ORIGINAL ARTICLE

Effects of Aquatic Backward Locomotion Exercise and Progressive Resistance Exercise on Lumbar Extension Strength in Patients Who Have Undergone Lumbar Diskectomy

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ABSTRACT. Kim Y-S, Park J, Shim JK. Effects of aquatic backward locomotion exercise and progressive resistance exercise on lumbar extension strength in patients who have undergone lumbar diskectomy. Arch Phys Med Rehabil 2010;91: 208-14.

Objective: To compare the effects of aquatic backward locomotion exercise and progressive resistance exercise with a machine on lumbar extension strength in patients who have undergone diskectomy for a lumbar disk herniation.

Design: Prospective comparative study.

Setting: Department of Kinesiology at a state university.

Participants: Male patients (N=30) with disk herniation at spinal levels L3 to S1 completed this study as subjects.

Intervention: After the diskectomy for a lumbar disk herniation, all patients had 6 weeks of rest time. At the end of the rest period, the aquatic backward locomotion exercise and progressive resistance exercise groups, respectively, started first 6 weeks of underwater training and lumbar extension training twice per week. After completion of the first 6-week training, subjects participated in a second 6-week training. After the whole 12-week training, subjects had no training for 6 weeks (detraining) and a follow-up 6-week training (retraining). The control (CON) group did not undergo any training.

Main Outcome Measures: For each test, maximum voluntary isometric lumbar extension strength was measured in 7 trunk positions (72°, 60°, 48°, 36°, 24°, 12°, and 0° of the trunk angle).

Results: The progressive resistance exercise and aquatic backward locomotion exercise groups showed increases in lumbar extension strength after the first 6-week training, although they were not statistically different from the CON group. After a second 6-week training, the progressive resistance exercise and aquatic backward locomotion exercise groups showed statistically significant increases in their strength levels as compared with the CON group. After the detraining period, the strength levels of the progressive resistance exercise and aquatic backward locomotion exercise groups did not statistically differ from the CON group. After the retraining period, the progressive resistance exercise and aquatic backward locomotion exercise groups showed increases in their strength levels, which were different from that of the CON group.

Conclusions: The results obtained suggested that the aquatic backward locomotion exercise is as beneficial as progressive resistance exercise for improving lumbar extension strength in patients after lumbar diskectomy surgery.

Key Word: Rehabilitation.

PREVIOUS STUDIES ON rehabilitation exercises for low back pain and a postsurgery lumbar disk herniation often used strength training with exercise machines.[1-4] These exercise machines were designed to strengthen the lumbar extensors and provide rehabilitation to these patients.[5-8] Although these measurement-based machines effectively provide exercise for strengthening the lumbar extensors, they have often been considered as cost-ineffective.[9,10] As a result, more cost-effective exercises have been developed as alternative strength training methods. These cost-effective exercises and exercise machines include Roman chairs, lumbar stabilization floor exercises, and stability balls.[11-15] However, these alternatives are prone to secondary injuries in the spine and paraspinal muscles.

Recently, aquatic exercise has become popular for fitness enhancement, general conditioning programs, and rehabilitation for patients with low back pain, those with rheumatic diseases, and the elderly.[15-23] Walking and jogging in water are effective exercises for subjects with lower extremity and lumbar spine injuries.[13] These exercises are also safe and effective for elderly and middle-aged persons whose physical fitness levels have deteriorated because of physical inactivity and aging.[24] Many previous studies have demonstrated the general benefits of in-water exercises, including increased metabolic expenditure,[22] psychologic improvements,[25] cardiovascular benefits,[26] and other physiologic benefits.[16,27]

Aquatic backward locomotion exercise has been shown to be an effective mode of exercise that can provide beneficial effects during rehabilitation and a general exercise regimen.[21] Backward locomotion has been demonstrated to provide beneficial effects to subjects with lower extremity injuries and provide greater cardiovascular demands regarding heart rate and oxygen consumption.[28] Backward walking has also been shown to decrease overstretching of the anterior cruciate ligament.[29,30] Recently, Masumoto et al[20] reported that activations of the paraspinal muscles, vastus medialis, and tibialis anterior were greater during in-water backward walking as compared with

