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Back Progressive Resistive Exercise Program to Reduce Risk of Vertebral Fractures

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Back Progressive Resistive Exercise Program to Reduce Risk of Vertebral Fractures

M. J. Borgo, M. Sinaki

Kurzfassung: Progressives Widerstandstraining für die Rückenmuskulatur – Programm zur Reduktion von Wirbelfrakturen. Die Axialbelastung der Wirbelsäule kann bei Patienten mit Knochenmasseverlust zu Kompressionsfrakturen führen. Wir berichten über die Wirksamkeit eines progressiven Widerstandstrainings (PRE – „progressive resistive exercise") der paravertebralen Muskulatur aus der Bauchlage, das zur Stärkung der Rückenmuskulatur mit Rücksicht auf etwaige Rückenschmerzen entworfen wurde. Es wurde eine randomisierte kontrollierte Studie eines PRE-Programms durchgeführt, um die Inzidenz an Wirbelfrakturen einige Jahre nach Ende des Übungsprogramms festzustellen. In unserer Studie wurden 67 weiße Frauen im mittleren Alter von 56 Jahren (range: 49–65 Jahre) randomisiert der Kontroll- (n = 33) oder der Übungsgruppe (n = 34) zugeteilt. Die Teilnehmerinnen wurden hinsichtlich der korrekten dynamischen und statischen Körperhaltung geschult. Alle Teilnehmerinnen wurden mittels biplanarem Röntgen der thorakalen und lumbalen Wirbelsäule zur Diagnose etwaiger Wirbelfrakturen zu Studienbeginn, nach 2 und nach 10 Jahren untersucht. Aktivitätslevel und Rückenstreckkraft (BES – „back extensor strength") wurden über 2 Jahre monatlich evaluiert. Die Übungsgruppe führte ein Trainingsprogramm aus der Bauchlage gegen gemessenen und progressiv ansteigenden Widerstand 4×/Woche mit einer Übungseinheit täglich durch, wohingegen die Kontrollgruppe kein Trainingsprogramm ausübte. Die isometrische Stärke der Rückenstreckmuskulatur wurde mit einem speziellen Rückendynamometer gemessen. Die Kräftigungsübungen wurden mit 30 % der Maximalkraft empfohlen. Nach 6 Monaten wies die Übungsgruppe eine beinahe 2-fach höhere BES (durchschnittl. 18,5 kg) wie die Kontrollgruppe (durchschnittl. 9,5 kg; p < 0,001) auf. Acht Jahre nach Beendigung des Trainingsprogramms wurden BES, Knochenmineraldichte der Wirbelsäule und Inzidenz von Wirbelfrakturen ausgewertet und die beiden Gruppen verglichen. Die statistische Analyse zeigte einen signifikanten Unterschied der BES zwischen den beiden Gruppen. Nach dem 10-jährigen Follow-up zeigte das Wirbelsäulenröntgen, dass die Anzahl der Patientinnen mit Wirbelfrakturen in der Kontrollgruppe 3x so hoch war wie in der Übungsgruppe. Diese Methode eines progressiven Widerstandstrainings der Rückenstrecker war effektiv hinsichtlich einer geringeren Inzidenz an Wirbelfrakturen und resultierte in einer größeren Stärke der Rückenstreckmuskulatur in der Übungsgruppe 8 Jahre nach Studienende.

Abstract: Axial loading of the spine in patients with bone loss can result in compression fracture. We report the efficacy of progressive resistive exercise (PRE) of paravertebral muscles from prone position, designed for increasing back strength without back pain. We conducted a randomized controlled trial of a PRE program to decrease vertebral fracture incidence several years after program discontinuation. In our study, 67 white women (age, mean [range], 56 [49–65] years) were randomly assigned to the control (n = 33) or exercise group (n = 34). Participants were instructed in proper dynamic and static posture principles. All participants had biplanar radiographs of the thoracic and lumbar spine to detect fracture at baseline, 2-year and 10-year follow up. Physical activity level and back extensor strength (BES) were evaluated monthly for 2 years. The exercise group performed PRE from prone position against measured and progressively increasing resistance 4 times weekly with 1 session per day; the control group performed no PRE. Isometric strength of back extensor muscles was measured with a special back strain-gauge dynamometer. For the strengthening exercises, 30 % of maximum BES was prescribed. At 6 months into the study, the exercise group had an increase in BES (mean increase, 18.5 kg) that was approximately twice that of the control group (mean increase, 9.5 kg; p < 0.001). Eight years after program discontinuation, BES, spine bone mineral density, and vertebral fracture incidence were compared between the 2 groups. Statistical analysis showed significant difference between back extensor strength in the exercise group compared with the control group. At 10-year follow-up, spinal radiographs demonstrated that the number of controls with vertebral fractures was about 3 times greater than the back exercise group. This method of PRE of the back extensors was effective in decreasing incidence of vertebral fracture and resulted in increased strength of back extensors in the exercise group 8 years after the end of this study. **J Miner Stoffwechs 2010; 17 (2): 66–71.**

