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Abstract

Among strength testing methods, varying degrees of stabilization are used. The purpose of this study was to compare isometric lumbar extension values obtained from two different restraint systems designed to isolate the lumbar extensors through pelvic stabilization. Both restraint systems stabilized the pelvis by preventing movement of the lower extremities during testing with the subject in a seated position. One restraint system (KNEE) applied pressure just below the knees while the lower leg was positioned at 120° of knee flexion. The other (FOOT) applied pressure to the bottom of the feet while the lower leg was positioned at 60° of knee flexion. Fifteen men (age = 37 ± 10 yr; height = 177.7 ± 5.3 cm; weight = 61.4 ± 10.9 kg) and six women (age = 43 ± 7 yr; height = 170 ± 7.9 cm; weight = 61.4 ± 10.9 kg) were tested at seven positions through 72° range of motion with each restraint system. Analysis of variance for repeated measures indicated a significant difference ($p \leq 0.05$) between restraint systems and a significant restraint system by joint angle interaction. Subjects were able to generate 9.4 to 10.9 percent more torque at 72, 60, 48, and 36° of lumbar flexion with the KNEE restraint system compared to the FOOT restraint system. No differences ($p < 0.05$) between restraints were noted at 24, 12, or 0° flexion. Thus, the restraint system employed can influence lumbar extension strength values and affect the shape of the isometric lumbar extension strength curve.

Article # 31

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Among strength testing methods, varying degrees of stabilization are used. The purpose of this study was to compare isometric lumbar extension strength values obtained from two different restraint systems designed to isolate the lumbar extensors through pelvic stabilization. Both restraint systems stabilized the pelvis by preventing movement of the lower extremities during testing with the subject in a seated position. One restraint system (KNEE) applied pressure just below the knees while the lower leg was positioned at 120° of knee flexion. The other (FOOT) applied pressure to the bottom of the feet while the lower leg was positioned at 60° of knee flexion. Fifteen men (age = 37 ± 10 yr; height = 177.7 ± 5.3 cm; weight = 61.4 ± 10.9 kg) and six women (age = 43 ± 7 yr; height = 170.9 ± 7.9 cm; weight = 61.4 ± 10.9 kg) were tested at seven positions through 72° range of motion with each restraint system. Analysis of variance for repeated measures indicated a significant difference ($p \leq 0.05$) between restraint systems and a significant restraint system by joint angle interaction. Subjects were able to generate 9.4 to 10.9 percent more torque at 72, 60, 48, and 36° of lumbar flexion with the KNEE restraint system compared to the FOOT restraint system. No differences ($p > 0.05$) between restraints were noted at 24, 12, or 0° flexion. Thus, the restraint system employed can influence lumbar extension strength values and affect the shape of the isometric lumbar extension strength curve.

Key Words: *isometric strength, lumbar extension, pelvic stabilization*

To accurately quantify the strength of a specific muscle or muscle group, isolation of that muscle or muscle group is required. Without effective isolation, accessory muscles can contribute to observed strength values. Strength testing of the lumbar extensor muscles is complicated by the fact that they act in conjunction with the gluteus, hamstring, and adductor muscles to rotate the pelvis backward (1, 3). To isolate the lumbar extensors and accurately quantify lumbar extension strength, pelvic stabilization is required (8, 9, 12).

One method of stabilizing the pelvis when testing lumbar extension strength in the seated position is to restrict pelvic rotation by applying a counterforce to the lower extremities (4, 5, 8, 9, 12). If the legs are adequately restrained, backward rotation of the pelvis is minimized. This process eliminates the contribution of the gluteus and hamstring muscles to observed lumbar extension strength values (12).

A variety of lower extremity restraint systems have been successfully employed to stabilize the pelvis dur-

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ing isometric lumbar extension strength testing. Smidt et al (12) used rigid pads "placed in firm contact with the anterior shank, anterior thigh, anterior-superior iliac spines and just below the level of L5-S1 interspace" to stabilize the pelvis and lower extremities. The legs were positioned at approximately 90° of knee flexion. Pollock et al (10), Graves et al (4), and Graves et al (5) used a system similar to the one described by Smidt et al (12), except that the firm pads contacting the anterior thigh and anterior-superior iliac spines were replaced by a "thigh restraint" consisting of a restraining belt secured over the anterior thigh while the legs were positioned at 120° of knee flexion.

