Comments on “Validation of equations to estimate the peak oxygen uptake in adolescents from 20 metres shuttle run test”

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We read the article by Menezes-Junior et al. (2020) entitled “Validation of equations to estimate the peak oxygen uptake in adolescents from 20 metres shuttle run test” by Menezes-Junior et al. (2020) with great interest. The authors adopt multiple linear regression methods to predict peak oxygen uptake (VO$_{2peak}$) in adolescents using a range of variables such as shuttle run performance (i.e., laps), body mass index (BMI), BMI-z score and body fat percentage (%FM). However, Nevill and Cook (2017), Nevill et al (2019) and Nevill et al. (2020) highlighted several concerns with these linear, additive models. These linear models suggest linear associations with all key predictors such as shuttle run performance, age, height, body mass and BMI. However, there is strong evidence, certainly from the findings reported by Myers et al., (2017), Nevill et al. (2019) and Nevill et al. (2020), that curvature (and the resulting lack of fit) exists suggesting that one or more of these associations is likely to be non-linear.

Menezes-Junior et al. (2020) also provide strong evidence of a lack of fit (curvature) in their data as observed in their residual plots reported in their Figure 1 (in all four models). To illustrate a possible cause of this curvature and lack of fit, VO$_{2max}$ was plotted against BMI using the FRIEND Consortium data set, originally published in Myers et al. (2017) and subsequently by Nevill et al. (2019) for Male (Figure 1a) and Female (Figure 1b) participants, see below.

**Figure 1a.** The association between Maximal Oxygen Uptake (VO$_{2max}$) and Body Mass Index (BMI) for Males using a linear ($R^2=0.32$) and a power function ($R^2=0.35$) model.
**Figure 1b.** The association between Maximal Oxygen Uptake (VO$_{2\text{max}}$) and Body Mass Index (BMI) for Females using a linear ($R^2=0.38$) and a power function ($R^2=0.45$) model.

Note that the power-function model identified in both Figures 1a and 1b (the association between VO$_{2\text{max}}$ and BMI) was the inverse BMI. That is the power-function BMI exponents were $b=-1.067$ for males and $b=-0.93$ for females, assuming a power function model VO$_{2\text{max}}=a\cdot\text{BMI}^b$.

For comparative purposes, the residuals versus the predicted values assuming a linear additive model between VO$_{2\text{max}}$ and BMI are given in **Figure 2**. Clearly the shape/curvature is very similar to those reported by Menezes-Junior et al. (2020) although with considerably more data available to Nevill et al. (2019) (4601 men and 3158 women).

**Figure 2.** The association between the residuals and the predicted values saved from fitting an additive linear model between VO$_{2\text{max}}$ and BMI
Figure 2 replicates/confirms the lack of fit similar to that reported by Menezes-Junior et al. (2020) in their Figure 1 (in all four models). Both Figures 1a and 1b reinforce the need to adopt a power-function or allometric model (such as VO$_{2\text{max}}$=a*BMI$^p$) to more accurately predict VO$_{2\text{max}}$ (Nevill et al., 2019) when adopting BMI as one of the predictor variables. Note that Nevill et al. (2019) identified the inverse BMI as a key predictor of VO$_{2\text{max}}$ (mL.kg$^{-1}$.min$^{-1}$).

We are also concerned with two of the predictor variables adopted by Menezes-Junior et al. (2020) in their models. The authors adopt both BMI (BMI-z) and age*height as predictor variables. However, BMI contains height as a denominator term and in age*height, height is incorporated as a numerator term. Incorporating the same term, height, as a common component/term in these two predictor variables will lead to spurious correlations/associations (see Aldrich, 1995, Pearson, 1897; Neyman, 1952).

Both of these concerns can be easily resolved by adopting multiplicative allometric models to estimate VO$_{2\text{max}}$, as recommended by Nevill and Cook (2017), Nevill et al (2019) and Nevill et al. (2020).
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