Isometric Progressive Resistive Exercise for Osteoporosis

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ABSTRACT. ***Objective.*** To assess the effect of site-specific resistive isometric exercises on muscle strengthening of 10 muscle groups over 2 months. A second study measured bone alkaline phosphatase (ALP) as a marker of bone formation and bone resorption [urine deoxypyridinoline (D-Pyr) crosslinks] in a similar cohort.

Methods. Twenty postmenopausal Caucasian women aged 56 to 69 yrs (mean 61) on a stable or no medication regimen for the previous 6 months participated in the initial exercise cohort. Twenty-one women ages 52-69 (mean 62) participated in the second cohort. All women had osteopenia (DXA T less than —1.0) or osteoporosis (DXA T less than —2.5). An inflatable ball with attached nonelastic straps provided progressive resistance. Exercises consisted of a 5 s maximum contraction against progressively increasing resistance of the ball or nonelastic straps. Muscle strengthening was measured by a hand held dynamometer at 0, 4, and 8 weeks. Twenty women completed 8 weeks of the initial study and 21 women completed the second study.

Results. Muscles showing increased strength in the first cohort were neck extensors ($p < 0.04$). hand grips ($p < 0.02$). elbow flexors ($p < 0.05$). quadriceps ($p < 0.04$). trunk extensors ($p > 0.05$. not significant = NS). Elbow extensors were purposely not exercised (as a control) and showed no significant strength increase. In the second cohort. increased muscle strength was measured in the neck extensors ($p < 0.001$). trunk extensors ($p < 0.001$). and left quadriceps ($p < 0.024$): and bone ALP increased ($p < 0.05$). with no change detected in bone resorption (urine D-Pyr).

Conclusion. Brief progressively resisted isometric exercises for 10 min daily are an adequate stimulus for muscle strengthening of the neck, back, upper and lower extremities, and are capable of enhancing bone formation measured by bone ALP. (J Rheumatol 2000;27:1260—4)

Key Indexing Terms:
OSTEOPOROSIS **PROGRESSIVE RESISTIVE** **ISOMETRIC EXERCISE**

Walking has long been considered the appropriate exercise for the management of osteoporosis[1-3]. There are now studies that challenge this view[1-2]. Whereas walking has not been found to be effective in terms of enhancing bone mineralization, a few studies utilizing vigorous aerobic weight bearing activities have described either enhancement of bone mineralization or attentuation of bone mineral density loss'[10,13-15]. In contrast, site-specific resistive (SSR) exercises have been shown to enhance bone mineralization in a variety of animals, and, more importantly, in well controlled studies in humans[1,3,5—10,16—19]. Increased bone formation markers have also been correlated with resistance exercise[20,21]. Examples of site specificity of enhanced bone mineralization as a consequence of vigorous activities have been reported in the dominant hands and forearms of tennis players. the feet of ballet dancers, and the femurs of runners' [1,8,22].

Whereas the amount of bone mineral that can be added to healthy adult bone by exercise is limited, the bones of adults with osteoporosis tend to show a greater response to therapeutic exercise[3,15]. Because of the impressive evidence that SSR exercise can enhance strength and bone mineralization, and particularly that muscle strengthening per se has been shown to help prevent falling and fractures, we hypothesized that a simple, brief, isometric progressive resistive exercise regimen could enhance muscle strength in key upper and lower extremity and paraspinal muscles, with the ultimate goals of attenuating bone mineral density loss and lowering fracture risk [8,9,16,24].

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MATERIALS AND METHODS

Case selection. The initial cohort consisted of 20 Caucasian women who were at least 5 years postmenopausal, with an age range of 56 to 69 (mean 61). All women had either osteopenia (1 less than —1.0) or osteoporosis (T less than —2.5) confirmed by dual x-ray absorptiometry (DXA of the hip and spine) within 6 months prior to the study[23,25]. All participants had been screened for cardiovascular, neurological or disabling musculoskeletal disorders, systemic illnesses, conflicting medications (e.g.. antidepressants. anticonvulsants. steroids), or recent fracture. All women continued stable dosages of calcium, vitamin D. hormones, or biphosphonales if these medications had been utilized before joining the study. Prior to study entry. all women were examined by either one of the authors (RLS) or their personal physician to determine the safety of study participation. All women gave signed informed consent after being interviewed by one of the research therapists and viewing a videotape demonstrating the exercises and testing procedures. In addition, all women agreed not to change medications or engage in any strengthening or aerobic exercises during the additional 2 month period of the experimental protocol.