List of Abbreviations

ANOVA	analysis of variance
CON	control group
HRmax	maximum heart rate
RM	repetition maximum

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forward walking. Although these positive traits of in-water locomotion justify the use of the in-water locomotion exercises, it is still unknown whether in-water locomotion exercises are more beneficial or equally beneficial as compared with strength training exercise with dynamometers specifically designed for the rehabilitation of patients with low back pain or lumbar disk herniation problems. The purpose of this study was to investigate this question by comparing the effects of aquatic backward locomotion exercise and progressive resistance exercise with a machine on lumbar extension strength in patients who have undergone diskectomy for a lumbar disk herniation. We hypothesized that the aquatic backward locomotion exercise and progressive resistance exercise result in similar improvements of lumbar extension strength after the training.

METHODS

Participants

Thirty male adult patients with traumatic disk herniation at spinal levels L3 to S1 completed this study as subjects (mean age ± SD, 38.90±4.77y; mean height ± SD, 176.64±5.75cm; mean body mass ± SD, 79.53±6.82kg; mean duration of back pain ± SD, 18.27±4.58mo; mean duration of leg pain ± SD, 9.13±2.54mo). The disk herniation of patients was confirmed by their physicians. Each subject had low back pain for at least 11 months before undergoing diskectomy surgery. There were 3 groups of participants (progressive resistance exercise group, aquatic backward locomotion exercise group, CON group). Subjects were pseudorandomly divided into the 3 groups so that the physical characteristics and strength levels were not statistically different across the groups (fig 1). The progressive resistance exercise group was subject to a training protocol on the MedX[a] training equipment, the aquatic backward locomotion exercise group was subject to the backward locomotion in water, while the CON group agreed not to follow any kind of exercise program for the duration of the study. Physical characteristics of the subjects who completed this study are presented in table 1. All subjects gave informed consent based on the procedures approved by the university's internal review board.

Instruments

The progressive resistance exercise group used the MedX lumbar extension dynamometer for training. The MedX machine was also used to assess the maximum isometric lumbar extension torque at different lumbar spine flexion angles ranging from 0° to 72° with 12° intervals (ie, 72°, 60°, 48°, 36°, 24°, 12°, and 0°) (fig 2). For the aquatic backward locomotion exercise group, most of the exercises were performed in water. The water pool size was 25 × 25m, water depth was 1.3m, water temperature was 28°C to 29°C, room humidity was 70% to 75%, and room temperature was 27°C to 28°C. Heart rate was monitored with a pulse meter.[b] Subjects in the aquatic backward locomotion exercise group wore Aqua Jogger RX Footgear[c] that created buoyancy and provided resistance for their legs in the water.

Training Protocol

After the diskectomy surgery, all patients had 6 weeks of rest time. At the end of the rest period, the progressive resistance exercise and aquatic backward locomotion exercise groups started their first 6-week lumbar extension training and underwent training twice per week. For the progressive resistance exercise group, the training protocol consisted of 10 minutes of stretching exercises at about 40% of their age-predicted HRmax (men: 220 – age; women: 226 – age).[31] After this warmup exercise, the progressive resistance exercise group was provided with 20 minutes of progressive aerobic exercise at 40% to 60% HRmax. The progressive aerobic exercise was included to follow the suggestions from the MedX manual. After the warmup and progressive aerobic exercise, the progressive resistance exercise group had lumbar extension training with the MedX machine (2 sets of 15–20 repetitions at 50%–60% of 1 RM; 1 RM was measured every 2 weeks). Progressive resistance exercise was achieved by increasing the weight load by approximately 5% when 20 or more repetitions could be achieved. Lastly, the subjects cooled down by performing some more stretching exercises at 40% HRmax. The total workout lasted approximately 60 minutes. For the aquatic backward locomotion exercise group, the workout started with 10 minutes of stretching exercise at 40% HRmax. This was followed by aquatic exercises, with 10 minutes of leg swing, leg raise, and slow walking in wide steps at 40% to 60% HRmax. Subjects then performed backward walking and jogging for 20 minutes at 60% to 70% HRmax. This was followed by 10 minutes of vertical jumping, whole body twist, and trunk flexion and extension at 60% to 70% HRmax. Lastly, the subjects came out of the water and cooled down while doing stretching exercises for the next 10 minutes at 40% HRmax. The total workout time was about 60 minutes. The CON group was instructed to maintain everyday activities without undergoing any intensive training exercise. The details of the training protocols of the 2 groups are shown in table 2.

