Polar Fitness Test

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Content

1. Introduction

Different types of tests exist for assessing aerobic fitness: non-exercise tests, field tests and laboratory tests. The Polar Fitness Test is a non-exercise test that predicts maximal aerobic power (maximal oxygen uptake, VO2max). The test includes resting measurements of heart rate and heart rate variability with personal information.

The main benefits of doing the Polar Fitness test are:

• You can easily and safely evaluate your aerobic (cardiovascular) fitness at rest. Understanding your aerobic fitness level (VO2max) is the cornerstone of efficient training. Fitness testing gives a base for exercise prescription

• You get to know your current fitness level in comparison to the average values of people of the same age and gender. Poor aerobic fitness is a risk factor for health.

2. Content of calculation

The Polar Fitness Test predicts a person's aerobic fitness from resting heart rate, heart rate variability, gender, age, height, body weight and self-assessment of the level of long-term physical activity. To obtain the measures for heart rate and heart rate variability, at least 240 heart beats (3–5 min) are measured during the test. Physical activity is assessed using a six-level scale (occasional to pro). The scale has been modified from the NASA/JSC physical activity scale (Ross et al. 1990) used also in a non-exercise test for maximal aerobic power prediction (Jackson et al. 1990). The physical activity level should remain the same, if a person's regular exercise habits have not changed during the previous 6 months.

Fitness Test takes into account heart rate variability (HRV). In general, high heart rate variability is linked to general good health and high cardiovascular (aerobic) fitness. HRV has been shown to have value in an individual's responsiveness to cardiorespiratory training (Bouchard et al.1999, Hautala et al. 2003, Tulppo et al. 2003, Kiviniemi et al. 2010). Higher vagally mediated HRV has been associated with larger improvements in cardiorespiratory fitness (Hautala et al.2003, Hedelin et al. 2001, Kiviniemi et al. 2007)

The effect of long-term physical activity on the result is essential: the greater the amount of activity, the better the fitness. In general, the test result is raised by a decrease in the resting heart rate and an increase in heart rate variability, and lowered by an increase in the resting heart rate and a decrease in heart rate variability. To achieve long-term changes in the resting heart rate and heart rate variability, regular physical activity of at least 6 weeks is needed.

The effects of the above mentioned variables in Fitness Test cannot be totally separated from each other – the variables always act in concert. In general, however, the activity assessment together with heart rate measurement explain about half of the result and the background variables (body weight, gender, age, and height) explain the other half. Since the VO2max value is given relative to body weight, the result is improved by a decrease in body weight and lowered by an increase in body weight.

3. Development of Fitness Test

Fitness Test has been developed for healthy adults using an artificial neural network (Väinämö et al. 1996,1997,1998) calculation, which is a widely used method in signal processing.

In the test development study, 305 laboratory fitness measurements of 15–65-year-old healthy men and women were performed (Väinämö et al. 1996, Väinämö et al. 1998). Maximal oxygen uptake was measured with an ergospirometer (Medikro M 909, Kuopio, Finland)) during graded maximal cycle ergometer tests. Before the maximal stress test, at least 250 R-R intervals (5 minutes) were recorded at complete rest in a lying position using Polar R-R Recorder™ (Polar Electro Oy, Kempele, Finland). Measurement errors were removed from R-R intervals using both the automatic method (Hearts software, Heart Signals Co, Kempele, Finland) and visual inspection. Development of VO2max prediction in the neural network was done in two phases: firstly 25 subjects were randomly selected as testing (validation) samples. After that, the rest of the 305 subjects were used for the teaching of the neural network. In addition to heart rate and heart rate variability, gender, age, and height were used as predictive variables. Body weight was used for the calculation of relative VO2max (ml/min/kg).

A high correlation coefficient (0.97) was reached between the laboratory measured VO2max and the predicted VO2max (i.e. Fitness Test result, previously OwnIndex), (Väinämö et al. 1996,1998). The mean error in the VO2max prediction was 6.5%. The measured maximal aerobic power values in the data varied between 1–6 l/min (25–60 ml/min/kg). In 95% of the cases in the teaching data and in 60% of the cases in the validation data, the error in VO2max prediction was less than 0.5 l/min. The mean error of the prediction is good compared to any other predictive tests of maximal aerobic power. Typically, the mean errors vary between 8–15%. In the laboratory measurements of VO2max, the test-to-test variation within an individual is 3–5% due to physiological day-to-day variation and technical parameters (e.g. calibration of the ergosprirometer).

The final development of the neural network was performed with 119 fitness measurements of healthy American men and women, whose maximal aerobic power was measured in a maximal graded treadmill exercise test. Thus the number of subjects used in the final stage was 424, 381 of which were randomly selected for the teaching of the network and 43 for the validation (Kinnunen et al. 2000). The artificial neural network was modified into Polar Fitness Test.