The second cohort consisted of 21 women, mean age 62, (range 52—69) screened in the same manner who were either taking no medication for osteoporosis or had made no change in medication. e.g., hormone replacement therapy, alendronate, calcitonin. calcium, vitamin D, etidronate, for at least 6 months before participation in the exercise program to minimize drug effect on bone formation or bone resorption markers[26-29]. All women agreed not to change medications or to engage in any strengthening or aerobic exercises in addition to the experimental protocol.

Exercises. An inflatable vinyl ball, with each exercise illustrated on the ball, measuring 18 in diameter with a nonelastic loop strap handle on each side, inflated to 2/3 capacity (for ease and comfort in positioning the ball for each exercise), provided the exercise resistance. Specific positioning of the ball and straps to create the isometric resistance accommodating to the neck, hand grip, elbow and thigh flexors and extensors, the hip abductors and adductors, and the ankle and trunk flexors and extensors were utilized in the exercise sequence (Figures 1 and 2).

Each participant was given individualized instruction by either the specially trained physical or occupational therapist to ensure proper performance of each exercise. All exercises were performed according to a written protocol supplemented by illustrations. Prior to the resistive exercises, participants did a 5 min walk and stretch warmup, and a similar cool down was performed after the exercise session. Each exercise was performed twice at the maximum comfortable resistance against either the strap or the ball, depending on the configuration of the exercise. As strength improved, a greater (progressively resisted) force could be applied.

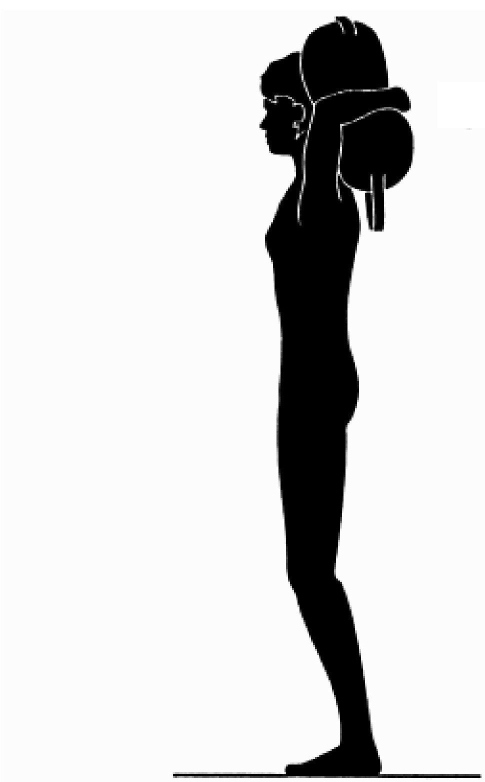

Figure 1. Neck extensor posture toner (3).

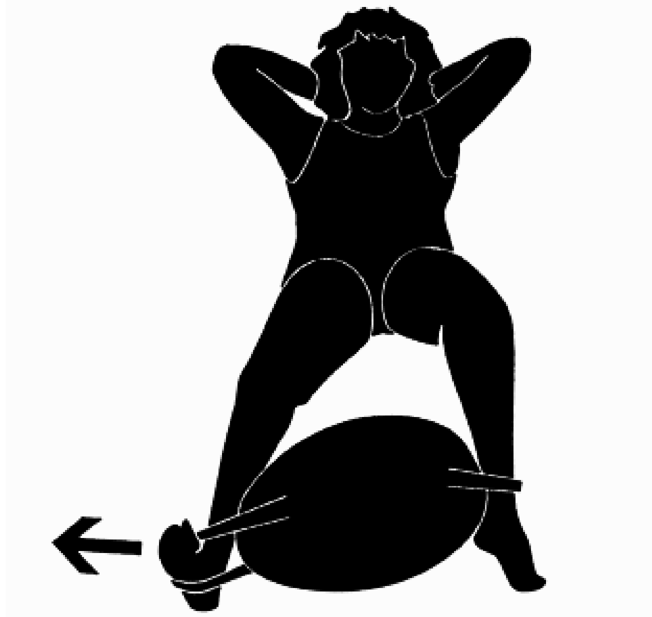

Figure 2. Hip abductor (outer thigh) strengthener (10).

