Pelvic Stabilization During Resistance Training: Its Effect on the Development of Lumbar Extension Strength

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ABSTRACT. Graves JE, Webb DC, Pollock ML, Matkozich J, Leggett SH, Carpenter DM, Foster DN, Cirulli J. Effect of pelvic stabilization during resistance training: its effect on the development of lumbar extension strength. Arch Phys Med Rehabil 1994;75:210-5.

• The purpose of this study was to evaluate and compare resistance exercise training with and without pelvic stabilization on the development of isolated lumbar extension strength. Isometric torque of the isolated lumbar extensor muscles was measured at seven positions through a 72° range-of-motion on 47 men and 30 women before and after 12 weeks of variable resistance lumbar extension training. Subjects were assigned to either a group that trained with pelvic stabilization (P-STAB, $n = 21$), a group that trained without pelvic stabilization (NO-STAB, $n = 41$), or a control group that did not train ($n = 15$). Subjects trained once a week with 8 to 12 repetitions to volitional exhaustion. The P-STAB and NO-STAB groups showed significant ($p \leq 0.05$) and similar increases in the weight load used for training (P-STAB = 24.1 ± 9.4kg; NO-STAB = 19.4 ± 11.0kg) during the 12-week training period. In contrast, posttraining isometric torque values describing isolated lumbar extension strength improved only for the P-STAB group (23.5%, $p \leq 0.05$) and not for the NO-STAB group (−1.2%, $p > 0.05$) relative to controls. These data indicate that pelvic stabilization is required to effectively train the lumbar extensor muscles. The increased training load for the NO-STAB group is probably the result of exercising the muscles involved in pelvic rotation (hamstring and buttock muscles).

Muscular strength can be defined as the ability of a muscle or group of muscles to generate force (or torque). Resistance exercise training develops muscular strength[1] and increases the structural integrity of bone and connective tissue.[2] For these reasons, resistance training is often prescribed by allied health professionals to promote physical fitness and for the prevention and rehabilitation of musculoskeletal injuries.

The prescription of resistance exercise for the prevention and rehabilitation of low-back disorders is complicated by the fact that it is difficult to isolate the lumbar musculature. The lumbar extensors, which consist primarily of the erector spinae and transverse spinae muscle groups,[3] work in conjunction with the gluteal (gluteus maximus, medius and minimus) and hamstring (biceps femoris, semitendinosus, semimembraneosus) muscle groups which rotate the pelvis backward (sometimes referred to as "derotation") during trunk extension. This compound movement, which is assisted by accessory muscles such as the quadratus lumborum and psoas major,[4] enables the trunk to extend through a range-of-motion (ROM) of approximately 180°.[5] Isolated lumbar extensor function (fig 1) is responsible for a ROM of approximately 72° in normal healthy subjects.[6]

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To isolate the lumbar extensor muscles, the pelvis must be stabilized to eliminate the contribution of the muscles that cause backward rotation of the pelvis.[7,8] One method of stabilizing the pelvis to isolate the lumbar extensors is to restrict pelvic rotation by applying a restraining force to the lower extremities when the subject is in a seated position.[5-9] Radiographic study has shown that when the legs and pelvis are adequately restrained, backward rotation of the pelvis is restricted to less than 3°.[10] This process helps eliminate the contribution of the gluteal and hamstring muscles during trunk extension.

The efficacy of isolating the lumbar extensor muscles through pelvic stabilization to develop lumbar extension strength is well documented. Pollock and colleagues,[11] Graves and associates,[12] and Carpenter and coworkers[13] have reported more than 100% increases in isometric lumbar extension torque production following resistance training of the isolated lumbar extensor muscles in asymptomatic normal populations. Risch and colleagues[14] found a significant improvement in lumbar extension strength as well as significant reductions in symptoms of pain and psychosocial dysfunction following resistance training of the isolated lumbar extensor muscles in chronic low-back pain patients.

