

Resilient, Responsive, and Healthy Developing Bones: The Good News About Exercise and Bone in Children and Youth

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Bone health as an outcome of a physically active lifestyle in young populations has taken a lower priority to cardiovascular and other metabolic health parameters. Reduced density and quality in bones increase fracture risk, which becomes evident later in life through recognition of osteoporosis as a “silent killer” (11). Yet, bone weakness is both detectable and often modifiable in childhood and adolescence. With closer investigations into sedentary behavior in children and youth (16), questions on the potential impact of lower physical activity on the skeletal system of children and youth warrant attention. Bone and exercise research in young populations typically attests to the benefits of a wide range of bone-stimulating exposures for healthy bone development, but it is rarely afforded a whole issue in peer-reviewed journals.

This special issue of *Pediatric Exercise Science* is dedicated collectively to understanding the responsiveness of bone to exercise in children and youth. Authors from around the globe have presented opinions, reviews, follow-up studies, as well as describing a variety of measures and means to analyze bone responses to exercise during the first 2 decades of life.

Most researchers in the field of bone in pediatrics are excited about responses to exercise, but some have extended this excitement to mixed interpretations of prepubescent responses, when the stronger evidence lies

in a potentially greater responsiveness to exercise bone at and around pubescent growth. There is no doubt that pubescent growth offers the greatest window for bone responsiveness as it is the time of greatest velocity of bone accrual. However, it is important to acknowledge some evidence that bone can respond to physical activity lifestyles even in children aged 5 years (12), and strategic exercise-related stimuli introduced to 7-year-old children can have sustainable outcomes 8 years later (9). This issue of *Pediatric Exercise Science* commences with an opinion piece advocating for care in the interpretation of comparisons and consistency in reporting and treating pubertal status in studies of bone and exercise in young populations (2). This opinion piece revisits and strengthens evidence around the period during which peak bone responses occur in young populations. A more uniformed approach in reporting peak bone responsiveness to exercise during growth will assist in tightening the rigor of pediatric bone and exercise research. Although bone responds at all time points during growth, some impacts can be transient. The most rigorous evidence to date shows the positive benefits during pubertal growth do not always translate into adult benefits and encourages weight-bearing activity across the whole life span and not just certain time points in growth (10).

Even from the earliest age, bone has the potential to respond to exercise-related stimuli. An update on the current understanding of assisting the bone-related responses to passive exercise in preterm infants is a timely reminder of how sensitive bone regulation can be and how early improvements can be instigated (14).

Beyond a consensus on the need for weight-bearing exercise in children and youth, exercise prescription for optimal bone development is imprecise. However, the

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leading original research article in this special issue shows that the *frequency* of bouts of vigorous physical activity on long-term bone development are more important than the total volume, a notion only previously supported by animal research (8).

Emerging evidence of the benefits of bone and exercise in young populations is strengthened by mathematical modeling, capable of monitoring and accounting for the timing and tempo of pubertal development. A variety of statistical treatments are observed in this issue of *Pediatric Exercise Science*, respecting the need to covary for likely differences in maturity. However, the elegant description of mixed-effects models to account for time-varying covariates in the article by Gabel et al (8) is particularly noteworthy.

Few observational or interventional studies receive follow-up attention. Yet, in this issue, there are 4 studies presenting longitudinal data: a remarkable hip structural analysis 10 years following initial scanning of young gymnasts (6); 4 years of observations involving vigorous physical activity in healthy young individuals (8); 1 year after the cessation of a school-based intervention in a peripubertal group of males and females (15); and after 9 months of exposure to martial arts training (7). Results vary; perhaps reigniting the debates on the importance of impact, exposure, and frequency of stimuli in discriminating among adaptive, transient, and optimal responses of bone in young populations.

In this special issue of *Pediatric Exercise Science*, bone parameters and processes are shown to be detectable with high-precision imaging technology such as high-resolution peripheral quantitative computed tomography (8) and highly reliable biochemical markers of bone metabolism (5,13). Advancing technology provides new frontiers for pediatric bone and exercise research, yet the rigor of the traditional, perhaps less costly measures of bone parameters such as dual-energy X-ray absorptiometry continue to provide insight into the sustainability of the responsiveness of bone to exercise over prolonged periods of time (6,7).

Some of the bone's responsiveness to exercise is time sensitive. An article on Wnt signaling-related osteokines and transforming growth factors shows the sensitivity of bone responsiveness following a single bout of high-impact exercise in adolescent females (5). Other measures of bone's responsiveness to exercise can also readily highlight a point of difference in cross-sectional comparisons of sporting and nonsporting populations of children (7,13) and yet also show sustainable advantages to exercise up to a decade later (6).

Although the bone health of girls is a frequent target for researchers (5,6), this issue also offers some insight into young male populations of gymnasts (4) and soccer players (13), and comparisons of males and females participating in martial arts (1).

The weight-bearing necessity of exercise for positive bone impact remains important. Comparisons of well-trained young swimmers show more bone deficits than their less swimming-exposed peers (1) and

highlight the need for global advocacy of weight-bearing exercise, particularly when the majority of time spent being physically active is indeed weight supported.

However, some caution may be required in interpreting the value of weight-supported sports participation. "More is better" does not always apply, and the stage of maturation should be seen at least as a moderating, if not mediating, factor in the dose-response relationship. The American Academy of Pediatrics provides a timely reminder of ongoing concerns for the health of elite-level participants in sports such as in gymnastics in which peak performance can be demanded prior to physical maturation (3).

Nonetheless, as the divide between sedentary and active young populations increases, bone research relating to exposure to physical activity from even the earliest stages of life will take on a new priority in health research. But research without policy lacks translation and policies without research lack relevance. Hopefully, this special issue of *Pediatric Exercise Science* on bone and exercise can be cited in health promotion policies to strengthen the significance of evidence of the potential of exercise to make a positive difference to bone parameters in the first 2 decades of life and possibly later in life.

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