The duration of each exercise was 5 s, with the patient exhaling and counting out loud, ‘Push I, Push 2, Push 3, Push 4, Push 5,” to minimize the Valsalva effect while forcefully contracting the exercised muscles. A one mm rest following each exercise included the positioning of the women and exercise ball for the subsequent exercise. Each day, 5 of the 10 exercises were performed, with the remaining 5 exercises performed on the alternate days, allowing for one exercise-free day each week. After initial instruction, the exercises were performed at the participants’ homes. The duration of each day’s exercise session ranged from 5 to 10 min.

Testing. Muscle strength tests were performed 2—3 days prior to starting the exercise program, and again at 4 weeks, with the final testing at 8 weeks. Testing and monitoring of exercise performance to reinforce compliance was done by either the specially trained physical therapist or the occupational therapist. Intratester reliability was established in preliminary studies before start of testing for the study. Each woman was tested by the same tester on all visits. Positions and procedures for testing each muscle group were standardized by a formal protocol (data not shown). Grip strength was measured with JAMAR hydraulic hand dynarnometer (Preston, Bissel, Jackson, Ml, USA) with a 200 pound force capacity. All other muscle groups were tested with a Spark handheld dynamometer (Spark Instruments, Coralville, LA, USA). Each muscle group (Table 1) was tested 3 times with a 5—10 s rest between tests, and a 45 s rest period was given prior to testing a subsequent muscle group. Each subsequent test was first practiced gently to assure comfort during testing. The mean of the 3 tests of each muscle group determined the muscle strength. In addition to grip strength, the muscle groups tested were the neck extensors, the elbow flexors and extensors, the quadriceps, and the trunk extensors. The elbow extensors were not specifically strengthened by any of the exercises in the protocol and were used as a control for consistency of measurement and site-specific effect of the exercises. Prior testing indicated that some patients became fatigued with more extensive testing, making it impractical to test all exercised sites.

Because of the lack of significant ($p > 0.05$) dorsolumbar strengthening effect in the first cohort, we attempted to gain better precision utilizing a Kin-Corn (Chattanooga Group. Hixon, TN, USA) isometric testing protocol[27]. This, however, proved to be less precise than the handheld dynamometer used in the same manner as in the initial cohort study.

In the second cohort, bone formation was measured by bone alkaline

Table 1. Cohort 1: pilot study. 8 week muscle strength increase.

Muscle Group	Pre	Post	Change	p
Head and neck	20.7	22.7	1.96	0.039
Hand				
Left	50.0	53.5	3.52	0.013
Right	54.5	58.7	4.20	0.002
Elbow flexors				
Left	24.1	25.8	1.64	0.025
Right	22.7	25.3	2.53	0.046
Quads				
Left	42.6	45.7	3.10	0.030
Right	40.3	45.5	5.25	0.002
Elbow extensors				
Left	17.4	17.2	—0.21	NS*
Right	16.7	17.2	0.52	NS
Trunk	26.4	27.1	0.71	NS

*Not significant.

phosphatase (ALP-B) and bone resorption by urine deoxypyridinoline (D-Pyr) tests (Metra Biosystems, Mountain View, CA, USA). Specimens were collected prior to exercise testing. Urine specimens were obtained at 9 am, 2—5 days prior to starting the exercise protocol and at the last day of the 8 week program. The blood specimens for bone ALP formation were also drawn at 9 am for testing at the same visits. The specimens were frozen and sent in 2 groups to Metra Biosystems Inc., for testing, with one final specimen sent separately[30].

RESULTS

Initial cohort. Twenty-seven women were recruited and 20 completed the initial cohort 8 week study. Three patients chose to discontinue the study before completion because of personal stress, 2 because of concerns for aggravating prior back pain, and one patient had an unrelated recurrence of pre-existing neck pain. One additional patient decided not to participate after the initial testing procedure.

Utilizing a paired 2 tailed t test comparison of muscle strength at 8 weeks to baseline, the following results were obtained.

The 8 week strengthening effect for the trunk musculature in the first cohort was not statistically significant, although it had the largest standard deviation of all the 8 week measurements.

Second cohort. In the second cohort, a more specific dorsolumbar extension exercise done in a standing position was introduced.

A slight modification of grip and elbow flexion in one resistance exercise apparently resulted in a lessened strength enhancement of grip and elbow flexion in the second cohort. Table 2 shows the 8 week muscle strength increases and the bone ALP and urine D-Pyr results for the second cohort.

Table 2. Cohort 2: final study. 8 week muscle strength increase.