Although the efficacy of resistance training with pelvic stabilization for the development of lumbar extension strength is established, many commercially available "low back" exercise machines make little or no attempt to stabilize the pelvis. The gluteal and hamstring muscles, which together have a far greater cross sectional area and a longer moment arm than the extensors of the spine,[15] are responsible for most of the trunk extension movement on exercise devices that allow pelvic rotation. The contribution of the lumbar extensors is not known. Therefore, the purpose of this investigation was to evaluate and compare resistance exercise training with and without pelvic stabilization on the

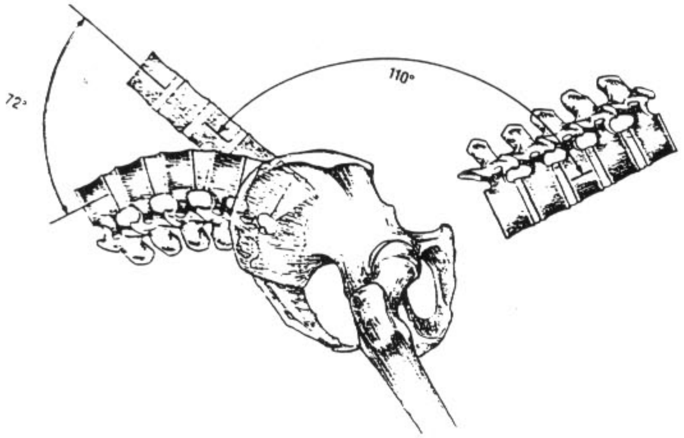

Fig 1—Compound lumbar-pelvic rhythm. Trunk extension in subjects asymptomatic for low-back pain is due to pelvic rotation (110°) and lumbar extension (72°). Please note that lumbar extension may occur earlier in the range-of-motion if the pelvis is stabilized.

development of isolated lumbar extension strength in a healthy asymptomatic population.

METHODS

Subjects

Forty-seven men (age = 32.6 ± 9.9 years; height = 179.3 ± 8.1cm; weight = 80.8 ± 13.3kg) and 30 women (age = 30.9 ± 9.1 years; height = 165.4 ± 7.9cm; weight = 64.2 ± 10.8kg) were recruited to participate. All subjects were sedentary volunteers who had no history of chronic low-back pain and no orthopedic or cardiovascular contraindications to resistance exercise testing or training. The study was approved by the Institutional Review Board of the University of Florida, College of Medicine, Gainesville. Written informed consent was obtained from each subject.

Testing

Prior to training, all subjects completed two lumbar extension strength tests administered on different days by the same examiner. The tests were done at least 72 hours apart to allow the subjects time to recover from residual fatigue or soreness that may have resulted from the first test. The first test was considered a practice test since previous research has shown that it is important to familiarize subjects with the testing procedure to obtain the most reliable results.[6] For each strength test, maximum voluntary isometric torque of the isolated lumbar extensor muscles was measured at seven positions through a 72° ROM with a MedX[a] lumbar extension machine. The seven positions measured were 72°, 60°, 48°, 36°, 24°, 12°, and 0° of lumbar flexion. The MedX lumbar extension machine stabilizes the pelvis and isolates the lumbar extensor muscles using the restraint system shown in figure 2. After the pelvis was stabilized, a counterweight was set to neutralize the influence of gravity on the subjects upper body mass (torso, head, arms). The restraint system and counterbalancing mechanism of the MedX lumbar extension machine have been described in detail[6] and validated[16] elsewhere.

To begin each test, the movement arm of the machine was locked into position and the subjects were instructed to extend back against the upper back pad (fig 2) by gradually building tension for 2 to 3 seconds. Once maximal tension was achieved, subjects were instructed to maintain the contraction for an additional 1 second before relaxing. The isometric torque generated was measured with a load cell attached to the movement arm of the machine and displayed to the subjects as concurrent visual feedback on a video display terminal. Following each isometric contraction, a 10-second rest interval was provided while the next testing angle was set. The testing positions were standardized with a mechanical goniometer attached to the movement arm of the testing machine.

Group Assignment

Following completion of the pretraining tests, subjects were randomly assigned to one of three training groups or a control group (n = 15) that did not train. A greater number of subjects were, by design, included in each of the training groups than in the control group. One group (n = 21) trained on a MedX lumbar extension machine that isolates the lumbar extensor muscles by stabilizing the pelvis with the restraint system shown in figure 2. A second group (n = 20) trained on a Nautilus[b] lower back machine that restrains the legs from vertical movement but does not stabilize the pelvis. The third group (n = 21) trained on a Cybex Eagle[c] back extension machine that also restrains the legs but does not stabilize the pelvis. All subjects were asked not to begin any other activity or alter their normal daily routine during the study.

