal effort were included. Agreement was assessed through calculation of the normalized VO_{2peak}. Normalized VO_{2peak} was calculated as $VO_{2peakGXTT}$/kg or $VO_{2peakSET}$/kg and expressed as millilitres per minute per kilogram (mL/kg/min). Normalized VO_{2peak} was calculated as Intraclass-Correlation-Coefficient, $ICC_{agreement}$, (model 2.1) was used to analyse agreement (33). The $ICC_{agreement}$ scores will be interpreted as Poor < 0.40, Fair 0.40 - 0.70, Good 0.70 – 0.90 and excellent > 0.90(34).

Acceptability

A custom-made questionnaire was used to evaluate the participants' acceptance of the familiarizations process and the test. There were questions about the experience, the difficulty and the acceptance of the participants of the total measurement procedure. The participants could mostly respond on a 5-point Likert scale. Some questions were open questions, so participants could give feedback in their own words *(see appendix I for the complete questionnaire in Dutch)*.

Materials

The same treadmill (Johnson Health Tech, JET-7000N) was used for practicing and testing. The VO_2 was measured with a calibrated mobile gas analysis system (Cortex Metamax B3, Cortex Medical GmbH, Leipzig, Germany) and MetaSoft® Studio Software. The Cortex Metamax is a valid and reliable system for measuring ventilatory parameters during exercise (35, 36). HR was measured with a Polar T31 heart rate monitor (Polar Nederland b.v., Almere, the Netherlands).

Procedure

Familiarization process

The familiarization process consisted of three steps for the participants to get acquainted with the materials and testing procedure, in order to optimize maximal testing results (17) (*see table 3).* Only when a participant was familiar with the current step, the next step was introduced.

Table 3*: Steps in the familiarization process*

Step 1	Explaining and demonstrating testing procedures, testing equipment and the testing environment.
Step 2	Walking on the treadmill at a comfortable speed of between 3 and 6 km/h for up to 5 min. While walking at the highest speed, the treadmill grade is gradually increased so the subjects could get accustomed to the changes in grade.
Step 3	Practising the GXTT and SET at the testing speed on the treadmill with the measurement gear, mask, and heart rate monitor in place.

GXTT= Graded Maximal Treadmill Test, SET= Supramaximal Exercise Test

GXTT and SET

A semi-individualized protocol was used (17). At the start of the GXTT, the walking speed was set at comfortable pace for the participant for 2 minutes. Then speed was increased to a fast walk for 2 minutes. The treadmill grade was increased by 2.5% every 2 minutes until 12.5%, after which the speed was further increased by 0.8 km/h every minute, until volitional exhaustion. Peak exercise parameters were defined as the values achieved during the last 30 seconds of the test.

The SET starts with a 30-second warm-up walk at comfortable pace, after which the speed was increased to a fast walk for another 30 seconds. Then the grade was increased 1% every 10 seconds to at least 110% of the maximum attained setting during the GXTT or until 15%. After which the grade was kept at 15% and the speed was further increased by 0.9 km/h every minute, until volitional exhaustion. Peak exercise parameters were defined as the values achieved during the last 30 seconds before stopping. During the whole test (GXTT and SET) the participants were positively encouraged, as much as needed, to continue walking.

Data analysis

Completion rate and the achievement of the Rowland criteria were analysed with descriptive statistics. VO_{2peak} was analysed with descriptive statistics. Associations between the normalized $VO_{2peakGXTT}$ and the $VO_{2peakSET}$ were examined with the use of the $ICC_{agreement}$ (model 2.1) (33). Bland and Altman plots were used to display the Limits of Agreement (LoA) between $VO_{2peakGXTT}$ and the $VO_{2peakSET}$ (37). The questionnaire was analysed with descriptive statistics and remarks of the participants were described. The results of the ID-fitscan were used to describe the participant characteristics. All statistical analyses were performed using SPPS for Mac (version 21 SPPS Inc., Chicago, III).