Muscle Group	Pre	Post	Change	p
Head and neck	18.6	20.9	2.33	0.001
Hand				
Left	50.7	50.8	0.05	NS*
Right	54.6	55.4	0.78	NS
Elbow fiexors				
Left	28.7	28.6	—0.06	NS
Right	27.5	28.3	0.81	NS
Quads				
Left	40.8	45.2	4.38	0.024
Right	41.9	43.5	1.55	NS
Elbow extensors				
Left	18.5	18.5	0.01	NS
Right	18.2	18.5	0.31	NS
Trunk	29.2	33.1	3.94	0.001
Formation	12.7	13.6	-0.88	0.05
Resorption	23.5	30.2	6.77	NS

*Not significant.

DISCUSSION

Recent studies support the idea of site-specific resistive exercises as an important component of osteoporosis therapies[3,6,8-10,18,19,24]. The role of generalized muscular strengthening in protecting against falls and subsequent fractures is well established[8,9,16]. It is also clear that walking or strolling, in contrast to vigorous aerobic weight bearing exercise, has a negligible effect on bone mineral density retention and cannot be relied upon as a therapeutic component of osteoporosis treatment[1-3,5,6,8-10,12].

If site-specific resistive exercises have greater potential for enhancing muscle strength and adjacent bone mineralization, then practical issues of availability, affordability, transportability, ease, time commitment, and safety of the prescribed exercise regimen (which can represent a lifetime commitment) must be given serious consideration[22,31,32]. With regard to safety, resistive exercises have been shown to be well tolerated in hypertensive and stable post-myocardial infarction patients[33-35]. Since the strengthening effects of isotonic (weight lifting) and isokinetic (mechanical resistance machines) and isometric exercises have been shown to have similar effects on muscle strength, the choice of isometric exercises, which can utilize inexpensive, lightweight, readily portable devices for a home exercise regimen, merits careful consideration[28,29,36,37]. The concept of utilizing a light inflatable ball as an exercise device for range of motion and strengthening was initially developed for a safe, comfortable, economical exercise program for patients with rheumatoid arthritis[37]. The exercises utilized in our study of osteoporosis were derived from the arthritis work and modified specifically for the treatment of osteoporosis. Because the partially inflated ball can be moderately compressed or stretched during the exercise it could be argued that the exercises are not technically isometric. In fact, once the ball is compressed or stretched to the extent possible, the exercise is then performed isometrically. Further, as strength increases, greater force is applied to the compressible ball or the handles, creating a progressive resistive exercise.

The site-specific isometric exercises utilized in the initial cohort resulted in an increase in strength in all regions tested, with 2 exceptions. One exception was the failure to show change over 8 weeks in the strength of the elbow extensors. Since the elbow extensors were deliberately not given SSR exercises, they served as a control. The second exception in the initial pilot cohort was the lack of increase in strength in the dorsolumbar spinal extensor muscles. There are 2 probable explanations for the failure to detect an increase in the strength of the paraspinal muscles. One is the lack of specificity of the dorsal and lumbar exercises in our initial cohort exercise regimen. Dorsal and lumbar strengthening was basically performed as a co-contraction of the dorsolumbar region during neck extensor strengthening, as well as concomitant spinal stabilization contractions occurring during the other exercises. This may have been an insufficient stimulus to provide a sufficient measurable muscle strengthening effect in the dorsal and lumbar paraspinal muscles.

The second possibility is that whereas handheld dynamornetry testing of extremities has proven reliability, the lack of observable change in the paraspinal muscles in the initial cohort may have been partly attributable to the technical difficulty of testing these muscles with a handheld dynamometer[38-41].

A protracted effort to increase precision testing of the spinal musculature was undertaken utilizing isometric testing with the Kin-Corn AP Model 57530 machine, which proved less precise than the Spark handheld dynamometer for assessment of spinal muscle strength. For the second cohort a specific spine extensor strengthening exercise was introduced, and strength tested by handheld dynamometry of the dorsolumbar paraspinal musculature proved sufficiently precise to measure strength changes resulting from the exercise protocol. The elbow extensors were designated as controls and therefore were not specifically isometrically exercised. In the second cohort, modifications in the exercise protocols resulted in no significant increases in grip and elbow flexor strength measurements.

In the second cohort, the bone resorption marker (D-Pyr) and the bone formation marker (ALP) were measured. The bone resorption marker was randomly distributed and revealed no change, but the bone formation marker reached significance ($p < 0.05$) in this small sample ($n = 21$).