Training

All training machines used dynamic variable resistance. Subjects trained on their respective machines once a week for 12 weeks. This frequency and duration of training has previously produced 19% to 102% increases in lumbar extension strength.[11,12] During each training session, subjects

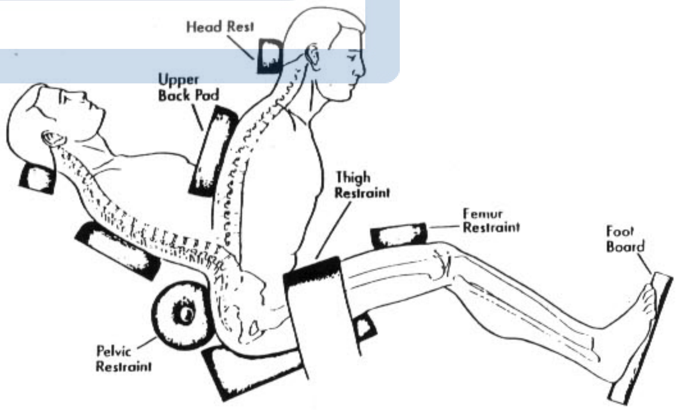

Fig 2—Restraint system used by the MedX lumbar extension machine to stabilize the pelvis. Pressure is applied to the bottom of the feet while the lower leg is positioned at approximately 60° of knee flexion. The resulting force drives the legs upward and back, fixing the pelvis in place against the pelvic restraining pad.

completed one set of variable resistance lumbar extension exercise through a full ROM with an amount of weight that allowed 8 to 12 repetitions to a point where the subject could not complete an additional full ROM repetition (volitional exhaustion). Range-of-motion for the group that trained with pelvic stabilization was limited to 72° of isolated lumbar extension. Compound trunk extension for the groups that trained without pelvic stabilization was through a ROM of approximately 90°. These ROMs were selected based upon what the respective training machines would allow.

Each repetition was performed in a slow, controlled manner with 2 seconds required for the concentric portion of the lift (lifting the weight) and 4 seconds required for the eccentric portion of the lift (lowering the weight). When subjects could complete more than 12 repetitions with a given amount of weight, the weight load was increased by approximately 5%. Low frequency/low volume training was used for the following reasons: (1) this type of training has previously produced significant improvements in isometric lumbar extension strength;[11,12] (2) the improvements observed with single set training one time per week in beginning exercisers are similar to those noted with more frequent training[12] and training with multiple sets;[17] and (3) this type of training is currently used in rehabilitation programs for chronic low back pain patients.[14] All training sessions were supervised by experienced laboratory personnel, the weight load used and number of repetitions completed during each training session were recorded.

Following the 12 weeks of training, each subject completed two posttraining isometric lumbar extension strength tests. The first posttraining test was administered 1 week after the last training session. The procedures were identical to those used for the pretraining strength tests.

Treatment of the Data

Isometric torque was measured in foot pounds (ft-lb) and converted to Newton meters (N · m). Training loads (kg) were obtained from the weight stacks of the training machines used to vary resistances. Group characteristics were compared using analysis of variance (ANOVA). Changes in isometric torques and in dynamic training weights following training were evaluated within each group with ANOVA for repeated measures. Comparison among groups with respect to training responses was done with analysis of covariance. Of the two posttraining isometric lumbar extension tests, the test yielding the greatest torque values (totaled over the seven test positions) was used as the criterion test. Torque values obtained during the second pretraining test were used as the covariates. Statistical significance was accepted at $p \leq 0.05$. Posthoc, single degree of freedom comparisons were made when required with a least squares means procedure.[18]

RESULTS

Results for the two groups that trained on machines that did not stabilize the pelvis did not differ statistically and, therefore, data from these two groups were pooled to create a single group (NO-STAB, $n = 41$) for further analysis.