Outcome Measurements

Before testing, the subjects completed 2 to 3 practice sessions to become familiar with the MedX machine and measurement procedure. After the familiarization sessions, maximum isometric lumbar extension torque was tested to measure the isometric lumbar extension strength. The test was performed 6 times: before diskectomy surgery, after the 6-week rest period, after the first 6-week lumbar extension training, after the second 6-week lumbar extension training, after detraining, and after retraining. All subjects completed 2 isometric lumbar extension strength tests on 2 separate days. The testing dates were separated by at least 72 hours to allow subjects enough time to recover from any residual fatigue or soreness that might have been associated with the testing outcomes.[32-35] The results of the 2 tests were averaged for later analysis. The isometric lumbar extension strength was measured using a MedX lumbar extension machine at 7 angular positions, which included trunk angles of 72°, 60°, 48°, 36°, 24°, 12°, and 0° of the trunk angle. For each isometric lumbar extension strength test, subjects were seated and secured in the MedX machine. Subjects were then asked to slowly increase the lumber extension torque over 5 seconds. Once they reached the maximum torque, they were instructed to slowly reduce the torque.[34] A 5-minute rest period was provided between angle conditions. Subjects were positioned in an upright sitting position in the equipment according to the standardized procedure as described in previous research.[34,36-38] Previous studies showed that the MedX machine is highly reliable (r=.94–.98) and valid for the quantification of isometric lumbar extension strength.[34,35]

Statistical Analysis

Maximal voluntary isometric torque was measured in newton meters to estimate the lumbar extension strength. In order to investigate the overall strength changes after the lumbar extension training, detraining, and retraining periods, the max-

