



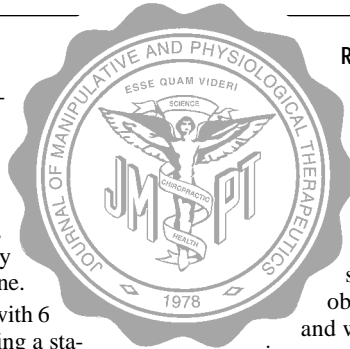
## Biomechanic Evaluation of the Rola Stretcher as a Passive Distraction Device

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### ABSTRACT

**Introduction:** Many devices have been marketed claiming to increase the mobility of the articulations of the spine with active or passive distraction. In this study, the Rola Stretcher (Unique Relief, Inc, Davenport, Iowa) and an earlier version, the True Back II (True Back, Inc, Clearwater, Fla), were evaluated to see if they have a measurable biomechanic effect on the spine.

**Methods:** Two studies were conducted, each with 6 male participants and 6 female participants, using a stadiometer to accurately measure a person's sitting height. The increase in sitting height after using the True Back II or Rola Stretcher for 10 minutes was compared with that after lying supine for 10 minutes. A third intervention, a firm foam block cut to the same size and shape as the True Back II, was also used in this study.



**Results:** The Rola Stretcher had a significantly greater lengthening effect on the spine compared with supine rest ( $P < .0050$ ). The True Back II had a similar but lesser effect ( $P < .0509$ ). Women demonstrated a greater height gain than men.

**Conclusion:** The True Back II and the Rola Stretcher in particular appear to lengthen the spine after a single use of 10 minutes. The observed discrepancy between the effects in men and women may be an experimental artifact occurring as a result of less effective resetting of the posturing mechanisms in men compared with women. A trend showed the Rola Stretcher to be more effective than the foam block. (J Manipulative Physiol Ther 2000;23:252-7)

**Key Indexing Terms:** Spine; Biomechanics; Passive Distraction

### INTRODUCTION

It is commonly thought that distraction of the spine has therapeutic value for a variety of spinal dysfunctions. Accordingly, many various methods have been marketed for inducing distraction of the spine, ranging from gravity boots to computer-controlled devices with continuously monitored biofeedback.

Some of these devices and approaches are used by chiropractors and other clinicians in conjunction with manual manipulation to increase the efficacy of the care of their patients. Some work has been done concerning the effects of hyperextension of the spine.<sup>1,2</sup> Twenty minutes of hyperextension were reported to have induced a significant but temporary height increase. This effect may have occurred as a result of water being imbibed into the intervertebral disks,

perhaps because the functional spinal unit "opens up" by pivoting on the facet joints during hyperextension.

Unfortunately, there is little specific information about most marketed devices for distracting the spine to support the theory that they have any measurable effect, other than anecdotal evidence provided by the manufacturer or distributor. A MEDLINE search yielded few papers concerning the use of active traction of the low back. One case history involved the flexion-distraction technique of manipulation,<sup>3</sup> two articles described the vertebral axial decompression therapeutic table (VAX-D) (Medical Technologies, Palm Harbor, Fla),<sup>4,5</sup> and three relevant articles were found text-searching for "passive traction."<sup>6-8</sup> These studies concerned complex equipment and procedures that must be administered by professional health care providers, reporting varying degrees of success. One study asked 20 patients with chronic low-back pain to use each of the 3 gravity traction devices in random order.<sup>9</sup> Of the 16 currently symptomatic patients, 13 (81%) reported improvement of low-back symptoms but 8 (50%) reported side effects, such as persistent headaches or persistent blurred vision.

This study was conducted to determine whether a simple device that can be used at home without professional supervision, the Rola Stretcher (Unique Relief, Inc, Davenport Iowa) and its precursor, the True Back II (True Back, Inc, Clearwater, Fla), induce a measurable biomechanic effect on the spine as a passive distraction device.