Abbreviations
BES, back extensor strength
MET, metabolic equivalent
PRE, progressive resistive exercise
PAS, physical activity score

Introduction

It has been hypothesized that progressive resistive exercise (PRE) of paravertebral muscles from prone position can reduce the risk of vertebral compression fractures [1]. An initial study reported in the medical literature indicated that back extensor strength (BES) is correlated with bone mineral density of the spine [2]. However, the actual method for performing the exercises to strengthen the back extensors has not been reported [3]. Therefore, in this communication, we report the exercise technique that was used and provide the data demonstrating its efficacy in terms of increased BES and decreased incidence of vertebral fractures [3].

Back strengthening exercises have been shown to increase the strength in the supportive musculature of the spine [4]. However, there has been little report on quantitative measurement of the strengthening effect of these exercise programs on vertebral fractures. With the development of a technique that accurately measures the strength of back extensors, further analysis can occur to investigate their role in chronic back pain, age-related bone density loss, and overall back health.

Three components of physical activity are considered of possible importance in age-related bone loss: a decrease in peak strength with advancing age, a decrease in strenuous activities, and a reduction in the diversity of activities. Exercise can have a role in decreasing the effect of these factors and can even help lessen the reduction in bone mineral density that is reportedly associated with aging [3]. This was demonstrated in one study where trunk muscular strength of ambulatory

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postmenopausal women was evaluated in relation to the amount of bone loss that the women experienced [2]. The investigators found that the eccentric trunk flexor and extensor torques provided the greatest effect on bone density. Furthermore, when the investigators evaluated only the extensor torque, they found that the women in the upper tertile had a 10-fold lower risk of rapid bone loss compared with those in the lower tertile [5].

The value of exercise, especially strengthening of the back extensors, has been demonstrated in prior studies. In one study, subjects with osteoporosis and back pain who performed back exercises to decrease their pain and strengthen their trunk muscles were divided into 4 groups with each performing different exercises. Vertebral fractures occurred most often (89 % of the time) in the individuals who performed only spinal flexion exercises (sit-ups). In contrast, vertebral fractures occurred the least often (16 % of the time) in the individuals who performed back extension exercises using the paraspinal muscles [6]. Furthermore, the incidence of vertebral fractures has reportedly been less in women with stronger back muscles [3]. In a study of 36 women with osteoporosis, the women with greater BES had both fewer compression fractures and a decreased severity of kyphosis [7]. This same relationship was also observed in a separate study at 10-year follow-up with 30.4 % of individuals in the control group experiencing vertebral fractures compared to 11.1 % of the individuals in the exercise group experiencing vertebral fractures [3]. With this background, we were especially interested in evaluating the effect of strengthening exercise programs on paraspinal muscles of women age 49 years and older.

The objective of the initial prospective study was to evaluate the effect of an isometric PRE program on bone mineral density of the spine. With this data in mind, the objectives of this communication are:

(1) To prescribe a PRE program that is safe for individuals after age 49 years to decrease the incidence of vertebral fractures without causing vertebral compression.

(2) To evaluate the effectiveness of a measurable, practical, progressive, resistive exercise program for improvement of BES without causing vertebral fracture or back pain.

