

How is rating of perceived capacity related to VO_{2max} and what is VO_{2max} at onset of training?

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ABSTRACT

Objective To evaluate how rating of perceived capacity (RPC) is related to maximal oxygen uptake (VO_{2max}) and examine VO_{2max} at onset of training in healthy adults.

Methods In total, 125 newly registered fitness centre members, equally men and women, answered the RPC scale and performed a treadmill test for measurement of VO_{2max} . Eligible criteria were <4 weeks of fitness centre membership, physically inactive, ≥ 18 years and not pregnant. The RPC is a one-page scale (1–20) based on metabolic equivalent tasks, where the individual chooses the most strenuous activity that can be sustained for at least 30 min.

Results The Bland-Altman plot demonstrated a tendency of overestimation, meaning that the participants ranked their own aerobic capacity 17.5% higher than objectively measured values of VO_{2max} . The mean difference between the two methods were $+4.92 \pm 1.96$ and $+6.35 \pm 1.96$ mL/min/kg VO_2 in men and women, respectively. The Pearson correlation coefficient was moderate, with $r=0.426$ ($p<0.01$). A linear regression analysis showed that both age and VO_{2max} were significant predictors of RPC ($p<0.01$). Measured VO_{2max} at onset of fitness centre membership was in men aged 38.7 ± 11.7 and women aged 34.7 ± 9.9 , 40.5 ± 7.2 and 35.0 ± 6.0 mL/min/kg, respectively. Estimated VO_{2max} from the RPC scale was 45.7 ± 9.8 and 41.4 ± 10.1 mL/min/kg in men and women, respectively.

Conclusions The RPC seems less accurate at the individual level and may overestimate VO_{2max} . Still, it may be considered useful in large-scale studies.

INTRODUCTION

To date, it is scientific evidence linking low cardiorespiratory fitness to cardiovascular disease and all-cause mortality,¹ and higher levels of cardiorespiratory fitness are associated with a lower risk of mortality from cardiovascular disease, independent of age, smoking and body composition.^{2–5} Cardiorespiratory fitness is usually expressed as maximal oxygen uptake (VO_{2max}) measured by exercise testing or in metabolic equivalent tasks (METs).

VO_{2max} is defined as the highest rate the body can transport and use oxygen during

What are the new findings?

- ▶ To the authors knowledge, this is the first study validating the rating of perceived capacity (RPC) against VO_{2max} , measured on a treadmill (gold standard).
- ▶ The results showed a moderate correlation ($r=0.426$) between the RPC scale and VO_{2max} .
- ▶ Untrained healthy adults overestimated their aerobic capacity 17.5% higher than objectively measured values of VO_{2max} .

How might it impact on clinical practice in the near future?

- ▶ The RPC scale may be used for the estimation of VO_{2max} in large-scale studies, but may be somewhat inaccurate at the individual level.
- ▶ The RPC scale may be considered a useful and valuable tool for estimation of aerobic capacity in the general healthy adult population without the major costs associated with exercise testing.

exercise, and cardiopulmonary exercise testing (CPET) is one of the most common and valid measurements of cardiorespiratory fitness.⁶ However, CPET is time consuming, expensive and requires exercise to volitional exhaustion. Therefore, it is not advisable for all individuals.⁷ Thus, several different submaximal testing protocols have been developed to reduce testing time, costs and increase the individuals motivation for strenuous exercise.⁸

Still, it would be advantageous to predict an individuals cardiorespiratory fitness without having to perform CPET. Wisen *et al* have developed a one-page scale based on different activities that are linked to a MET.⁹ An estimated VO_{2max} is obtained by asking the individual to choose the most strenuous activity that can be sustained for at least 30 min. The corresponding selected MET value can then be transformed into



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oxygen uptake or workload, valuable when questionnaires are conducted in epidemiological studies.⁹

To our knowledge, only one study has investigated RPC and the relationship with VO_{2max} . Wisen *et al* compared the RPC scale with work capacity assessed by a ramp cycle test, which is not considered the gold standard to examine cardiorespiratory fitness.^{9–11} In addition, CPET are important to evaluate exercise programmes and to encourage individuals to have a physically active lifestyle.^{6 10 12} Despite this, it is rarely measured in new beginner exercisers. To our knowledge, no study has investigated aerobic capacity at onset of fitness centre membership.