RESULTS

Participants

This study included 16 participants. Four participants were excluded; two for not obtaining medical clearance en two for the inability to perform the tests within the test period. A total of 12 adults with ID (9 male) participated in this study. None of the participants had Down syndrome. The baseline characteristics and results of the ID-fitscan of the participants are presented in table 4. The group is very divers with regard to age, weight, height and ID-fitscan performance.

***Table 4**: Baseline characteristics of participants*

Participants		
Gender n (% male)		12 (75%)
Level of ID n (% male)	**Borderline**	-
	Mild	4 (75%)
	Moderate	8 (75%)
	Severe	-

Baseline characteristics			
	Mean	**SD**	**Range**
Age (y)	30.1	8.0	20 – 45
Weight (kg)	83.4	35.1	53.9 – 182.0
Height (cm)	177.2	11.0	156.0 – 198.0
BMI (kg/m^2)	26.0	7.9	18.3 – 46.4
Waist Circumference (cm)	94.7	20.4	71.0 – 138.0

ID-fitscan (n=12)			
	Mean	**SD**	**Range**
30sCS (number)	14.6	3.1	9 – 20
5tCS (sec)	9.75	1.94	8.13 – 14.06
Max. grip strength right (N)	40.7	11.1	18 – 52
Max. grip strength left (N)	38.4	11.6	18 – 51
Static Balance (av. time in sec)	9.12	2.32	2.00 – 10.00
Walking Speed (km/hr)	5.3	1.2	2.6 – 7.0

GXTT (n=12)			
	Mean	**SD**	**Range**
HR_{peak} (beats/min)	164	29	112 – 218
Time (min:sec)	16:26	4:41	4:11 – 23:16
Peak Speed (km/hr)	8.6	3.2	4.0 – 15.0
$VO_{2peakGXTT}$ (L/min)	2.48	0.85	1.10 – 4.16
VO_{2peak}/kg (mL/min/kg)	32.2	12.4	15.6 – 51.0
VCO_{2peak} (L/min)	2.94	1.11	1.19 – 5.33
VE_{peak} (L/min)	83.71	31.67	35.91 – 156.48
RER_{peak}	1.18	0.20	0.94 – 1.66

	SET (n=11)		
	Mean	**SD**	**Range**
HR_{peak} (beats/min	170	23	128 – 212
Time (min:sec)	6:29	2:30	4:23 – 12:34
Peak Speed (km/hr)	8.9	2.4	5.8 – 12.8
$VO_{2peakSET}$ (L/min)	2.54	0.81	1.26 – 4.03
VO_{2peak}/kg (mL/min/kg)	33.6	11.2	16.4 – 49.4
VCO_{2peak} (L/min)	2.82	0.94	1.23 – 4.33
VE_{peak} (L/min)	85.80	25.98	35.89 – 125.83
RER_{peak}	1.13	0.27	0.85 – 1.80

ID= Intellectual Disability; SD= Standard Deviation; BMI= Body Mass Index; 30cCS= 30 second chair stand; 5tCS= 5 times chair stand; SD= standard deviation; kg= kilogram; cm= centimeters; m= meters; sec= seconds; N= newton; y= years, GXTT= Graded Maximal Treadmill Test, SET= Supramaximal Exercise Test, Norm= normalized, SD= standard deviation, VO_{2peak}= peak volume of oxygen, RER= respiratory exchange ratio, HR= heart rate, VCO_{2peak}= maximal volume of carbon dioxide, VE= total volume, L= liter, min= minute, sec=second, km= kilometer, hr=hour

Completion rate

The completion rate was 75%, which is defined as excellent (9 out of 12 participants)(38). Eleven participants performed both the GXTT and the SET. One participant did not want to perform the SET, because of discomfort of the mask and fatigue. The Rowland criteria for maximal effort were met by 9 of the remaining 11 participants *(see table 5)*. The 2 participants who did not meet the Rowland criteria did not meet any of the objective criteria.