Study Design

Population

After approval by our Institutional Review Board, 67 volunteer female participants were recruited from the local population and adjacent towns through advertisements in local newspapers. Inclusion criteria were the following:

- Age 49–65 years
- No history of metastatic or metabolic bone disease or connective tissue disorder
- No history of excessive alcohol intake or smoking
- No history of treatment with corticosteroids
- No recent (< 5 years) history of spinal injury
- Willingness to be randomly assigned to back strengthening exercise or no exercise groups
- No radiographic evidence of vertebral fracture at time of inclusion
- No history of back support use
- Absence of contraindication to measurement of extensor muscle strength
- Absence of contraindication to any of the prescribed exercises
- Logistically suitable (in the local area) for follow-up

Randomization

The study coordinator in charge of volunteer registration alternated assignments to the exercise group or the control group on the basis of their sequence on the list. If a volunteer did not meet the inclusion criteria, the next individual on the volunteer list took the volunteer's place. With this method, no bias was present regarding the participant's willingness to perform the required exercises or her physical activity. Written consent was obtained from each participant in the study.

Participant Groups and Exercise

During the study, all participants continued their regular diet and were asked to report whether they initiated any new athletic activities or changed their occupation. Both the exercise group and the control group received instruction regarding principles of posture and proper lifting and bending techniques.

All participants had baseline x-rays of the thoracic and lumbar spine to detect vertebral fracture and bone mineral density of the spine and hip to rule out osteoporosis. All participants also had baseline evaluation to determine the strength of their back extensors at the beginning of the study. Reevaluation of muscular strength and postural changes with the same technique occurred monthly over a period of 24 months (duration of the study), and then 8 years after cessation of the study (10 years after initiation of the study).

All subjects had baseline and monthly measurements of their back strength. The participants, regardless of group, were encouraged by the examiner to demonstrate their maximum strength, with the examiner using the most effective verbal encouragement technique each time strength was evaluated. Also at this time, the physical activity scores of all participants were evaluated and recorded. All participants received a 4-week diary at the initial evaluation, and at every visit thereafter for recording their physical activities. In addition, the exercise participants recorded their compliance with the study exercises, separate from their other physical activities.

<u>Exercise Group</u>

Participants in the exercise group were instructed to lie in the prone position with 2 standard pillows under the lower half of the abdomen in order to achieve approximately 30° of flexion of the spine. The exercise was then to perform back extension until a neutral spine position was achieved. A backpack with proper padding was positioned over the upper back at the level of the scapulae. The weight in the backpack was calculated to approximate the use of 30 % of the maximum strength of the participant's back extensors, as measured at the evaluation sessions. At each visit, the prescribed weight was recalculated on the basis of 30 % of back strength. The sandbags were then specifically prepared and provided for each participant in the exercise group. The participants were asked to lift their upper body (with backpack in place) 10 times with each contraction

Figure 1: Model demonstrating resistive exercise, with weighted backpack in place. The exercise involves lifting a prescribed weight (10 repetitions with prescribed weight), with each contraction lasting 5 seconds and followed by 5 seconds of rest.

Figure 2: Model showing positioning for measurement of maximum isometric strength of the back extensors with use of a dynamometer and with the lumbar spine in the neutral position to avoid lumbar flexion or hyperextension.

lasting 5 seconds and followed with 5 seconds of rest (Fig. 1). These exercise sessions were repeated 4 times weekly, 1 session per day. With each reevaluation appointment, a new maximum strength was obtained and the participant was given an appropriately weighted sandbag to place into the backpack and use for the exercises. Although a few participants achieved the level where 30 % of maximum isometric back strength equaled 50 lb or more, we did not increase the weight beyond 50 lb to avoid unnecessary straining.

Control Group

Participants in the control group were instructed to maintain their regular daily activities and to record any substantial changes in their weekly physical activity diary. Both groups had monthly re-evaluation of back strength and physical activity score.

Methods of Evaluation

Measurement of BES

The maximum isometric strength of the back extensors was measured by our specifically designed dynamometer with coefficient of variation of 2.33 % [8]. The participant was positioned on the table with the lumbar spine in neutral position (to avoid lumbar flexion or hyperextension) (Fig. 2). Contact with a transducer head was made over the spine at the level of the scapulae, with the cephalad edge at the first thoracic spinous process. Extensor muscle strength was measured with the participant pushing against the transducer head with max-