Hence, the aims of the present study were to (1) validate the RPC scale against VO_{2max} measured on a treadmill (gold standard) and (2) assess VO_{2max} at onset of training in healthy men and women.

MATERIALS AND METHODS

Design

This study was part of a longitudinal prospective cohort study, following up a group of new members at 25 fitness centres in Oslo, Norway, to gather repeated measures of physical activity level and health status, including a wide range of psychosocial and physiological parameters. The present study was financed by and conducted at the Norwegian School of Sports Sciences in Oslo, during the period October 2015 to April 2016. The study was reviewed by the Regional Committee for Medical and Health Research Ethics (REK 2015/1443 A), who concluded that, according to the Act on medical and health research (the Health Research Act 2008), the study did not require full review by REK. The study was approved by the Norwegian Social Science Data Service (NSD 44135). In accordance with the Declaration of Helsinki, all participants received written information about the projects purpose and procedures, and gave consent to participate. Further, it was emphasised that the participants could withdraw from the project at any time with no explanation required. No economic compensation was given.

Participants

Participants for the present study were recruited by an email invitation from the local fitness centre. Eligibility criteria were <4 weeks membership, untrained, ≥18 years, healthy and not pregnant. Untrained was classified as exercising <60 min once a week at moderate or vigorous intensity. Being healthy was defined as no chronic serious disease or pathology (heart disease or severe hypertension).

Measurements

An electronic questionnaire including the RPC scale was answered before measurement of VO_{2max} at the laboratory. The questionnaire also contained questions

about background information, motives and barriers for physical activity,^{13 14} social support to physical activity,^{15 16} subjective health complaints,^{17 18} perceived quality of life,^{19–21} body image²² and exercise dependence.²³

Rating of perceived capacity scale

To estimate and classify the energy cost of physical activity, it is usual to express the energy cost as METs.^{24–26} The MET value is defined as the ratio of work metabolic rate to a standard resting metabolic rate (RMR) of 1 kcal/kg/hour. One MET is considered the energy cost of a person at rest (3.5 mL/min/kg).²⁴

The RPC scale is based on MET values, and each number on the scale is linked to different activities such as sitting, walking and running, derived from several sources (table 1).^{8 26 27} The scale is designed to be useful for both genders, with maximal MET values in gender differences (20 for men and 18 for women).⁹ The participants were told to select one distinct MET value, the most strenuous activity that could be sustained for at least 30 min.⁹ A Norwegian version of the scale was used in the present study.²⁸

Table 1 Rating of perceived capacity (RPC) scale⁹

Are you able, for half an hour or more, to	
1	Sit
2	
3	Walk slowly
4	
5	Walk at normal pace/cycle slowly
6	
7	
8	Jog/cycle
9	
10	Run
11	
12	Run fast/cycle fast
13	
14	
15	Run very fast (more than 15 km/hour)
16	
17	
18	Perform elite aerobic training (women)
19	
20	Perform elite aerobic training (men)

VO_{2max}

For accurate measurements of VO_{2max} , body weight was measured with Inbody 720 (Biospace), in light clothing without shoes.²⁹ Height and body weight were measured to the nearest 0.5 cm and 0.1 kg, respectively.

The stepwise modified Balke protocol started with a 3 min warm-up at an initial speed of 4.5 km/hour with no inclination.³⁰ Then, the treadmill inclination increased by 5% every minute up to 20%, while the speed was kept constant (4.8 km/hour). Accordingly, the speed increased every minute with 0.5 km/hour, while inclination was constant (20%).³⁰ The Borg scale (range 6-20) was used for rating perceived exertion.³¹ The exercise test was stopped when the participants reached maximal exhaustion (≥ 19 on the Borg scale). An additional criterion was a respiratory exchange ratio (RER) between 1.10 and 1.30 according to age.³² The highest VO_{2max} and highest RER measured before or corresponding to the last 30 s were reported.

