

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

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29 Allometry

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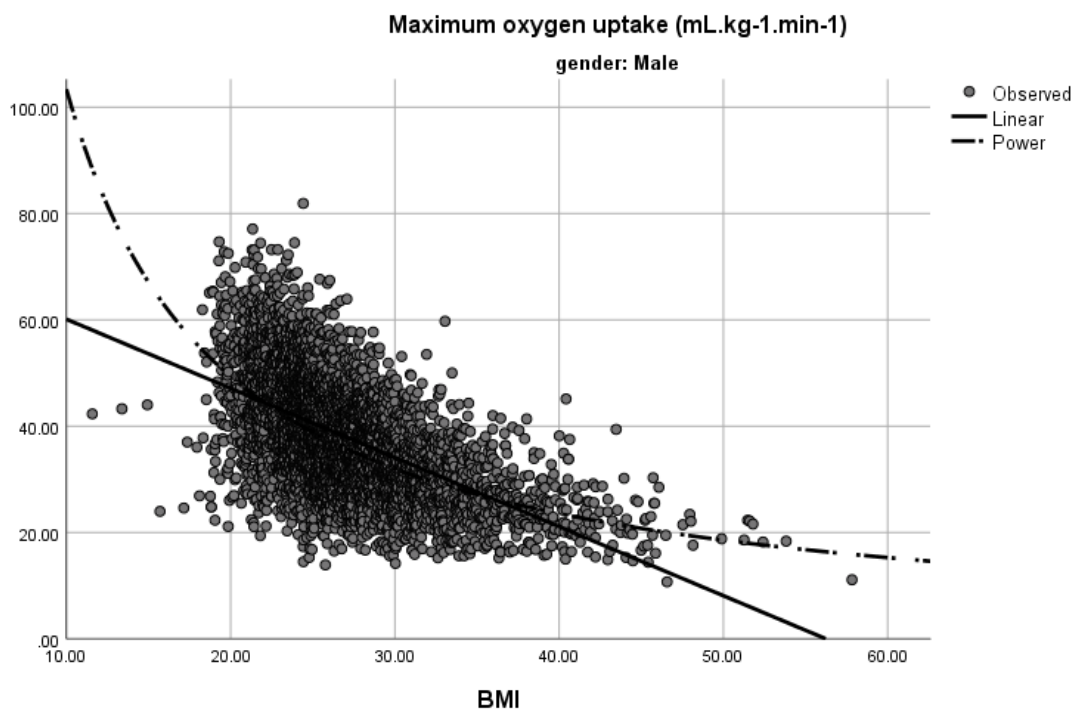
31 We read the article by Menezes-Junior et al. (2020) entitled “Validation of equations  
32 to estimate the peak oxygen uptake in adolescents from 20 metres shuttle run test”  
33 by Menezes-Junior et al. (2020) with great interest. The authors adopt multiple linear  
34 regression methods to predict peak oxygen uptake ( $VO_{2peak}$ ) in adolescents using a  
35 range of variables such as shuttle run performance (i.e., laps), body mass index  
36 (BMI), BMI-z score and body fat percentage (%FM). However, Nevill and Cook  
37 (2017), Nevill et al (2019) and Nevill et al. (2020) highlighted several concerns with  
38 these linear, additive models. These linear models suggest linear associations with  
39 all key predictors such as shuttle run performance, age, height, body mass and BMI.  
40 However, there is strong evidence, certainly from the findings reported by Myers et  
41 al., (2017), Nevill *et al.* (2019) and Nevill et al. (2020), that curvature (and the  
42 resulting lack of fit) exists suggesting that one or more of these associations is likely  
43 to be non-linear.

