Commentary on the article "Improving the prediction of maturity from anthropometric variables using a maturity ratio".

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We applaud the attempt of Fransen et al. (4) to improve on the original maturity offset article of Mirwald et al. (5). Both articles derive equations for predicting age at peak height velocity (APHV) but both are at best misleading and at worst fundamentally flawed. As their response variables, Mirwald et al. (5) used 'maturity offset' (CA-APHV) where CA is chronological age, and Fransen et al. (4) used 'maturity ratio' (CA/APHV). The problem is that their equations contain the subject's CA in both sides of the prediction equations. In the statistical analyses, this will result in spuriously high values of R^2.

For ease of reference, the equation given by Fransen et al. (4) is reported below. This, and subsequent equations, are re-written with fewer unnecessary decimal places/significant figures.

$$\begin{aligned} &Maturity\ ratio \\ &= 6.99 + (0.116.\mathrm{CA}) + (0.00145.\mathrm{CA}^2) + (0.00452 \times Body\ Mass) - (0.0000341 \times Body\ Mass^2) - (0.152 \\ &\times Stature) + (0.000933 \times Stature^2) - (0.00000166 \times Stature^3) + (0.0322 \times Leg\ Length) - (0.000269 \times \\ &Leg\ Length^2) - (0.000761 \times [Stature \times \mathrm{CA}]) \end{aligned}$$

The equation was derived for ages 11-16 years. Over this range the quadratic expression $\{(0.116.\mathrm{CA}) + (0.00145.\mathrm{CA}^2)\}$ proves to be numerically equal, within 0.7%, to $\{0.154.\mathrm{CA} – 0.242\}$. This fact might be used to make the above equation simpler and more "user-friendly".

Pearson (10) and later Neyman (9) warned that spuriously high correlations will be found between some indices that have a common component. In both of the articles above (4, 5), the authors have made the mistake of regressing the maturity offset difference or ratio (CA-APHV or CA/APHV) with predictors that include CA (i.e., CA is common to both the response and predictor variables), a calculation that will always lead to a spuriously high correlation (2). To illustrate the inevitable danger of this effect, consider the following example adapted from Nevill et al. (7). Table 1 includes two randomly generated normally distributed columns of data (population means ± standard deviations being 10 ± 1), arbitrarily named *CA* and *APHV*.

Table 1 about here

Clearly, there is no significant correlation (or regression) between the two random variables (r = -0.060; P = 0.85). However, if we correlate the "maturity offset" difference (*CA* - *APHV*) with either the *CA* or *APHV* values, we obtain significant but spurious correlations r = 0.757 (P = 0.004) or with *APHV* r = -0.697 (P = 0.012). Similarly, if we correlate the maturity ratio (*CA*/*APHV*) with either *CA* or *APHV*, once again we obtain significant but spurious correlations, with *CA* r = 0.782 (P = 0.003), or with *APHV* r = -0.666 (P = 0.018). These significant correlations would lead to the erroneous conclusion that maturity-offset differences or maturity ratios are meaningfully and positively associated with *CA* or negatively associated with *APHV*.

Moore et al. (6) have proposed much simpler prediction equations than those of Mirwald et al. (5) and Fransen et al. (4), but have made the same mistake of including CA on both sides. Their equations are nevertheless worth looking at here in providing a simple object lesson as to how spuriously high R^2 will occur when a common variable appears on both sides of the regression equation.

For boys they have:

$$\text{CA - APHV} = -8.1 + 0.0070 \times (\text{CA} \times \textit{sitting height})$$

For a representative sitting height of, say, 80 cm,

$$\text{CA - APHV} = -8.1 + 0.0070 \times (\text{CA} \times 80) = -8.1 + 0.56.\text{CA}$$

For girls they have:

$$\text{CA - APHV} = -7.7 + 0.0042 \times (\text{CA} \times \textit{height})$$

For a height of, say, 150 cm,

$$\text{CA - APHV} = -7.7 + 0.0042 \times (\text{CA} \times 150) = -7.7 + 0.63.\text{CA}$$

In both cases CA makes a major contribution to both sides of the equation. Unsurprisingly, the values of R^2 for the full (original) equations are therefore high, namely 0.906 and 0.898 respectively. So high are these that the addition of other predictors to the equations was found to increase R^2 by less than 1%. For either sex, (CA-APHV) is thus being predicted only from CA and one other variable, either sitting height of total height. Yet, as Mirwald et al. (5) illustrate, the ratio of leg length to sitting height (and so also of height to sitting height) tends to be maximum when CA tends towards APHV. One would therefore expect the equations to include two of the three variables height, sitting height and leg length (but not all three, since height is the sum of the other two).

The equations of Fransen et al. (4) and Mirwald et al. (5) contain more terms. However, the remarkably high values of R^2 associated with these must also be spurious—once again due to the presence of CA on both sides of the equations.

Another major concern with the article of Fransen et al. (4) is that the authors are analysing repeated measures data (that contains both between- and within-subject errors). Each subject has just one APHV but a series of repeated observations over time where predictor variables such as leg length, height and CA are repeatedly recorded over their growth cycle, that are incorporated as predictor variables. These should be analysed using a multilevel modelling software approach that will accommodate the hierarchical or nested observational units associated with these data, as recommended and adopted by Baxter Jones et al. (1) and Nevill et al. (8).

Finally, the use of multiplicative allometric models (log-linear) rather than additive polynomials would almost certainly improve the fit and overcome the obvious heteroscedastic errors (often referred to as the shot-gun effect) seen clearly in Figures 3 and 4 (4). This approach was demonstrated to be superior on several data sets associated with modelling the developmental changes in strength and aerobic power in children (9). Note that the data structure reported in Nevill et al. (8) is hierarchical or nested, very similar to the structure reported by Fransen et al. (4).

We see from the three papers (4-6), that estimating the APHV is practically very useful, and that a valuable body of relevant data exists. However, the proposed equations, with their inflated values of R^2 are likely to be misleading and may well be flawed. We believe that the predicted variable should simply be AHPV. It is also desirable that any finally recommended formula should look simple enough that people actually use it. It would also be good if it obviously reflected, or suggested, known relationships amongst potential predictor variables. These might include the tendency of the ratio of sitting height to total height to rise from a minimum at 12-15 years and for the Rohrer Index, (body mass)/height^3, to rise after ~12-16 years (3). The ratio of leg length to sitting height tends to be highest when CA equals APHV (5).

References

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Table 1 Two randomly generated normally distributed columns of data (population means ± standard deviations being 10 ± 1), arbitrarily labelled *CA* and *APHV*. Also shown are values of *CA-APHV* and *CA/APHV*.

CA	*APHV*	*CA-APHV*	*CA/APHV*
11.9	9.7	2.2	1.23
11.7	10.7	1.0	1.09
9.5	11.7	-2.2	0.81
10.7	12.4	-1.7	0.86
8.3	10.5	-2.2	0.79
8.2	11.0	-2.7	0.75
9.6	9.5	0.1	1.01
9.9	10.7	-0.8	0.93
9.7	10.1	-0.4	0.96
9.8	10.1	-0.3	0.97
9.8	9.0	0.8	1.09
9.7	11.8	-2.1	0.82