***Table 5**: Rowland criteria of maximal effort*

	GXTT		**SET***	
Subjective Criteria	**Yes**	**No**	**Yes**	**No**
Unsteady walking	0	12	0	11
Sweating	11	1	11	
Facial flushing	10	2	10	1
Clear unwillingness to continue despite encouragement	12	0	11	0
Objective Criteria	**Yes**	**No**	**Yes**	**No**
HR_{peak} > 95% $HR_{predicted}$*	3	8	4	7
RER_{peak} > 1.00	10	2	8	3
VO_2 plateau in the last minute	0	12	0	11

HR_{peak}= peak heart rate; RER_{peak}= peak Respiratory Exchange Ratio; $HR_{predicted}$: 210 - (0.56 age) - (15.5 DS) (31); VO_2 = *volume of oxygen*
** 1 participant had problems with the heart rate monitor, so no HR-score for the GXTT could be measured and another participant did not perform the SET. Therefore only 11 scores were counted for both the GXTT and SET*

Agreement of VO_{2peak}

The $ICC_{agreement}$ between the normalized $VO_{2peakGXTT}$ and the normalized $VO_{2peakSET}$ was excellent; ICC= 0.99 (95%CI 0958 – 0.998; p=< 0.000). The LoA was displayed in a Bland Altman Plot with the difference of the $VO_{2peakSET}$ from the $VO_{2peakGXTT}$ presented in percentage and ranging between -6.4% to 5.7% with an average of 0.95% *(see figure 1)*. The differences of the VO_{2peak} of the participants who did not meet the Rowland criteria of maximal effort were -14.8% and 13.4%.

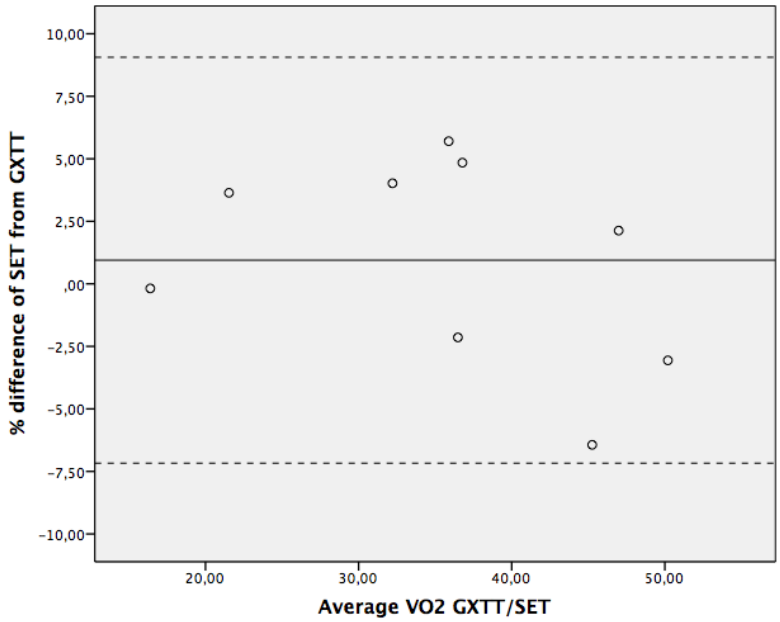

***Figure 1**: Bland Altman Plot of percentage of difference of $VO_{2peakSET}$ compared to $VO_{2peakGXTT}$ and the average VO_{2peak} of the GXTT and SET in ml/min/kg (N=11). N=9; LoA= -7,2 – 9,1 % (mean ±1.96*SD); Mean difference= 0.95%; Standard Deviation of the difference= 4,1%; Range of -6.4% - 5.7%.*

Acceptability

The questionnaire showed no major problems in acceptance of the total test procedure for the participants *(see table 6)*. The participants most frequently had problems with the breathing mask. Eight participants commented, that they didn't like the mask. One participant didn't want to wear the mask anymore halfway through testing and stopped the test. Another participant removed the mask between the GXTT and the SET, but finished testing. Furthermore the increase in walking speed after reaching the maximal inclination was difficult for 2 participants. It was not the increase in speed itself, but they commented their locomotion skills made it difficult to keep up with the increase in speed.

