TWO AUTHORS REPLY

We thank Dr. Chiolero (1) for his interest in our article (2) on the meta-analysis that compared the strength of associations of the waist-to-height ratio and 3 other anthropometric indicators (body mass index, waist circumference, and waist-to-hip ratio) with future type 2 diabetes risk. As Dr. Chiolero pointed out (1), we agree that interobserver measurement differences are larger for waist and hip circumferences compared with those for height and body weight, with the result that reliability is lower for waist circumference, waist-to-height ratio, and waist-to-hip ratio than for body mass index (3). We also acknowledge that we should have addressed the issue of measurement errors in the Discussion in our article. Nevertheless, it is unlikely that we must change the conclusion that waist circumference and waist-to-height ratio are stronger indicators for predicting future diabetes risk than body mass index, although the predictive value of the waist-to-hip ratio might have been substantially underestimated.

The observed standard deviation (SD) combines the real SD and the SD derived from measurement error (4). Accordingly, the diabetes risk per 1 SD also would be overestimated in proportion to the difference between the observed and real SD. However, the overestimation is counterbalanced, possibly to excess, by underestimation due to the dilution effect of measurement bias on the regression coefficient (i.e., diabetes risk per 1 SD in this case).

A simple simulation for explaining the effect of the measurement error on the coefficient (β) is presented as follows. The relationship between the observed and real coefficient is indicated by the formula:

\[
\beta_{\text{observed}} = \beta_{\text{real}} \times \frac{SD_{\text{real}}}{SD_{\text{observed}}} = \beta_{\text{real}} \times \frac{SD_{\text{real}}}{SD_{\text{real}} + \text{SD-measurement error}^2},
\]

where X is an exposure (i.e., anthropometric indicators in this case) (4). Supposing that the variance (i.e., square of SD) due to measurement error is added to the observed variance by 10% and 20% of the real variance, the observed SD will be increased by 4.9% (\(\sqrt{1.1} - 1 = 0.049\)) and 9.5% (\(\sqrt{1.2} - 1 = 0.095\)), respectively, compared with the real SD. In contrast, when the real and observed SDs are brought into the above formula, the observed β would be reduced by 9.1% (1 - (1/1.1) = 0.091) and 16.7% (1 - (1/1.2) = 0.833), respectively, compared with the real β. The dilution effect on the coefficient is always larger than the enlarging effect of the measurement error on the SD.

The SD reported in each study would have been more greatly overestimated in waist-to-height ratio, waist circumference, and waist-to-hip ratio than in body mass index given that the measurement errors mainly due to interobserver differences were larger for waist-to-height ratio, waist circumference, and waist-to-hip ratio compared with body mass index. However, the overestimated diabetes risk due to the enlargement of the SD will be compensated to a larger extent by the underestimation due to the dilution effect. This “overcompensation” becomes larger as the measurement error is expanded. Consequently, the actual diabetes risk in relation to the anthropometric indicators should be larger than the observed diabetes risk, especially with regard to waist-to-height ratio, waist circumference, and waist-to-hip ratio.

Needless to say, every possible effort is being made to minimize the unreliability mainly due to interobserver differences by increasing the number of anthropometrists adequately trained in measurements of waist circumference and standardizing the location on the body where the waist is measured (5). Unfortunately, the number of such well-trained individuals is too small in comparison with the number of reliable instruments to measure height and body weight, and no universally accepted method exists for measuring waist circumference (5). Moreover, it cannot be ignored that the time needed to measure waist circumference is possibly longer than for a calculation of body mass index. Therefore, the obstacles in using waist circumference for diabetes screening may be related to feasibility rather than to reliability.

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