### MATERIALS AND METHODS

The True Back II (Fig 1) is a modification of an earlier device called the Ultimate Back Stretcher (Unique Relief, Inc) and a precursor to the Rola Stretcher. The central sup-

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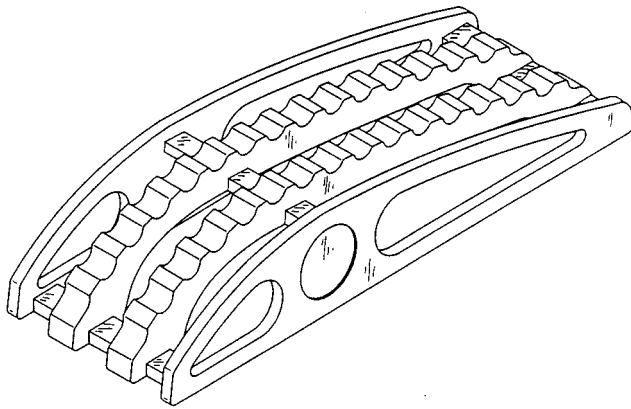


Fig 1. True Back II passive distraction device.



Fig 2. Rola Stretcher passive distraction device.

port is provided by 2 rigid rungs running the length of the device with knobs believed to have an acupuncture-type effect on the paraspinal muscles. To use the True Back II, the patient must sit on a firm surface with the device positioned immediately behind, just touching the person. The user then lays down over it in the supine position with the body as relaxed as possible. The objective is to have the user lay back as far as possible and still have all the paraspinal muscles in a relaxed state. If the user believes that his or her head was positioned too far back causing muscular tension, the head must be supported (as with a pillow) as much as needed to allow the musculature to relax.

The Rola Stretcher (Figs 2 and 3) has the same overall size and shape as the True Back II. However, the central support of the Rola Stretcher is provided by transverse symmetric rungs similar to the rungs of a bannister. These rungs are allowed to rotate freely about their longitudinal axis except for the first one and last one, which hold the unit together. This design is more comfortable for the patient because the freely rotating rungs do not pinch the skin when the patient shifts positions slightly, which can happen with the True Back II.

The third item tested was a piece of rigid foam cut to the same overall size and shape as the True Back II and Rola Stretcher. All three items were provided for evaluation by the Unique Relief Company of Davenport, Iowa.

The sitting length of the spine was measured by use of stadiometer (Fig 4). This device has guides that reach out to



Fig 3. Subject demonstrating proper use of the Rola Stretcher.



Fig 4. Stadiometer with subject in place and weights on shoulders.

the subject's back to ensure uniform posture and uses a linear variable differential transducer (LVDT) type D2/3000 (RDP Electronics) to accurately measure the relative position of the top of the head. The cylinder is held firmly in place and the plunger in the center of the cylinder rests on the top of the head of the subject because of gravity. The plunger is allowed to move freely relative to the cylinder. This provides a means of sensing the relative sitting height of the subject because the output voltage of the LVDT instrumentation is proportional to the distance that the plunger is outside of the cylinder. An aluminum block with was cut so as to have 10-mm steps to provide a means to calibrate the stadiometer. The stadiometer was used to determine a conversion factor incorporated into the software, which resulted