A new lower extremity restraint system that stabilizes the pelvis by applying pressure to the bottom of the feet with the legs positioned at 60° of knee flexion is currently being used for clinical and research purposes (6). Peterson et al (9) showed that different pelvic stabilization systems can yield different results during isometric trunk extension testing. This has potential implications when comparing strength values from studies that have incorporated different restraining systems. To date, no study has compared the effect of different lower extremity restraint systems to stabilize the pelvis on lumbar extension strength test results. The purpose of the present study was to compare two lower extremity restraint systems designed to isolate the lumbar extensor muscles through pelvic stabilization during isometric lumbar extension strength testing in the upright seated position.

METHODS

Subjects

Fifteen men (age = 37 ± 10 yr; height = 177.7 ± 5.3 cm; weight = 79.9 ± 10.3 kg) and six women (age = 43 ± 7 yr; height = 170.9 ± 7.9 cm; weight = 61.4 ± 10.9 kg) volunteered to participate in this study, which was part of an on-going investigation related to testing and training the lumbar extensor muscles. The subjects were primarily university students and professional people from the Gainesville, FL community. Prior to participation in the present study, the subjects had participated in a lumbar extension exercise training program for one year. The training for this program involved dynamic variable resistance lumbar extension exercise, and the effect of this training was evaluated at 3 months, 6 months, and 12 months.

Without effective isolation, accessory muscles can contribute to observed strength values.

Some of the results from this testing and training program have been previously published (4, 5).

All subjects initially completed a detailed medical history questionnaire. Those who were accepted for study were asymptomatic for low back pain and had no orthopaedic problems or other medical conditions that would contraindicate lumbar extension exercise. The present investigation was approved by the Institutional Review Board of the University of Florida College of Medicine. Written informed consent was obtained from each subject following a detailed verbal and written explanation of the study.

Testing

Each subject completed two isometric lumbar extension strength tests in the upright seated position. For each test, isometric lumbar extension torque production was measured at 72, 60, 48, 36, 24, 12, and 0° of lumbar flexion with a MedX® (MedX Corp. Ocala, FL) lumbar extension machine (Figure 1). Previous research has indicated that a single practice session is required to obtain highly reliable isometric lumbar extension strength test results (4). Because the subjects in the present study had participated in a lumbar extension strength training program for one year and had been tested on multiple occasions prior to this investigation, they were familiar with lumbar extension strength testing.

The pelvis was stabilized during each test by pushing the femurs down and back into the pelvis, thus fixing the pelvis in place against a pelvic restraint pad. The only difference between the two tests was the restraint system used to push the femurs. One test employed a restraint system (KNEE) that applied pressure to the femurs just below the tibial tuberosity (Figure 2). The lower leg was positioned at 120° of knee flexion. A thigh restraint was used to prevent vertical movement of the pelvis and thighs. The second test employed a restraint system (FOOT) that applied pressure to the bottom of the feet with the lower leg positioned at 60° of knee flexion (Figure 3). Thigh and knee restraints were used with the FOOT restraint system to prevent any vertical movement of the pelvis and thighs.

The two tests were conducted on different days and were separated by a minimum of 72 hours to avoid any fatigue or residual muscular soreness that may have been associated with the testing. A 24-hour history questionnaire was completed prior to each test to ensure complete recovery from the previous test. Not more than one week elapsed between the two tests. The order of testing (restraint system) was randomly assigned.