Table 1: Group Characteristics

Group	n	Age (years)	Height (cm)	Weight (kg)
P-STAB				
Men	13	35.5 ± 7.4	180.7 ± 8.3	86.4 ± 15.5
Women	8	33.1 ± 7.5	164.0 ± 6.9	61.0 ± 7.4
Total	21	34.6 ± 7.3	174.4 ± 11.3	76.7 ± 18.0
NO-STAB				
Men	24	32.2 ± 10.8	178.5 ± 9.1	78.4 ± 13.1
Women	17	30.9 ± 9.7	164.8 ± 8.6	65.6 ± 12.6
Total	41	31.7 ± 10.3	172.8 ± 11.2	73.1 ± 14.2
Control				
Men	10	29.8 ± 10.2	179.6 ± 5.0	79.0 ± 8.7
Women	5	27.6 ± 10.0	169.6 ± 6.4	64.7 ± 9.4
Total	15	29.1 ± 9.9	176.3 ± 7.2	74.3 ± 11.0

Values are mean ± SD.
P-STAB, pelvic stabilization; NO-STAB, no pelvic stabilization.

Descriptive characteristics for the resulting pelvic stabilization (P-STAB), NO-STAB and control groups are presented by gender in table 1.

Both training groups (NO-STAB, P-STAB) significantly increased ($p \leq 0.01$) the amount of weight used to complete one set of 8 to 12 repetitions during the 12 weeks of training (table 2). Increases in training loads were 29% for the NO-STAB group and 39% for the P-STAB group. The difference between groups with respect to increases in training loads was not statistically significant ($p > 0.05$). The NO-STAB group completed more repetitions during the first week of training than the P-STAB group ($p \leq 0.05$) but the number of repetitions completed during the last week of training did not differ ($p > 0.05$) between the two training groups.

Isometric torque production of the isolated lumbar extensor muscles increased ($p \leq 0.05$) only for the P-STAB group (fig 3). There were no differences ($p > 0.05$) noted before and after training at any of the seven angles measured for either the control (average change = 3.6%, $p > 0.05$) or the NO-STAB (average change = 1.2%, $p > 0.05$) groups. The P-STAB group showed greater isometric torque values after training at all seven angles measured. Relative increases in isometric torque for the P-STAB group ranged from 9.0% at 48° of lumbar flexion to 120.0% at 0° of lumbar flexion (average change = 23.5%, $p \leq 0.05$).

Training responses are compared among groups in fig 4. Adjusted posttraining isometric torque values (from analysis of covariance) did not differ statistically ($p > 0.05$) between the NO-STAB and control groups at any angle. Adjusted posttraining torques for the P-STAB group were significantly greater ($p \leq 0.05$) than both the NO-STAB and control groups at 0°, 12°, 24°, 36° and 72° of lumbar flexion and significantly greater than the NO-STAB group at 48°, and 60° of lumbar flexion.

DISCUSSION

Results comparing the pretraining and posttraining dynamic exercise loads indicate that the variable resistance exercise training was effective for developing trunk extension strength in both the NO-STAB and P-STAB training groups. The 29% to 39% improvements in training loads that resulted from completing a single set of 8 to 12 repetitions to volitional exhaustion represent moderate to high increases in muscular strength for a 12 week training program. A

Table 2: Pretraining and Posttraining Exercise Loads (WT) and Repetitions*

	Group	
	NO-STAB (n = 41)	P-STAB (n = 21)
Pre WT (kg)	67.4 ± 18.3	61.3 ± 20.6
Post WT (kg)	86.8 ± 23.3†	85.4 ± 27.3*
Pre Reps	13.1 ± 2.8‡	11.6 ± 2.7
Post Reps	10.7 ± 1.7	10.5 ± 2.4

Values are mean ± SD.
* Pretraining weight and repetitions represent the average weight used and repetitions completed during the first week of training. Posttraining weight and repetitions represent the average weight used and repetitions completed during the last week of training.
† Post > Pre, $p \le 0.01$.
‡ N-STAB > P-STAB, $p = 0.05$.
NO-STAB, no pelvic stabilization; P-STAB, pelvic stabilization.

review of the literature by Fleck and Kraemer[19] indicates that dynamic strength increases of 20% to 30% are typical of resistance training programs lasting 10 to 12 weeks. Graves and colleagues[12] have previously reported 37% to 41% increases in training loads following 12 weeks of isolated lumbar extension strength training at frequencies of one time to three times per week.