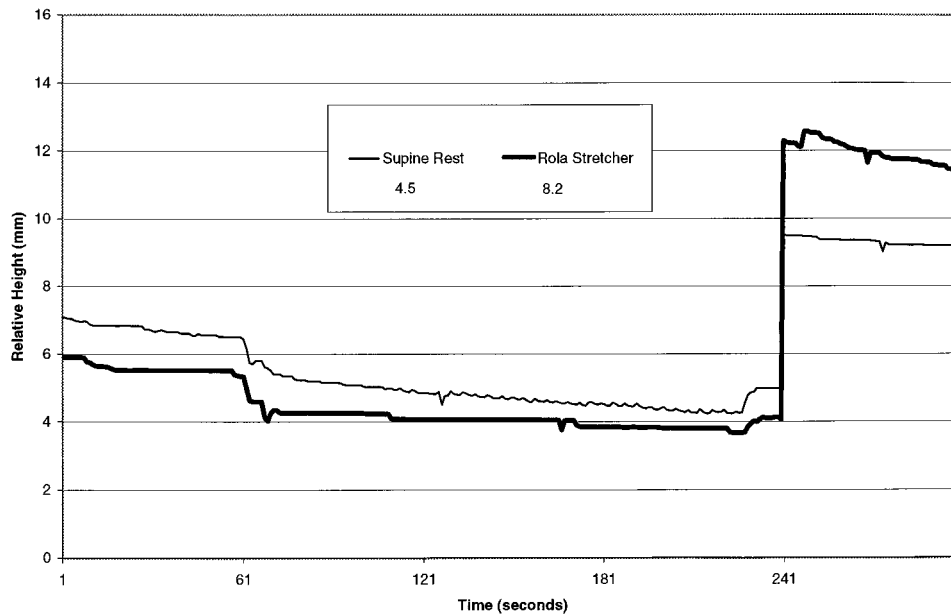


Fig 5. Plot of stadiometer data from Rola Stretcher and supine rest.

in the output of the LVDT being shown in millimeters on the computer screen in real time and on the disk file. The analog data from the LVDT was digitized with a Hewlett-Packard analog/digital board (Hewlett Packard, Inc) installed in a personal computer and used in conjunction with the stadiometer. The software that collected and stored the data from the stadiometer was written in Hewlett-Packard's HP Vee, which is specifically designed to be used with data acquisition systems. Measurements made with the LVDT are accurate to within 0.1 mm. Thus the only source of significant error is from the positioning of the subject within the stadiometer. Consequently, the study protocol calls for each subject to practice getting in and out of the stadiometer until height measurements can be made consistently, usually within 1 mm. Stadiometers are not commercially available but several have been manufactured in various countries and their use is well-documented in the literature.<sup>10-14</sup>

Two similar but separate studies were done, each including twelve subjects (6 men and 6 women). All were screened for back problems; after this evaluation, all the participants were considered normal without any known pathologic conditions. None of the subjects in the first study was used in the second study, making a total of 24 participants in the two studies.

#### Study 1: True Back II vs Curved Foam vs Supine Rest

All participants were exposed to the 3 treatments in a treatment order factorial experiment, including reclining in the supine position for 10 minutes with no support (S), lying on the curved foam cut to the shape and size of the True Back II device (C), and lying on the True Back II device (T). Subjects were randomly assigned to 1 of 6 possible orders for undergoing the treatments (TSC, TCS, CTS, CST, SCT, or STC). With twelve subjects (6 men and 6 women) in the experiment, this design permitted evaluation of sex, treatment, and order main effects, and sex by treatment and treat-

ment by treatment-order interaction effects. The sex by treatment order 2-way interaction and the sex by treatment by treatment order 3-way interaction cannot be evaluated. However, if treatment by treatment order and sex by treatment interactions are observed, concerns about a sex by treatment by treatment order interaction would arise. This design was analyzed with analysis of variance techniques by using the general linear model procedure in version 6.12 of the SAS System (SAS Institute, Cary, NC).

The procedures and requirements of the study were described, and each subject signed an informed consent form to participate. Subjects were instructed on how to use the stadiometer and practiced getting in and out of it until 3 consecutive measurements were within 2 mm. Most subjects were able to decrease the variation to less than 1 mm by completing 8 to 10 measurements. The researcher then consulted the randomization scheme established for subjects within each sex to determine the treatment order. Subjects were then instructed how to recline in the supine position with the True Back II and the curved foam devices correctly.

