Australian Journal of Basic and Applied Sciences, 5(12): 981-985, 2011
ISSN 1991-8178

The Effect of Isometric Training on Prevention of Bone Density Reduction in Injured Limbs During a Period of Immobilization

[1]Mohammad Reza Yousefi, [2]Nassour Ahmadi, [3]Mohammad Reza Abbaszadeh, [4]Kaveh Kheybari,[5]Ahmad Valizadeh and [6]Mohammad Nasiri

[1]Department of Physical Education, Ilam Branch, Islamic Azad University, Ilam, Iran.
[2]Member of the Academic Staff, ShahidBeheshti University, Tehran, Iran.
[3]Ph.D in Orthopedics.
[4]Ashtiyan Branch, Islamic Azad University,Ashtiyan,Iran.
[5]Ilam Branch, Islamic Azad University, Ilam, Iran.
[6]Department of Physical Education,Central Tehran Branch, Islamic Azad University ,Tehran ,Iran.

Abstract: The purpose of the present research was to study the effect of isometric trainingonprevention of bone density reductionin injured limbs during a period of immobilization. In this semi-empirical research, 60 individuals injuries to thefemur and needed at least one month of post-injury immobilization and had come to the medical centers of Ilam Province were selected and randomly divided into a control group (mean and standard deviation: 27.87±3.10 years of age, 172.03±2.46 cm of height, and 68.14±2.94 kg of weight) and an experimental group(mean and standard deviation: 28.68±4.26 years of age, 172.18±2.59 cm of height, and 66.46±3.65 kg of weight). The bone mineral density of the samples was measured using the DEXA system. Mean and standard deviation were used for statistical description and correlated t-test andmixed analysis of variance (2×2)were used for inferential analysis of the data. The findings of the research revealed that isometric training not only prevents the reduction of bony mineral density in the neck and greater trochanter of the femur, but also significantly increasesthe bonemineral density in these regions. Isometric exercises are not only effective for preventing reduction of bone density in the injured limb, but it also increases the density of the injured bone.

Key words: Injury, lower limbs, a period of immobilization, femur.

INTRODUCTION

Injury and immobility of the injured limb are inevitable phenomena. One of the problems that usuallystay with injured individuals is muscle atrophy and reduction of bone density. Like muscles, bones are living tissues that can be strengthened through training. Young men and women who oftenexercise regularly will have greaterpeak bone mass than those who do not exercise (Ljunghall, S. *et al.*, 1988). Fractures are of the problems that human beings have for long been faced with and in the contemporary life, due to industrialization of societies and the increasing number of vehicles, the number of fractures due to impact has increased. Along with the increased prevalence of this type of fractures, the number of pathologic fractures is also increasing due tolongevity on one hand and technological advancements on the other which distinguish this type of fracture from the impact-related one. Pathologic fractures occur in bones that have already been weakened due a disease and usually fractures occur following an insignificant trauma; the underlying disease may be local or general of which one can mention benign and malignant tumors as well as systemic, infectious, and congenital diseases (Davodpour, K., 2003). According to the theory of mechanical load, bones gains strength in response to the mechanical forces exerted on them. Thus, physical exercise, in particular strength training, leads to increased bone density (http://www.gorhams.dk/html/what_is_dexa_scanning.html).

Many research studies have been carried on measuring bone mineral density (BMD) suggesting that sports lead to an increase in BMD in the femoral region and lower limbs. Moreover, the results of research studies show that during an immobilization period or detraining, BMD decreases in people with injuries to the spine (Exercise for Your Bone Health, 2009). Many studies have shown that bone density depends on body composition and the amount of daily physical activity and scientific and experimental evidence has always shown that people with regular constant physical exercise have greater and better bone density than those who are sedentary (Shilin, D., 2009; Frotzler, A. *et al.*, 2009). Physiologically, physical exercise improves blood supplyand nutrient flow to joints and muscles. With the increase of blow flow, more oxygen and nutrients reach the bone cells and when sports exercises exert proper pressure on the bones, bones in turn respond to this pressure by becoming bigger and stronger and absorbing much more calcium (Barlet, J.P. *et al.*, 1995).