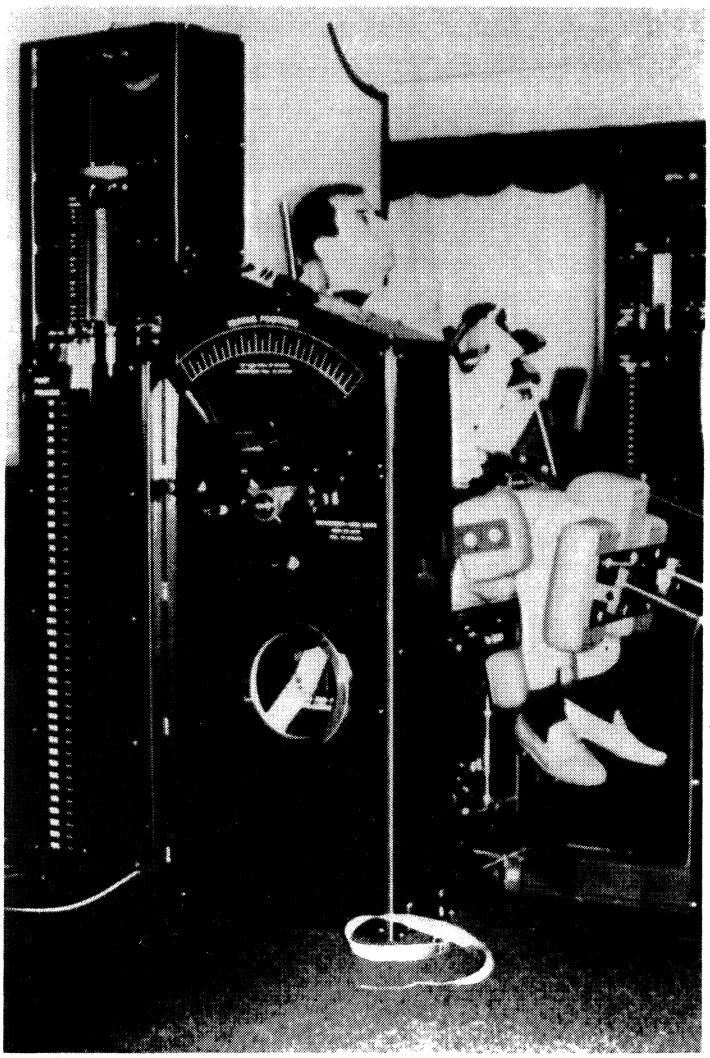

FIGURE 1: *The MedX (Ocala, FL) lumbar extension machine.*

Eleven subjects were tested with the KNEE restraint system first. The remaining 10 subjects were tested with the FOOT restraint system first. Because the order of testing at different joint angles can influence the torque values obtained during multi-position isometric tests (7), the order of testing angles was standardized within tests. Each test started at 72° of lumbar flexion and progressed to 0° of lumbar flexion. This standardized protocol has been previously evaluated and found to be highly reliable for the quantification of isometric lumbar extension strength through 72° range of motion (4).

After the pelvis was stabilized, the subject was moved into a neutral position with respect to gravitational influence on upper body mass (torso, head, and arms). This center-line of upper body mass varied between 18 and 36° of lumbar flexion for different subjects (Figure 4). A counterweight was locked into place at this position and the subject was moved to 0° of lumbar flexion (full extension). The counterweight was adjusted while the subject rested against the upper back pad (movement arm of the machine) at 0° of lumbar flexion to neutralize the gravitational force on the head, torso, and upper extremities. The subject was then checked for any limitations in their range of lumbar motion between 0 and 72° of lumbar flexion. None of the subjects participating in the present study had less than a 72° range of isolated lumbar motion.

To begin each test, the movement arm of the testing machine was locked into place at 72° of flexion, and subjects were instructed to extend their back against the upper back pad by gradually building tension over a 2 to 3 sec period. The

There was a significant difference for the isometric torque values obtained with the two restraint systems.

isometric torque generated was displayed to the subjects as concurrent visual feedback on a video display screen, and verbal encouragement was provided. Once maximal tension had been achieved, the subject was instructed to maintain the contraction for an additional 1 sec before relaxing. Following each isometric contraction, a 10-sec rest period was provided while the next testing angle was set. To insure pelvic stabilization, the femur and thigh restraints were tightened if pelvic movement was noted during the test. This was easily checked by observing any rotation of the pelvic restraint.