***Table 6**: Summary of responses of questionnaire*

	Acceptance	Annoying	Remarks
Breathing mask	4	8	Mask is annoying Reminds me of narcosis
Heart rate monitor	11	1	-
Walking speed	10	2	The increasing speed was hard to maintain with my locomotion skills
Treadmill inclination	12	0	-
Familiarization process	11	1	Very useful
Total test	12	1	When can we do it again

DISCUSSION

The purpose of this study was to determine three aspects of feasibility (completion rate, agreement and acceptability) of measuring VO_{2max} with a GXTT followed by a SET. Prior to testing there was a 3-step familiarization process for the participants to get acquainted with the test equipment and test protocol. The completion rate was excellent (75%), the agreement was excellent (ICC 0.99) and the questionnaire showed good acceptance. The results of this study show, that it is feasible to measure the VO_{2max} through the GXTT and SET, and no major adaptations to the measuring procedure are necessary.

The completion rate of the measurement procedure was 75% of the participants. The predetermined standards for acceptable completion rate were >50% as good and >75% as excellent (27). This standard was an arbitrary choice. A completion rate of 75% was considered excellent for this study, because of the large heterogeneity of adults with ID and the possible motivational problems of adults with ID (27). The completion rate of 75% can be used in for future research when calculating the necessary sample size.

It is difficult to verify if a participant has performed with maximal effort in adults with ID. Therefore, the Rowland criteria were used to establish maximal effort. These criteria were divided in subjective and objective. The objective criteria contain thresholds of HR, RER and VO_2 plateau. As stated in the introduction, these thresholds have been questionable for establishing VO_{2max}, because of between-subject differences in maximal attainable physiological values (24). Regarding the Rowland criteria, it is of interesting that only 3 participants reached the $HR_{predicted}$ in both the GXTT and the SET and 1 participant reached it once. One participant even remained more than 30 beats per minute below $HR_{predicted}$. The equation of the predicted maximal heart rate as described by Fernhall et al. (2001) (31) was based on group-level calculations and seems not suited for individual use in people with ID to rely on, because of the huge variations in actual maximal heart rates. This is also in line with the study of Oppewal et al. (2014) into heart rate recovery in older adults with ID (39). Regarding the other criteria, none of the participants reached a VO_2-plateau during the tests. The RER_{peak} was >1.0 for 8 of the participants in both tests, with a lower RER_{peak} of the SET for all participants compared to the RER_{peak} of the GXTT. Although these criteria were questionable ways to establish VO_{2max}, they seem to give a good impression, of whether the performance was with maximal effort, since we found participants meeting an objective Rowland criterion had a much smaller percentage of difference of VO_{2peak} between the GXTT and the SET.

The $ICC_{agreement}$ between the VO_{2peak} on the GXTT and the SET was very high with a score of 0.99. This is very promising, but it has to be taken into account that the wide range of VO_{2peak}/kg scores amongst the participants, the small differences of the GXTT and the SET, and the low number of participants (9), may have caused an overestimation of the intraclass-correlation-coefficient. The Bland Altman Plot of the LoA in percentage showed an average difference in VO_{2peak}/kg scores of 0.95% of the participants performance on the GXTT and a range of -6.4% to 5.7%. So some scores are above the 3.9%, Astorino et al. (2009) found in a study of sedentary man and women (25), but clinically relevant differences for adults with ID need to be determined in future studies.

Overall, the acceptance of the measurement procedure was good, but the use of a breathing mask was annoying for 8 out of 12 participants. A breathing mask had to be used to measure the

ventilation of the participants. So even though we used a user-friendlier mask, which covers mouth and nose, instead of a mouthpiece with a nose clip, the mask was still considered uncomfortable. However, the breathing mask is in our opinion the best choice to measure the ventilation, but introduction and familiarization of the breathing mask seems important to ensure acceptance and therefore performance of the participants.