Polar Fitness Test was further developed to create OwnIndex_S, an advanced modification of OwnIndex. In the test development study, 450 laboratory fitness measurements of 15–65-year-old healthy men and women were performed. The correlation coefficient between the laboratory measured VO2max and OwnIndex_S prediction was 0.96 and the mean error in the prediction was 8.2% (3.7 ml/kg/min). In 95% of the cases the error in the prediction was less than 9.4 ml/kg/min. Thus, the accuracy of OwnIndex_S can be considered good. OwnIndex_S was further validated in studies (Peltola et al. 2000, Tschopp et al. 2000) on trained subjects. It was shown that the VO2max prediction associated reasonably highly with VO2max measured in the laboratory in both men and women.

4. Validity and reliability

Polar Fitness Test has been validated in a study, where 52 healthy 20–60-year-old men were measured before and after an 8-week program of exercise training. There were fifteen men were in the control group. Before the training period the mean error in VO2max prediction by Polar Fitness Test™ was 2.2% and after the training -0.7% compared to the laboratory measurement of maximal aerobic power. The mean deviation in the prediction before and after the training was 4–5 ml/min/kg in all groups. Because this is less than the standard deviation of the mean VO2max values within an age group (5–7 ml/min/kg), the validity of Polar Fitness Test can be considered good. (Kinnunen et al. 2000, Tulppo et al. 2003).

The repeatability of Polar Fitness Test in consecutive tests for the same individual is good. When 11 subjects repeated the test in the morning, in the middle of the day and in the evenin for 8 days, in both sitting and lying positions, the average individual standard deviation of the consecutive test results was less than 8% from the individual mean value. The standard deviations calculated separately for each time of the day were smaller than the standard deviation of all results. This indicates that the test can be conducted at any time of the day but it should always be repeated at about the same time (unpublished).

Fitness Test has been studied also in overweight men (Pokki and Laukkanen, unpublished 2000). In this study, the predicted maximal aerobic power in 60 men (average age 45 years and BMI 31 kg/m2) with

VO2max (average, SD) scored between 34.9(5.7) and 34.6(5.4) ml/kg/min in repeated measurements, while the laboratory measured mean(SD) value was 36.7(6.1). The conclusion from this is that the Polar Fitness Test is repeatable and reliable in overweight men.

Further, the result measured with the Polar M52 HR monitor was compared to laboratory measured gas analysis values by Crumpton et al. (2003). They compared the Polar Fitness Test result to a laboratory measured gas analysis in 28 men and found no statistical difference between these two. The maximal aerobic power according to the laboratory scores was 47.2(7.8) on average (SD) and 47.4(12.1) according to the Polar Fitness Test. A similar result was found in the study by Cooper and Shafer (2019), which demonstrated that Polar Fitness Test is a valid method for assessing fitness level.

Polar Fitness Test has been used in large health and exercise studies (e.g. Borodulin et al. 2003, Jauho et al. 2015, Tornberg et al. 2019). Borodulin et al. (2003) have reported the relationship of Fitness Test to self-reported fitness and leisure-time physical activity in a sizeable sample of Finnish adults (n=5346). In these studies Polar Fitness Test was proven to be a feasible way to assessa aerobic fitness in thousands of subjects in field settings.

In a thesis by Borodulin (2006) it was also shown that Polar Fitness Test result is related to cardiovascular health: those with a better health status score higher results. A higher fitness and a lower waist-hip ratio (WHR) were independently associated with lower systolic and diastolic blood pressure (BP), lower total cholesterol and trigyceride levels, and with higher high-density lipoprotein (HDL) cholesterol and HDL to total cholesterol ratios. The associations of the fitness and diastolic BP, trigycerides and HDL to total cholesterol ratio were stronger in men with higher WHR.

5. Polar Fitness Test in practice

Depending on the Polar product, the test can be done with a heart rate sensor and/or with a Polar sports watch utilizing optical heart rate (beat-to-beat) measurement from the wrist. For reproducible heart rate and heart rate variability measurements, the test should be conducted in standardized conditions. There is normal daily variation in the resting heart rate and heart rate variability, and breathing and momentary changes in blood pressure cause normal momentary variation. There can also be undesired, transient changes in the measured heart rate values due to coughing, speaking, body movement, excitement, or other disturbances. The test is recommended to be performed in a peaceful environment, since talking (even a cough), noisy music, and the ringing of telephones disturb the testing. Eating a heavy meal or smoking 2–3 hours prior to the testing should be avoided. Unusually heavy physical effort as well as alcoholic beverages or pharmacological stimulants should be avoided on the test day and the day before. It is important to stay as still as possible during the test, as even small movements can interfere with the test and cause it to fail. There is no need to control the effects of breathing on the normal variation of heart rate and heart rate variability during the test.