Treatment of the Data

Maximal voluntary isometric torque at each angle was measured in foot-pounds and converted to Newton-meters (N·m) by multiplying by 1.356 (13). Descriptive statistics (means and standard deviations)

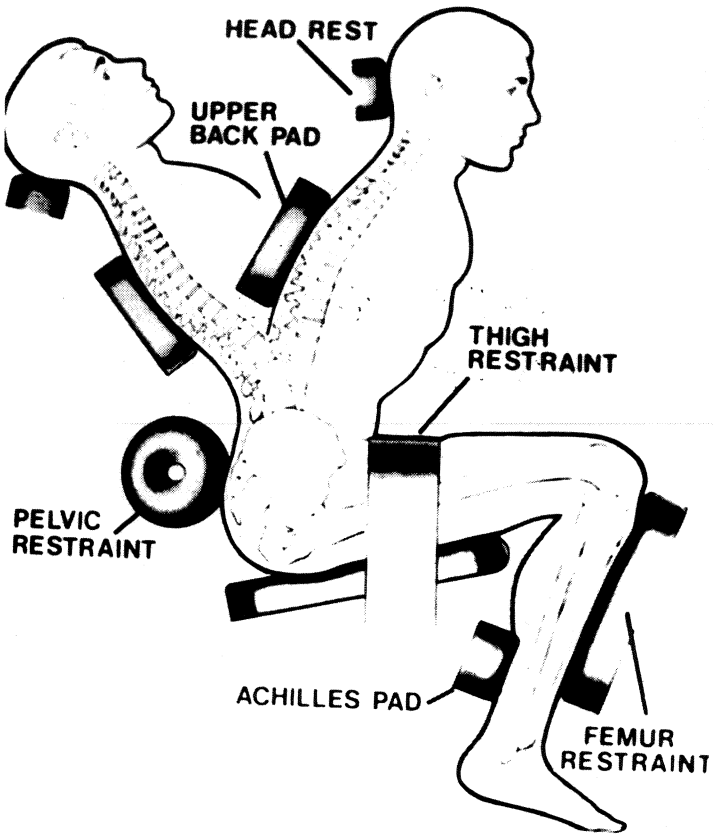

FIGURE 2. *KNEE restraint system used to stabilize the pelvis. Pressure is applied just below the knees while the leg is positioned at 120° of knee flexion. (Reproduced with permission from MedX Corporation, Ocala, FL and Graves JE, Pollock ML, Carpenter DM, Leggett SH, Jones A, MacMillan M, Fulton M: Quantitative assessment of full range of motion isometric lumbar extension strength. Spine 15(4):289-294, 1990).*

