

Shifts in Pelvic Inclination Angle and Parasympathetic Tone Produced by Rolfing Soft Tissue Manipulation

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The effects of soft tissue manipulation (Rolfing method) were evaluated on young healthy men using two dependent variables: 1) angle of pelvic inclination and 2) parasympathetic activity. Pelvic inclination was assessed by determining the angle of standing pelvic tilt (SPT) with an inclinometer. Autonomic tone was assessed by a measure of cardiac vagal tone (amplitude of respiratory sinus arrhythmia) derived from monitoring heart rate. Thirty-two subjects, preselected for exhibiting an anteriorly tilted pelvis, were randomly assigned to either an Experimental Group (n = 16) that received a 45-minute Rolfing pelvic mobilization session or a Control Group (n = 16) that received a 45-minute control session without manipulation. Dependent variables were assessed before the 45-minute session, immediately after the session, and 24 hours later. Comparing pretest to posttest assessments, the Experimental Group demonstrated a significant decrease in SPT angle and a significant increase in vagal tone. The Control Group did not show significant pretest or posttest differences. The results provide theoretical support for the reported clinical uses of soft tissue pelvic manipulation for 1) certain types of low back dysfunction and 2) musculoskeletal disorders associated with autonomic stress.

Key Words: *Autonomic nervous system, Manual therapy, Parasympathetic nervous system, Soft tissue syndromes.*

Advocates of manual therapy have largely based their methods on the traditional osteopathic premise that an integrated or balanced musculoskeletal structure will be reflected in optimal physiological function.^{1,2} According to A. T. Still

There is no real difference between structure and function; they are two sides of the same coin. If structure does not tell us anything about function, it means we have not looked at it correctly.³

It has been reported in the manual therapy literature, for example, that shifts in autonomic activity accompany

derotation of the anteriorly tilted pelvis in the sagittal plane.³⁻⁵ As the anteriorly tilted pelvis is released, a posterior pelvic shift occurs that is accompanied by changes in body temperature, arterial pulse, and breathing patterns. Presumably, these autonomic shifts involve an afferent-efferent feedback loop with mediation of peripheral autonomic outflow via higher neural centers.

According to Rolf, the founder of the Rolfing method of soft tissue manipulation and movement education, the angle of pelvic inclination is a keystone to "integrating" the body's "weight masses" in the gravitational field.⁶ Rolf hypothesized that the "balanced" or "horizontal" pelvis in the erect, standing position could be approximated clinically by the following anatomical landmarks: 1) a horizontal line connecting the superior border of the pubic symphysis and the tip of the coccyx and 2) a vertical line connecting the pubic symphysis and the anterior superior iliac spine (ASIS).³ These relationships are shown in Figure 1.

Physical therapists and physiatrists have also reported the angle of pelvic inclination in the standing position as a method of clinical assessment.⁶⁻¹⁰ 4

technique for measuring this angle⁷⁻¹⁰ that has shown strong intratester reliability⁷ is the standing pelvic tilt (SPT). **Standing pelvic tilt** is defined as the angle of inclination made by the line between the ASIS and the posterior superior iliac spine (PSIS) and its intersection with the horizontal plane (Fig. 2). Standing pelvic tilt has been assessed by three different procedures, all with intratester reliabilities of .88 or greater: 1) by determining the angle directly from radiographs,⁸ 2) by marking the ASIS and PSIS bony landmarks on the subject and calculating the angle from trigonometric formulas,^{8,9} and 3) by marking the bony landmarks on the subject and reading the angle directly from an inclinometer.^{10,13} Note that Rolf's proposed balanced pelvis would have a SPT angle of about 6 degrees (Fig. 2), as compared with an actual mean SPT angle of 8.4 degrees found in a group of 20 young healthy male subjects.⁸

Considerable clinical evidence exists that soft tissue manual therapy to the pelvic girdle reduces the angle of inclination in the anteriorly tilted pelvis.⁴⁻⁷ Thus, pelvic mobilization has been recommended as a treatment modality for certain low back dysfunctions.⁴⁻⁷ Unfor-

