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Investigation of the predictions and relationships between selected cardiopulmonary variables in sports cardiology

Abstract in English

Introduction: CPET is a gold standard to assess CRF, with its main indicator being $\dot{V}O_{2max}$. Results of athletes' CPET differ from those of the general population. Despite a substantial number of normative values and prediction equations for CPET and $\dot{V}O_{2max}$ having been developed, the majority focused on the general population or recreational athletes. The normative values tailored for competitive athletes are limited, with particular emphasis on variables other than $\dot{V}O_{2max}$ and bivariate parameters. Athletes also suffer from cardiovascular diseases, which aggravate CRF. However, the epidemiology of cardiovascular diseases in those populations differs from that of the untrained subjects.

Aims: The primary aim of the NOODLE study was to develop specific reference values and prediction equations for CPET tailored for competitive athletes, with particular emphasis on bivariate indices. Secondary objectives were: (1) to discuss the epidemiology of cardiovascular diseases and the application of indirect methods for their assessment among athletes, (2) to optimize the interpretation of CPET results in the athlete's population, and (3) to summarize reference values and prediction equations for CPET in the physically active population with particular emphasis on athletes.

Materials and methods: Maximal CPET was performed on a cycle ergometer by 140 elite athletes (55% males; age=22.7±4.6 years; BMI=22.6±1.7 $kg \cdot m^{-2}$; $\dot{V}O_{2max}$=55.2±8.6 $mL \cdot kg^{-1} \cdot min^{-1}$) and on a treadmill by 94 elite athletes (66% males; age=27.5±5.3 years; BMI=22.4±2.5 $kg \cdot m^{-2}$; $\dot{V}O_{2max}$=56.7±8.6 $mL \cdot kg^{-1} \cdot min^{-1}$). 25 prediction equations for $\dot{V}E/\dot{V}CO_2$, OUES, OUEP, and O_2P_{peak} were selected and externally validated. The assumptions for the multivariate stepwise linear regression were tested and found to be acceptable. Therefore, this method was used to derive new prediction equations and calibrate the existing ones. Developed equations were additionally validated. The most illustrative and promising studies in the area of CPET and sports cardiology were selected and discussed narratively.

Results: $\dot{V}E/\dot{V}CO_2$ was significantly higher in females than in males (27.7±2.6 vs. 26.1±2.0, P<0.001) and differed between the plotting methods (P<0.001–0.043). $\dot{V}E/\dot{V}CO_2$ increased with age

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in young endurance athletes, regardless of the plotting method (β=0.066–0.127). Although OUES was significantly higher in athletes, there were no significant differences between 75%-, 90%-, and 100%-time intervals during CPET in males (*P*=0.65) and females (*P*=0.69). Extreme fitness had minimal effect on OUEP in males (−0.42 $mL \cdot L^{-1}$; *P*=0.39) and females (+0.33 $mL \cdot L^{-1}$; *P*=0.59). Calibration for endurance athletes of the original FRIEND equation for O_2P_{peak} reduced the bias in males from 2.9±2.9 $mL \cdot beat^{-1}$ (*P*<0.001) to 0.1±2.9 $mL \cdot beat^{-1}$ (*P*=0.82) and in females from 2.2±2.1 $mL \cdot beat^{-1}$ (*P*<0.001) to 0.2±2.1 $mL \cdot beat^{-1}$ (*P*=0.65). The available prediction equations in their original form presented limited accuracy for $\dot{V}E/\dot{V}CO_2$ (R^2=0.003–0.031; –3.6, +0.2), OUES (R^2=0.004–0.388; $ICC_{3.1}$=0.062–0.529), OUEP (R^2=0.099; RMSE=4.16–4.84 $mL \cdot L^{-1}$), and O_2P_{peak} (R^2=0.62; *P*<0.001). The new prediction equations tailored for athletes were accurate and presented negligible bias (R^2 [OUES]=0.36; R^2 [OUEP]=0.129; R^2 [O_2P_{peak}]=0.62).

Conclusions: The relationships between selected CPET variables differ significantly between endurance athletes and the general population. Direct adaptation of general reference values and prediction equations to the athletic population poses a risk of misinterpretation of CPET results. Prognostic/diagnostic prediction models can be implemented in the cardiovascular care of athletes. Specific principles should be applied to optimize the interpretation of CPET results among athletes.