Bone Mineral Density and Lean Body Mass Response to Selective Exercise Program in Burned Children

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Abstract: The aim of this work was to evaluate the efficacy of weight bearing exercise and resisted exercise on bone mineral density BMD and lean body mass LBM in post burned children. Forty burned children (ages from 7 to18 years) with 40% or more total body surface area (TBSA) burned (after 6 months of burn) had been participated in this study. The patients were randomly divided into two groups. Group A: participated in a 12-week of physical rehabilitation program supplemented with an individualized and supervised exercise training program (Resisted ex. + Weight bearing ex. + Traditional ex.). Group B: participated in a 12-week of physical rehabilitation program (traditional exercise only) (stretching ex, scar rehabilitation, R.O.M and ADL) three times per week for both groups. Measurements of BMD and LBM by Dual-energy x-ray absorptiometry (DEXA) were collected before treatment and after three months of treatment. There was a significant difference and increase in BMD and LBM values ($P<0.05$) post treatment in group A compared to group B. Conclusion: BMD and LBM of pediatric patients post burn can significantly increase through participation in a supervised exercise training program.

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1. Introduction

Morbidity and mortality are associated with burn size [(1)]. Severe burn injuries are associated with a significant inflammatory, hypermetabolic and hypercatabolic state that arises acutely and persists for up to 3 years after initial burn injury and even following wound healing. Consequently, patients develop a systemic loss of muscle mass, lean body mass, and bone mineral density [(2)].

Burn injuries of≥40% TBSA has markedly reduced bone formation in both adults and children. Burn induces a systemic catabolic response characterized by increased energy expenditure. This increased expenditure produces a rapid and severe depletion of body energy stores, which are associated with a loss of bone calcium and subsequently osteopenia [(3)]. In addition, it is suggested that bone loss begins in the first 24 hours following injury due to a rise in proinflammatory cytokines and the surge of glucocorticoids over the first week. Both of these responses are directly linked to an increase in osteoclastogenesis resulting in bone resorption [(4)].

It is well established that the hypermetabolic state is not resolved rapidly after burn and complete wound healing, but lasts for at least 9–12 months after burns over 40% TBSA. This results in continuous erosion of lean body mass, from a reduction in muscle protein synthesis, and increase in protein catabolism thus delayed recovery in muscle strength during convalescence [(5)].Patients with a 40% TBSA burn can lose up to 25% of their total body mass in 3–4 weeks, with generally fatal consequences [(6)].

Exercise would be an ideal tool in the rehabilitation of burned children [(7)]. Various therapeutic approaches have been investigated in burn care in an attempt to ameliorate the adverse effects of burn. One of these therapies is exercise, which has been reported to improve functional outcome of burned patients [(8)].

Load bearing activities seem to be the “gold standard” with respect to bone mass increases [(9)]. Resistance exercise is a potent physiological intervention that increases muscle mass [(10)]. Supervised resistance exercise have been shown to offer considerable benefits during outpatient rehabilitation of pediatric burn injury. These include improvements in lean body mass (LBM) [(11)].The exercise program started at 6 months post burn because the majority of pediatric patients with burns on >40% are ambulatory and have had the opportunity to return home, placing them in a more favorable psychological disposition for another long-term institutionalization (e.g., 12 wk). patient's wounds are considered to be 95% healed [(12)].

The current study had been conducted to assess lean body mass and bone mineral density before and after a 12-week of supervised exercise program (resistance and weight bearing exercise) in a group of severely burned children.

2. Subjects and methods

Forty burned children (after 6 months of burn) randomly selected from outpatient clinic of faculty of physical therapy (burn units), Cairo University, were included in the study. Their ages ranged from 7 to18 years. All patients had thermal burn injuries with 40% or more total body surface area (TBSA) burned, as assessed by the "rule of nines" method[13].Patients were excluded if they had one or more of the following: leg amputation, any limitation of R.O.M of joints of lower limb, anoxic brain injury, psychological disorders, quadriplegia, or severe behavior or cognitive disorders.

