Comparing the Roles of Physical Activity and Fitness in Arterial Stiffness: How Important Is Exposure Measurement Error?

To the Editor:

The article by Boreham et al1 in the November 2004 issue of Hypertension reports the associations between physical activity and cardiorespiratory fitness with pulse-wave velocity (PWV), a measure of arterial stiffness. One of the objectives of the study was to compare the relative relationships of physical activity and fitness with the outcome PWV. Indeed, the authors’ interpretation of their data leads them to state that “arterial stiffness related benefits of exercise are most likely to accrue if exercise prescription in young adults targets improvements in cardiorespiratory fitness”, implying that fitness is more important than physical activity in preventing stiffening of the arteries.

Clearly, understanding the manner in which modifiable factors such as low physical activity and poor fitness relate with cardiovascular health is important for disease prevention. However, the conclusions and recommendations in the present study are based on data in which differential exposure measurement error is probably a pivotal factor; this possibility receives little attention in the article.

Cardiorespiratory fitness, as assessed through a maximal oxygen consumption test, is not a simple construct, because fitness is determined by both modifiable factors, such as habitual physical activity (volume, intensity, and mode), smoking, and cardiovascular pathology, as well as nonmodifiable factors, such as genotype and intrauterine environment. Therefore, in considering the risk predisposed by low fitness and physical inactivity, one should preferably measure both exposures to a similar level of precision and then assess them in combination, thereby accounting for any shared variance. However, this is difficult to achieve. Even when physical activity is measured objectively, differences in measurement precision persist between activity and fitness.2,3 Only by measuring activity and fitness objectively and by undertaking multiple measures of both exposures combined with the appropriate statistical analyses can this problem be adequately addressed.

In the present study, the correlation between the estimate of physical activity derived using a questionnaire and the true level of physical activity is likely to be $r=0.30$;4 whereas the correlation between the estimate of cardiorespiratory fitness and true fitness is likely to exceed $r=0.80$.5 Thus, measurement error will be much greater in the estimate of physical activity compared with the estimate of fitness and will inappropriately decrease the probability of detecting a significant association for physical activity. Moreover, an exercise stress test using respiratory gas exchange to determine fitness is an objective measure, whereas physical activity questionnaires are subjective instruments and are thus prone to response bias. If, for example, the young adults who had stiffer arteries in the present study over-reported their sports physical activity, this would cause the magnitude of effect ($\beta$ coefficient) for the association between activity and PVW to appear less than it truly is. By contrast, if under-reporting of occupational activity occurred in those with high arterial tonicity, this could cause overestimation of the magnitude of the relationship with PVW. The nature of this reporting bias is known to be modified, among other factors, by gender and by level of obesity,6 and simply adjusting for these factors may not be adequate. However, it is not possible to know the extent or direction of such biases without a concurrent objective criterion measure.

In conclusion, whereas the association between cardiorespiratory fitness and PVW in the present study is highly plausible, the associations, or lack thereof, between the physical activity subdomains and PVW are likely to be far less reliable, owing to the high degree of measurement error and response bias characteristic of physical activity estimated via questionnaire.

Paul W. Franks
Diabetes Epidemiology & Clinical Research Section
National Institute of Diabetes and Digestive and Kidney Diseases
Phoenix, Arizona


Response: Physical Activity and Fitness in Arterial Stiffness: What Role Does Exposure Measurement Error Occupy?

In his Letter to the Editor, Franks questions to what extent exposure measurement error may have influenced the strength of the associations we reported for cardiorespiratory fitness and arterial stiffness, compared with those reported for physical activity and the same outcome.1 Specifically, we found the former to be stronger than the latter and, additionally, that these associations were not confounded/mediated by physical activity levels, whereas the latter associations were highly mediated by cardiopulmonary fitness levels. This led us to conclude that physical activity may need to be cardiovascular in nature and of a type leading to improvements in cardiopulmonary fitness levels (maximal oxygen uptake) for a decrease in arterial stiffness to be seen.

We agree with Franks that disentangling the separate effects of fitness and physical activity on a given outcome variable depends on the precision with which these variables are measured; this is believed to differ substantially, such that cardiopulmonary fitness, as measured in our study, yields more precise values than those obtained for physical activity levels, which were assessed by questionnaire. We have acknowledged this limitation in our manuscript and are aware that the associations we found between physical activity and arterial stiffness may, therefore, have been an underestimation of the real associations.
In his letter, Franks specifically raises 2 points regarding the potential influence that different levels of measurement error associated with fitness and physical activity may have had on our findings: (1) the problem of random measurement error (regression dilution bias), which is believed to be higher for physical activity than for fitness and therefore can influence (ie, underestimate) the strength of the association investigated, and (2) the problem of recall bias, which is another source of measurement error particularly associated with the assessment of physical activity levels by questionnaire; this source of measurement error can lead to both under- or overestimation of the associations and therefore is not likely to have impaired the validity of our findings.

Regarding the problem of regression dilution bias, Franks suggested the use of correction factors to overcome this problem, thereby obtaining closer-to-real associations. These correction factors are based on repeated measures obtained for both fitness and physical activity levels. Although recognizing the virtues of this method, we think that these repeated measurements should be obtained within a relatively short period of time, because fitness and, in particular, physical activity levels may differ considerably throughout the year, for instance due to seasonal influences. That has not been the case in the studies called to our attention by Franks in which a total of 4 measurements of fitness and physical activity levels were obtained within 1 year. As such, a lower correlation between repeated measurements of physical activity may have been due not only to random measurement error, but also to real changes in physical activity over time. Therefore, the phenomenon reported by Franks that, after adjustments for measurement error, physical activity was in fact more strongly associated with the study outcome(s) than was fitness, may have also been an overestimation of the facts. In other words, the influence of higher random error associated with the measurement of physical activity than that associated with the measurement of cardiopulmonary fitness may, after all, not be as strong as suggested by Franks.

Finally, we would also like to emphasize that although we have investigated the relative associations of fitness and physical activity with arterial stiffness, another crucial aspect of our study was the investigation of whether physical activity performed in different settings (sports-, work-, and leisure-time-related) would be similarly related to stiffness estimates. We have found sports-related but not work- or leisure-related activities to be associated with decreased stiffness, a finding that is in line with the evidence that not all types of physical activity have beneficial effects on arterial properties; indeed some, such as strength training, may even be deleterious.
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