Measurement of VO_{2max} was registered with indirect calorimetry (Oxycon Pro; Jaeger). The participants breathed through a Hans Rudolph mask (US) covering both mouth and nose attached to a non-rebreathing hose. Expired air/gases were continuously sampled each 30 s during the whole exercise test. A heart rate monitor (Polar RS800) was used to record maximal heart rate (HR_{max}). Prior to each test day, all analysers were calibrated after the manufacturers guidelines and all exercise tests were supervised by the same research fellow.

Data processing

In prolonged periods of physical activity/exercise (approximately 30 min), a healthy untrained individual will be able to use about 70% of their VO_{2max} .²⁵ Hence, the MET value from the RPC scale may express about 70% of an individual's VO_{2max} .²⁵

The average RMR in adults is 3.5 mL/min/kg, and this is equal to one MET.²⁴⁻²⁶ In order to compare the RPC scale with VO_{2max} , MET values from the RPC scale were transformed into MET_{max} and then calculated to estimated VO_{2max} using the following equations:

$$MET_{max} = \frac{VO_{2max} \text{ (mL} \cdot \text{min}^{-1} \cdot \text{kg}^{-1})}{3.5}$$

$$\text{Estimated } VO_{2max} = MET_{max} \cdot 3.5$$

Statistical analysis

Data analysis was conducted with SPSS Statistical Software V.24.0 for Windows. Background variables, estimated VO_{2max} (RPC) and measured VO_{2max} are presented as means with SD or frequencies and percentages. The strength of agreement between the two methods was analysed by Bland-Altman plot.³³ Additionally, to enable comparison of these results with other studies, the Pearson correlation coefficient was used to evaluate the RPC scale (estimated VO_{2max}) and measured VO_{2max} . The correlation values were interpreted as good=0.501.0, moderate=0.300.49 and fair=0.100.29.^{34 35} A linear regression analysis was calculated to examine if RPC was predicted by VO_{2max} , age or gender. Level of significance was set at $p < 0.05$.

RESULTS

Of 275 who contacted the research group, 146 were excluded due to exercising regularly and four due to various diseases. Hence, our final sample included 125 participants, equally men and women. Demographic characteristics and health factors are given in table 2. Age ranged from 18 to 71 and 2159 years in men and

Table 2 Comparisons of demographic and health factors between men and women (n=125)

Variable	Men (n=62)	Women (n=63)	p Value
Age (years)	38.8 (± 11.7)	34.8 (± 10.0)	0.04
BMI (kg/m^2)	25.6 (± 3.2)	24.6 (± 4.5)	0.13
Waist:hip ratio	0.90 (± 0.03)	0.87 (± 0.05)	<0.01
Fat mass (%)	20.0 (± 5.4)	30.5 (± 7.9)	<0.01
Fat-free mass (kg)	67.9 (± 7.4)	47.0 (± 4.9)	<0.01
Muscle mass (kg)	38.6 (± 4.4)	25.6 (± 4.0)	<0.01
Self-perceived health \geq good	38 (61.3%)	40 (63.5%)	0.94
Higher education \geq 4 years	26 (41.9%)	31 (49.2%)	0.1
Daily smoker	3 (4.8%)	4 (6.3%)	0.7
Household income \geq 400 000 (Kr/year)	52 (83.9%)	49 (77.8%)	0.1

Data are presented as mean (SD) for continuous variables and n (%) for categorical variables. BMI, body mass index.