Strengths

This study is the first to study the feasibility of cardiorespiratory fitness (VO_{2peak}) measuring through supramaximal testing of adults with ID living in a residential setting. In this study the VO_{2peak} of the GXTT reflected a true VO_{2max} for 75% of the participants. The other 25% did perform the GXTT but it was not certain that a true VO_{2max} score was reached. Previous studies of maximal testing in adults with ID, are not focused on residential living setting (17, 40), concern younger adults with DS (15, 41), and/or have no supramaximal verification of VO_{2peak} (17, 40, 42).

A strong aspect of this study is the careful familiarization process to allow the participants to become familiar and comfortable with the testing procedures. The use of a familiarization process is necessary for a good result as recommended in previous studies (15, 17). The equipment is unknown to most participants (especially the breathing mask and the treadmill), most of them are not familiar with test protocols and most of them are not used to performing with maximal effort. The questionnaire on acceptability showed high appreciation of the familiarization process. So, a familiarization process helps the participants to feel confident their ability to perform the test, resulting in better performances of the test.

Limitations:

A major limitation of this study is the use of a convenience sample. The adults with ID, who participated in this study, liked to be physically active and most of them had an active lifestyle. They were used to getting tired and were more likely to perform with maximal effort. Most of the adults with ID however, lead a sedentary lifestyle and are not used to sweating, to feeling their heartbeat and to getting exhausted. The findings of this study cannot be generalized to all adults with ID, but this study is a promising start and more research is needed to see if VO_{2max} can be measured in other groups of adults with ID.

For a good measurement it is necessary to choose the right speed for the fast walk. An underestimation of the fast walk speed results in a test time above the desired test time and could lead to muscle fatigue instead of volitional exhaustion. For the GXTT and SET a certain amount of time and effort is needed for a good score (24, 25). Although the wide range of VO_{2max} scores underline using a semi-individualized protocol, the average test time for both the GXTT and the SET in this study were above the intended duration of 10-15 and 2-5 minutes. Possibly the chosen fast walk speed of most participants underestimated their possibilities, which led to an increase in test time. In this study muscle fatigue could have caused an underestimation of the true VO_{2max}. Some extra time in the familiarization process should be spend in getting the participants familiar with walking on the treadmill, and choosing the fast walk speed fast enough, but not too fast, so the test time stays between the preferred timeframe.

The treadmill had a maximum inclination of 15%, after which it was necessary to increase the speed.

It was noted, that some participants had problems with their locomotion skills when the speed was increased, which could have led to an early stop of the test. For future research it would be advised to use a treadmill with higher inclination possibilities.

Future directions/clinical implications

This study was performed in adults with a mild to moderate ID, living in a residential setting, with a more active lifestyle. The feasibility of the measurement procedure in adults with ID with a more sedentary lifestyle as well as in adults with a more moderate to severe ID remains to be determined. Furthermore, it is not known, what the minimal clinical difference in VO_{2peak} of the GXTT and the SET is, so it still reflects a true VO_{2max} in adults with ID. The Bland Altman plot on LoA showed a range of differences of VO_{2peak} between -6.4% and 5.7% in this study, but the clinical relevant difference for adults with ID still needs to be determined. The findings of this feasibility study are promising for future research to use the measurement procedure with supramaximal verification of the VO_{2peak} of the GXTT, when focusing on establishing more valid norm scores on the cardiorespiratory fitness of the adults with ID. This study is just the first step, which could in time lead to the much-needed validation of submaximal exercise tests, through comparison with the potential gold standard of the GXTT-SET measurement procedure. These submaximal exercise tests for adults with ID can then be used to determine health risk factors and evaluating therapy in clinical practice.

CONCLUSION

This first study investigating maximal and supramaximal cardiorespiratory testing in adults with ID shows it seems feasible to perform the measurement procedure of a familiarization process, a maximal treadmill test (GXTT) followed by a supramaximal exercise test (SET) in adults with mild to moderate ID. Therefore, it can be possible to verify the VO_{2peak} of the GXTT as a true VO_{2max} in adults with an ID. The results of this feasibility study encourage further research on measuring the cardiorespiratory fitness of adults with ID.