44

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

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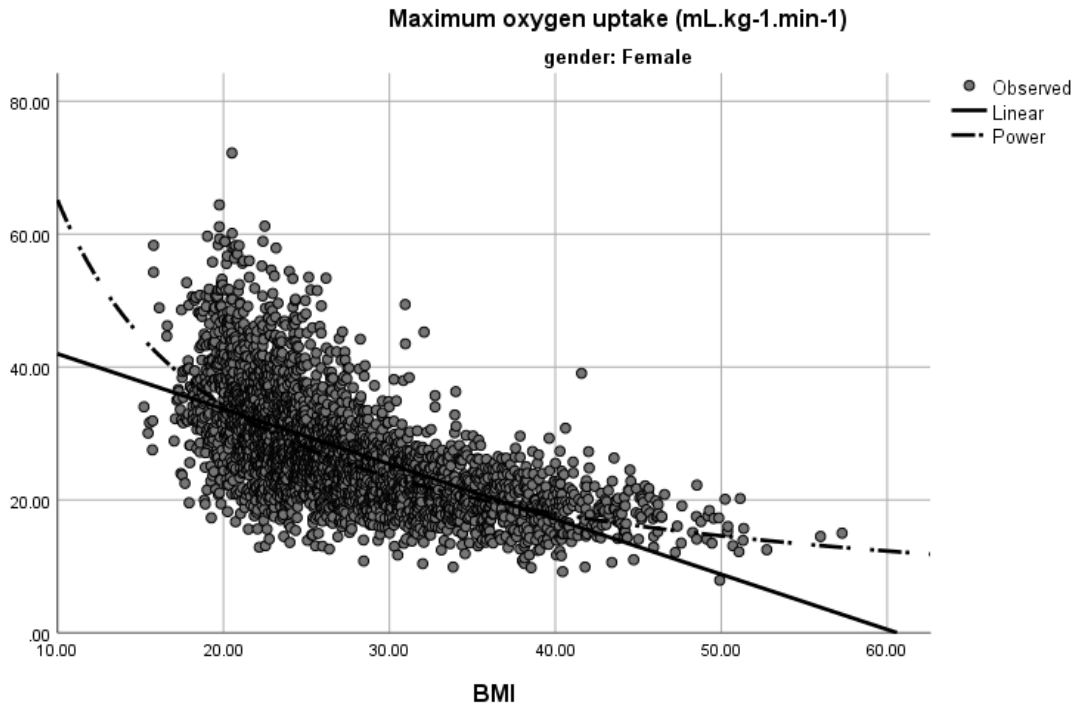
52 **Figure 1a.** The association between Maximal Oxygen Uptake ( $VO_{2max}$ ) and Body  
53 Mass Index (BMI) for Males using a linear ( $R^2=0.32$ ) and a power function ( $R^2=0.35$ )  
54 model.



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57 **Figure 1b.** The association between Maximal Oxygen Uptake ( $VO_{2max}$ ) and Body  
58 Mass Index (BMI) for Females using a linear ( $R^2=0.38$ ) and a power function  
59 ( $R^2=0.45$ ) model.

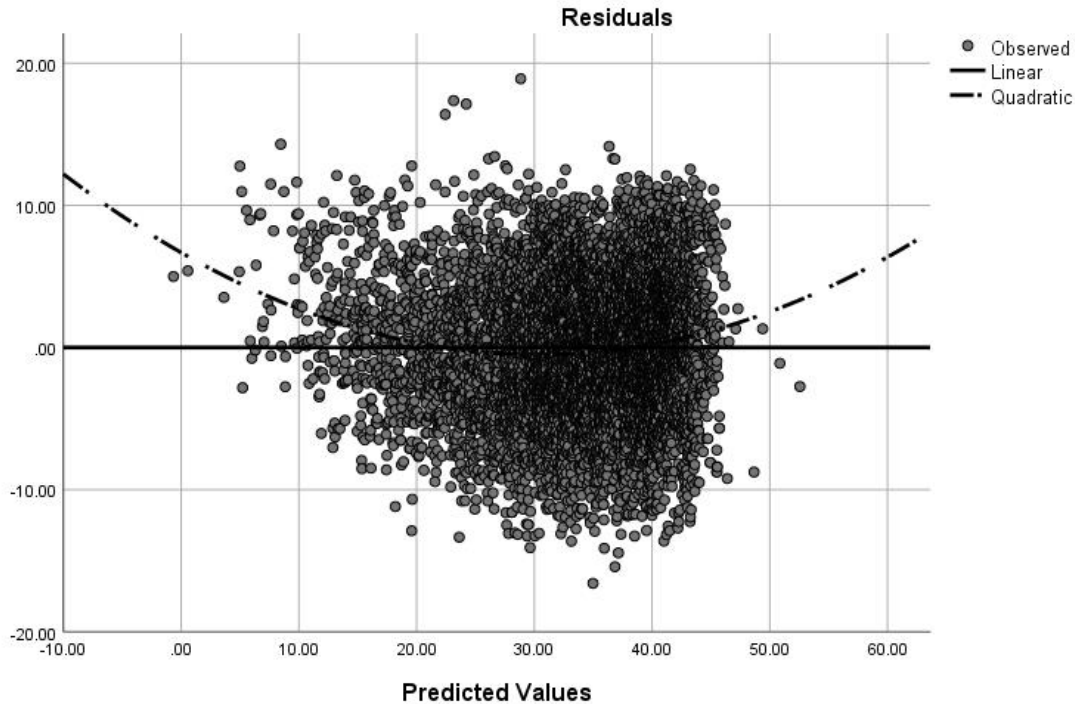
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62 Note that the power-function model identified in both **Figures 1a and 1b** (the  
63 association between  $VO_{2max}$  and BMI) was the inverse BMI. That is the power-  
64 function BMI exponents were  $b=-1.067$  for males and  $b=-0.93$  for females, assuming  
65 a power function model  $VO_{2max}=a*BMI^b$ .  
66