The sports watch utilizes user settings for background variables (gender, age, height body weight, and physical activity level). Height must be given to the nearest centimetre (or in feet and inches) and weight to the nearest kilogram (or in pounds).

Activity levels (training background) are:

1. Pro **(12+ hours per week)**: You are an endurance athlete. You participate in heavy physical exercise to improve your performance for competitive purposes.

2. Semi-Pro **(8–12 hours per week)**: You participate in heavy physical exercise almost daily, and you exercise to improve performance for competitive purposes.
3. Heavy **(5–8 hours per week)**: You participate in heavy physical exercise at least 5 times a week, and you may sometimes take part in mass sports events.

4. Frequent **(3–5 hours per week)**: You participate in heavy physical exercise at least 3 times a week, e.g. you run 20–50 km/12–31 miles per week or spend 3–5 hours per week in comparable physical activity.

5. Regular (1–3 hours per week): You participate regularly in recreational sports, e.g. you run 5–10 km or 3–6 miles per week or spend 1–3 hours per week in comparable physical activity, or your work requires modest physical activity.

6. Occasional (0–1 hour per week). You do not participate regularly in programmed recreational sport or heavy physical activity, e.g. you walk only for pleasure or only occasionally exercise hard enough to cause heavy breathing or perspiration.

6. How to interpret the results

The result from the Polar Fitness Test equivalent to the maximal aerobic power, VO2max, in ml/min/kg. This indicates how many millilitres of oxygen your body is able to transport and use per each kilogram of your body weight in one minute. The maximal aerobic power, as any other fitness test result, is most meaningful when used in comparing individual values and changes.

For international use, the fitness classification by Shvartz & Reibold (1990) presented in Table 1 is recommended.

Table 1. Classification of maximal oxygen uptake (Shvartz & Reibold 1990). Data from adults in USA, Canada and 7 European countries.

MEN / MAXIMAL OXYGEN UPTAKE (VO2max, ml/kg/min)

AGE	1	2	3	4	5	6	7
20–24	<32	32–37	38–43	44–50	51–56	57–62	>62
25–29	<31	31–35	36–42	43–48	49–53	54–59	>59
30–34	<29	29–34	35–40	41–45	46–51	52–56	>56
35–39	<28	28–32	33–38	39–43	44–48	49–54	>54
40–44	<26	26–31	32–35	36–41	42–46	47–51	>51
45–49	<25	25–29	30–34	35–39	40–43	44–48	>48
50–54	<24	24–27	28–32	33–36	37–41	42–46	>46
55–59	<22	22–26	27–30	31–34	35–39	40–43	>43
60–65	<21	21–24	25–28	29–32	33–36	37–40	>40

WOMEN / MAXIMAL OXYGEN UPTAKE (VO2max, ml/kg/min)

AGE	1	2	3	4	5	6	7
20–24	<27	27–31	32–36	37–41	42–46	47–51	>51
25–29	<26	26–30	31–35	36–40	41–44	45–49	>49
30–34	<25	25–29	30–33	34–37	38–42	43–46	>46
35–39	<24	24–27	28–31	32–35	36–40	41–44	>44
40–44	<22	22–25	26–29	30–33	34–37	38–41	>41
45–49	<21	21–23	24–27	28–31	32–35	36–38	>38
50–54	<19	19–22	23–25	26–29	30–32	33–36	>36
55–59	<18	18–20	21–23	24–27	28–30	31–33	>33
60–65	<16	16–18	19–21	22–24	25–27	28–30	>30

In this classification, class 1 corresponds to "very poor", class 2 "poor", class 3 "fair", class 4 "average", class 5 "good", class 6 "very good" and class 7 "excellent" cardiovascular fitness compared to individuals of the same gender and age. In the general population, 11% of people belong to classes 1–2 and 6–7, 22% in classes 3 and 5 and 34% in class 4. This corresponds to normal distribution, because the classification has been developed in representative samples of individuals from different countries.

Fitness class is a useful reference when interpreting the individual test results. Because cardiovascular health is related to aerobic fitness, the people in fitness classes 1–3 would obtain lots of heath benefits and improve their fitness by starting regular exercise. Those in class 4 should at least maintain their exercise habits to ensure better health. However, an increase in exercise is recommended for fitness improvement. The people in classes 5–7 most probably are already in good health, and increases in their exercise are aimed at improving their performance. Top athletes in endurance sports typically score VO2max values (ml/kg/min) above 70 (men) and 60 (women). The values differ to some extent according to the sport. Regular exercisers participating occasionally in competition events score 60–70 (men) and 50–60 (women). Individuals exercising regularly, but not in competitive level, have values between 40–60 (men) and 30–50 (women) and sedentary adults most probably below 40 (men) and 30 (women).

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