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Validity and reliability of a submaximal cycle ergometer test for estimation of maximal oxygen uptake

av

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Abstract:

Maximal oxygen uptake (VO2max) is the highest obtained rate of oxygen consumption during a physically intense dynamic whole-body activity. VO2max is an important factor for many types of physical performance, as well as a strong independent predictor of health and longevity. Thus, it is important to have accurate and precise methods for assessment of VO2max. A direct measurement of VO2max is often conducted via indirect calorimetry during maximal exercise. The demand for maximal effort from an individual, along with the need for laboratory equipment, makes direct measurements unsuitable in the general, non-athlete population. There are also a number of contraindications that limit the possibility to conduct direct measurements of VO2max in many settings. Instead, several other exercise tests have been developed in order to facilitate the procedure of determination and evaluation of cardiorespiratory fitness in different populations. These tests can be either of submaximal or maximal character. Commonly used work modes are stepping, walking, and cycling. The overall aim of this thesis was to describe the background to, and the development of, submaximal cycle ergometer tests for estimation of VO2max. The present thesis focuses on the validity and reliability of a new submaximal cycle ergometer test – the Ekblom-Bak test (EB test). The first study described the test procedure for the new cycle ergometer test and the creation of an accompanying mathematical model (prediction equation) for estimation of VO2max. The development of the test and its associated prediction equation was continued in study II, while it was further validated in adults and adolescents in study II and IV. Study III examined the ability to use a submaximal cycle ergometer test in order to detect changes in VO2max over time.

The EB test comprises of 8 minutes of continuous cycling – 4 minutes at 0.5 kp, followed by 4 minutes at a higher, individually chosen work rate – with a pedalling rate of 60 revolutions per minute. The test measures the change in HR (ΔHR) between the two different work rates (ΔPO), and the variable ΔHR/ΔPO was obtained and linked to measured VO2max. In study I, the validity and reliability of the EB test and the associated prediction equation was tested in a mixed population with regard to sex, age, and physical activity status. The subjects performed repeated submaximal cycle ergometer tests and maximal running tests for direct determination of VO2max (reference value). There was a strong correlation between estimated and measured VO2max, with an adjusted R2 of 0.82 and a corresponding coefficient of variation (CV) of 9.3%. Although there was a relatively high precision in the estimation of VO2max by the prediction equation, it was evident that individuals with high VO2max were underestimated and individuals with low VO2max were overestimated. This issue was further addressed in study II.

In study II, the size of the study population was increased, in order to broaden the valid range and evaluate the use of sex-specific prediction equations. The estimation error was slightly decreased, and the sex-specific prediction equations resulted in an adjusted R2 of 0.91 and a CV of 8.7% in the whole group. The new models were also evaluated in a cross-validation group, where the adjusted R2 was 0.90 and CV 9.4%. The relation between the estimation error and changes in VO2max over time was investigated in study III. Follow-up tests were conducted in 35 subjects, in order to examine the conformity between changes in measured and estimated VO2max over a timespan of 5 to 8 years. Results showed a moderate correlation between change in measured VO2max and change in estimated VO2max (r = 0.75). Changes in body mass or changes in work efficiency did not relate to the change in assessment error. In study IV, the aim was to determine the applicability and validity of the EB test in pre-pubertal and pubertal adolescents. Medical examinations and assessment of sexual maturity (according to the stages of Tanner) were performed in addition to the physical tests. The included subjects (n = 50) were 10 to 15 years old and in Tanner stages I–IV. The measurement error (the difference between measured and estimated VO2max) was related to maturity in boys, but not in girls. The measurement error decreased for the whole group when the equation developed for women was used for the boys in Tanner I and II. This modification in the calculations of VO2max resulted in an adjusted R2 of 0.83 and SEE 0.23 L/min. Hence, the most accurate prediction of VO2max from the EB test is generated if the test result is accompanied by ratings of sexual maturity in adolescents. Analysis of the test-retest values showed no significant change in estimated VO2max from repeated tests within two weeks of each other.

In summary, the EB test proved to be a reliable and valid test throughout a wide range of ages (20 to 85 years) and fitness levels (1.33 to 3.94 L/min in women, and 1.67 to 5.97 L/min in men). The test was also found to be useful and reasonably valid for determination of VO2max in pre-pubertal and pubertal adolescents, preferably after adjustment for sexual maturity status in boys. Furthermore, it was shown that the EB test captured fairly well an actual change in VO2max during a period of 5 to 8 years. However, it is still unknown whether the test has an acceptable sensitivity for detection of a training-induced increase in VO2max. Further studies are needed to evaluate if the test can be used in diseased individuals with or without different medications. The EB test can be used in health-related clinical settings, sports and fitness clubs.

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