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Conference Abstract

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Modeling vs. Measuring: How Accurate Is the Calculated Maximal Lactate Steady State?

Mattice Sablain [1,*], Kobe Vermeire [1,2], and Jan Boone [1,2]

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[1] Department of Movement and Sports Sciences, Ghent University, Belgium

[2] Center of Sports Medicine, Ghent University Hospital, Ghent, Belgium

Correspondence

Mattice Sablain

Affiliation Department of Movement and Sports Sciences, Ghent University, Belgium

mattice.sablain@UGent.be

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1 Introduction

The maximal lactate steady state (MLSS) represents the highest sustainable workload without net lactate accumulation. In 1986, Mader & Heck proposed a model estimating MLSS by determining the steady state oxygen consumption at the crossing point ($\dot{V}O_{2ss}$) between the rate of lactate formation and elimination. The sole input variables in this model are the $\dot{V}O_{2max}$ and the maximal rate of blood lactate (BLa^-) accumulation ($\dot{V}La_{max}$) which is believed to represent the maximal glycolytic flux (Mader, 1994; Mader & Heck, 1986). Subsequently, an equation is often used to transform $\dot{V}O_{2ss}$ into a power output using the resting oxygen consumption ($\dot{V}O_{2rest}$) and cycling efficiency (K_{ef}). Previous research found no significant difference between the calculated power at MLSS (cPMLSS) and experimentally measured power at MLSS (mPMLSS) (Hauser et al., 2014). However, the Bland-Altman plots showed quite broad limits of agreements (LoA). It remains unclear if these broad LoA are caused by an error in the determination of $\dot{V}O_{2ss}$ or the conversion into a power output as no prior studies have directly compared the measured ($m\dot{V}O_{2ss}$) and calculated $\dot{V}O_{2ss}$ ($c\dot{V}O_{2ss}$). Therefore, this study wanted to compare $m\dot{V}O_{2ss}$ and mPMLSS with $c\dot{V}O_{2ss}$ and cPMLSS. Furthermore, we examined whether individualizing specific model constants ($\dot{V}O_{2rest}$ and K_{ef}) improved the LoA, potentially enhancing the model's applicability.

2 Material and Methods

2.1 Participants

7 healthy male participants (age: 31 ± 9 years; $\dot{V}O_{2max}$: 58.1 ± 8.6 mL·min^{-1}·kg^{-1}) visited the lab on 4-7 occasions with a minimum of 24h in between.

2.2 Methodology

On the first test day, individualized $\dot{V}O_{2rest}$ was measured by means of gas exchange measurements during 20' of reclined resting, followed by a familiarization of a 15" isokinetic sprint test at 120 rpm (Cyclus2 ergometer; RBM Electronics, Leipzig, Germany). The second day consisted of the same seated 15" isokinetic sprint test with BLa^- measurements to determine $\dot{V}La_{max}$. After a 12' warm-up at 1.5 W.kg-1, baseline [BLa^-] (La_{pre}) was determined using capillary blood samples from the fingertip. Following the test, capillary blood samples were collected each minute for 9 minutes to determine the maximal [BLa^-] after the test ($La_{max\text{-}post}$). $\dot{V}La_{max}$ was then determined using equation 1 (Mader, 1994):

$$\dot{V}La_{max} = \frac{La_{max-post} - La_{pre}}{T_{test} - T_{alac}}$$

Equation (1)

where $La_{max\text{-}post}$ = maximal blood lactate concentration measured after the test (mmol·L^{-1}); La_{pre} = blood lactate concentration before the test (mmol·L^{-1}); T_{test} = duration of the test (s); and T_{alac} = alactic time interval (s).