After this instruction, subjects began the first of 3 cycles, 1 cycle for each of 3 interventions (True Back II, curved foam, supine rest). The first part of each cycle served to reset the posturing mechanisms by having the subject lay supine on the examination table for 10 minutes followed by sitting in the stadiometer for 4 minutes. After 1 minute in the stadiometer, 10-lb weights were placed on each shoulder and removed 15 seconds before the end of the 4 minutes. The height at the end of this phase was considered the baseline for intervention. The basic protocol for use of the stadiometer was developed and reported for previous studies.<sup>1,2</sup>

The second part of each cycle served to determine how much lengthening effect a specific intervention had on the spine compared with the sitting height at the end of the first part of the cycle. After assessment of the first phase of the

**Table 1.** Summary of seated height change data from study 1 (True Back II vs supine rest vs curved foam)

Subject	Sex	Order of treatment	True Back II (mm)	Supine rest (mm)	Curved foam (mm)	T-S II-S (mm)	T-C II-C (mm)
1	M	TSC	10.5	3.4	15.8	7.1	-5.3
2	M	TCS	-0.1	4.5	8.1	-4.6	-8.2
3	M	STC	4.0	2.0	3.7	2.0	0.3
4	M	SCT	13.4	3.4	3.4	10.0	10.0
5	M	CTS	7.4	5.6	4.3	1.8	3.1
6	M	CST	0.4	2.1	2.4	-1.7	-2.0
Males			5.9	3.5	6.3	2.4	-0.4
7	F	TSC	6.4	2.8	6.1	3.6	0.3
8	F	TCS	8.2	11.6	10.8	-3.4	-2.6
9	F	STC	18.8	1.2	12.1	17.6	6.7
10	F	SCT	8.2	6.6	8.1	1.6	0.1
11	F	CTS	5.8	5.0	4.0	0.8	1.8
12	F	CST	6.4	3.7	3.4	2.7	3.0
Females			9.0	5.2	7.4	3.8	1.6
Total			7.5	4.3	6.9	3.1	0.6

TB, True Back II; S, supine rest; C, curved foam; T, True Back II.

**Table 2.** Summary of seated height change data from study 2 (Rola Stretcher vs supine rest)

Subject	Sex	Order of treatment	Rola Stretcher (mm)	Supine rest (mm)	R-S (mm)	T1 (mm)	T2 (mm)
1	M	RS	12.5	10.6	1.9	12.5	10.6
2	M	RS	8.0	8.1	-0.1	8.0	8.1
3	M	RS	3.8	7.7	-3.9	3.8	7.7
4	M	SR	8.2	3.5	4.7	3.5	8.2
5	M	SR	8.2	4.5	3.7	4.5	8.2
6	M	SR	6.9	3.4	3.5	3.4	6.9
Males			7.9	6.3	1.6	6.0	8.3
7	F	RS	8.4	9.4	-1.0	8.4	9.4
8	F	RS	12.6	-1.1	13.7	12.6	-1.1
9	F	RS	7.5	7.3	0.2	7.5	7.3
10	F	SR	15.9	6.7	9.2	6.7	15.9
11	F	SR	13.2	-1.7	14.9	-1.7	13.2
12	F	SR	20.7	1.6	19.1	1.6	20.7
Females			13.1	3.7	9.4	5.9	10.9
Total			10.5	5.0	5.5	5.9	9.6

R, Rola Stretcher; S, supine rest; T1, seated height change from the intervention applied first; T2, seated height change from the intervention applied second.

cycle, the patient was directed to recline on an examination table for 10 minutes with the intervention appropriate for their random treatment order assignment. The researcher monitored the patient during this intervention portion of the cycle to ensure proper subject positioning. After 10 minutes of an intervention, the patient's height was again measured. The outcome measure used in this study was the change in height from the end of the baseline measurement in the first part of a cycle to the height measured immediately after the application of an intervention in the second part of a cycle. Each subject completed this cycle 3 times, once for each of 3 interventions used (True Back II, curved foam, supine rest). Consequently, there are 3 outcome measurements for each subject in the first study. All measurements were taken in the morning to reduce the variability of the day's activity.