The patients were randomly divided into two groups. Group A: (study group) included 20 patients who was participated in a 12-week of physical rehabilitation program supplemented with an individualized and supervised exercise training program (Resisted ex. + Weight bearing ex. + Traditional ex.). Group B: (control group) included 20 patients who was participated in a 12-week of physical rehabilitation program (traditional exercise only) (stretching ex, scar rehabilitation, R.O.M and ADL). Treatment sessions were conducted three times per week for 12-week. The study protocol was explained in detail for each parent before the initial assessment and signed informed consent form was obtained from each parent before enrollment in the study.

All patients received similar standard medical care and treatment from the time of emergency admission and acute care of the burn injury until time of discharge. In addition, both groups was discharged with similar standard medical and rehabilitation care.

Bone mineral density and lean body mass and measurement:

Measurement of bone mineral density BMD and lean body mass LBM were taken for both groups pre treatment and after three months of training by Dual-energy x-ray absorptiometry (DEXA) (Lunar Corp., model DPX, manufactured in USA). The child removed all external opaque (metal and plastic) objects like Jewelry and asked to wear minimal clothing (e.g., swimsuit, or a gown). Weight and height scale was used to measure the weight and the height of each child. The protocol of total body measurement was used. With Pediatric software can measure the attenuation of 2 x-ray Beams, of which one is high energy and the other low energy. These measurements are then were been compared with standard models Of thickness use for bone and soft tissue. Subsequently, the Calculated soft tissue is separated into LBM, BMD and fat mass[14, 15].

BMD = BMC (g)/Area (cm^2)

Three-repetitions maximum test:

Only the patients in the exercise group were tested, after a 30-minute rest, to determine the amount of weight or load to use as baseline loads in the first week of the 12-week program. They were tested in the following order of exercises: bench press, leg press, shoulder press, leg extension, biceps curl, leg curl, and triceps curl. The three-repetition maximum (3-RM) load was determined as follows. After an instruction period on correct weight-lifting technique, the patient was warm up with lever arm and bar (or wooden dowel) and was allow to become familiar with the movement. After this, the patient lifted a weight that was be allowed successful completion of four repetitions. If the fourth repetition was be achieved successfully and with correct technique, a 1-min resting period was be allowed. After the resting period, a progressively increased amount of weight or load was be instructed to be lifted at least four times. If the patient lifted a weight that allow successful completion of three repetitions, with the fourth repetition not being volitionally possible, because of fatigue or inability to maintain correct technique, the test was terminated and the amount of weight lift from the successful set was be recorded as their individual 3 RM.

Exercise Training Program

All exercise sessions and exercise prescriptions were supervised by physical therapy and were conducted according to the guidelines set by the American College of Sports Medicine (ACSM) and the American Academy of Pediatrics (AAP) [16-18]. No strength training activities were permitted outside the supervised training session; however, both groups were allowed to pursue their normal daily activities.

All subjects were sedentary before starting the exercise program. All sessions were preceded by a 10-minute warm-up on the treadmill and end with cooling down on the treadmill at intensity decreased gradually to resting heart rate. Training sessions consisted of resistance and weight bearing exercises.

Resisted exercise: We used 8 basic resistive exercises: bench press, leg press, shoulder press, leg extension, biceps curl, leg curl, triceps curl, and toe raises. All exercises were done using variable resistance machines or free-weights, and were done 3 days a week. During the first week, the patients became familiar with the exercise equipment and were instructed in proper weightlifting techniques. The weight or load lifted was set at 50% to 60% of their individual 3-RM. During the second week, the lifting load was be 70-75% (4 -10 repetitions) of their individual 3-RM and was maintained for weeks 2 through 6. After this, training intensity was increased to 80% to 85% (8–12 repetitions) of the 3-RM for weeks 7 through 12.

Weight bearing exercise: Weight-bearing aerobic activities involve doing aerobic exercise on feet, with bones supporting weight. Examples include walking, dancing, elliptical (cross) training machines and stair climbing. These types of exercise work directly on the bones in the legs, hips and lower spine to slow bone loss. **Jumping exercise**: the patient do only three to five small, low jumps for the first few sessions. Build up gradually by adding five jumps at a time. Progress until he can do 50 in total. Take a brief rest between each group of 10 and pause briefly between each jump. Build up to 50 jumps per session that lift him about three inches off the floor.