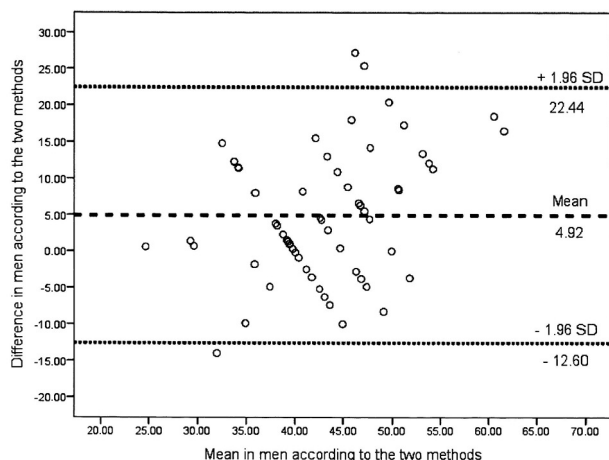


Figure 1 Bland-Altman plot for men showing the difference plotted against the mean of the two estimates assessed with the RPC scale and measured with a stepwise modified Balke protocol.

women, respectively. In terms of body mass index (BMI), 9.6% men and 9.5% women were classified as obese (BMI >30), and 58.0% men and 33.3% women were classified as overweight (BMI >25). Abdominal obesity (waist/hip ratio >0.90 for men and >0.85 for women) was assessed in 50% of the men and 61.9% of the women.³⁶ With respect to fat percentage, 47.5% of the participants had measurements above reference values (>20% for men and >30% for women).³⁷

The visual agreement of the Bland-Altman plot demonstrated an overestimation (figures 1 and 2). The mean difference between the two methods was 4.921.96 and 6.351.96 mL/min/kg VO₂, with 95% confidence limits of agreement varying from +22.44 to 12.60 and +26.49 to 13.79 mL/min/kg VO₂ for men and women, respectively. Three men and four women were outliers of the 95% limits of agreement. The

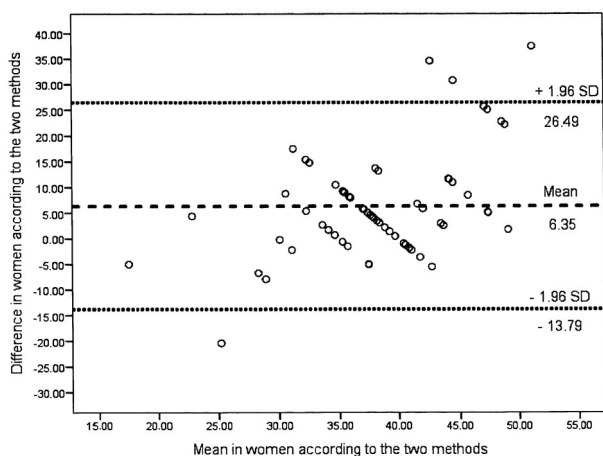


Figure 2 Bland-Altman plot for women showing the difference plotted against the mean of the two estimates assessed with the RPC scale and measured with a stepwise modified Balke protocol.

Table 3 Measured and rated values from VO_{2max} and rating of perceived capacity (RPC)

Variable	Men (n=62)	Women (n=63)	p Value
Measured VO _{2max} (mL/min/kg)	40.5±7.2	35.0±6	<0.01
Estimated VO _{2max} (mL/min/kg)	45.7±9.8	41.4±10.1	<0.01
HR _{max} (beats/min)	183±15	176±26	0.1
Borg scale	19.3±0.6	19.1±0.7	0.2
RER	1.38±0.09	1.36±0.07	0.2

Values are presented as mean (SD). HR_{max}, maximal heart rate; RER, respiratory exchange ratio.

Pearson correlation coefficient between the two methods was moderate, with $r=0.426$ ($p<0.01$).

The linear regression analysis showed a significant association between age ($p<0.01$), VO_{2max} ($p<0.01$) and the prediction of RPC. The beta coefficient was 0.26 and 0.55 for age and VO_{2max}, respectively. No significant association was found between gender and RPC ($p=0.53$).

We had no dropouts or error at measurement with respect to the stepwise modified Balke protocol. Measured and estimated VO_{2max} at onset of training are shown in table 3. Women had on average 13.6% lower measured VO_{2max} compared with the men ($p<0.01$). The participants ranked their own aerobic capacity 17.5% higher than objectively measured values of VO_{2max}. The mean duration of the stepwise modified Balke protocol was 10.431.50 min and 9.031.19 min for men and women, respectively ($p=0.07$) (table 3).