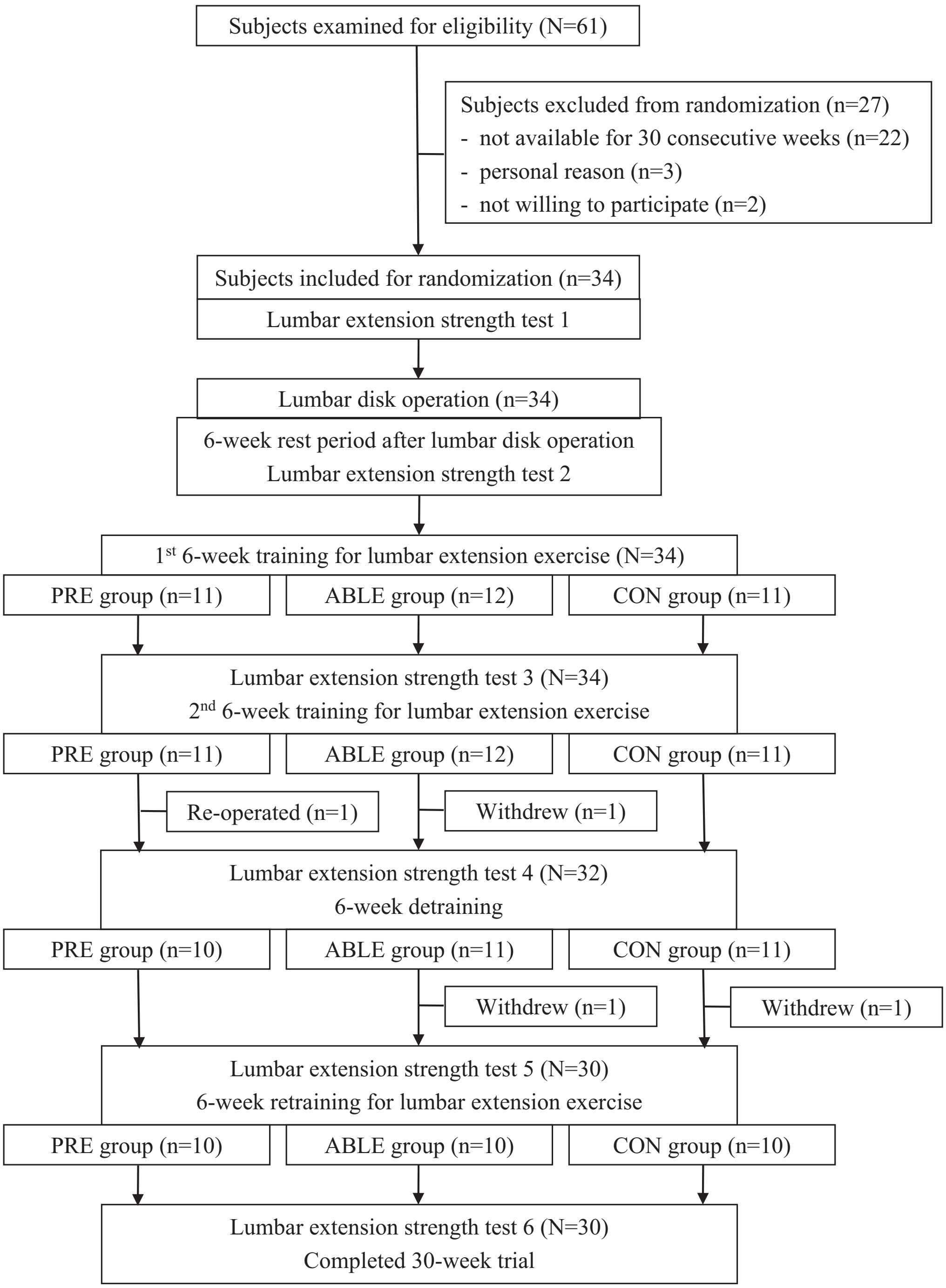

Fig 1. Flow diagram for randomized patient assignment. Abbreviations: ABLE, aquatic backward locomotion exercise; PRE, progressive resistance exercise.

imum torque values were averaged over all angle conditions for each measurement and each subject. Data were analyzed using the SPSS version 16 statistical package.[d] ANOVA was performed with the between-subject factor of group (3 levels: progressive resistance exercise group, aquatic backward locomotion exercise group, and CON group) and the within-subject factor of period (6 levels: lumbar extension strength test 1, 2, 3, 4, 5, and 6) on the maximum torque values averaged over all angles. The critical value for significant difference was set at P equal to .05. Bonferroni corrections were used for multiple comparisons. All values are expressed as mean ± SD. We calculated the same sizes using the data from previous studies with similar study designs.[33,39]

RESULTS

The isometric lumbar extension strength values at each different lumbar spine flexion angle (ie, 72°, 60°, 48°, 36°, 24°, 12°, and 0°) of measurement for the lumbar extension strength tests 1, 2, 3, 4, 5, and 6 are shown in table 3.

All 3 groups showed similar increases in the lumbar extension strength after the surgery with a 6-week rest period (fig 3).