Corresponding Author: Mohammad Reza yousefi, Department of Physical Educaiton, Ilam Branch, Islamic Azad University, Tehran, Iran.

Not only is the bone mineral density higher in those who perform physical exercises, but evidence show that increased physical exercise is accompanied by a decrease in age-related bone loss rate. Weight-bearing exercises help to improve bone mineral density (Hamrick, M.W. *et al.*, 2006).

Lack of physical activity (or resting in bed) quickly leads to bone atrophy.This issue has been taken into consideration for many years, ever since patients with fractures were placed in full length casts. These patients quickly lost their bone tissue and lostmuch calcium through urine. Studies on these patients showed that this condition can be ameliorated by performing simple movements that involve bearing the body's weight. The results of research studies show that physical exercises than do not involve bearing the weight of the body will be less able to prevent the body against bone density reduction.For instance, arm's muscle mass is proportionate to its bone mass.In the research carried out on athletes, there are evidence regarding increased bone mass (Aloia, J.F., 1989).

Chien-Hung Lai (2010) studied the effect of electrical stimulation on the reduction of bone mineral density in 24 individuals with spinal cord injury 26 to 52 days after the injury and found that the bone mineral density decrease rate in the distal femur of the exercise group was significantly lower than that of the control group (Kosalanan, S., 2005). Hamrick *et al.*, (2006) studied the increased osteogenic response to exercise in metaphyseal versus diaphyseal cortical bonein rats and found that exercise increases bone mineral density in the metaphyseal region by approximately 35% and in thediaphyseal region by approximately 20% (Habibzadeh, N., 2010). Cavalié *et al.*, (2003) studied the effect of isometric training on bone mass in ten growing male Wistar rats. They applied 69 days of strength isometric training and found that the training program led to a significant increase in muscle mass and femoral trabecular and cortical bone mineraldensity in comparison with the control group (Cavalié, H. *et al.*, 2003). Snow *et al.*, (2001) studied the effect of training and detraining on BMD in gymnasts. After a 24-month training period, they observed an increase by 4.3% in BMD of the lumbar vertebrae and a decrease by 1.3% in bone densityduring the offseason (Bijeh, N., H.R. Hatef, 2008). Deng (2009) studied the effects of exercise therapy on bone mineral density in early postmenopausal women through a controlled trial. All the subjects had decreased BMD in lumbar spine and hip, but the rate of bone loss was lower in the exercise group than the control group (Saremi, A., 2008).

During the recent years, there have been many research studies regarding the use of sports exercises for strengthening bones. Studies carried out on the effect of physical exercise on humans and animals have shown that sports exercises have a significant effect on the development, preservation, and maintenance of bone mass. However, there has not yet been a comprehensive study regarding the effect of sports exercises on the density and recovery of the injured bone. Thus, the purpose of the present research was to study the effect of isometric training on prevention of bone density reduction after injury and during an immobilization period.

Methodology:

The present research is semi-empirical. 60 individuals with 25-30 years of age who had fracture in the femur or sprains in the lower limbs voluntarily participated in the research; they needed at least one month of immobilization and had come to medical centers ofIlam Province for therapy. After filling out the medical questionnaire and the consent form, the subjects were randomly divided into two equal groups - the control group (mean and standard deviation: 27.87±3.10 years of age, 172.03±2.46 cm of height, and 68.14±2.94 kg of weight) and the exercise group (mean and standard deviation: 28.68±4.26 years of age, 172.18±2.59 cm of height, and 66.46±3.65 kg of weight); after taking the preliminary bone density scan test inthe neck and greater trochanter of the femur,the exercise groupperformed isometric exercises for one month and after that period, both groups were again tested for bone density in the two mentioned regions and the results were statistically analyzed.

