Heart Online First, published on January 13, 2015 as 10.1136/heartjnl-2014-307379

CORRESPONDENCE

Does TCPC power loss really affect exercise capacity?

To the Editor,

We read with interest the article by Khiabani *et al*,[1] where the authors examine the relationship between power loss in the total cavopulmonary connection (TCPC) and clinical exercise testing. Using an indexed power loss, 'iPL', they report that higher iPL correlates with worse minute oxygen consumption and exercise work at anaerobic threshold. Based on this, the authors suggest that power loss in the TCPC could affect exercise performance in a patient with Fontan circulation. In the manuscript, the authors attempt to discover a correlation of the hydraulics of the Fontan circulation with exercise performance. In doing so, they use the unique parameter, iPL, instead of the unadjusted power loss. We believe that this approach is misleading and leads to the wrong conclusion.

The term iPL was defined as:

$$\text{iPL} = \frac{\text{PL}}{\rho Q^3/\text{BSA}^2}$$

where PL, ρ, Q and BSA are the TCPC power loss, blood density, TCPC flow and patient body surface area, respectively. The justification for using iPL is that it 'accounts for differences in flow and BSA between different patients'.[1] Therefore, after adjusting for flow and BSA, the iPL should become a constant value for any particular 'functional TCPC resistance', akin to a Reynolds number (Re), a dimensionless quantity that predicts similar flow patterns in different fluid flow situations. However, we cannot know if this is true based on the evidence provided in this and prior studies. While the authors state that the iPL is a flow-independent resistance index,[2] there are no data supporting that iPL is independent of BSA. This is critically important, because if iPL is dependent on BSA, then using the iPL to correlate against exercise parameters (such as minute oxygen consumption, anaerobic threshold and work) that are themselves dependent on BSA, would mandate a 'self-correlation'. Such a comparison would just confirm that exercise capacity correlates with BSA. Using Re as an example, one can imagine proposing to show a correlation between Re and exercise. Since Re directly depends on blood flow velocity, and velocity does indeed change with exercise, a compulsory correlation would be uncovered without being clinically useful.

The problem with using iPL, as defined by the authors, rests with indexing power loss by BSA^2 through a dimensional analysis of the flow physics in the TCPC. Here BSA was used as a repeating variable.[2] Since BSA itself is not a quantity directly relating to the physics of fluid flow, BSA should not be directly used in a dimensional analysis of flow physics. Instead, the BSA is related to blood flow through empirical correlations that can only be identified experimentally (this is the field of allometric scaling). To illustrate this, while the age of a child is empirically related to body size and blood flow parameters, it would be an error to use the patient age as a time dimension in a dimensional analysis of TCPC flow physics. In the same way, it is incorrect to use BSA as a length dimension in a dimensional analysis of TCPC flow. A more appropriate choice would be to use an anatomic length measurement such as diameter of a major blood vessel.

Until it is shown that iPL is indeed independent of BSA, the correlation between iPL and peak VO_2 does not convincingly support the conclusion that TCPC power loss is related to exercise capacity. The iPL likely exhibits an artificially introduced correlation to BSA as a result of inappropriate indexing, and therefore does not represent the properly normalised TCPC power loss. Another study which did not use the authors' iPL parameter as a metric found no correlation between power loss and exercise capacity.[3] Multiscale simulations that consider the TCPC power loss in the context of systemic circulation have shown that TCPC power loss represents only a tiny fraction of total systemic power,[4] making it questionable whether power loss is physiologically significant. We encourage the authors to analyse their Fontan exercise data using alternative metrics, and carefully assess whether a correlation can truly be identified between TCPC power loss and exercise capacity.

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Competing interests None.

Provenance and peer review Commissioned; internally peer reviewed.

To cite Kung E, Marsden A, Baker C, *et al*. *Heart* Published Online First: [*please include* Day Month Year] doi:10.1136/heartjnl-2014-307379

Linked

► http://dx.doi.org/10.1136/heartjnl-2014-306337

Heart 2015;**0**:1. doi:10.1136/heartjnl-2014-307379

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