**Study 2: Rola Stretcher vs Supine Rest**

As in the first study, 12 normal subjects without known pathologic conditions were included (6 men and 6 women). In this study, 2 treatments, supine rest and the Rola Stretcher device, were considered in conjunction with subject sex and the order of treatment presentation. This study was conceptualized as the combination of two 2 x 2 Latin squares with the effects of sex and treatment order between subjects considered factors and time of presentation and treatment within subjects considered factors. Unlike study 1, all interactions involving sex and treatment were estimable.

The study 1 procedure was modified for study 2 with the obvious difference that each subject underwent only 2 cycles of the procedure because only 2 interventions were used (Rola Stretcher and supine rest).

**RESULTS**

All data taken from 1 subject testing the Rola Stretcher are shown in Fig 5. Each line represents one complete cycle. The data for each cycle begin when the subject sits in the

stadiometer immediately after 10 minutes of rest in the supine position. The relative height decreased slightly over time with a noticeable drop at 1 minute, the point at which the 10-lb weights were added to each shoulder. A slight increase can be seen at 2 minutes and 45 seconds later, when the weights were removed. The large jump just after that occurs because of the increase in height resulting from the subject lying on the intervention device for 10 minutes (which is either the Rola Stretcher or lying flat in the supine position). The specific measurement used in this study is the magnitude of the change in relative height from the end of the data with the subject in the stadiometer immediately after the initial resting for 10 minutes to the beginning of the data after the 10 minutes with the subject testing an intervention.

The subjects in study 1 (True Back II) ranged in age from 20 to 27 years, with a mean age of 23.1 years. Height changes for all patients with summary statistics for sex and treatment groups are summarized in Table 1. The height change of the patient during the curved foam test compared with supine rest and from use of the True Back II compared with the curved foam test did not show statistical significance ( $P < .11$ ,  $P < 0.70$ , respectively). The greater increase of height after use of the True Back II compared with that after supine rest was nearly statistically significant ( $7.45 \pm 5.21$  mm vs  $4.32 \pm 2.78$  mm;  $F_{1,22} = 4.27$ ;  $P < .051$ ). Examination of the overall model did not indicate statistical significance for sex ( $P < .35$ ), order effects ( $P < .72$ ), sex and treatment ( $P < .78$ ), or order and treatment ( $P < .30$ ). Although the sex and order effects were not shown to be significant, when they were incorporated into an analysis of the overall treatment effect, treatment was no longer statistically significant ( $P < .12$ ).

Although the sex and order effects were not significant, across all treatments, women showed greater height increase than men. For 4 of the 6 orders, the True Back II treatment showed greater height increases relative to the curved foam

and the supine rest conditions. In fact, only when the True Back II condition was first in order did this condition fail to demonstrate greater height increases. These results were not statistically significant; however, the power associated with these tests was low because of the small sample size. Thus the possibility of sex differences in treatment efficacy were still considered potentially relevant. The possibility that the ordering of treatments might have an effect was still considered possible. The potential for an order effect may be related to the possibility that the repeated assessment of height within a subject has some accumulated effect. Therefore to reduce this effect, the number of repeated assessments should be minimized.

The subjects in study 2 ranged in age from 19 to 55 years, with a mean age of 25.9 years. Height changes for all patients with summary statistics for sex and treatment groups are summarized in Table 2. Examination of the overall model indicated no statistical significance for sex ( $P < .38$ ), order ( $P < .83$ ), or sex by order interaction effects ( $P < .12$ ). However, statistical significance was shown for treatment, time, and sex by treatment effects. Examination of the mean height changes across the time main effect indicated that, regardless of the treatment condition, height increases were greater from the second assessment compared with the first assessment (Table 2) ( $9.6 \pm 5.34$  mm vs  $5.9 \pm 4.23$  mm;  $F_{1,8} = 6.51$ ;  $P < .035$ ). Examination of the mean height changes across the 2 treatments indicated that the Rola Stretcher produced significantly greater height increases compared with the supine position ( $10.49 \pm 4.64$  mm vs  $5.00 \pm 3.98$  mm;  $F_{1,8} = 14.42$ ;  $P < .006$ ). However, the presence of the significant sex-by-treatment interaction clouds the interpretation of the treatment main effect. Examination of the mean height increases across the 2 treatments for the male and female subjects separately indicated that although the Rola Stretcher resulted in greater height increases compared with the supine condition, the results of the Rola Stretcher for use in men was not statistically significant ( $7.93 \pm 2.80$  mm vs  $6.30 \pm 2.94$  mm;  $F_{1,8} = .64$ ;  $P < .45$ ) but was statistically significant for use in women ( $13.05 \pm 4.88$  mm vs  $3.70 \pm 4.71$  mm;  $F_{1,8} = 20.90$ ;  $P < .002$ ).