Table 1: Physical Activity Score for Various Physical Activities

Score[a]	Housework	Job	Sports/Recreation[b]
0 (very light) (1.5–2 METs)	Has help at home	Has sedentary job and drives to work	None
1 (light) (2–3 METs)	Light housework, no heavy lifting; 1–2 persons in household	Sedentary job and walks up to 1 mile to work	Very rarely participates in sports; infrequently walks 1 mile
2 (light to moderate) (4–5 METs)	More than light housework (e.g., shopping, cooking); 3-person household; light yard work, yard maintenance; no heavy lifting	No regular heavy lifting and moderate walking in job; homemaker with score of 2 and housework activity level or office work with frequent light manual labor	Slowly walks about 1 mile 3 times/wk; bowling
3 (moderate) (5–6 METs)	Average housework with rare lifting; 4–6-person household; yard work, yard and house maintenance with heavy lifting	Light manual labor on job; 1-mile walk to/from work; no regular heavy lifting	Regular daily calisthenics with relatively low energy consumption; moderate walking of 1 mile 3 times/wk
4 (moderate to heavy) (6–7 METs)	Moderately active; does gardening; heavy lifting < 3 times/wk	Homemaker with score of 4 or moderate manual labor on the job with infrequent heavy lifting	Outdoor sports (e.g., golfing, horseback riding) 2–3 times/wk; swimming 2 times/wk; bicycling; recreational (doubles) tennis
5 (heavy) (7–8 METs)	Household with 1 small child or more; regular heavy lifting	Moderate heavy manual work with regular heavy lifting on the job; considerable carrying of heavy loads and climbing stairs	Light sports 3 times/wk (e.g., stationary biking 30 min 3 times/wk, swimming 30 min 3 times/wk, jogging 20 min 3 times/wk); fast walking; aggressive singles tennis
6 (very heavy) (8–10 METs)	Regular yard work and yard and house maintenance; regular heavy lifting (e.g., shoveling show, washing windows, washing floors); gardening (digging, tilling, planting)	Agricultural business with active participation as farmwife; homemaker who performs housework at a score of 6 most of the day; heavy physical labor work; heavy construction work	Jogging 5–10 miles/wk, skiing 3 times/wk, or swimming 30–60 min ≥ 3 times/wk; bicycling ≥ 3 times/wk

Abbreviation: MET = the metabolic oxygen requirement under basal conditions, which is equal to the metabolic rate; [a] Any additional physical activities not included in this table can be categorized according to METs involved; [b] Requiring defined physical activity. Adapted from [9]. Used with permission.

imal force. This technique has been described in a previous communication [8]. The measurement was repeated 3 times, with each contraction lasting 5 seconds and with 1 minute of relaxation between measurements.

Physical Activity Score
Every participant was asked about her overall daily physical activities. The level of physical activity was evaluated on a scale based on multiples of basal metabolic rates (METs, or metabolic equivalents) involved in each daily activity (Table 1), as published by the American Heart Association [9]. For example, the activities that require 1.5–4.5 METs were considered light to moderate and were performed in a sitting position with primarily the upper extremities being used. Activities that require more METs were graded higher on the scale.

Physical activity was calculated for each participant using the physical activity score table and was based on information provided by the participant in face-to-face discussion with the investigator [9]. The score for physical activity of the exercise group did not include the prescribed PRE program. The score for level of physical activity of each individual was reassessed at the time of each reevaluation of BES.

The reproducibility of this measurement modality has been evaluated by application of the METS Scale to 10 volunteer women by 6 physicians independently (the coefficient of variation has been 19.5 %) and found to be acceptable for clinical evaluation and follow-up [9].

Table 2: Back Extensor Strength of Study Participants

Duration of Follow-up, mo	Group	Participants, No.	Pounds, mean (range)
0	Exercise	34	83 (37–144)
	Control	33	85 (41–145)
6	Exercise	34	143 (72–225)
	Control	31	117 (56–192)

Table 3: Patient Characteristics for the Study Groups

Characteristic	Group[a]	Mean (Range)
Age, y	Exercise	51 (49–64)
	Control	55 (49–65)
Weight, kg	Exercise	65 (45–87)
	Control	65 (51–97)
Height, cm	Exercise	162 (145–176)
	Control	161 (151–175)

[a] Exercise group, n = 34; control group, n = 33.

Table 4: Physical Activity Scale (PAS) of Study Participants Over Time

Duration of Follow-up, mo	Group	Participants, No.	PAS, mean (range)
0	Exercise	34	8.0 (4–13)
	Control	33	8.0 (3–13)
6	Exercise	34	11.7 (5–19)
	Control	31	11.8 (4–17)
0–6	Exercise	34	8.8 (NA)
	Control	31	8.9 (NA)

Abbreviation: NA = not applicable.