DISCUSSION

In this study, we compared estimated VO_{2max} (RPC) with directly measured VO_{2max} on a treadmill using a stepwise modified Balke protocol until exhaustion in 125 healthy untrained adults. The Bland-Altman plot of the two methods showed an overestimation in aerobic capacity at the individual level. Overestimation of estimated VO_{2max} was 14.5% and 20.3% in men and women, respectively. The correlation between the two methods was moderate ($r=0.426$, $p<0.01$). VO_{2max} at onset of training was 40.5 mL/min/kg and 35.0 mL/min/kg for men and women, respectively.

Participants

All participants were defined as untrained, possibly influencing the participants estimation of their own aerobic capacity. Knapik *et al* showed that trained individuals are more capable to predict their aerobic capacity subjectively.³⁸ Still, a sedentary lifestyle is becoming more and more common worldwide, and the

majority of participants in large population-based studies are physically inactive or insufficiently physically active, with a low VO_{2max} .^{39–42} Our participants may therefore be considered representative of a general urban European population.^{40–43}

Measurements

Rating of perceived capacity scale

The RPC scale has a limited number of aerobic activities, which is believed to make it easier to evaluate aerobic capacity. Still, there may be a challenge in relation to the interpretation of the RPC scale. The aerobic activities presented in the RPC scale include walking, running and cycling at different speeds. It may be a limitation if an individual has no appreciation to perform these activities. The risk of over-reporting or under-reporting may also be present when an individual is asked to subjectively assess their aerobic capacity based on a simple scale.^{8 42} For example, running fast will not necessarily have the same meaning to an untrained and a trained individual.^{9 10 44}

VO_{2max}

Assessment of VO_{2max} using CPET is considered the most valid measure of cardiorespiratory fitness, and an increase in VO_{2max} is the most common measure of demonstrating a training effect.^{6 10 11} However, CPET may not be suitable for individuals who have different health challenges related to pain or fatigue.⁶ Further, the method requires exercise to volitional exhaustion, qualified personnel, as well as being expensive and time consuming.⁶

The secondary aim of the present study was to evaluate VO_{2max} at onset of training in healthy men and women. To verify a valid VO_{2max} , RER had to be between 1.10 and 1.30 according to the age-dependent results reported by Edvardsen *et al.*³² In addition, the Borg scale had to be ≥ 19 , reflecting a combination of exhaustion from central and peripheral factors, as well as psychological factors.³¹ Both physiological and psychological end criteria are of importance to determine maximal exhaustion due to that untrained individuals often overestimate perceived exertion.⁴⁵ Our participants expressed more muscular fatigue than shortness of breath. One explanation for this may be the chosen test protocol, and lower anaerobic threshold in untrained individuals, meaning that local muscle fatigue was a determining limitation more than central factors.^{46–51}

Results

VO_{2max} related to the RPC scale

The present results showed large individual differences, with 17.4% overestimation in subjectively estimated VO_{2max} compared with measured values. This is in contrast to the findings of Wisen *et al.*, where the participants underestimated their aerobic capacity

by 17%. It should be noted that Wisen *et al.* compared RPC with a ramp cycle test.⁹ Myers *et al.* also found an underestimation in self-rated aerobic capacity, using veterans specific activity questionnaire and maximal exercise testing on a treadmill in 212 elderly.^{9 52}

Prieto *et al.* compared VO_{2max} on a treadmill with Subjective Appraisal of Aerobic Capacity (SAAC) scale and found that 94.4% of the participants with a low VO_{2max} (<43.0 mL/min/kg) classified their aerobic capacity as high or very high.^{53 54} The major difference between the RPC and SAAC scale is how the participants rank their aerobic capacity. The SAAC scale uses values related to aerobic capacity levels from 1=Very poor to 7=Excellent. Furthermore, the scale is not related to MET values. The RPC scale has multiple MET values (120), most likely making it simpler for each individual to predict their aerobic capacity.⁹ Hence, we believe that the RPC scale may be more accurate and relevant to aerobic capacity in individuals with a low VO_{2max} .^{9 25} Still, the present study found an overestimation in estimated VO_{2max} , with an average of 17.5%.