Since both bone formation and resorption markers have been shown to decrease with hormone replacement therapy, bisphosphonate therapies, or vitamin D therapy, the evidence for bone formation in this short term isometric resistive exercise study is noteworthy[23,26,27,29,30]. It would be of interest to see if our results, which are consistent with other studies showing bone formation marker increase as well as bone mineral density enhancement by other forms of resistive exercise, would be validated in longterm controlled studies utilizing bone densitometry and fracture prevention outcomes[12,15,20].

Brief progressively resisted isometric exercises performed 6 days per week for 8 weeks in a simple daily 5 to 10 mm exercise regimen are an adequate stimulus for muscle strengthening of the upper and lower extremities, dorsolumbar and cervical musculature, and are capable of increasing bone formation markers in postmenopausal women with osteopenia and osteoporosis as measured by bone alkaline phosphatase. Our findings add support for the efficacy of site-specific resistive exercise for the prevention and treatment of osteoporosis.

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REFERENCES

1. Allen S. Exercise considerations for postmenopausal women with osteoporosis. Arthritis Care Res 1994;7:205—14.
2. Dalsky G, Stocke KS, Ehsani AA. Weight bearing exercise training and lumbar bone mineral content in postmenopausal women. Ann Intern Med 1988;108:224—82.
3. Snow-Harter C, Marcus R. Exercise, bone mineral density, and osteoporosis. Exerc Sport Sci Rev 1991;19:351—88.
4. Blumenthal JA, Emery CF, Madden DJ, et al. Effects of exercise training on bone density in older men and women. J Am Geriatr Soc 1991;39:1065—71.
5. Forwood MR, Burr DB. Physical activity and bone massage: exercises in futility? 3 Bone Miner Res 1993;21:89—112.
6. Gutin B, Kasper MJ. Can vigorous exercise play a role in osteoporosis prevention? A review. Osteoporosis Int 1992:2:55—69.
7. Heikkinen J, Kurttila-Matero E, Kyllonen E, et al. Moderate exercise does not enhance the positive effect of estrogen on bone mineral density in post-menopausal women. Calcif Tissue Int 1991;49 Suppl:S83—S84.
8. Marcus R, Drinkwater B, Dalsky G, et al. Osteoporosis and exercise in women. Med Sci Sports Exerc 1992;24:5301—7.
9. Nelson ME, Fiatarone MA, Morganti CM, Trice I, Greenberg RA, Evans WJ. Effects of high-intensity strength training on multiple risk factors for osteoporotic fractures. A randomized controlled trial. JAMA 1994:272:1909-14.
10. Prince R, Devine A, Dick I, et al. The effects of calcium supplementation (milk powder or tablets) and exercise on bone density in postmenopausal women. J Bone Miner Res 1995:10:1068—75.
11. Prince R, Devine A, Dick 1, Kerr D, Criddle A. Price R. A randomized trial of the effects of calcium supplementation, as a tablet or milk powder, and exercise on bone density on women ten years past the menopause. J Bone Miner Res 1993;8 Suppl 1:S130.
12. Swezey RL. Exercise for osteoporosis: is walking enough? The case for site specificity and resistive exercise. Spine Update 1996;21:2809—14.
13. Martin D, Notelovitz M. Effects of aerobic training on bone mineral density of postmenopausal women. J Bone Miner Res 1993;18:931—6.
14. Nelson ME, Fisher EC, Dilmanian FA, Dallal GE, Evans WJ. A l-y walking program and increased dietary calcium in postmenopausal women: Effects on bone. Am J Clin Nutr 1991;53:1304—11.
15. Heinonen A, Oja P, Sievanen H, Pasanen M, Vuori 1. Effect of two training regimens on bone mineral density in healthy perimenopausal women: a randomized controlled trial. J Bone Miner Res 1998;13:483—90.
16. Martin A. Osteoporosis: a geriatric public health issue. Top Geriatr Rehabil l995;10:1—11.
17. Sinaki M. Mikkelsen BA. Postmenopausal spinal osteoporosis. Arch Phys Med Rehabil 1984;65:593—6.
18. Kerr D, Morton A. Dick I, Prince R. Exercise effects on bone mass in postmenopausal women are site-specific and load-dependent. I Bone Miner Res 1996;11:218—25.
19. Lohman T, Going S, Pamenter R, et al. Effects of resistance training on regional and total bone density in premenopausal women: a randomized prospective study. J Bone Miner Res 1995;10:1015—24.
20. Fujimura R, Ashizawa N, Watanabe N, et al. Effect of resistance exercise training on bone formation and resorption in young male subjects assessed by biomarkers of bone metabolism. J Bone Miner Res 1997;12:656—62.