Bone Density Measurement Method:

The bone mineral density of the subjects was measured by radiologists using a DEXA system which is the most precise and valid BMD scanning systems.In this absorptiometry, two beams are produced - one with low energy and one with high energy - which are differently absorbed by soft and bony tissues. In the DEXA system, the energy source is X-ray which, unlike radioactive material, is not attenuated over time and thus the precision of the system increases considerably (up to 99%), where the error rate is between 0.6 and 1.5, and it can most efficiently measure the changes in density over time. In this method, the X-ray passes through the bones and tissues and a computer calculates the difference between the input and output beam. After deducting the amount of beam absorbed by the soft tissue from the total amount and calculating the amount of beam absorbed by the bone, the BMD is calculated (Wilmore, J.H. and D. Costill, 2004). Based on this method, bone mineral density was calculated in g/cm^2.

The Training Program of the Experimental Group:

The injured individuals whose lower limbs become immobile are often unable to perform much physical movements and thus the present research was faced with limitations in designing a training program for the experimental group, but in the end the training program was conducted with three main exercises which will be mentioned below. The chosen exercises were performed on a daily basis and the subjects performed the exercises three times a day and with five 10-second repetitions with maximum power (contraction to the threshold of pain). 50 seconds of resting interval was considered between each two repetitions and 90 seconds between different movements.

Isometric Exercises:

1. In the seated, extended-knee position, the subjects generated tension in the lower limbs by contracting the quadriceps and biceps femoris.
2. In the seated, extended-knee position, the subjects generated tension in the lower limbs by pressing the tip of their toes against the wall.
3. In the standing position, the subjects generated the maximum tension in the lower limbs to the threshold of pain by exerting pressure on the ground and putting the body weight on the injured leg.

Statistical Analysis:

Mean and standard deviation were used for statistical description and correlated t-test and mixed analysis of variance (2×2) were used for inferential analysis of the data. Statistical operations were done using SPSS 18 software and at the $p \leq 0.05$ confidence level.

Results:

Mean and standard deviation of the neck and greater trochanter of the femur density are presented in table 1 as separated by the studied groups.

Table 1: Mean and standard deviation of bone density of the neck and greater trochanter of the femur.

Variable	Group / Statistic / Level	Control (N = 30)		Experimental (N = 30)	
		M	SD	M	SD
Greater Trochanter	Pre-Test	1.0076	0.0778	0.9715	0.1017
	Post-Test	1.0008	0.0795	1.0067	0.1036
	Changes	0.0068	0.0049	0.0562	0.0049
Femur Neck	Pre-Test	0.8682	0.0922	0.8342	0.0911
	Post-Test	0.8620	0.0938	0.8418	0.0975
	Changes	0.0062	0.0026	0.0143	0.0143

The results of correlated t-test revealed that the immobilization period due to injury has ledto a significant decrease in the BMD of the neck of the femur ($p < 0.0005$, $\mathrm{df} = 29$, $t = 7.63$) and the greater trochanter ($p < 0.0005$, $\mathrm{df} = 29$, $t = 12.99$).

Regarding the effect of isometric exercise on prevention of bone loss in the neck of the femur after injury, the results of mixed analysis of variance (2×2) showed that the main effect of measurement time was significant ($p < 0.008$, $\mathrm{df}_{1,58} = 7.63$); that is, the mean BMD of the femur neck in the post-test (1.0038 ± 0.0916) was significantly higher than that of the pre-test(0.9896 ± 0.0916). But the main effect of group was not significant ($F < 1$). Moreover, an analysis of the interactive effects showed that the interaction between measurement time and group was significant ($p < 0.0005$, $\mathrm{df}_{1,28} = 16.70$, $\mathrm{t} = 7.63$) and considering the significance of this interaction, t-test was applied for two-by-two comparisons and the results revealed that in the control group, the BMD of the femur neck decreased significantly after the immobilization period. However,a significant increase was observed in the control group ($p < 0.002$, $\mathrm{df} = 29$, $\mathrm{t} = -3.44$;). Further, the results of comparing the changes in BMD (pre-test minus the post-test) showed that the changes in the experimental group (-0.0352 ± 0.0562) is significantly higher than the control group (0.0068 ± 0.0049) ($p < 0.0005$, $\mathrm{df} = 29.44$, $\mathrm{t} = 4.09$).Thus, based on the findings, it can be concluded that isometric training not only prevents the reduction of bone mineral density of the femur neck after injury, but it also significantly increases its BMD.