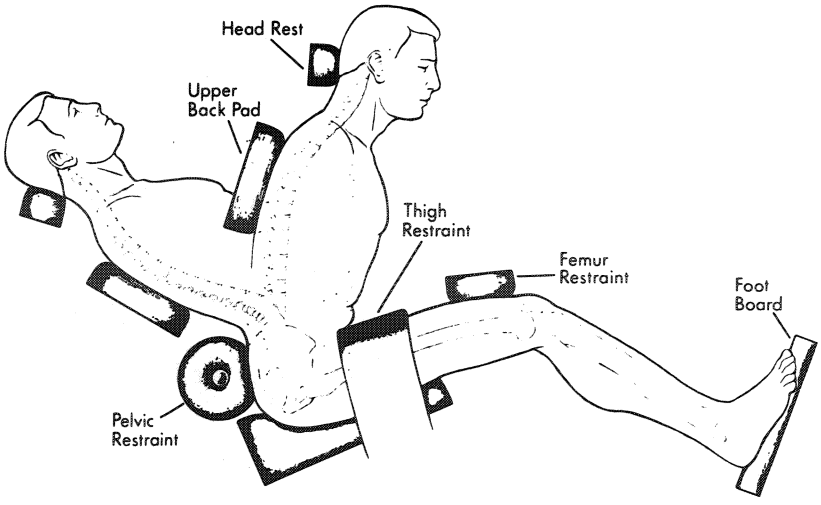

FIGURE 3. *FOOT restraint system used to stabilize the pelvis. Pressure is applied to the bottom of the feet while the lower leg is positioned at 60° of knee flexion. (Reproduced with permission from MedX Corporation, Ocala, FL and Graves JE, Pollock ML, Leggett SH, Carpenter DM, Fix, CK, Fulton MN: Limited range of motion lumbar extension strength training. Med Sci Sports Exerc 24(1), 1992, in press).*

were calculated for each angle of each test. Results obtained with the two restraint systems were compared with a two-way analysis of variance with repeated measures on both factors. Main effects evaluated were the restraint system and joint angle. The restraint system by joint angle interaction was used to compare the shape (slope) of the isometric lumbar extension strength curve obtained with the two restraint systems. In addition to the evaluation of the isometric torque values, the angle of lumbar flexion noted for the gravitationally neutral position and the

Previously published normative data for isometric lumbar extension strength obtained with the KNEE restraint system are not valid when testing is conducted with a different restraint system.

counterbalance setting (weight load) were compared for the two restraint systems with paired *t*-tests. Statistical significance was accepted at $p \leq 0.05$. When statistically significant main effects were noted, post hoc comparisons were made using single degree of freedom contrast transformations (11).

RESULTS

Torque values obtained for the two multiposition isometric lumbar extension strength tests are illustrated graphically in Figure 5, and results of the repeated measures ANOVA are presented in Table 1.

Source of Variation for Within Subjects Effects	df	Mean Squares	F
Restraint system (RS)	1	24474.4	5.27*
Error RS	20	4647.1	
Angle (A)	6	125649.9	49.05**
Error A	120	2561.6	
RS × A	6	2867.2	6.42**
Error (RS × A)	120	446.5	

* $p \leq 0.05$.
** $p \leq 0.01$.

TABLE 1: *Summary of the two-way ANOVA with repeated measures.*

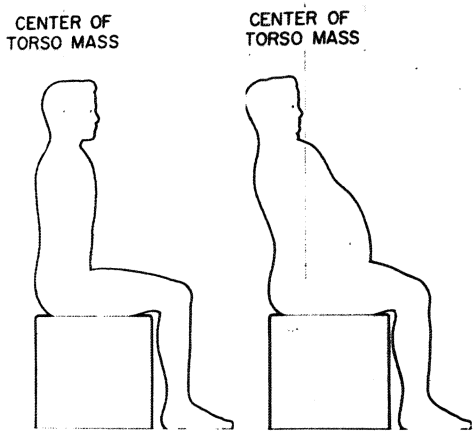

FIGURE 4. *Determination of the center-line of upper-body mass. Note that the angle of trunk flexion may vary slightly among subjects. (Reproduced with permission from MedX Corporation, Ocala, FL).*

There was a significant difference ($p \leq 0.05$) for the isometric torque values obtained with the two restraint systems. Post hoc contrast transformations showed that the subjects were able to generate more force at 72, 60, 48, and 36° of lumbar flexion with the KNEE restraint system compared to the FOOT restraint. The magnitude of the differences observed ranged from 9.4 to 10.9 percent. At 24, 12, and 0° of lumbar flexion, the difference between the two restraint systems was negligible ($p > 0.05$). A significant test-by-angle interaction indicated that the FOOT restraint system produced a flatter (smaller slope) lumbar extension strength curve ($p \leq 0.05$) and, therefore, a more uniform distribution of isometric strength throughout the range of motion when compared to the KNEE restraint system (Figure 5).

The joint angle at which the counterbalancing mechanism was attached was significantly greater ($p \leq 0.01$) for the FOOT restraint system (27.6° ± 5.1° of lumbar flexion) than for the KNEE restraint system (25.0° ± 4.4° of lumbar flexion). The different positions for counterbalance attachment did not significantly affect the counterbalance load required to neutralize the weight of the torso, head, and arms.