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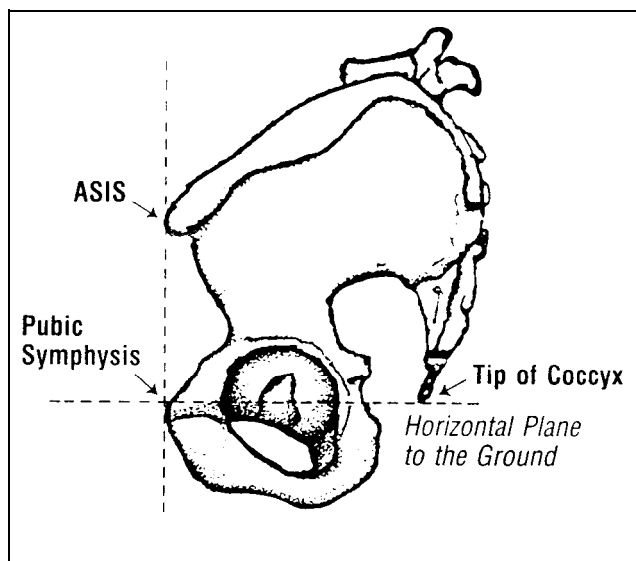


Fig. 1. Rolf's proposed "horizontal" pelvis in standing position with clinical landmarks of a horizontal line connecting the superior border of the pubic symphysis and the tip of the coccyx and a vertical line between the pubic symphysis and the anterior superior iliac spine (ASIS).

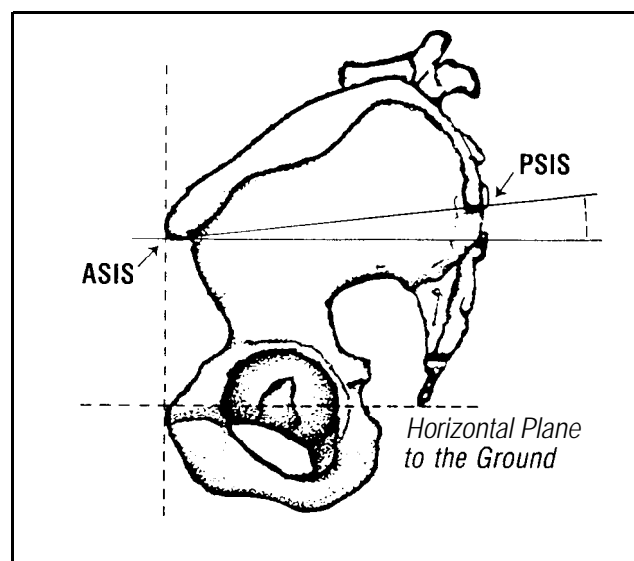


Fig. 2. Standing pelvic tilt is defined as the angle of pelvic inclination made by the line between the anterior superior iliac spine (ASIS) and the posterior superior iliac spine (PSIS) and its intersection with the horizontal plane.

tunately, these accounts are usually descriptive, involving palpation, photographs, and radiographs without proper quantification, controls, and follow-up testing.^{14,15}

Cottingham et al previously reviewed clinical accounts that describe pelvic mobilization as a treatment for certain musculoskeletal disorders associated with autonomic stress (eg, myofascial pain syndrome, restricted breathing patterns).¹⁶ They also reviewed accounts of human and animal experimental investigations concerning tactile and electrical stimulation to the pelvic region and associated autonomic reflexes.¹⁷⁻²³ Overall, both the clinical accounts and the experimental work support the contention that soft tissue pelvic manipulation increases parasympathetic nervous system (PNS) tone while dampening sympathetic nervous system (SNS) response.

Cottingham et al also demonstrated that a single three-minute manipulation—Rolfing pelvic lift—elicited a somatovisceral-PNS reflex in a group of healthy young male subjects.¹⁶ This reflex was characterized by a significant increase in PNS tone for the duration of the manipulation. A control procedure administered to the same subjects did not produce this reflex response.

Parasympathetic activity for Cottingham et al's study was assessed from variations in the heart rate pattern associated with breathing known as

respiratory sinus arrhythmia (RSA).¹⁶ Respiratory sinus arrhythmia is the rhythmic acceleration of heart rate associated with inspiration and deceleration in heart rate associated with expiration. It has been shown to be predominantly mediated by cardioinhibitory fibers of the vagi; hence, it has been proposed to be an index of cardiac PNS activity or vagal tone.²⁴⁻²⁷ Experimental investigations involving pharmacological and electrophysiological manipulations have demonstrated that the amplitude of RSA is a reliable and valid estimate of cardiac PNS tone.²⁸⁻³¹ Porges developed an accurate technique of quantifying the RSA amplitude through the application of time-series statistical techniques and labeled this procedure **vagal tone.**³¹

The purpose of this study was to examine the immediate and sustained effects of Rolfing soft tissue pelvic mobilization on two dependent variables: 1) an anatomical, "structural" variable (angle of pelvic inclination) and 2) a physiological, "functional" variable (cardiac PNS tone).