Corrections

Swezy RL, Swezey AM, Adams J. Isomethc progressive resistive exercise for osteoporosis. J Rheumatol 2000: 27:1260-4. References 21 to 42, shown below, were omitted from the bibliography. We regret the error.

21. Woitge HW. Friedmann B. Sutmer S. et al. Changes in bone turnover induced by aerobic and anaerobic exercise in young males. I Bone Miner Res 1998:13:1797-804.
22. Burr DB. Muscle strength, bone mass and age-related bone loss. J Bone Miner Res 1997:12:1547-51.
23. Garnero P, Weichung JS, Gineyts E. Karpf DB, Delmas PD. Comparison of new biochemical markers of bone turnover in late postmenopausal osteoporotic woman in response to aiendronate treatment. J Clin Endocrinol Metab 1994:79:1693-700.
24. Marcus R. Exercise: Moving in the right direction. [Editorial]. J Bone Miner Res 1993:13:1793.
25. Miller PD, Bonnick SL, Rosen CJ, for the Society for Clinical Densitometry. Clinical utility of bone mass measurements in adults: consensus of an international panel. Semin Arthritis Rheum 1996:25:361-72
26. Rosen CJ. Chestnut CH. Mallinak NJS. Bone turnover biochemical measurements. J Clin Endocrinol Metab 1997:82:1904-10.
27. Prcstwood K. Pilbeam CC. Burleson J. et al. The short term effect of conjugated estrogen on bone turnover in older women. J Clin Endocrinol Metab 1994:79:366-71.
28. Gallagher JC. Kinyamu HK, Fowler S, Dawson-Hughes B, Dalsky GP, Sherman SS. Calciotropic hormones and bone matters in the elderly. J Bone Miner Res I 998:13:475-82.
29. Sanders MT. A comparison of two methods of training on development of muscular strength and endurance. J Ortho Sports Phys Ther 1980:1:210-3.
30. Kanpik JJ. Mawdsley RH. Ramos MU. Angular specificity and test mode specificity of isometric and isokinetic strength training. J Ortho Sports Phys Ther 1983:5:58-65.
31. Ferretti JL, Schiessl H. Frost HM. On new opportunities for absorptiometry. J Clin Dens 1998:1:41-53.
32. Preisinger E. Alacamlioglu Y, Pils K, Saradeth T, Schneider B. Therapeutic exercise in the prevention of bone loss. A controlled trial with women after menopause. Am J Phys Med 1995;74: 120-3.
33. Stewart KJ, McFarland LD, Winhofer JJ, Cottrell E, Brown CS, Shapiro EP. Safety and efficacy in weight training soon after acute myocardial infarction. J Cardiopulmonary Rehabil 1998;18:37-44.
34. Stewart KJ. Weight training in coronary artery disease and hypertension. Progr Cardiovasc Dis 1992;35:159-68.
35. Bertagnoli K, Hanson P, Ward A, Attenuation of exercise-induced ST depression during combined isometric and dynamic exercise in coronary artery disease. Am J Cardiol 1990;65:3l4-7.
36. Bollen A, Martin MD, Leroux BG, Eyre DR. Circadian variation in urinary excretion of bone collagen cross-links. J Bone Miner Res 1995;10:1885-9.
37 Petersen S, Wessel J, Bagnall K, Wilkins H, Quinney A, Wenger H. Influence of concentric resistance training on concentric and eccentric strength. Arch Phys Med Rehabil 1990;71:101-5.
38. Swezey RL. Exercises with a beach ball for increasing range of joint motion. Arch Phys Med Rehabil 1967;48:253-7.
39. Stratford PW, Balsor BE. A comparison of make and break tests using a hand-held dynamometer and the Kin-Com. J Ortho Sports Phys Ther l994;19:28-32.
40. Newton M, Waddel G. Trunk strength testing with isomachines. Spine 1993;18:801-11.
41. Sullivan SJ, Chesley A, Hebert G, McFaull S, Scuilion D. The validity and reliability of hand-held dynamometry in assessing isometric external rotator performance. J Ortho Sports Phys Ther 1988;12:213-7.
42. Andrews AW, Thomas MW, Bohannon RW. Normative values for isometric muscle force measurements obtained with hand-held dynamometers. Phys Ther 1996;76:248-59.