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Effects of whole-body vibration exercise on bone mineral content and density in thermally injured children

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ABSTRACT

Background: Loss of bone mass, muscle mass, and strength leads to significant disability in severely burned children. We assessed the effects of exercise combined with whole-body vibration (WBV) on bone mass, lean mass (LM), and muscle strength in children recovering from burns.

Methods: Nineteen burned children ($\geq$30% total body surface area [TBSA] burns) were randomly assigned to a 6-week exercise regimen either alone (EX; $n = 10$) or in combination with a 6-week WBV training regimen (EX + WBV; $n = 9$). WBV was performed concurrent to the exercise regimen for 5 days/week on a vibrating platform. Dual-energy X-ray absorptiometry quantified bone mineral content (BMC), bone mineral density (BMD), and LM; knee extension strength was assessed using isokinetic dynamometry before and after training. Alpha was set at $p < 0.05$.

Results: Both groups were similar in age, height, weight, TBSA burned, and length of hospitalization. Whole-body LM increased in the EX group ($p = 0.041$) and trended toward an increase in the EX + WBV group ($p = 0.055$). On the other hand, there were decreases in leg BMC for both groups (EX, $p = 0.011$; EX + WBV, $p = 0.047$), and in leg BMD for only the EX group (EX, $p < 0.001$; EX + WBV, $p = 0.26$). Truncal BMC decreased in only the EX group (EX, $p = 0.009$; EX + WBV, $p = 0.61$), while BMD decreased in both groups (EX, $p < 0.001$; EX + WBV group, $p < 0.001$). Leg strength increased over time in the EX group ($p < 0.001$) and the EX + WBV group ($p < 0.001$; between-group $p = 0.31$).

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Abbreviations: BMC, bone mineral content; BMD, bone mineral density; DEXA, dual energy X-ray absorptiometry; EX, exercise only group; EX + WBV, exercise + whole-body vibration group; LM, lean mass; TBSA, total body surface area; OT/PT, occupational therapy/physical therapy; WBV, whole-body vibration.

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Conclusions: Exercise in combination with WBV may help attenuate regional bone loss in children recovering from burns. Studies are needed to determine the optimal magnitude, frequency, and duration of the vibration protocol, with attention to minimizing any potential interference with wound healing and graft closure.

1. Introduction

Individuals with severe burns experience a dramatic catabolic and hypermetabolic state for up to 2 years after injury [1,2]. Children recovering from burns ≥30% of their total body surface area (TBSA) suffer long-term disturbances in bone metabolism, leading to deficits in bone mineral density (BMD) and bone mineral content (BMC) that can be detrimental to physical development and maturity of the skeleton [3–5]. These marked changes may result in decreased mineral anabolism and possibly decreased resorption. In some instances, these metabolic abnormalities may be present for up to 5 years, possibly resulting in failure to achieve appropriate peak bone mass [4]. Klein and colleagues have suggested that bone loss in children with burns may be partially attributed to immobilization during recovery along with metabolic abnormalities [6]. Such bone disturbances may increase fracture risk, further contributing to personal and economic burden during rehabilitation.

Exercise is an effective intervention for augmenting muscle strength and lean mass (LM) in children recovering from severe thermal injuries [7–11]. However, whether exercise increases or even prevents burn-induced loss of bone mass and density is unknown. One exercise modality that has been used in the nonburned pediatric population to increase bone mass is whole-body vibration (WBV). WBV involves standing on an oscillating platform that vibrates at a preselected frequency and amplitude of displacement; this vibratory stimulus, in turn, accelerates the entire body, imparting force onto the skeleton [12,13]. Vibration exercise may increase BMD [14], muscle strength [15], and power in humans [16]; there is also strong evidence supporting the use of WBV to preserve bone and muscular function during activity restriction, such as bed rest in adults [17–20]. Mechanistically, WBV may increase bone mass directly through the force imparted by the metal plate onto the skeleton or through the pull of the tendon attachment site on the bone. In nonburned children, several studies show benefits of WBV on BMD. Six months of WBV (10 min daily for 5 days a week) significantly increased proximal tibia and spine BMD in a group of ambulatory boys and girls (mean age, 9.1 years) with limited mobility due to disabling conditions [21]. Likewise, significant gains in cancellous bone in the lumbar vertebrae and cortical bone in the femoral midshaft were seen in a group of young women with low BMD (age range, 15–20 years) after they completed a WBV program (10 minutes daily for 12 months) [22]. Another group of eight females with low bone density (mean age, 9.7 years) showed a significant increase in cancellous tibia trabecular bone density and cortical bone density of the femur after 8 weeks of WBV (30 minutes a day, 3 days a week) [23].

Although there is support for the use of WBV and exercise in children without burns to improve bone mass and density, the effects of WBV and exercise on these parameters in children recovering from burns have not been reported. We studied the effect of a 6-week WBV training intervention in conjunction with exercise on bone and muscular strength in children recovering from burns. We hypothesized that both exercise alone and exercise in combination with WBV would minimize losses of whole-body, regional leg, and truncal BMC and BMD but that these positive results would be greater with exercise in combination with WBV.

2. Methods

2.1. Participants

Nineteen severely burned children (5 female and 14 male) with burns covering ≥30% of the TBSA completed this study. Seventeen of the injuries were characterized as flame injuries, while two were scalding injuries. After consent, children were randomly allocated to either an exercising control group (EX) or an intervention group that completed exercise in addition to a WBV intervention (EX + WBV). Participants were recruited immediately after discharge from the hospital and prior to beginning the 6-week exercise program, which was implemented at discharge. All participants and their legal guardians read and signed the informed consent, which was approved by the Institutional Review Board of the sponsoring university and hospital unit.

2.2. Experimental overview

A prospective, randomized controlled trial design was implemented in this study. Participants were recruited from a specialized pediatric burn hospital for children. All participants underwent occupational and physical therapy (OT/PT) specific to their impairments and medical treatment for their burns. The OT/PT rehabilitation programs were offered as an outpatient service. Inclusion criteria were as follows: severe burns covering ≥30% TBSA, ability to safely tolerate ambulatory activity and exercise, and reliable transportation to return to the exercise unit of the hospital five times per week. Participants were excluded if they were prescribed any medication that would affect muscle or bone metabolism.

The EX and EX + WBV groups completed an identical exercise protocol with sessions 5 days per week [11,24]. Children in the EX + WBV group also completed a 5-day-per-week WBV intervention, which had parameters of previously published protocols [21,22,25]. Baseline testing for strength, LM, BMD, and BMC were completed the week before the start