Data analysis

The equivalence of both groups was checked by conducting independent t-test on BMD and LBM. Paired t-test was calculated on the pretest to posttest change within each group. Finally to assess whether any difference existed in the posttest scores, an independent t-test was calculated on the posttest change for both groups. The level of significance $P < 0.05$ was used.

3. Results

The descriptive characteristics of both groups are shown in Table (1). There were no statistical differences between both groups regarding to the age, weight, height and TBSA.

Results of lean body mass

The mean value of LBM pretreatment in the group A was 36.75± 8.62 and after treatment was 40.71±8.28. The paired t-test demonstrated a statistically significant difference between pre and post treatment for LBM in this group as shown in table 2.

The mean value of LBM pretreatment in the group B was 34.67± 8.55 and after treatment was 35.16±8.6. The paired t-test demonstrated a statistically significant difference between pre and post treatment for LBM in this group as shown in Table 2.

The independent t-test results for the LBM pre and post treatment between groups A and B. There was no significant difference in pre treatment values where the $t = 0.76$ and $p = 0.45$. But there was a significant difference in the post treatment values ($P<0.05$) where the t-value was (2.08) and p-value was (0.04) as shown in Table 3 and Figure 1.

Results of Bone mineral density

The mean value of BMD pretreatment in the group A was 0.86± 0.08 and the value after treatment was 0.93±0.1. The paired t-test demonstrated a statistically significant difference between pre and post treatment for BMD in this group as shown in Table 4.

The mean value pretreatment in the group B was 0.85± 0.08 and the value after treatment was 0.87±0.07. The paired t-test demonstrated a statistically significant difference between pre and post treatment for BMD in this group as shown in Table 4.

The independent t-test results pre and post treatment between groups A and B. There was no significant difference in pre treatment values where the t-value was (0.2) and p-value was (0.83). But there was a significant difference in the post treatment values ($P<0.05$) where the t =2.19 and p= 0.03, as shown in Table 5 and figure 2.

Table (1): General characteristics of patients in both groups (A&B).

General characteristics	Group A		Group B		Comparison		
	Mean	±SD	Mean	±SD	t-value	*P*-value	S
Age (yrs)	11.77	±2.85	11.51	±2.61	0.3	0.76	NS
Weight (Kg)	44.11	±15.0	45.29	±13.45	0.26	0.79	NS
Height (cm)	147.25	±16.15	147.8	±14.66	0.11	0.91	NS
TBSA	50.75	±5.52	49.45	±6.2	0.7	0.48	NS

*SD: standard deviation, *P*: probability, S: significance, NS: non-significant

4. Discussion

In this study our results indicate that there was an increase in BMD and LBM in the exercise group after 12- week of exercise.

The analysis of the results can be divided into two main points: The first point of analysis is the effect of weight.

Table (2): Mean and ±SD, t and P values of Lean body mass pre and post treatment of group (A, B).

	Group A		Group B	
	Pre treatment	Post treatment	Pre treatment	Post treatment
Mean	36.75	40.71	34.67	35.16
±SD	±8.62	±8.28	±8.55	±8.6
Mean difference	3.96		0.48	
Percentage of improvement	10.77 %		1.38 %	
t-value	18.61		14.49	
P-value	0.0001		0.0001	
S	S		S	

*SD: standard deviation, *P*: probability, S: significance.

Table (3): Independent t-test between groups A and B for Lean body mass pre and post treatment.

Independent t-test	Lean body mass			
	Pre treatment		Post treatment	
	Group (A)	Group (B)	Group (A)	Group (B)
Mean	36.75	34.67	40.71	35.16
±SD	±8.62	±8.55	±8.28	±8.6
Mean difference	2.07		5.55	
t-value	0.76		2.08	
P-value	0.45		0.04	
S	NS		S	

*SD: standard deviation, *P*: probability, S: significance, NS: non-significant S.