67 For comparative purposes, the residuals versus the predicted values assuming a  
68 linear additive model between  $VO_{2max}$  and BMI are given in **Figure 2**. Clearly the  
69 shape/curvature is very similar to those reported by Menezes-Junior et al. (2020)  
70 although with considerably more data available to Nevill et al. (2019) (4601 men and  
71 3158 women).  
72

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

84

85 We are also concerned with two of the predictor variables adopted by Menezes-  
86 Junior et al. (2020) in their models. The authors adopt both BMI (BMI-z) and  
87 age\*height as predictor variables. However, BMI contains **height** as a denominator  
88 term and in age\*height, **height** is incorporated as a numerator term. Incorporating  
89 the same term, height, as a common component/term in these two predictor  
90 variables will lead to spurious correlations/associations (see Aldrich, 1995, Pearson,  
91 1897; Neyman, 1952).

92

93 Both of these concerns can be easily resolved by adopting multiplicative allometric  
94 models to estimate  $VO_{2max}$ , as recommended by Nevill and Cook (2017), Nevill et al  
95 (2019) and Nevill et al. (2020).

96

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## 105 **References**

106

107 Aldrich, J. (1995). Correlations genuine and spurious in Pearson and Yule. *Statistical*  
108 *science*, 10(4), 364-376.

109 Menezes-Junior FJ, Íncare Correa de Jesus , Jorge Mota , Maria de Fatima Aguiar  
110 Lopes , Patricia Ribeiro Paes Corazza , Maiara Cristina Tadiotto , Tatiana  
111 Aparecida Affornali Tozo , Kátia Sheylla Malta Purim , Enio Ricardo Vaz Ronque  
112 & Neiva Leite (2020): Validation of equations to estimate the peak oxygen uptake  
113 in adolescents from 20 metres shuttle run test, *Journal of Sports Sciences*, DOI:  
114 10.1080/02640414.2020.1794255.

115 Myers, J., Kaminsky, L. A., Lima, R., et al. A reference equation for normal  
116 standards for VO<sub>2</sub> max: analysis from the Fitness Registry and the Importance of  
117 Exercise National Database (FRIEND Registry). *Prog Cardiovasc Dis*  
118 2017;60:21-29.

119 Nevill, A.M. and Cooke, C.B. The Dangers of Estimating VO<sub>2</sub>max Using Linear,  
120 Non-exercise Prediction Models. *Med. Sci. Sports Exerc.* 2017;49:1036–1042  
121 <[https://journals.lww.com/acsm-](https://journals.lww.com/acsm-msse/Fulltext/2017/05000/The_Dangers_of_Estimating_V_O2max_Using_Linear_.22.aspx)  
122 [msse/Fulltext/2017/05000/The\\_Dangers\\_of\\_Estimating\\_V\\_O2max\\_Using\\_Linear](https://journals.lww.com/acsm-msse/Fulltext/2017/05000/The_Dangers_of_Estimating_V_O2max_Using_Linear_.22.aspx)  
123 [,22.aspx](https://journals.lww.com/acsm-msse/Fulltext/2017/05000/The_Dangers_of_Estimating_V_O2max_Using_Linear_.22.aspx)>.

124 Nevill, A. M., Myers, J., Kaminsky, L. A., & Arena, R. (2019). Improving reference  
125 equations for cardiorespiratory fitness using multiplicative allometric rather than  
126 additive linear models: Data from the Fitness Registry and the Importance of  
127 Exercise National Database Registry. *Progress in cardiovascular diseases*, 62(6),  
128 515-521.

129 Nevill AM, Ramsbottom R, Sandercock G, Bocachica-Gonzalez CE, Ramirez-Velez  
130 R, Tomkinson G. Developing a new curvilinear allometric model to improve the fit  
131 and validity of the 20-m shuttle run test as a predictor of cardiorespiratory fitness  
132 in adults and youth. *Sports Med.* 2020; doi.org10.1007/s40279- 020-01346-0.

133 Neyman, J. (1952) *Lectures and Conferences on Mathematical Statistics and*  
134 *Probability*, 2nd ed. p. 143-154. Washington DC: US Department of Agriculture.

135 Pearson, K. (1897) Mathematical contributions to the theory of evolution-on a form of  
136 spurious correlation which may arise when indices are used in the measurement  
137 of organs. *Proceedings of the Royal Society, London*, 60, 489-497.  
138