It may be important to recognize that the observed strength increases were the result of only 12 sessions of exercise. Moritani and deVries[19a] have shown that the initial changes in muscle force generating capacity are largely due to neural as opposed to morphological or biochemical mechanisms. Although the determination of the specific mechanisms of adaptation to lumbar extension resistance training is beyond the scope of the present study, it is likely that relatively large increases in strength resulting from only 12 exercise bouts are associated with a large neural component.[11]

The most interesting and significant finding of the present study was that training without pelvic stabilization resulted in no improvement in the torque production capacity of the isolated lumbar extensors despite an increase in trunk extension strength (table 2). Most likely, the increase noted in dynamic trunk extension strength for the NO-STAB group was the result of increasing the strength of the muscles that rotate the pelvis backward during trunk extension. The mechanism of backward or "derotation" of the pelvis is not questioned.[3] The gluteal and hamstring muscles are the primary pelvic rotators during trunk extension.

The group that trained with pelvic stabilization showed a significant improvement in isolated lumbar extensor muscle torque. The magnitude of average individual improvement noted in the fully extended ROM (120% at 0° of lumbar flexion) is similar to the 102.3% increase reported by Pollock[11] and the 129.7% increase reported by Graves[12] at 0° of lumbar flexion following similar training protocols. This finding further demonstrates the unique potential of the lumbar muscles to adapt to specific resistive exercise. The increases noted at 48°, 60°, and 72° of lumbar flexion (9.0 to 14.4%) in the present study were somewhat less than the improvements reported by Pollock[11] (42.1% to 54.7%) but similar to the increases reported by Graves[12] (13.2% to 23.8%) at these same angles.

Pollock[11] and Graves et al[12] have speculated that the relatively large increases in the ability of the isolated lumbar extensor muscles to generate torque, particularly in the more extended portions of the range-of-motion, are due to the fact that these muscles are initially very weak. Because the lumbar extensors are rarely isolated during normal daily activities, they seldom encounter an overload stimulus required to gain strength. These muscles are weak before training because they exist in a state of chronic disuse. The functional significance of the observed results is that the trained lumbar extensors have a greater force generating capacity and would therefore be able to handle greater external loads and be more resistant to fatigue.

In evaluating the observed training responses, we must

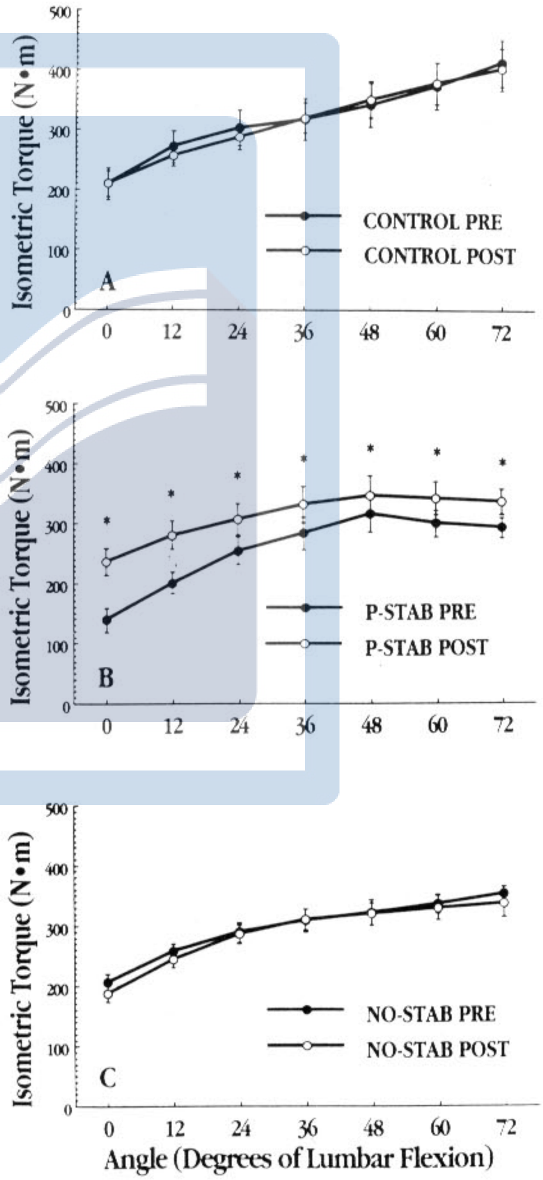

Fig 3—Pretraining and posttraining isometric torque values (mean ± SE) for the control (panel A), pelvic stabilization (P-STAB, panel B), and no stabilization (NO-STAB, panel C), groups. *Post > Pre, $p \le 0.05$.