Regarding the effect of isometric exercise on prevention of bone loss in the greater trochanter of the femur, the results of mixed analysis of variance (2×2) showed that the main effect of measurement time ($F < 1$) and group ($p < 0.027$, $\mathrm{df}_{1,58} = 1.26$) was not significant. But the interaction betweenmeasurementtime and group is significant ($p < 0.0005$,$\mathrm{df}_{1,28} = 26.82$). Considering the significance of the interaction between time and group, t-test was applied for two-by-two comparisons and the results revealed that in the control group, the BMD of the greater trochanter of the femur decreased significantly after the immobilization period. Yet a significant increase was observed in the experimental group ($p < 0.007$, $\mathrm{df} = 29$, $\mathrm{t} = -2.89$). Further, the results of comparing the changes in bone density (pre-test minus the post-test) revealed that the changes in the experimental group (-0.0076±0.00143) are significantly higher than those in the control group (00.0062±0.0143) ($p < 0.0005$, $\mathrm{df} = 30.93$, $\mathrm{t} = 5.18$). Thus, based on the findings, it can be concluded that isometric training not onlyprevents the decrease of bone mineral density of the greater trochanter of the femur after injury, but it also significantly increases its BMD.

Discussion and Conclusion:

The results showed that the immobilization period due to injury led to a significant decrease in the mineral density of the neck and greater trochanter of the femur in the controlgroup. This result is consistent with the results of Habibzadeh (2009), Saremi (2008), Deng (2009), Cavalié (2003), and Angela Frotzler et al. (2009), and Chien-Hung Lai (2010). The reason forthis similarity of results is the effect of an immobilization period on decomposition of bone mineral and decrease in bone density in which bone minerals are lost from the body due to increased excretion of urinary calcium from the body and because of immobility, bone metabolism decreases and as a result, bone mineral will not be replaced.

Furthermore, it was shown that isometric training prevents the reduction of mineral density of the femur neck after injury which is consistent with the results of Saremi (2008), Bijeh and Hatef (2007), Hamrick et al. (2006), and Cavalié (2003). The reason is that in all these research studies, sports movements involved weight-bearing and pressure to the threshold of pain and physiologically, physical exercise improves blood supply and nutrient flow to joints and bones and with the increase of blood flow, more oxygen and nutrients reach the bone cells and with proper pressure applied by the exercise, bones respond to such a pressure by becoming bigger and stronger and absorbing much more calcium. In addition, release of osteogenic hormones such as estrogen increases through exercise. This hormone stimulates the production of collagen and consequently increases the strength of bones. In fact, estrogen practically activates Vitamin D and leads to increased reuptake of calcium from the kidneys which will lead to absorption and maintenance of calcium in bones and will strengthen them.

One of the other results of this research was that isometric training prevented the reduction of the mineral density of the greater trochanter of the femur. This finding is consistent with the results of Bijeh and Hatef (2007), Hamrick *et al.,* (2006) and Cavalié (2003) and the reason for such a correspondence is that in all these studies, sports movements involved weight-bearing and pressure to the threshold of pain and physiologically, physical exercise improves blood supply and nutrient flow to joints and bones and with the increase of blood flow, more oxygen and nutrients reach bone cells and with proper pressure applied by the exercise, bones respond to such a pressure by becoming bigger and stronger and absorbing much more calcium. In addition, release of osteogenic hormones such as estrogen increases through exercise. This hormone stimulates the production of collagen and consequently increases the strength of bones. In fact, estrogen practically activates Vitamin D and leads to increased reuptake of calcium from the kidneys which will lead to absorption and maintenance of calcium in bones and will strengthen them.In addition, training and physical exercise enhance the process of ossification. This enhancement is due to increased intestinal absorption of calcium, decreased urinary excretion of calciumion, and increased levels of parathyroid hormone (PTH). In contrast, immobility or sheer rest increases bone atrophy and during the immobilization period, the levels of PTH decrease (Turner, C.H., 1998). PTH reinforces the reuptake of calcium by the kidneys while stimulating the bones and as a result increases the level of plasma calcium. Physical exercise increases the level of secretion and concentration of this hormone in plasma (Lai, C.H. *et al.,* 2010; Ljunghall, S. *et al.,* 1986).