Radiographic evaluation
Biplanar spinal radiographs were done on each subject, regardless of group randomization, at baseline, at 24 months, and at 10-year follow up. All of the x-rays were compared by a radiologist for any evidence of development of spinal compression fractures during the study period.

Statistical Analysis
Statistical analysis was performed through use of JMP software (SAS Institute, Inc, Cary, North Carolina) with unpaired *t* test with pooled variances.

Results

In the 67 healthy women, initial isometric back strength ranged from 37–145 lb (mean [SD], 84 [23] lb) (Table 2). Height ranged from 145–177 cm (mean [SD], 161.7 [5.7] cm) (Tab. 3). Weight ranged from 45–97 kg (mean [SD], 65.4 [10.0] kg), and the total physical activity score ranged from 3–13 (mean [SD], 7.0 [2.6]) (Table 4).

At completion of the 6-month period, the isometric back strength of the exercise group ranged from 48–170 lb (mean, 101 lb). The isometric back strength of the control group ranged from 48–134 lb (mean, 87 lb). The absolute change in BES was 60.1 lb (SD, 28.6 lb) in the exercise group and 31.6 lb (SD, 18.5 lb) in the control group ($p < 0.001$; unpaired t test with pooled variances).

During the first 6 months of study, only 2 participants from the control group did not return at the 4-week milestones, whereas all individuals from the exercise group returned in accordance with protocol. The results of the individuals who were able to attend a recheck appointment but were more than 1 week past the target day were also included in this study.

Statistical analysis of the results showed a significant difference between the control and exercise groups. We found that no participant had back pain with the exercise program. The

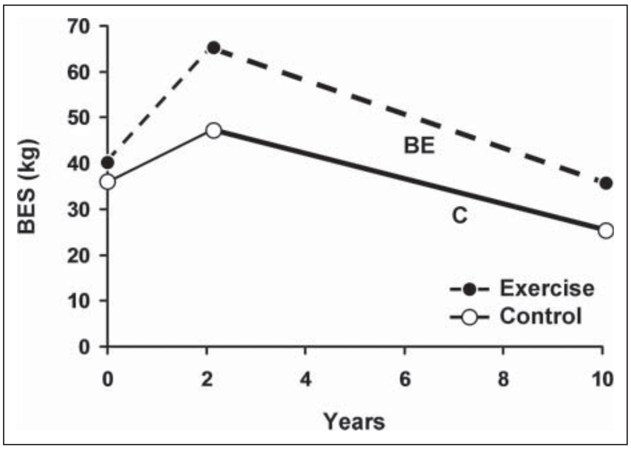

Figure 3: Muscle strength in 2 study groups: back exercise (BE) and control (C). Subjects participated in self-selected physical activities during years 3–10. Back extensor strength (BES) increased at 2 years ($p = 0.001$) and decreased at 10 years ($p = 0.001$). The BES of the BE group was significantly greater than that of the C group at both 2 years ($p = 0.0005$) and 10 years ($p = 0.0357$). The values are mean ± SD. (From [3] with permission from Elsevier).

Table 5: Absolute Change of Back Extensor Strength

Duration of Follow-up, mo	Group	Participants, No.	Change, lb Minimum	Maximum	Mean (SD)
0–6	Exercise	34	7	122	60.1 (28.6)
	Control	31	–9	70	31.6 (18.5)

change in height was not statistically significant in either group. Statistical analysis showed that the exercise group had a significant increase in strength compared with the control group. Over the 6 months, the exercise group had an absolute change in BES that was approximately double that of the control group (mean, 18.5 vs 9.5 kg) (Tab. 5). Interestingly, the difference in BES between the 2 groups was statistically significant, even at 10-year follow-up ($p = 0.0357$) (Fig. 3).

The evaluation of BES on a monthly basis allowed us to observe the incremental increases in BES exhibited by each study participant. Mean physical activity levels for both the control and exercise groups did not increase dramatically from the initial levels during the study (Tab. 4).

After 2 years, the back PRE was discontinued in the exercise group but the subjects in both groups were free to do their own physical activities. At this time, none of the study participants in either control or the exercise group had experienced a vertebral fracture. Interestingly, at 10-year follow-up (8 years after cessation of the monthly follow-up study), the incidence of vertebral compression fracture was 14 fractures in 322 vertebral bodies examined (4.3 %) in the control group and 6 fractures in 378 vertebral bodies examined (1.6 %) in the back extensor exercise group (χ^2 test, $p = 0.0290$). This led to a relative risk for compression fracture of 2.7 times greater in the control group [3].