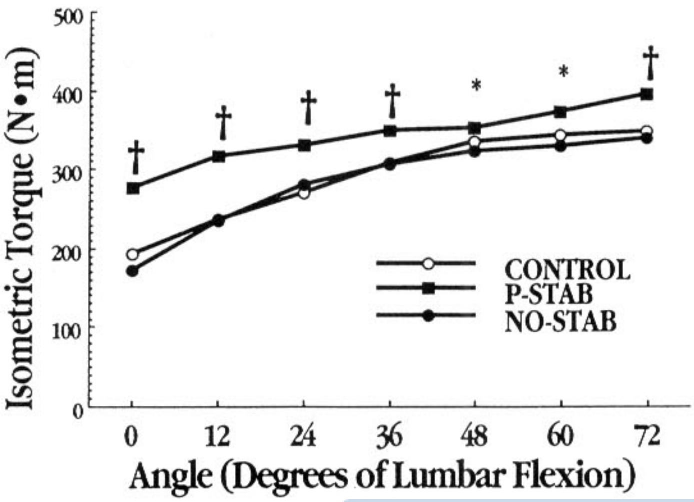

Fig 4—Adjusted post-training isometric torque values (from analysis of covariance) for the control (n = 15), pelvic stabilization (P-STAB, n = 21), and no pelvic stabilization (NO-STAB, n = 41) groups. +P-STAB > NO-STAB, control ($p \leq 0.05$). *P-STAB > NO-STAB, ($p \leq 0.05$).

acknowledge that a specificity of training related to the testing machine may exist. Even though the training groups all participated in dynamic exercise training and were tested isometrically, the P-STAB group may have had an advantage over the NO-STAB groups because they exercised on the testing device whereas the NO-STAB group did not. However, this does not alter the fact that the NO-STAB group showed no change in isolated lumbar extension strength relative to controls. Thus, the NO-STAB training devices were not effective for developing lumbar extension strength.

A low level of lumbar muscle strength is recognized as a risk factor for, or a direct result of, the development of low-back pain.[20-26] Additionally, rehabilitation programs for low-back pain patients often strive to improve lumbar extension strength.[27-30] The results of our study indicate that pelvic stabilization to isolate the lumbar extensor muscles is required to improve lumbar muscle strength. These findings have important implications for injury prevention and rehabilitation programs for the low back.

During normal daily activities the pelvis is not stabilized and trunk extension is accomplished by compound lumbar-pelvic rhythm. One might argue that the most effective way to train for the activities of daily living and specific industrial tasks is to use an exercise that most closely resembles these types of movement and, therefore, pelvic stabilization is not necessary. One problem with this approach is that as the large gluteus and hamstring muscles develop strength, the lumbar muscles remain in a state of disuse. In this case the lumbar extensors become chronically weak and may eventually be exposed to resistive loads that they can not tolerate. Thus, if in fact the lumbar extensors represent the weak link in the musculoskeletal system responsible for trunk extension, neglecting the lumbar extensors during resistance training may actually increase the risk of low back injury by contributing to an already existing muscle imbalance between the lumbar extensors and hip extensors.

In summary, resistive exercise training with and without pelvic stabilization can effectively improve dynamic trunk extension strength. However, pelvic stabilization is required to isolate and strengthen the lumbar extensor muscles. Improvements in dynamic trunk extension strength noted for subjects who trained without pelvic stabilization were likely due to strength gains in the primary muscles that rotate the pelvis backward (the gluteus and hamstring muscles). Resistive exercise training programs for the prevention and rehabilitation of low-back pain should incorporate trunk extension exercise with pelvic stabilization to develop strength of the isolated lumbar extensor muscles.

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Suppliers

a. MedX, 1155 NE 77th Street, Ocala, FL 32670.
b. Nautilus, 709 Powerhouse Road, Independence, VA 24348.
c. Cybex, 2100 Smithtown Avenue, Ronkonkoma, NY 11779.