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Review

Weight-bearing exercise and bone mineral accrual in children and adolescents: A review of controlled trials

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Abstract

Introduction: Osteoporosis is a serious skeletal disease and as there is currently no cure, there is a large emphasis on its prevention, including the optimisation of peak bone mass. There is increasing evidence that regular weight-bearing exercise is an effective strategy for enhancing bone status during growth. This systematic review evaluates randomised and non-randomised controlled trials to date, on the effects of exercise on bone mineral accrual in children and adolescents.
Methods: An online search of Medline and the Cochrane database enabled the identification of studies. Those that met the inclusion criteria were included in the review and graded according to risk for bias.
Results: Twenty-two trials were reviewed. Nine were conducted in prepubertal children (Tanner I), 8 in early pubertal (Tanner II–III) and 5 in pubertal (Tanner IV–V). Sample sizes ranged from $n=10$ to 65 per group. Exercise interventions included games, dance, resistance training and jumping exercises, ranging in duration from 3 to 48 months. Approximately half of the trials ($n=10$) included ground reaction force (GRF) data (2 to 9 times body weight). All trials in early pubertal children, 6 in pre pubertal and 2 in pubertal children, reported positive effects of exercise on bone ($P<0.05$). Mean increases in bone parameters over 6 months were 0.9–4.9% in prepubertal, 1.1–5.5% in early pubertal and 0.3–1.9% in pubertal exercisers compared to controls ($P<0.05$).
Conclusions: Although weight-bearing exercise appears to enhance bone mineral accrual in children, particularly during early puberty; it remains unclear as to what constitutes the optimal exercise programme. Many studies to date have a high risk for bias and only a few have a low risk. Major limitations concerned selection procedures, compliance rates and control of variables. More well designed and controlled investigations are needed. Furthermore, the specific exercise intervention that will provide the optimal stimulus for peak bone mineral accretion is unclear. Future quantitative, dose–response studies using larger sample sizes and interventions that vary in GRF and frequency may characterise the most and least effective exercise programmes for bone mineral accrual in this population. In addition, the measurement of bone quality parameters and volumetric BMD would provide a greater insight into the mechanisms implicated in the adaptation of bone to exercise.

Keywords: Bone mineral density; Children; Exercise; Peak bone mass

Contents

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Introduction

Osteoporosis is a systemic, skeletal disease characterised by low bone density and micro-architectural deterioration of bone tissue, with a consequent increase in bone fragility [1]. It is a serious disease that is increasing at an epidemic rate and it is predicted that osteoporosis and osteoporotic fractures will rise exponentially over the next 50 years, as the population ages [2]. Thus, there is a large emphasis on preventative measures to combat or offset osteoporosis and fracture. One major preventive measure is the optimisation of peak bone mass in the early years. *Peak bone mass* can be defined as the greatest amount of bone mass achieved during life at a given skeletal site and is based on observations that bone mass increases during childhood and puberty, consolidates during young adulthood and declines with age [3,4]. One strategy to increase peak bone mass is through regular, weight-bearing exercise [5–7]. The definition of *weight-bearing exercise* that has been adopted for this review is that of a structured, force-generating activity that provides loading to skeletal regions, above that provided by activities of daily living [8]. Weight-bearing exercises can include aerobics, circuit training, jogging, jumping, volleyball and other sports that generate impact to the skeleton. There is evidence to suggest that the years of childhood and adolescence represent an opportune period during which bone adapts particularly efficiently to such loading [9,10].

Evidence supporting the role of weight-bearing exercise in bone health has accumulated from cross sectional, retrospective, prospective and intervention studies. Cross sectional studies report higher bone mass in athletes than non athletes [11,12], and in highly active children compared to those who are more sedentary [13,14]. Retrospective studies report greater bone mass in retired dancers compared to controls [15], and an increase in physical education (PE) within the school curriculum is associated with positive skeletal effects in children [16]. Prospective studies following children with different physical activity levels also report greater increases in the bone mass of active children compared to those who are less active [17–19]. Although such studies have contributed to the literature, they do not provide robust and causal inferences between exercise and bone mineral accrual. As such, there is a need to assess randomised controlled trials (RCT), which are regarded as the primary source for more valid and reliable evidence. The number of investigations has increased over the last 5 years [20–33] therefore the purpose of this review was to evaluate this literature to date.

Methods

Search strategy to identify relevant trials

The aim of the literature search was to identify all available RCTs and controlled studies concerning the effects of weight-bearing exercise on bone mineral accrual in children and adolescents, aged 8 and 17 years. To do so, a computerised search of the MEDLINE database was performed on articles published between the years 1964 and 2005. The keywords entered were: 'exercise, children, girls, boys, adolescents, bone, bone mineral and bone mass'. A total of 573 articles were found, and their titles and abstracts (or complete papers when the abstracts contained insufficient information) were reviewed to see whether they met the inclusion criteria. Papers from all journals were considered and retrieved either online or by interlibrary loan. A search was also conducted using The Cochrane Controlled Trials Register (CENTRAL), using the following keywords: 'exercise, bone and children'. An additional search using 'Google' was performed to identify any further trials that were currently underway.

Considered studies were reviewed according to a general criterion and graded through a quality assessment, based on bias risk. The risk for bias was based on the extent to which the study design may influence the results in such a way that may prejudice the conclusions.

Nineteen studies met the inclusion criteria (Fig. 1), were graded according to the quality assessment categories described below (Table 1), and were reviewed in terms of their contribution to the literature. Studies were grouped according to the maturity status of the participants: prepubertal (Tanner I), early pubertal (Tanner II–III) and pubertal (Tanner IV–V). Three studies were divided into 2 parts (a and b) for analysis, as the authors provided results for both prepubertal and pubertal children [26,31,33]. Thus, 22 trials were reviewed. Studies using samples of mixed maturity subjects that did not provide separate analyses for each group, and which used small numbers (<10 per group), were not included.

Grading the trials

The 22 trials were graded according to bias risk. In exercise intervention trials, blinding of the investigators and of the participants is not feasible and thus, was not used as a criterion for validity. The grading system can be seen in Table 1. It is recognised that not all categories are equal in terms of influencing the bias of the study conducted, for example, the compliance rate might be more important than whether the ground reaction forces generated by the exercise intervention were measured or not. Although weighting the categories would have provided greater accuracy in the grading scheme, this was problematic to undertake. According to our criteria, the highest grade a study could be given was 21. For the purpose of this review, a grade of 19–21 indicates a low risk of bias; 16 and 18 indicates a moderate risk, and those at 15 or below, indicate a high risk.

Results

Table 2 summarises the design, execution and outcomes of the studies reviewed. These are grouped according to the participants' Tanner Stage because maturity status is critical