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Appendix I: Questionnaire [in Dutch]

Vragenlijst Toepasbaarheid GXTT en SET bij volwassenen met een verstandelijke beperking

Client ID: ……. datum: ……..

Beleving

1. Hoe was het om de test te doen?
    - Heel erg vervelend
    - vervelend
    - Gewoon
    - Leuk
    - Heel leuk
2. Hoe was het om te oefenen voor de test?
    - Heel erg vervelend
    - vervelend
    - Gewoon
    - Leuk
    - Heel leuk
3. Hoe was het om met een mondkapje op te lopen?
    - Heel erg vervelend
    - Vervelend
    - Gewoon
    - Geen last van
    - Totaal geen last van
4. Hoe was het om met een hartslagmeter om te lopen?
    - Heel erg vervelend
    - Vervelend
    - Gewoon
    - Geen last van
    - Totaal geen last van
5. Hoe vond u de snelheid waarmee u moest lopen op de loopband?
    - Veel te langzaam
    - Langzaam
    - Goed
    - Snel
    - Veel te snel
6. Hoe vond u het om schuin omhoog te moeten lopen op de loopband?
    - Heel erg vervelend
    - vervelend
    - Gewoon
    - Leuk
    - Heel erg leuk
7. Zou u de inspanningstest nog een keer willen doen?
    - Nee
    - Ja, namelijk……
8. Zou u anderen personen aanraden om de inspanningstest ook een keer te doen?
    - Nee
    - Ja, namelijk……

Moeilijkheidsgraad

9. Begreep u de uitleg en oefenen van de test?
    - Ja
    - Nee
10. Begreep u wat u moest doen tijdens de test?
    - Ja
    - Nee, namelijk…….
11. Hoe zwaar was het om de test uit te voeren?
    - Heel zwaar
    - Zwaar
    - Gewoon
    - Makkelijk
    - Heel makkelijk

Uitvoerbaarheid

12. Kon u het eerste deel van de test goed uitvoeren?
    - Ja
    - Nee, namelijk…….
13. Was u moe na afloop van het eerste deel van de test?
    - Nee
    - Ja, namelijk……
14. Had u nog langer kunnen lopen dan u nu gedaan heeft tijdens het eerste deel van de test?
    - Nee
    - Ja, namelijk……
15. Kon u het tweede deel van de test goed uitvoeren?
    - Ja
    - Nee, namelijk…….
16. Was u moe na afloop van het tweede deel van de test?
    - Nee
    - Ja, namelijk……
17. Had u nog langer kunnen lopen dan u nu gedaan heeft tijdens het tweede deel van de test?
    - Nee
    - Ja, namelijk……
18. Kreeg u ergens last van?
    - Nee
    - Ja, waar ……..
19. Zo ja, Ging dat daarna ook weer weg?
    - Ja, na …… minuten
    - Nee

Heeft u nog overige opmerkingen of tips over de maximale inspanningstest en/of de introductieprocedure?

……
……
……
……
……

Vragen aan onderzoeker

1. Was de introductieprocedure praktisch uitvoerbaar bij deze cliënt
    - Ja, evt problemen……
    - Nee, vanwege……..
2. Had u tijdens de introductieprocedure de indruk dat de deelnemer de uitleg begreep en de oefeningen goed uitvoerde?
    - Ja
    - Nee, omdat…… Welke onderdelen niet?……..
3. Had u tijdens het uitvoeren van de test de indruk dat de deelnemer de opdrachten begreep en kon uitvoeren?
    - Ja
    - Nee, omdat…… ……..
4. Heeft u op de testdag de inspanningstest nog extra moeten toelichten/verduidelijken?
    - Nee
    - Ja. Welke?…….....
5. Heeft u nog overige opmerkingen of aanvullingen met betrekking tot de introductie procedure en de test?

    ……
    ……
    ……
    ……
    ……
    ……
    ……

    Hoe lang duurde de metingen? … min.

    Hoe lang duurde het afnemen van de vragen? … min