Generally, training and physical exercise will maintain or even increase bone mineral density during an immobilization period after injury through increasing blood supply to joints and bones and consequently increasing the flow of oxygen and nutrients to bone cells,increasing the absorption of calcium by the intestines, calcium reuptake by the kidneys, and secretion ofosteogenic hormones such as estrogen and parathyroid.

ACKNOWLEDGEMENTS

This research is carried out using the financial support of Islamic Azad University, Ilam Branch. The author expresses his gratitude to the honored head of Islamic Azad University, IlamBranch,the Research Department, and all the colleagues for their contributions in the process of conducting the research.

REFERENCES

Aloia, J.F., 1989. Osteoporosis: A guide to prevention and treatment. Human Kinetics.

Barlet, J.P., V. Coxam, M.J. Davicco, 1995. Physical exercise and the skeleton.ArchPhysiol Biochem., 103(6): 681-98.

Bijeh, N., H.R. Hatef, 2008. A study of bone mineral density (BMD) and muscle strength in female Taekwondokas and non-athletes.Journal of Research in Sports Sciences, 19: 85-96.

Cavalié, H. *et al.,* 2003. Progressive isometric force training and bone mass in rats.JMusculoskel Neuron Interact., 3(1): 47-52.

Davodpour, K., 2003. An assessment of pathologic fractures in hospitalized patients of ShahidMobasher Hospital during the years 1991-1997. Journal of Medical Sciences and Hygiene-Medical Services, Hamadan, 1: 47-51.

Exercise for Your Bone Health, 2009. National Institutes of Health Osteoporosis and Related Bone Diseases ~ National Resource Center, 2 AMS Circle Bethesda, MD., pp: 20892-3676.

Frotzler, A., S. Coupaud, C. Perret, T.H. Kakebeeke, K.J. Hunt and P. Eser, 2009. Effect of detraining on bone and muscle tissue in subjects with chronic spinal cord injury after a period of electrically-stimulated cycling: A small cohort study. Journal Compilation, pp: 1650-1977.

Habibzadeh, N., 2010. Effects of a two-month walking exercise on bone mass density in young, thin women. J Biomedical Human Kinetics, 2: 5-8.

Hamrick, M.W., J.G. Skedros, C. Pennington, P.L. McNeil, 2006. Increased osteogenic response to exercise in metaphyseal versus diaphyseal cortical bone.JMusculoskelet Neuronal Interact., 6(3): 258-263.

Kosalanan, S., 2005. The effects of exercise on bone Biomechanics, 763: 1-2.

Lai, C.H. *et al.,* 2010. Effects of functional electrical stimulation cycling exercise on bone mineral density loss in the early stages of spinal cord injury. J Rehabil Med., 42: 150-154.

Ljunghall, S. *et al.,* 1986. Prolonged low-intensity exercise raises the serum parathyroid hormone levels.*Clinical*Endocrinology, 25: 535-42.

Ljunghall, S. *et al.,* 1988. Increase in serum parathyroid hormone level after prolonged exercise.Medicine andScience in sports exercise, 20: 122-25.

Reference at http://www.gorhams.dk/html/what_is_dexa_scanning.html.

Saremi, A., 2008. The effect of strength training on bone density and the level of serum myostatin in young men.Journal of Science and Research, Arak University of Medical Sciences, 2(47): 89-97.

Shilin, D., 2009. Effects of exercise therapy on bone mineral density in early postmenopausal women: A controlled trial. Front. Med. China, 3(3): 323-329.

Turner, C.H., 1998. Exercise as a therapy for osteoporosis: the drunk and the street lamp, revisited. *Bone Journal*, 23: 83-85.

Wilmore, J.H. and D. Costill, 2004. Physiology of Sport and Exercise.Human Kinetics Publishers.