Table 1: Characteristics of Subjects

Variables	All Subjects Before Dropout (N=34)	PRE Group (n=10)	ABLE Group (n=10)	CON Group (n=10)
Age (y)	39.00±4.51	38.50±5.04	37.40±4.95	40.80±4.10
Height (cm)	176.64±5.63	174.65±5.84	178.60±4.57	176.67±6.56
Body mass (kg)	79.52±6.78	76.67±5.88	79.84±6.84	82.10±7.22
Duration of back pain (mo)	18.53±4.37	18.20±4.21	19.20±4.10	17.40±5.58
Duration of leg pain (mo)	9.09±2.40	9.00±2.87	9.70±2.36	8.70±2.54
Location of the prolapse				
Right	15	4	4	5
Left	17	5	6	4
Central	2	1	0	1
Level of herniated disk				
L3-4	1	1	0	0
L4-5	16	4	5	5
L5-S1	16	5	4	5
L4-5 and L5-S1	1	0	1	0
Operation type				
ELD	18	5	6	6
OLM	16	5	4	4

NOTE. Values are mean ± SD or n.
Abbreviations: ABLE, aquatic backward locomotion exercise; ELD, endoscopic laser diskectomy; OLM, open laser microdiskectomy; PRE, progressive resistance exercise.

As compared with the CON group, the progressive resistance exercise and aquatic backward locomotion exercise groups showed greater increases in lumbar extension strength after the first 6-week lumbar extension training. After the second 6-week lumbar extension training, the progressive resistance exercise and aquatic backward locomotion exercise groups showed statistically significant increases in the lumbar extension strength ($P<.05$). During the detraining period, the lumbar extension strength decreased similarly in the progressive resistance exercise and aquatic backward locomotion exercise groups from the 12-week measurements, although the lumbar extension strength did not change in the CON group. The strength level of the progressive resistance exercise group and the aquatic backward locomotion exercise group became similar to that of the CON group after the detraining period. After the retraining period, the progressive resistance exercise and aquatic backward locomotion exercise groups recovered the lumbar extension strength which was greater than that of the CON group ($P<.05$). The CON group did not show any visible changes after the 6-week retraining period and maintained the strength throughout. These findings were supported by the 2-way ANOVAs with group and period factors, which showed statistically a significant effect of period ($F_{5,135}=640.49$, $P<.001$) and group × period interaction ($F_{10,135}=56.05$, $P<.001$). There were no significant overall differences of lumbar extension strength between groups, which was shown by no significant effect of group ($F_{2,27}=1.55$, $P=.230$). We also ran the statistical analysis with the 4 participants who dropped out because of reoperation and withdrawal by including them in the CON group. The results showed the same trends as the analysis performed above.

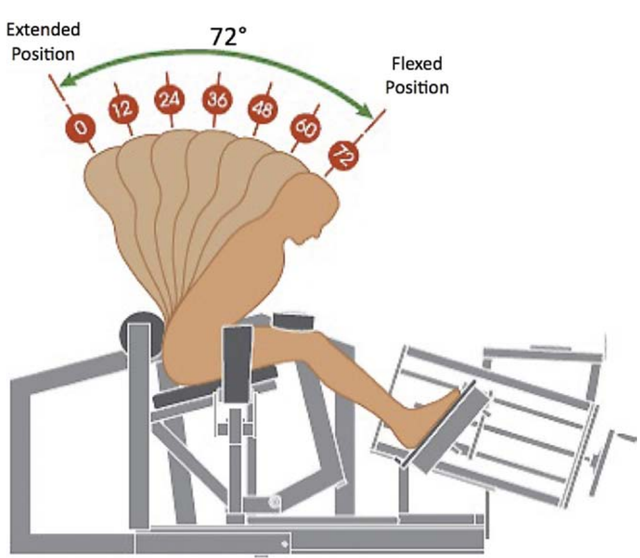

Fig 2. Illustration of lumbar positions on the MedX training system.