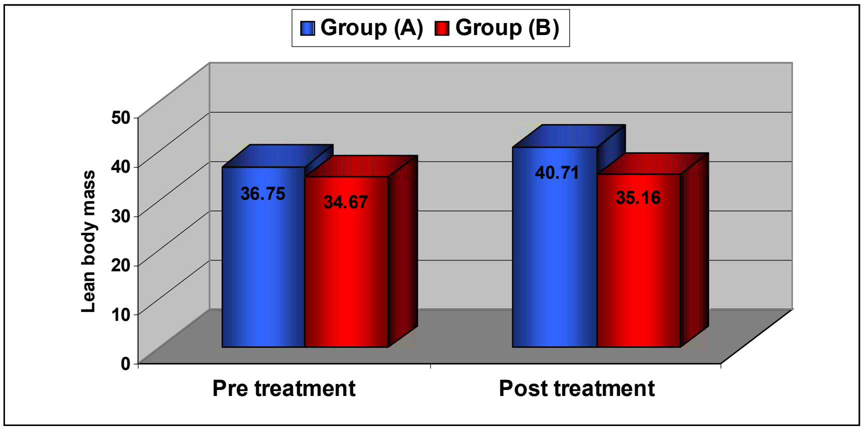

Fig.(1): Mean and ±SD of Lean body mass pre and post treatment of group (A, B).

Bearing exercise on bone mineral density. The results of the current study came in support with the results stated by MacKelvie *et al.,* [9] who reported that high-impact exercise implemented three times a week for 12 minutes was an effective strategy for site-specific gains in bone strength, resulted in 4.3% greater bone mass gains and 7.4% greater bone bending strength gains at the femoral neck.

Table (4): Mean and ±SD, t and P values of Bone mineral density pre and post treatment of group (A, B).

	Group A		Group B	
	Pre treatment	Pos treatment	Pre treatment	Post treatment
Mean	0.86	0.93	0.85	0.87
±SD	±0.08	±0.1	±0.08	±0.07
Mean difference	0.07		0.014	
Percentage of improvement	8.13 %		1.64 %	
t-value	10.91		4.94	
P-value	0.0001		0.0001	
S	S		S	

*SD: standard deviation, *P*: probability, S: significance.

Table (5): Independent t-test between groups A and B for Bone mineral density pre and post treatment.

Independent t-test	Bone mineral density			
	Pre treatment		Post treatment	
	Group (A)	Group (B)	Group (A)	Group (B)
Mean	0.86	0.85	0.93	0.87
±SD	±0.08	±0.08	±0.1	±0.07
Mean difference	0.005		0.06	
t-value	0.2		2.19	
P-value	0.83		0.03	
S	NS		S	

*SD: standard deviation, *P*: probability, S: significance, NS: non-significant S.

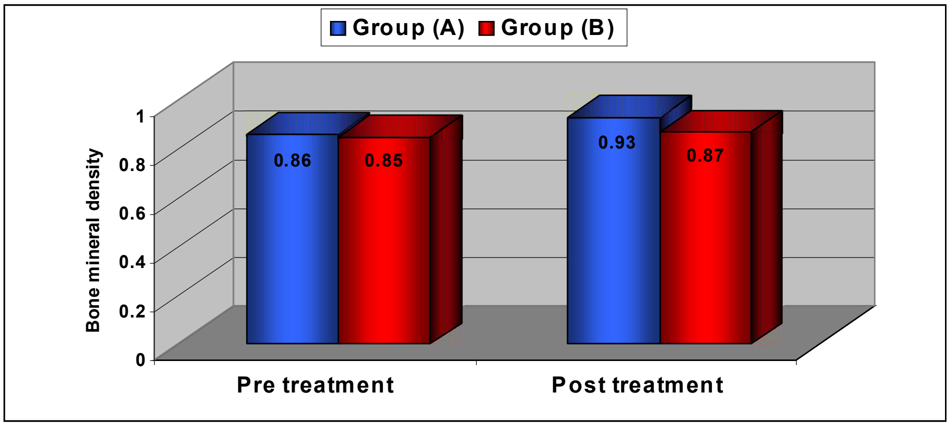

Fig.(2): Mean and ±SD of Bone mineral density pre and post treatment of groups (A,B).

Similarly, Marques *et al.,* [19] stated that resistance exercise training plus a multicomponent weight-bearing impact exercise training reduces bone inflammation and increases BMD. This reinforces the role of exercise to counteract levels of inflammation and BMD reduction. Also, Gunter *et al.,* [20] mentioned that the children completed high-impact jumping exercises had 3.6% more BMC at the hip than control subjects whom completed nonimpact stretching activities ($p < 0.05$).