Based on the preceding review of the literature,¹⁶ we formulated two hypotheses regarding the immediate and sustained effects of soft tissue pelvic manipulation. First, for an experimental group of subjects who were preselected for exhibiting an anteriorly tilted pelvis and who received Rolfing pelvic manipulation, a decrease in the angle of

anterior pelvic tilt would be evident immediately after the session and after a 24-hour follow-up assessment. (A control group would show no changes in anterior pelvic tilt.) Second, the same experimental group would display a concurrent increase in PNS activity immediately after and 24 hours after the Rolfing pelvic manipulation. (A control group would exhibit no change in PNS tone.)

METHOD

Subjects

A sample of 32 healthy men between the ages of 21 and 35 years ($\bar{X} = 27$ years) was selected for this investigation. All subjects reported no known health problems and were nonsmokers. Subjects were also preselected for exhibiting an anteriorly tilted pelvis in the sagittal plane. An investigation by Gajdosik et al found a mean SPT angle of 8.4 degrees for 20 young healthy men, with a range of 1.66 to 17.15 degrees and a standard error of .46.⁸ Because we wanted to observe possible reductions in pelvic inclination angle, we therefore defined anterior pelvic tilt as having a SPT angle of about one standard error above this mean value (ie, $>9^\circ$). The subjects were then randomly assigned to either an Experimental Group ($n = 16$) or a Control Group ($n = 16$). At least one month before the study, both groups had received a standardized 10-session

series of the Rolwing method' and thus were equally familiarized with this soft tissue manipulative procedure. Four of the 10 sessions involved substantial pelvic manipulation.' All subjects were selected on a volunteer basis from the professional practice of the primary investigator (J.T.C.). Each subject signed an informed consent statement to participate. The consent form and procedure were approved by the Frances Nelson Health Center Board of Directors.

Instrumentation and Materials

The angle of pelvic inclination for SPT was measured by an inclinometer consisting of a universal protractor' and a bar-clamp caliper. The inclinometer was used to determine the angle formed by the horizontal plane and a line drawn between the ASIS and PSIS (Fig. 2).

Parasympathetic activity was assessed with a Vagal Tone Monitor,' a micro-computer-based device that calculates vagal tone and heart rate on-line. Electrodes were placed bilaterally on the ventral wrists of the subject, and electrocardiographic activity was monitored by an ECG amplifier.* The output of the ECG amplifier was the input to the Vagal Tone Monitor. A quiet environment was maintained with an average temperature of 25°C (range = 24°–26°C).

Procedure

Before data collection, the subjects were informed about the nature of the study. The SPT angle and PNS tone measurements were taken during three test trials: 1) before the 45-minute treatment period, 2) immediately after the treatment period, and 3) 24 hours after the treatment period. One experimenter performed and recorded all measurements for the study and was aware of subjects' group assignments. The primary investigator administered the manipulative procedure.

Pretest measurement of standing pelvic tilt. With the subject dressed in gym shorts and standing with feet parallel (internal malleoli 2 in[§] apart), the experimenter palpated the ASIS and PSIS bilaterally and marked these bony landmarks with adhesive tape. The subject

was then instructed to assume a normal standing posture with weight evenly distributed on both feet. The experimenter placed the arms of the caliper on the marked ASIS and PSIS of the right ilium and recorded the inclination angle directly from the inclinometer. This procedure was repeated for the left ilium.

Pretest measurement of parasympathetic activity. Following the SPT assessments, the subject was positioned supine on a treatment table with the electrodes on the ventral wrists. The subject was allowed five minutes to adapt to the environment. The subject's ECG activity was then monitored with the Vagal Tone Monitor for a 2.5-minute period.

Treatment period. Following the pretest assessments, the subjects in the Experimental Group received Rolwing soft tissue manipulation of the pelvic region. The three primary myofascial regions manipulated were the iliopsoas, deep hip rotator, and hamstring muscles.' The adductor and paravertebral musculature was also manipulated briefly. Each subject was positioned for the first 15 minutes on his right side, then for 15 minutes on his left side, and for the final 15 minutes in a supine position. During the treatment period, Control Group subjects were placed in the identical three positions, 15 minutes each, but did not receive the manipulative procedure.

Posttest measurements. Assessments of SPT angle and PNS activity were taken in the same manner described for the pretests.

Data Quantification and Analysis

Angle of SPT was read from the inclinometer to the nearest one-half degree. The two readings from the right and left ilia were averaged to compensate for any asymmetry between the ilia in the sagittal plane.