## DISCUSSION

In the initial study testing the True Back II, the curved foam was used to determine if the knobby shape of the individual rungs of the True Back II had a significant effect. It was hypothesized that the irregular shape of the rungs might stimulate muscular trigger points in a manner similar to the use of acupressure, thereby increasing the effectiveness of the device. The first study found only a slightly greater lengthening of the spine, which was not statistically significant, from the use of the True Back II compared with the use of firm foam cut to the same shape and size. The results of the spine lengthening from the use of the True Back II was nearly statistically significant compared with the results of rest in the supine position ( $P < .0509$ ). Ordering difference, based on a cumulative effect from repeated exposure to different interventions, may have been present. Therefore the

experiment was simplified by eliminating the curved foam as an intervention from the second study with the later version of the device, the Rola Stretcher.

In the second study, the Rola Stretcher was clearly more effective than supine rest. The average lengthening effect of the Rola Stretcher in study 2 was considerably greater than the lengthening effect of the curved foam in study 1 (10.5 mm vs 6.9 mm). Because different subjects were used in the Rola Stretcher and True Back II study, comparing the results of the Rola Stretcher in study 2 with the curved foam in study 1 is difficult. However, the lengthening effect of supine rest was approximately the same in both cases (5.0 mm in study 2 vs 4.3 mm in study 1). This finding suggests that the 2 sets of subjects in the 2 studies were adequately homogenous to support comparison of their results. A Student *t* test comparing the firm curved block foam with the Rola Stretcher groups ( $6.85 \pm 4.21$  mm vs  $10.49 \pm 4.64$  mm) indicated a trend toward statistical significance ( $t_{10} = 1.03$ ,  $P < .07$ ).

In study 1 testing the True Back II device, a not statistically significant trend demonstrated that women responded more than men to the use of the device. This difference was repeated in study 2 testing the Rola Stretcher; however, this time the difference in response between men and women was much greater and was statistically significant.

Anatomic or physiologic differences between men and women could cause this sex difference. However, this apparent disparity may also be caused in part by experimental artifact, such as insufficient resetting of the posturing mechanisms. In the posture-resetting effort, each shoulder was weighted with 10 lbs for all subjects, despite the fact that men are typically larger than women. The idea of a problem in resetting the posturing mechanisms is strengthened by the observation that interventions are measured as more effective when they are not the first intervention: rest yields a greater gain in height when it follows the True Back II or Rola Stretcher than it does when it precedes them. Similarly, patients tested with the True Back II or Rola Stretcher demonstrated a greater gain in height after rest in the supine-position cycle than before the supine-position cycle. Although an ordering effect may result from incomplete resetting of structuring mechanisms, it does not explain the observed sex difference.

Perhaps the best way to avoid problems that may result from incomplete resetting of the posturing mechanisms would be to begin the second cycle on the next day. Of course, beginning the second cycle on the next day raises concerns about consistency between testing periods, such as the amount of sleep the patient received the night before and the amount of time and activity since the patient woke in the morning. Furthermore, this testing strategy may cause attrition because all subjects cannot be guaranteed to return for subsequent visits.

In addition, this study involved only one 10-minute use of the device being tested. A greater effect could be induced by use for a different length of time or by repeated use of the device over a period of weeks or months. In addition, this study involved subjects without any known pathologic conditions whose spines were presumed to be functioning normally.