There is a large body of literature supports the effectiveness of weight bearing exercise on bone mineral density; Bone is living tissue that reacts to exercise by becoming stronger. Exercise slows down the progression of osteoporosis, augments bone density, and keeps bones flexible not brittle. Muscle straining on bone builds bone, so weight-bearing activity produces denser, stronger bones. Weight bearing exercises which compel you to counteract gravity cause the cells to respond by producing more bone in that area **[21].** When bone overload, the mechanical actions generate differences in the bones' electrical power that actuates as an electrical field stimulating the cellular activity, and leading to the deposition of minerals at stressed spots [22].

Researchers have been trying to determine what variables can potentially increase calcium levels in the blood, while at the same time increasing bone absorption of this extra calcium. Exercise has long been associated with its influence to help facilitate movement of calcium into the bone for absorption. Load bearing activities seem to gain most of the recognition for maximal increases in bone mineral density. Studies have shown increases of BMD from jumping exercise **[9, 23].**

Bones can adapt their strength to increased loads through surface-specific changes on the periosteal or endosteal surface either independently or in combination. For example, loading can increase cortical thickness through periosteal apposition, resulting in an increase in bone size and/or via the addition or reduced resorption of bone on the endocortical surface **[24]**.

Treadmill exercise stimulates bone formation and suppresses bone resorption, increases the serum 1,25-dihydroxyvitamin D3 level and decreases the serum parathyroid hormone level, resulting in an increase in bone mass with stimulation of longitudinal bone growth, especially at weight-bearing sites, in young growing rats [25].

The second point of analysis is the effect of resistance exercise training on lean body mass. The results of the present study also go ahead with that reported by Suman and Herndon, [11] who mentioned that severely burned children, with a 40% TBSA or greater, were participated in 12-week of resistance exercise, the mean percentage increase in LBM was significantly greater in the exercise group (6.4%+/-1.9%) than in the no-exercise group (1.9%+/-2.6%). Suman *et al.,*[26] who demonstrated an increase in muscle strength and LBM in response to a 12-week resisted exercise program in severely burned children.

Al-Mousawi *et al.,* [27] investigated the effects of resistive exercise programs on severely burned pediatric patients (aged 7–17 years) with 40% TBSA and greater. patients participated in a 12-week exercise program (EX) commencing 6 months after injury. A significant increase in LBM was found for exercise program. Exercise training significantly enhanced lean mass, without observed exacerbation of postburn hypermetabolism. Therefore, the use of exercise conditioning as a safe and effective component of pediatric burn rehabilitation is advocated.

Structural basis underlying resistance exercise gains in lean body mass attributed to: Exercise stimulate anabolic intracellular signaling, muscle protein synthesis, and in particular the synthesis of mitochondrial muscle proteins during recovery [28]. Regardless of exercise mode, the mechanical strain associated with the contractile forces generated by exercise is a central physiological driver of protein accretion [29].

Physical exercise is known to stimulate growth hormone (GH) release. This subsequent stimulation of insulin- like growth factors from the liver further influences skeletal growth. In addition, assuming the development of exercise-induced metabolic acidosis, the subsequent decrease in serum Ca is sufficient to stimulate increased parathyroid hormone (PTH) secretion. Intermittent PTH administration has an anabolic effect on skeletal tissue [30].

Energy sources necessary to fuel muscle contraction increase after resistive training. In general, levels of creatine phosphate, ATP, myokinase, and phosphofructokinase increase [31].

Resistance exercise is a potent physiological intervention that increases muscle mass [10]. An increase in muscle mass occurs when myofibrillar protein synthesis exceeds myofibrillar protein degradation. Resistance exercise- training increases muscle mass by accelerating the rate of protein synthesis in the contracting muscle [32].

In conclusion, loss of bone mineral density and lean body mass are frequent complications in post burned patients. Exercise (weight bearing exercise and resisted exercise) was the optimal mode to enhance bone mineral density and lean body mass. Therefore, the use of exercise conditioning as a safe and effective component of pediatric burn rehabilitation.

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