DISCUSSION

Previous studies have suggested numerous benefits of aquatic exercise. Konlian[14] showed that aquatic exercise could reduce the rehabilitation time and accelerate the healing process as compared with other rehabilitation methods such as a land exercise program. Danneskiold-Samsoe et al[40] showed that patients with arthritis increased their strength and aerobic capacity as well as functionality in their daily activities through aquatic exercise. Another study by Norton et al[41] reported that patients after anterior cruciate ligament surgery showed faster rehabilitation of range of motion with aquatic exercise as compared with traditional exercise. Olsen[42] reported that aquatic exercise in patients with chronic pain could reduce medication usage, improve personal care independence, increase the ability to sleep, and result in a larger percentage of patients returning to work.

Despite these positive clinical observations, there is little research to support the assumption that aquatic exercise benefits patients who have undergone diskectomy surgery. The results of the present study showed that after diskectomy, lumbar extension training with either progressive resistance exercise or aquatic backward locomotion exercise for 12 weeks

Table 2: Lumbar Training Program

Classification	Modality	Intensity	Time (min)
PRE group			
Warmup	Stretching exercise	HRmax 40%	10
Workout	Stepping and cycling exercise	PAE program: HRmax 40%–60%	20
	Lumber extension exercise	PRE program: 2 sets of 15–20 repetitions at 50%–60% of 1 RM	20
Cooldown	Stretching exercise	HRmax 40%	10
ABLE group			
Warmup	Stretching exercise	HRmax 40%	10
Workout	Leg swing, leg raise (forward, backward, cross, lateral); Slow walking in wide steps (forward, backward, left, right)	HRmax 40%–60%	10
	Backward walking and jogging	HRmax 60%–70%	20
	Vertical jumping	HRmax 60%–70%	10
	Whole body twist		
	Trunk flexion and extension		
Cooldown	Stretching exercise	HRmax 40%	10

Abbreviations: ABLE, aquatic backward locomotion exercise; PAE, progressive aerobic exercise; PRE, progressive resistance exercise.

was effective in increasing lumbar extension strength. During the 6-week detraining period, the lumbar extension strength decreased similarly in both the progressive resistance exercise and the aquatic backward locomotion exercise groups, while the lumbar extension strength increased after the 6-week retraining period. The CON group showed no statistically significant changes of the lumbar extension strength, although there were slight strength increases during the whole period. These results provide evidence that the aquatic backward locomotion exercise training program is as effective as the progressive resistance exercise training program at increasing lumbar extension strength for patients treated with diskectomy.

Many orthopedic clinicians advocate early, aggressive training for rehabilitation after surgery. However, immediately after

Table 3: Isometric Lumbar Extension Strength Values (Nm) at 7 Angles and Mean Lumbar Spine Flexion Angle in Lumbar Extension Strength Tests 1, 2, 3, 4, 5, and 6

