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REPLY

Motor development in children and adolescents: role of body mass index and socioeconomic status

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Thank you for your interest in our article [1] on typically developing children and adolescents between 3 and 18 years of age, where we demonstrated that the norms for motor abilities' development as measured with the Zurich Neuromotor Assessment-2 (ZNA-2) were largely independent of BMI and SES. We are thankful that we are given the opportunity to clarify some points, which were raised by Dr. Sharawat.

We are well aware that motor performance is strongly dependent on age and gender. For this reason, the ZNA-2 proceeds by calculating Standard Deviation Scores (SDS) which refer to motor scores adjusted for both age and gender. The effect of BMI and SES was then investigated on motor SDS (which do no longer depend on age or gender) rather than on raw motor scores (e.g., time performance, which do depend on both age and gender). Multiple imputations were also carried out on motor SDS rather than on raw motor scores. As mentioned in the statistical appendix, the imputation model did still include age and gender as "predictors" of motor SDS in addition to BMI and SES. Therefore, we believe our analysis did properly account for age and gender when calculating motor SDS in the first place and also when performing multiple imputations for missing motor SDS.

In contrast to the studies by Morrison et al. [2] and Guo et al. [3], the focus of our study was on the effect of BMI and SES on the norms for motor performance in typically developing children. We did not perform any subgroup analysis in obese/overweight children because our sample did not include many such kids: only 7 children in our sample (2.2%) had a BMI>25. We agree, however, that subgroup analyses could provide more insight into specific research questions regarding the effect of SES and especially BMI in different age groups. For this reason, our paper mentioned results from a post hoc analysis where we quantified the effect of BMI and SES separately in younger children (≤12 years) and in older children and adolescents (>12 years). Most notably, the BMI effect was found to be different in the two age groups. For instance, the positive association between BMI and pure motor scores seen in younger children disappeared in the elder. We postulated that changes in fat-free mass occurring over age could possibly explain why this association disappears in older children.

We argue that the study by Smits-Engelsman and Hill [4] is not comparable to ours for essentially two reasons. First, among the 460 children included in their study, only 52 were

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attending mainstream schools and had no history of motor difficulties. The vast majority of their sample included children with either some form of learning disabilities or suspected Developmental Coordination Disorder (DCD). In contrast, our study only included children and adolescents attending mainstream schools and children with suspected DCD were excluded from the analysis. This difference in clinical and educational settings is important to make. In former studies of our team measuring motor performance with the ZNA-1 in a clinical population (children born < 1250 grams), correlations between motor performance (measured with the ZNA) and cognitive functions were significant [5] as expected. On the other hand, in healthy children, we demonstrated that the correlations between motor and intellectual domains are largely independent [6]. Secondly, Smits-Engelsman and Hill [4] used the Movement ABC (M-ABC) test battery to quantify motor performance in children. Unlike ZNA-2 which aims at quantifying *motor abilities* (i.e., which depends more closely on the maturation state of the neurologic system of the child), M-ABC quantifies *motor skills* which can be trained with exercise. Therefore, it is expected that motor scores as measured with M-ABC will probably depend more on external factors such as IQ or SES compared to those measured with the ZNA-2. For more references on the comparison between these two tests, we refer to Kakebeeke et al. [7, 8].

Regarding the application of Rubin's rule for multiple imputations, recall that regression coefficients (i.e., fixed effects) in linear mixed models are known to be asymptotically normally distributed (see for example [9]). Consequently, they can be pooled using Rubin's rules without requiring any additional transformation. On the other hand, other estimated quantities such as R-squared values or the intra-class correlation coefficient are not normally distributed. For these estimates, we used Fisher's Z transformation [10] prior to pooling and only reported the point estimate for the pooled result. We believe this strategy is adequate for the purpose of the analysis.

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