T_{alac} was defined as the time until maximal power output during the isokinetic test dropped by 3.5% (Weber, 2003). On the second day, a ramp incremental exercise test (30 W·min^{-1}) was done to determine $\dot{V}O_{2max}$, defined as the highest 30-s $\dot{V}O_2$ average. On the following testdays mPMLSS was determined as per method of 30-min constant load tests with BLa^- measurements every 5 min. mPMLSS was defined as the highest power-output where the rise in [BLa^-] between the 10th and 30th minute was ≤ 1 mmol·L^{-1} (Heck et al., 1985). Constant load trials were repeated on different occasions, and the power output was increased or decreased by 10 W based on whether or not the criteria were met. The reference cPMLSS was determined using the Mader & Heck model using a fixed $\dot{V}O_{2rest}$ = 5 mL·min^{-1}·kg^{-1} and K_{ef} = 11.7 mL·min^{-1}·W^{-1} (Nolte et al., 2022). The individualized cPMLSS used the measured $\dot{V}O_{2rest}$ and individualized K_{ef} which was determined as the difference between $\dot{V}O_{2ss}$ and $\dot{V}O_{2rest}$ divided by the mPMLSS. Related-samples Wilcoxon tests were used to compare measured and calculated $\dot{V}O_{2ss}$ and PMLSS. Additionally, the same test was applied to assess whether individualization improved cPMLSS. Bland-Altman plots were used to visualize differences between measurements.

3 Results

No significant differences were observed between m$\dot{V}O_{2ss}$ (μ = 45.9 mL·min^{-1}·kg^{-1}) and c$\dot{V}O_{2ss}$ (μ = 43.6 mL·min^{-1}·kg^{-1}) (p = 0.176; effect size = -0.511) nor between mPMLSS (μ =255 W) and cPMLSS (μ = 256) (p = 0.917; effect size = -0.040), despite broad LoA (-8.5 – 13.1 mL·min^{-1}·kg^{-1} and -45 – 43 W respectively) (Fig. 1). Moreover, while not statistically significant, individualizing $\dot{V}O_{2rest}$ (μ = 263 W; p = 0.398; effect size = -0.32), K_{ef} (μ = 236 W; p = 0.176; effect size = -0.51) or both (μ =241 W; p = 0.176; effect size = -0.51) led to larger biases between mPMLSS and cPMLSS, further widening the LoA.

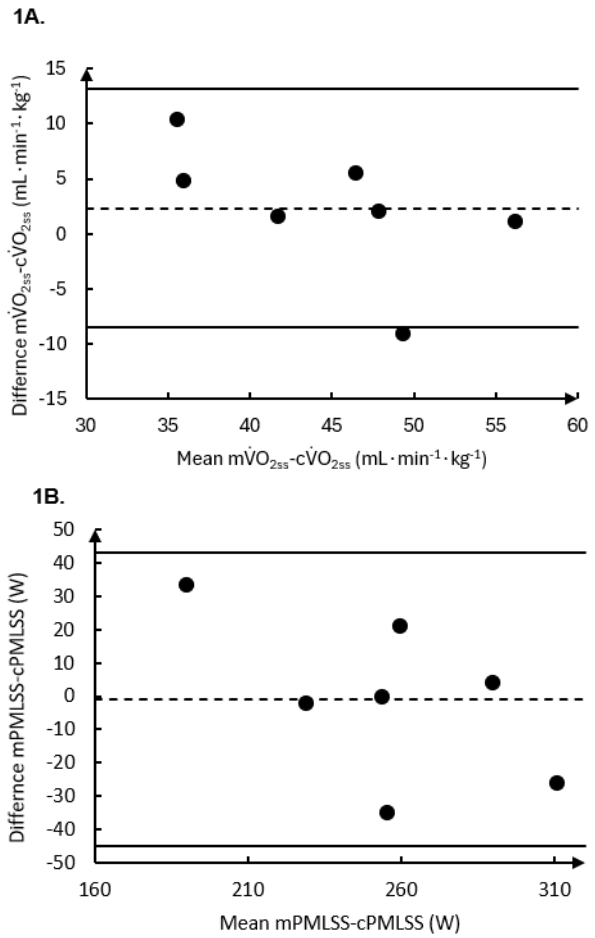

Figure 1. Bland-Altman plots showing the differences between mVO_{2ss} and cVO_{2ss} (Fig. 1A) and between mPMLSS and cPMLSS (Fig. 1B). The black line depicts the mean bias and the dashed lines depict 95% LoA.

4 Conclusions

In conclusion, our study shows that while the Mader & Heck model is effective at the group level, it lacks accuracy for individual assessments. The errors in VO_{2ss} calculation may stem from the input variables, model constants, or the model itself. Especially the lack of standardization and absence of research on the validity associated with VLa_{max} measurements is a topic of contention. This highlights the need for caution when applying the model in training and performance settings. Further research is needed to identify the source of these inaccuracies.

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Conflicts of Interest: The authors declare no conflict of interest.

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