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**Author(s):** Laukkanen, Jari

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## Is Cardiorespiratory Optimal Point Measured During the Maximal Cardiopulmonary Exercise Test a Relevant Indicator of Sports Performance?

Jari A. Laukkanen

*Institute of Public Health and Clinical Nutrition - University of Eastern Finland,<sup>1</sup> Kuopio - Finland*

*Faculty of Sport and Health Sciences, University of Jyväskylä,<sup>2</sup> Jyväskylä - Finland*

*Central Finland Health Care District, Department of Medicine,<sup>3</sup> Jyväskylä - Finland*

Cardiorespiratory fitness (CRF) is considered the gold standard for assessing aerobic performance among athletes and normal population and has recently been named as a clinical vital sign, being an essential indicator of cardiovascular and pulmonary function.<sup>1</sup> Cardiorespiratory fitness is associated with lower risk of non-fatal and fatal cardiovascular disease (CVD) events, with studies demonstrating a consistent, inverse association between CRF and mortality even after adjustment for the traditional risk factor burden.<sup>2</sup> Additionally, both maximal oxygen consumption ( $\text{VO}_{2\text{max}}$ ) and  $\text{VO}_2$  at ventilatory threshold (VT) have been associated with a reduced risk of adverse health outcomes.<sup>1,3-5</sup> A literature-based meta-analysis of 33 observational cohort studies has better delineated the relationship of CRF with CVD and all-cause mortality outcomes.<sup>2</sup> However,  $\text{VO}_{2\text{max}}$  and VT are often used to evaluate athletes' performance and to monitor their training responses. During the cardiopulmonary exercise test (CPX), many variables could be used to assess specific training responses to the cardiovascular, respiratory and musculoskeletal systems based on the analysis of submaximal and maximal responses to a progressively incremental exercise.

Modern CPX systems allow for the analysis of gas exchange at rest, during mild, moderate and maximal exercise levels, and during recovery and yield measures of  $\text{VO}_2$ , carbon dioxide output ( $\text{VCO}_2$ ), and ventilation (VE).<sup>6</sup> These advanced computerized systems provide both simple and complex analyses of these data that

are easy to retrieve and store, which makes CPX widely available. Oxygen uptake at VT, often referred to as the anaerobic threshold, is a variable assessed at submaximal level of CPX.<sup>6</sup> For majority of healthy individuals, the anaerobic threshold lies at exercise intensities between 50% and 75% of  $\text{VO}_{2\text{max}}$ , while in trained endurance athletes, it can reach intensities as high as 80% of  $\text{VO}_{2\text{max}}$ .<sup>6</sup>

Observing the oxygen ventilatory equivalents (the ratio between VE in l/min and  $\text{VO}_2$  in l/min,  $\text{VE}/\text{VO}_2$ ) in a given minute during CPX, it is possible to identify a U-shaped pattern with a clear minimal value. Ramos et al.<sup>7</sup> have named this minimal  $\text{VE}/\text{VO}_2$ , a dimensionless variable, as cardiorespiratory optimal point (COP) with age- and sex-reference data and suggested that COP reflects circulation-respiration integration and the most economical use of ventilation to obtain oxygen for the active tissues during exercise.

In this context, it is worthwhile to comment that  $\text{VO}_{2\text{max}}$  depends on performing a truly maximal exercise test. Although VT can be assessed at the submaximal level,<sup>5</sup> it also requires a more intense exercise level compared to the assessment of COP, and VT measurement may be hindered by the existence of several distinct criteria for its identification and/or characterization, because it cannot be accurately defined in all cases, limiting its use in both clinical practice and sports performance.

Applicability of the COP for the assessment of the athletes' exercise performance is potentially interesting.<sup>8</sup> In addition to the fact that, as a submaximal variable of CPX, the use of COP is particularly interesting for people unable to achieve a maximal CPX because of functional limitations. In the sports scenario, where

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#### Mailing Address: Jari A. Laukkanen

Seminaarinkatu 15. PO Box 35. FI-40014. University of Jyväskylä, Jyväskylä - Finland

E-mail: jari.a.laukkanen@jyu.fi

there are very limited opportunity or intention to have the athletes performing repeated maximal CPX during the competition season, COP could be a much easier and acceptable variable to be measured and followed along the season.<sup>8</sup> As previously described by the same research group,<sup>9</sup> the COP value increases with age and tends to be slightly higher in women, with associations being modest with other ventilation measures, suggesting an independent and potential contribution in the interpretation of the cardiorespiratory response at the CPX. Indeed, Ramos and Araujo,<sup>9</sup> have also showed that COP provides valuable information on the risk of all-cause mortality in middle-aged and older men and women. In healthy subjects with COP < 22, there were no deaths during the six-year follow-up suggesting that the lowest level of COP is an indicator of good prognosis. Over the years, one can consider that there is a worsening in VE and a reduction in VO<sub>2</sub>max, i.e. variables directly involved in the calculation of the COP. However, it is possible that the decline in pulmonary ventilation is less significant or numerically important than the reduction in VO<sub>2</sub>, thereby explaining the higher COP values in older individuals.<sup>9</sup>

The study published in this issue of the Int J Cardiovasc Sci by de Souza e Silva et al.<sup>10</sup> is the first one to describe the COP profile in athletes, as it was based on high-level soccer players undergoing CPX on a treadmill following the ramp protocol. They found that COP values did not significantly vary within the

athlete's field position.<sup>10</sup> The absence of association with VO<sub>2</sub>max and VT indicates that COP provides additional information on the top of conventional CPX parameters; however, it remains to be determined if this COP plays a significant role in terms of soccer performance and/or to the monitoring of the training responses along the competitive season. Notwithstanding, the information provided by this novel study<sup>10</sup> is original and it should be confirmed by future studies including the interpretation of the various CPX variables in athletes, especially for those participating in very long endurance sport events, such as marathon or triathlon, situations in which the athlete performs at an exercise intensity that is below VT and likely closer to COP.

In conclusion, COP, defined as the lowest VE/VO<sub>2</sub> value in a given minute of CPX, has been associated with all-cause mortality in a population that is frequently seen for routine clinical exercise testing. COP is a reproducible and physiologically-based CPX variable. Additionally, the availability of age- and sex-reference data in a large sample of healthy subjects is an advantage compared to other CPX indices often obtained in a maximal CPX. The recent study by de Souza e Silva et al.<sup>10</sup> moves COP one step ahead by suggesting its potential use among adult professional soccer players. Future longitudinal studies are needed to confirm COP relevance and if its measurement would become a possible substitute for some other relevant CPX ventilatory variables, such as VT or VO<sub>2</sub>max in athletes.

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