DISCUSSION

Both the KNEE and FOOT restraint systems employed in the present study were used to isolate the lumbar extensor muscles through pelvic stabilization. Stabilization of the pelvis prevents backward pelvic rotation and, thus, eliminates the contribution of the gluteus and hamstring muscles during trunk extension. In this fashion, the lumbar extensor muscles are isolated for exercise testing and training. Petersen et al (9) and Smidt et al (12) have previously discussed the importance of pelvic stabilization during lumbar extension strength testing to eliminate the contribution of accessory muscles.

The primary differences between the two restraint systems evaluated in the present study were the position of the lower leg and the point of force application to push the lower extremities. With the lower leg positioned at 120° of knee flexion and the force applied just below the knee (KNEE), the subjects were able to generate 10.9 percent more force at 72° of lumbar flexion compared to testing with the FOOT restraint system which positioned the lower leg at 60° of knee flexion and applied the force to the bottom of the feet.

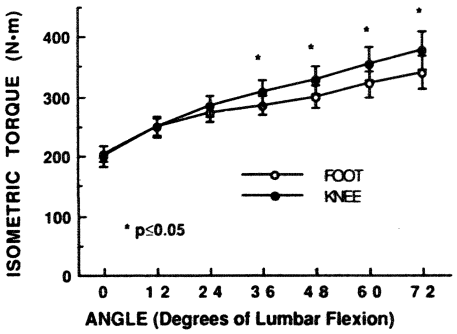

FIGURE 5. *Isometric torque values generated during isometric lumbar extension strength testing in the sitting position with the KNEE and FOOT restraint systems.*

The authors are not certain why the observed difference between the two restraint systems exists. One possible explanation is that the FOOT restraint system places the subject in a position with a biomechanical disadvantage in the more flexed positions of the lumbar range of motion when compared to the KNEE restraint system. This may be related to the fact that the hamstring muscles are stretched to a greater extent when the lower leg is positioned at 60° knee flexion than when it is positioned at 120° of knee flexion.

For any given muscle or group of muscles acting to produce a specific movement, there are at least three mechanical factors that can influence external force production (2): *1*) the angle of pull of the muscle, *2*) the length of the muscle, and *3*) the velocity of muscle shortening. Pelvic movement was minimized and the seven test positions were identical for the KNEE and FOOT restraint systems. Thus, differences in the angle of trunk flexion or the length of the lumbar muscles prob-

ably cannot explain the different torque values observed.

Because isometric muscle actions were evaluated, the velocity of muscle shortening was certainly not a factor. The two restraint systems differed only slightly in the position of the counterbalance attachment and did not differ with respect to the weight load required to counterbalance the mass of the upper body. Thus, a change in machine mechanics related to the position of counterbalance engagement and the amount of weight used to neutralize gravitational forces on upper body mass is probably not responsible for the differences observed. An alternative explanation could be that the FOOT restraint system was more effective at completely restricting pelvic movement in the more flexed positions of lumbar movement, although there was no visible evidence of pelvic rotation during testing with either restraint system.

In addition to the different torque values obtained at four of the seven angles tested with the two restraint systems, an important finding of the present study is that the different restraint systems significantly influenced the shape of the isometric lumbar extension strength curve. The lumbar strength curve obtained with the FOOT restraint system was flatter (as indicated by the statistically lower slope) and, thus, was associated with a more uniform distribution of strength throughout the range of lumbar motion. Therefore, the restraint system employed has important implications when using a multiposition isometric exercise test to quantify lumbar extension strength through a range of motion.

The most significant implication of the findings of the present study is that previously published normative data for isometric lumbar extension obtained with the KNEE restraint system (4) are not valid when testing is conducted with a different restraint system. Standardization of the testing position, including the restraint system employed, is important for comparative purposes. Separate norms should be developed for the FOOT restraint system (or with other restraint systems) to improve its utility in the clinical evaluation of lumbar extension strength. JOSPT

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