Both the True Back II and Rola Stretcher are targeted for persons with back pain or stiffness. It is possible that persons in that targeted group could show a greater response to the use of these devices than persons without back pain or stiffness.

This study does not directly address the issue of the therapeutic value of these devices. What this study has done is address the question of whether or not the True Back II and the Rola Stretcher have a measurable biomechanic effect on the human spine. An increased intervertebral disk height is commonly thought to lead to decreased constriction of the structures associated with the functional spinal unit and to increased freedom of motion, resulting in a better-functioning spine and a better state of being. The increase in sitting height observed in this study may occur as a result of increased intervertebral disk height resulting from water imbibition. Although the observed biomechanic effect of increased height lays the groundwork for the idea that these devices actually help their users in a significant manner, clinical studies of persons with back pain or stiffness are required to firmly establish this point.

## CONCLUSION

The Rola Stretcher and its precursor, the True Back II, appear to induce the biomechanic effect of lengthening the spine after a single use of 10 minutes, although use of the Rola Stretcher demonstrated a greater effect than use of the True Back II. The data suggest that the Rola Stretcher has a greater lengthening effect on the spine than a piece of rigid foam cut to the same size and shape. The lengthening effect appears stronger for women than for men, especially with the Rola Stretcher. This apparent disparity may be caused at least partially by insufficient resetting of the posturing mechanisms for men: ten pounds were placed on each shoulder of all subjects, despite the fact that men are typically larger than women.

## REFERENCES

1. Magnusson ML, Aleksiev AR, Spratt KF, Lakes RS, Pope MH. Hyperextension and spine height changes. *Spine* 1996; 21:2670-5.
2. Magnusson ML, Pope MH, Hansson T. Does hypertension have an unloading effect on the intervertebral disc? *Scand J Rehabil Med* 1995;21:5-9.
3. DuPriest CM. Nonoperative management of lumbar spinal stenosis. *J Manipulative Physiol Ther* 1993;16:411-4.
4. Ramos G, Martin W. Effects of vertebral axial decompression on intradiscal pressure. *J Neurosurg* 1994;81:350-3.
5. Gose EE, Naguszewski WK, Naguszewski RK. Vertebral axial decompression therapy for pain associated with herniated or degenerated discs or facet syndrome: an outcome study. *Neurol Res* 1998;20:186-90.
6. Andersson GB, Schultz AB, Nachemson AL. Intervertebral disc pressures during traction. *Scand J Rehabil Med Suppl* 1983;9:88-91.
7. Tesio L, Luccarelli G, Fornari M. Natchev's auto-traction for lumbago-sciatica: effectiveness in lumbar disc herniation. *Arch Phys Med Rehabil* 1989;70:831-4.
8. Tesio L, Merlo A. Autotraction versus passive traction: an open controlled study in lumbar disc herniation. *Arch Phys Med Rehabil* 1993;74:871-6.
9. Gianakopoulos G, Waylonis GW, Grant PA, Tottle DO, Blazek JV. Inversion devices: their role in producing lumbar distraction. *Arch Phys Med Rehabil* 1985;66:100-2.
10. Bourne ND, Reilly T. Effect of a weightlifting belt on spinal shrinkage. *Br J Sports Med* 1991;25:209-12.
11. Dowzer CN, Reilly T, Cable NT. Effects of deep and shallow water running on spinal shrinkage. *Br J Sports Med* 1998;32:44-8.
12. Garbutt G, Boocock MG, Reilly T, Troup JD. Running speed and spinal shrinkage in runners with and without low back pain. *Med Sci Sports Exerc* 1990;22:769-72.
13. McGill SM, van Wijk MJ, Axler CT, Gletsu M. Studies of spinal shrinkage to evaluate low-back loading in the workplace. *Ergonomics* 1996;39:92-102.
14. Michel DP, Helander MG. Effects of two types of chairs on stature change and comfort for individuals with healthy and herniated discs. *Ergonomics* 1994;37:1231-44.