For the pretest, posttest, and 24-hour follow-up assessments, vagal tone and heart rate were assessed during sequential 30-second periods for 2.5 minutes. Mean values of vagal tone and heart rate were calculated for each 2.5-minute test period. The Vagal Tone Monitor calculated cardiac vagal tone by extracting the variance associated with the amplitude of RSA. The RSA amplitude variance was then transformed to the natural logarithm to normalize its distribution." Thus, vagal tone is expressed in logarithmic units on a scale of 1 to

IO. A detailed description of this procedure was presented previously."

Mixed-design analyses of variance (ANOVAs) with group as the between-subject factor and test trial as the repeated within-subject factor were calculated for SPT angle, vagal tone, and heart rate. Subsequent *post hoc* testing to identify paired differences between test trial means was determined by Tukey's Honestly Significant Difference (HSD) test. Reciprocal shifts in SPT angle and vagal tone were analyzed by sign tests for matched pairs. An alpha level of .05 was used for statistical significance.

RESULTS

Standing Pelvic Tilt

The ANOVA for SPT angle demonstrated a significant main effect for trial ($F = 20.6$; $df = 2,56$; $p < .01$) (Tab. 1). A significant group by trial interaction ($F = 12.2$; $df = 2,56$; $p < .01$), however, was also found. *Post hoc* simple-effects tests with ANOVAs for each group indicated that only the Experimental Group showed significant differences in SPT angle over the three test trials ($F = 21.3$; $df = 2,23$; $p < .0001$). To identify paired differences, Tukey's HSD test was calculated on all combinations of the three trial means of the Experimental Group. The pretest mean SPT angle was found to be significantly higher than the posttest and 24-hour follow-up test means ($p < .01$). The posttest mean was not found to be significantly different than the 24-hour follow-up mean. These relationships are illustrated in Figure 3.

Vagal Tone

The ANOVA for vagal tone demonstrated a significant main effect for trial ($F = 7.35$; $df = 2,56$; $p < .01$) (Tab. 2). A significant group by trial interaction ($F = 10.4$; $df = 2,56$; $p < .01$), however, was also found. Simple-effects tests indicated that only the Experimental Group exhibited significant mean differences in vagal tone over the three assessment trials ($F = 12.3$; $df = 2,28$; $p < .01$). Tukey's HSD test demonstrated that the posttest and 24-hour follow-up means were significantly higher than the pretest ($p < .01$). The posttest and 24-hour follow-up means for vagal tone did not differ significantly (Fig. 4).

Heart Rate

The ANOVA for heart rate indicated a significant main effect for trial ($F =$

* Sears Craftsman Universal Protractor. Sears, Roebuck & Co, Sears Tower, Chicago, IL 60684.

† Delta-Biometrics, Inc. 941 I Locust Hill Rd. Bethesda, MD 20814.

‡ Scope Service, Inc. 1015 W Main, Urbana, IL 61801.

§ 1 in = 2.54 cm.

3.26; $df = 2,56$; $p < .05$) (Tab. 3). A significant group by trial interaction ($F = 3.7$; $df = 2,56$; $p < .05$), however, was also found. Simple-effects post hoc analyses demonstrated that only the Experimental Group exhibited differences across the test trials ($F = 3.8$; $df = 2,28$; $p < .05$). To determine significant differences between the trials, Tukey's HSD test was performed. The heart rate pretest mean was found to be significantly higher than the heart rate posttest mean ($p < .05$). The heart rate pretest mean did not differ significantly from the 24-hour follow-up mean. The posttest and 24-hour follow-up means were not significantly different (Fig. 5).

Reciprocal Shifts in Standing Pelvic Tilt Angle and Vagal Tone

In the Experimental Group, 13 subjects who demonstrated a decrease in SPT angle from the pretest to the posttest showed a corresponding increase in vagal tone levels. Twelve Experimental Group subjects exhibited this reciprocal relationship from the pretest to the 24-hour follow-up assessment. Sign tests for matched pairs indicated the negative sign of the differences was significant in both cases ($p < .01$).

Identical comparisons were made in the Control Group. Sign tests for matched pairs indicated the negative sign of the differences was not significant in either case.

DISCUSSION

Data and Hypotheses

The data strongly support both hypotheses concerning the effects of soft tissue pelvic manipulation on the angle of pelvic inclination and PNS function. To our knowledge, this is the first experimental investigation that demonstrates the traditional manual therapy premise concerning anatomical structure and physiological function. Specifically, shifts in pelvic alignment are accompanied by concurrent changes in PNS activity.