	Angle (Degrees of Lumbar Flexion)							
Group	0*,†	12*,†	24*,†	36*,†	48*,†	60*,†	72*,†	Mean*,†
PERIOD								
PRE group (n=10)								
LEST 1	84.84±31.30	110.40±32.47	128.64±32.44	144.98±34.51	154.06±36.87	159.24±38.75	169.36±39.12	135.93±34.85
LEST 2	91.59±31.54	116.72±31.32	136.77±32.55	153.79±36.50	160.04±36.52	172.43±38.85	183.38±39.59	144.95±34.95
LEST 3	134.06±35.22	163.52±29.03	185.85±52.30	194.32±56.08	202.21±56.91	222.60±60.64	230.78±62.64	190.47±49.84
LEST 4	159.88±40.61	187.59±30.19	207.48±54.68	224.78±54.61	240.05±55.88	253.26±54.11	262.48±63.75	219.35±49.40
LEST 5	144.87±40.24	174.95±26.84	193.59±52.26	208.57±52.71	221.77±54.37	238.32±50.55	244.75±59.07	203.83±47.03
LEST 6	156.97±39.69	184.97±28.51	204.65±51.56	220.68±53.04	234.96±55.19	250.43±50.90	260.61±62.93	216.18±47.67
ABLE group (n=10)								
LEST 1	85.04±25.87	109.47±28.98	127.06±29.95	143.14±32.34	153.54±35.75	158.61±36.88	168.92±37.53	135.11±32.38
LEST 2	91.42±26.12	116.44±27.76	137.81±35.40	154.79±38.14	159.58±36.27	170.56±36.45	181.39±36.22	144.57±33.56
LEST 3	123.65±30.28	144.97±25.47	171.15±45.29	183.71±49.54	191.35±52.17	204.96±52.13	212.11±54.81	175.99±43.69
LEST 4	159.71±35.13	185.98±26.47	206.64±45.54	223.15±45.84	234.00±48.29	248.01±57.58	255.35±52.15	216.12±43.06
LEST 5	144.53±33.09	175.96±24.01	196.01±44.92	204.44±46.37	219.12±46.88	233.04±54.86	240.69±49.36	201.98±41.66
LEST 6	157.95±35.64	184.98±25.61	204.26±43.41	218.73±45.98	231.97±47.59	246.70±58.29	256.52±52.61	214.44±42.56
CON group (n=10)								
LEST 1	86.17±34.17	111.32±34.49	128.68±33.07	144.58±34.96	154.68±39.18	159.85±40.09	170.01±42.71	136.47±36.92
LEST 2	92.67±32.62	117.74±32.67	136.29±35.23	152.83±37.65	160.77±40.93	171.24±41.10	182.10±40.24	144.79±37.09
LEST 3	112.23±32.61	131.79±32.72	154.28±41.66	170.43±38.07	177.32±41.00	182.91±41.79	195.71±40.76	160.67±38.12
LEST 4	115.58±32.33	135.68±34.09	159.46±41.87	174.65±36.41	181.89±39.91	188.17±41.19	200.30±40.27	165.12±37.74
LEST 5	117.50±32.61	134.75±33.32	160.19±42.11	174.15±37.23	180.94±39.93	187.87±41.27	199.65±40.07	165.01±37.81
LEST 6	115.21±32.91	133.54±33.01	157.47±40.51	172.74±36.25	179.69±39.65	187.09±41.37	198.85±40.13	163.53±37.40

NOTE. Values are mean ± SD.
Abbreviations: ABLE, aquatic backward locomotion exercise; LEST, lumbar extension strength test; PRE, progressive resistance exercise.
*Statistically significant period effect ($P<.001$).
†Statistically significant group × period interaction ($P<.001$).

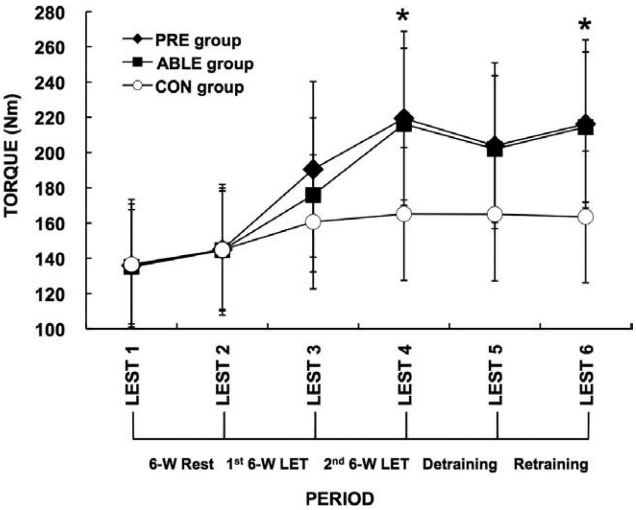

Fig 3. Isometric lumbar extension strength values expressed in newton meters (Nm). The values averaged over all angles used to calculate the mean ± SD. *PRE group, ABLE group >CON group; $P<.05$. Abbreviations: ABLE, aquatic backward locomotion exercise; LEST, lumbar extension strength test; LEST, lumbar extension strength training; PRE, progressive resistance exercise; W, week.