Discussion

In this study, we evaluated the effect of our PRE program on the paraspinal muscles of women aged 49–65 years. Our goal was to report a quantifiable, well-defined, safe, progressive back exercise program on the immediate supportive muscles of the spine which has been successful in reducing the incidence of vertebral fracture.

In usual back extension (i.e., conventional exercises), the amount of force that a person's back extensors are exposed to is dependent on the effect of the weight of the individual's torso, any additional weight, and the starting and ending angles of the exercise. Often, the range of motion and the overall mass lifted in an exercise of this type are variable and not well controlled. By emphasizing the importance of keeping the range of motion constant throughout the exercise program, we tried to remove some variability that would have otherwise been present. The amount of weight that the exercise participants were lifting was calculated as requiring 30 % of their maximum back strength and was updated at each subsequent evaluation appointment. The nature of this PRE program allowed us to continually challenge the women in the exercise group and to see the increase in the strength of the back extensors that can occur over a short period. The objective of the weight-lifting exercise was to load the horizontal trabeculae rather than the vertical trabeculae, thereby avoiding the application of compressive forces on the vertebral bodies which, over time, could result in vertebral anterior wedging.

The change in strength of the back extensors usually occurs after 6 weeks of a trial [1, 10]. Among our participants, 15 of 34 individuals in the exercise group increased their strength in less than 6 weeks. By adding weight with each subsequent visit, we found that the strength of the back extensors could be increased in as little as 4 weeks. However, it is difficult to discern whether this initial increase in measured BES was due to better recruitment of paraspinal muscles instead of increase in the strength of the individual muscles. The ability of this exercise program to effectively increase BES over the duration of this study provides a potential opportunity to aid in improvement of back strength in deconditioned patients and osteopenic patients in danger of suffering vertebral fractures in addition to improving the strength of healthy individuals in need of improvement.

In a subsequent study, investigators showed that in women with osteoporosis or osteopenia, an increase in BES resulting from the exercise described herein also resulted in improvement in the quality of life of the exercise group compared with the control group [11]. In addition, it showed that although our designed PRE exercise as described in this paper provided the best results (39 % increase in BES), reductions in the frequency, the weight, or the number of repetitions of the back extension exercise from prone position also provided significant gains in strength (25 %, 22 %, and 20 %, respectively) [12].

Moreover, other investigators have also shown that the most supportive muscles of the spine are spinal extensors, with their strength being greatest in extension [13, 14]. In comparison to the back flexors, the typical ratio of the strength of back extensors to back flexors is about 1.5 [14]. As such, exercises that increase the strength of these muscles are of particular interest, especially when working with osteoporotic women [3].

Limitations

Several limitations are present in this study. Participants in the control group also increased their muscle strength because of monthly strength evaluations and postural exercises. However, this increase in measured strength did not affect their increased risk of fracture at the 10-year follow-up, and the PRE group fared substantially better [3]. The examiner conducting the BES measurements was not blinded to group assignment. However, the examiner made every effort to provide the same verbal motivational encouragement for every individual. To control the similarity of this encouragement, the examiner used standard words and phrases (e.g., "push hard", "push harder", "push real hard", "relax") each strength evaluation to encourage maximum effort. The same process was repeated for each measurement.

The exercises were conducted at home and thus were unsupervised. To detect noncompliance, the participants' strength was measured every 4–5 weeks. To detect participation in other exercises that affect BES, the physical activity scale and weekly diary were used. To prevent dropouts and loss of interest in participation, the principal investigator used the same motivational technique for all participants – especially given that in our small community, participants could communicate with each other regarding their evaluations and provided instructions.

Conclusion

This PRE program provided a safe and effective method for strengthening the back extensors in healthy and osteopenic women aged 49 years and older. The exercise was designed to be nonaxial loading to affect the horizontal trabeculae. In addition, this program did not result in any vertebral compression fracture or back pain. Additionally, we have shown that even when the exercise is not performed at the medical center, the strength of the spinal extensors can be greatly increased with the PRE program for back extensors by using the exercise that we have described. This BES exercise needs to be modified according to the individual's BMD or fragility. In cases of osteoporosis, the starting exercise can be performed from sitting position as we have described in previous publications.

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