Peek oxygen uptake

Myth and truth about an internationally accepted reference value

Introduction

Since the first description of maximal oxygen uptake (VO₂max) as an indicator of endurance capacity [45] no other single parameter derived from cardiopulmonary exercise testing has gained such wide accept-
symptoms both of which are quite common in cardiology settings. Although alternative measures like the anaerobic threshold [104, 106] exist, the vast majority of scientific publications utilizes VO$_2$peak as variable to assess functional capacity, document fitness changes, and to refer exercise (intensity) prescriptions. Even prognosis in cardiac disease and, thus, decisions about invasive therapeutic measures, e.g. heart transplantation, have been linked to the results of maximal ergometric testing [62]. However, there are certain methodological and subject/patient-bound sources of error in the determination of VO$_2$peak which might render its use unreliable when not accounted for. This overview aims to sensitize readers about important shortcomings of maximal ergometric variables which have to be considered during their interpretation. Some examples from the literature are given to illustrate the practical relevance of such matters. For the most part, examples are taken from studies in chronic heart failure (CHF) patients because in this population VO$_2$peak is considered to be of outstanding importance and, thus, very frequently determined within scientific investigations. However, the general statements and recommendations given here are also valid for other cardiac entities. It is the additional aim of this paper to enforce and popularize methodological necessities when conducting tests to accurately determine VO$_2$peak values. Although it is also possible to elicit VO$_2$peak during constant load tests, this article focuses on the more common incremental exercise protocols because they were considered to be much more prevalent.

**Applications for the determination of VO$_2$peak**

The determination of VO$_2$peak is widely considered to be valuable in determining endurance capacity in healthy subjects [77, 96] and to assist in the evaluation of a variety of cardiac diseases, most prominently in CHF [61, 94]. Acknowledging this, recent guidelines from several authorities include maximal exercise testing as an obligatory/recommended tool within the management of patient populations [19, 48, 91, 101]. Four main purposes of determining VO$_2$peak can be distilled: assessing (changes in) functional capacity, evaluating the necessity of invasive diagnostic/therapeutic measures, obtaining a reference for exercise prescriptions, determining prognosis.

**Assessment of functional capacity**

Whereas in healthy individuals VO$_2$peak is mainly considered as an indicator of (aerobic) endurance capacity [16] it is often – partly in concert with other variables – regarded as a descriptor of “functional capacity” in cardiac patients [10, 11, 106]. However, it is probably more appropriate to emphasize the correlation between high maximal ergometric measures (e.g. VO$_2$peak) and the ability to sustain submaximal exercise (i.e. endurance) because there are studies in CHF patients challenging a close “functional” link between performance in daily life, central hemodynamics, and VO$_2$peak [30–32, 37, 108]. Even the term “exercise capacity” does not adequately address what VO$_2$peak really reflects because there are certainly aspects of exercise (coordination, strength) which are surely important for patients but rarely measured by determining VO$_2$peak. The most appropriate description might be “maximal ergometric capacity”.

In addition, several studies that used certain forms of physical training – mostly endurance stimuli – reported increases in VO$_2$peak [1, 11, 21, 39, 53]. But other authors cast doubt if small improvements in the clinical status – albeit meaningful for the single patient – are sufficiently reflected in detectable increases of VO$_2$peak [22]. Altogether, VO$_2$peak is not adequately addressed as “functional capacity” which is a more sophisticated term also covering other aspects of daily life. VO$_2$peak rather represents a global measure of endurance capacity which in cardiac patients might lack the sensitivity to detect tiny changes of the clinical state. Larger differences in cardiac performance will, nevertheless, be reflected appropriately.

**Evaluation of the necessity to conduct invasive diagnostic/therapeutic measures**

A disproportionally low peak VO$_2$ compared to what is expected for the given sex, age and training history (tables of normative values) is frequently regarded as an indicator of probable cardiovascular disease. In such cases, additional diagnostic measures are to be initiated. When cardiac volume is related to VO$_2$peak or to the peak oxygen pulse, a more sensitive parameter for the detection of early cardiac disease might result [90, 97]. However, the most momentous function of VO$_2$peak measurements for an individual patient is undoubtedly its role in determining the indication for heart transplantation in CHF [53]. With regard to prognosis, Mančini et al. calculated a VO$_2$peak of 14 ml·min$^{-1}$·kg$^{-1}$ as the cut-off point below which life expectancy after heart transplantation exceeds that without surgery [62]. Although the precise value of 14 ml·min$^{-1}$·kg$^{-1}$ has been questioned [82], an important role within the decision process about transplantation remained for VO$_2$peak. It has to be emphasized that prior to any such decision the attainment of