Differences in self-reported and objectively measured aerobic capacity may be explained by the variations in chosen questionnaires/scales, exercise tests (VO_{2max} /submaximal, treadmill/bicycle) and participants (untrained/trained).^{9 52–54} In addition, it is not possible to sustain prolonged activity at the maximal level, and differences in perception of activity will affect the risk of underestimation or overestimation.

The difference in objectively measured VO_{2max} and the RPC scale in the present study may be of importance at the individual level, but not in large-scale surveys, where the purpose is to get an overview of maximal aerobic capacity at the population level.^{53–55}

Several mathematical non-exercise models have been developed with the aim of predicting VO_{2max} .^{56 57} The studies of Jurca *et al.* and Nes *et al.* concluded that VO_{2max} may be accurately estimated with a non-exercise model including several variables such as gender, age, body composition, physical activity level and resting heart rate.^{56 57} Still, the results of Nes *et al.* indicated that the non-exercise model underestimated VO_{2max} among the most fit subjects and overestimated VO_{2max} among the least fit participants,⁵⁷ in accordance with the findings in the present study.

It is suggested that for untrained individuals, direct measurement of VO_{2max} should be used for a more accurate examination.⁵⁷ Still, this method may not increase an untrained individuals motivation for exercise, mainly because it requires vigorous intensity and voluntary exhaustion.

VO_{2max} at onset of training

Several studies have investigated VO_{2max} in the general adult population (2090 years).^{39 58–61} The present study showed a lower VO_{2max} than these studies.^{39 58–62} Compared with Norwegian data, the participants in the present study had in general 16.5% and 9.6% lower

VO_{2max} in men and women, respectively.^{39 60} This may be explained by the fact that our participants were classified as untrained by inclusion due to our secondary aim. Edvardsen *et al* and Aspenes *et al* had no inclusion/exclusion criteria with respect to physical activity level, and it is not unlikely that those who are physically active had more interest in participating in studies aiming to investigate aerobic capacity.^{39 60} Only one study showed a lower VO_{2max} than our results. Mishra and Budholia compared VO_{2max} between trained and untrained men, and found on average a VO_{2max} of 37.2 mL/min/kg in the untrained group.⁶² Our men had a slightly higher VO_{2max} (40.5 mL/min/kg). A limitation of Mishra and Budholia was a sample size of 24 untrained participants only and measurement of VO_{2max} using a bicycle ergometer.⁶²

STRENGTHS AND LIMITATIONS

In this methodological comparison study, a sample size of 125 participants, with a wide range in age (1871 years), equal number of men and women, and valid and reliable exercise test (Balke protocol) to measure VO_{2max} may be considered major strengths. In addition, the same personnel tested all participants. Furthermore, we used several statistical methods to enable comparison of our results with other studies.

A limitation of the study is that we should have included a more diverse group, counting both untrained and trained individuals with very low to very high VO_{2max} . Even though the RPC scale is designed for both men and women, from the completely untrained athletes, the individuals perception of the the RPC scale may affect the individuals choice.

CONCLUSION

The RPC scale may be used for the estimation of VO_{2max} in healthy adults in large-scale studies, but may be somewhat inaccurate at the individual level. Hence, it may be a valuable tool for monitoring the effects of endurance exercise programmes in the general population.

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Contributors CG plotted all data, developed the questionnaire together with LAHH and outlined the manuscript. TS developed the treadmill protocol together with CG and LAHH and supervised the testing. CG and LAHH were responsible for data collection and recruited the participants. LAHH originated the idea for the present study, led on its design and supervised the project. All authors participated in discussing the design of the study, read and corrected draft versions of the manuscript and approved the final manuscript.

Competing interests None declared.

Patient consent Obtained.

Ethics approval The Norwegian Social Science Data Service (NSD 44135).

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement All published data from the present study are available to those who are interested (by contacting the first author). Unpublished data are currently only available to the projects group.

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