a low back injury, patients may not be able to tolerate the land exercise program because of the large mechanical loading on the spine during exercise. Aquatic exercise, however, is known to decrease these weight-bearing stresses, therefore allowing a more aggressive rehabilitation program to be pursued in the early rehabilitation process without overloading the spine.[14] The resistance and buoyancy allowed by aquatic exercise provide flexible means for rehabilitation while minimizing movement and weight-bearing stress on muscles and joints.[22] For example, it has been suggested that aquatic exercise can be an effective mode of rehabilitation for individuals with arthritis or various orthopedic dysfunctions who may have difficulties with the weight-bearing components of land exercise.[43] Because the impact load acting on the spine during aquatic exercises can be easily manipulated by the extent of submersion of the body in water, aquatic exercise may provide another benefit for individuals with low back pain.

Another benefit of aquatic exercise recognized by previous studies includes the greater exercise loading on the paraspinal muscles that are critical for rehabilitation of trunk movements. Chaloupka,[29] Takeshima,[18] and colleagues hypothesized that the peripheral muscle requirements might be different during backward or forward walking. Cole et al[23] speculated that aquatic backward walking might cause isometric contraction of the paraspinal muscles with extended duration of paraspinal muscle activity. In fact, Masumoto et al[20] recently reported that muscle activity during aquatic backward walking was 61% higher for the paraspinal muscles, 83% higher for the vastus medialis, and 47% higher for the tibialis anterior as compared with aquatic forward walking.

Masumoto et al,[19] in a recent study, compared aquatic backward walking and land backward walking for muscular activities by using electromyography. They found that all muscles, except for the paraspinal muscles, revealed decreased activities in aquatic backward walking as compared with land backward walking. The paraspinal muscles, on the other hand, showed a 15% to 20% increase in muscular activities during aquatic walking as compared with land walking. This result suggests that aquatic backward walking is an excellent means to target the paraspinal muscles while providing less burden on the other muscles. However, the benefits of aquatic backward walking should not be overstated for other muscle groups because the decreases in the activations of other muscle groups may not be beneficial for overall rehabilitation of the whole body.

Considering these positive traits of aquatic exercises and no reported adverse effects of the training in our study, aquatic backward walking may be recommended as a safe and effective method of lumbar extension strength rehabilitation for patients who have undergone diskectomy for a lumbar disk herniation. Especially, those who do not have access to expensive rehabilitation machines such as MedX can take advantage of aquatic exercise for lumbar extension strength improvements. However, this suggestion should be evidenced by further scientific investigation into the effects of aquatic forward and backward walking training on rehabilitation outcomes.

Study Limitations

There are a few areas of limitation to the findings presented in this study. First, the sex of recruited subjects was limited to males. The generalization of the current findings could be done in a larger scale with female subjects. Second, we examined the effect of 2 different types of lumbar extension training (aquatic backward locomotion exercise and progressive resistance exercise). However, other factors that are important for training outcomes, such as frequency and intensity, were not considered in the current study. Follow-up studies are needed to investigate the influences of frequency and intensity of the lumbar extension training. Pseudorandomization was used in this study to have 3 groups with similar physical characteristics and lumbar extension strength before the training period, which may have affected the results reported in this study. The study participants are relatively young (39.00±4.51y), and the results found in this study may not be generalizable to older patients, especially frail, elderly patients. This study used isometric torque production as a strength measure, and the study results may not be generalizable to other measurements such as isokinetic torque. Controlling muscle activations using electromyography may strengthen the results.

CONCLUSIONS

The results suggest that aquatic backward locomotion exercise is as beneficial as machine exercises for lumbar extension strength improvements in patients after diskectomy surgery.

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Suppliers

a. MedX, 1155 Northeast 77th St, Ocala, FL 32670.
b. Polar Electro Oy, Professorintie 5, FIN-90440 Kemplele, Finland.
c. Aqua Jogger Inc, 4660 Main St, #270, Springfield, OR 97478.
d. SPSS Inc, 233 S Wacker Dr, 11th Fl, Chicago, IL 60606.