The Experimental Group demonstrated a significant reduction in the SPT angle (ie, reduction in anterior pelvic tilt) following the manipulative procedure. Not only did an immediate decrease in SPT angle result in relation to the pretest, but the 24-hour follow-up assessment indicated that this shift in pelvic angle continued without a significant return toward the pretest level. The Control Group, receiving no manipula-

TABLE 1

Analysis of Variance Results for Effects of Group Classification and Trial on Standing Pelvic Tilt

Source	df	SS	MS	F
Between subjects				
Group	1	16.90	16.90	1.53
Error	28	309.74	11.06	
Within subjects				
Trial	2	16.30	8.15	20.55 ^a
Group x trial	2	9.69	4.84	12.21 ^a
Error	56	22.22	0.40	

^a $p < .01$

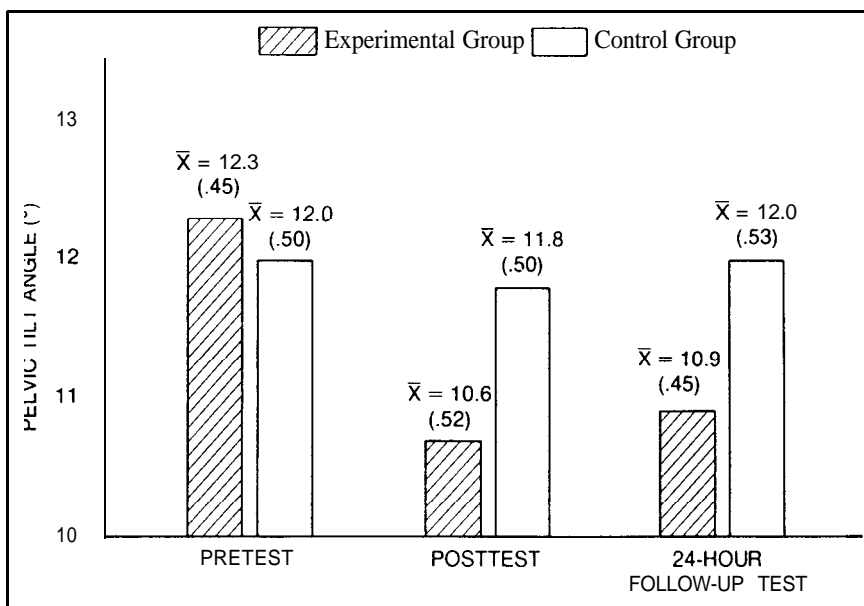


Fig. 3. Mean standing pelvic tilt angle (with associated standard error in parentheses) as a function of the test trials for the Experimental Group (Rolfing pelvic manipulation) and Control Group (no manipulation).

TABLE 2

Analysis of Variance Results for Effects of Group Classification and Trial on Vagal Tone

Source	df	SS	MS	F
Between subjects				
Group	1	5.66	5.66	3.80
Error	28	41.67	1.49	
Within subjects				
Trial	2	2.80	1.40	7.35 ^a
Group x trial	2	3.98	1.99	10.45 ^a
Error	56	10.66	0.19	

^a $p < .01$

tion, did not exhibit a significant change in anterior pelvic tilt.

Parasympathetic function, as measured by vagal tone, was found to significantly increase in the Experimental Group for both the posttest and the 24-hour follow-up test. The enhanced vagal tone showed no significant reduction from the posttest to the 24-hour follow-up. No significant changes in vagal tone were found in the Control Group. For the Experimental Group, heart rate dis-

played a significant increase in PNS activity (ie, a decrease in heart rate) in the posttest but not in the follow-up assessment. The difference in magnitude of statistical effect between vagal tone and heart rate may be due to the specificity of vagal tone as a PNS index; that is, the vagal tone measure is determined predominantly by cardio-vagal inhibitory efferents, whereas heart rate is determined by several non-PNS components in addition to vagal activity.^{16,31}

Physiological Mechanisms

Standing pelvic tilt. Manipulation and stretching of the fascial sheaths, ligaments, and tendons have long been reported by physical therapists, occupational therapists, and other manual therapists as methods of correcting pelvic rotations and related problems.^{2-4,16,33} Certainly, the reduction in anterior pelvic tilt found in those subjects who received Roling manipulation supports these clinical observations.

One possible mechanism underlying the decrease in anterior pelvic tilt may involve connective tissue's essential quality of plasticity, that is, its capacity to change shape when mechanical pressure is administered. Rolf⁴ and others^{34,35} proposed that manual pressure applied to the soft tissues produces a phase transition in the ground substance of connective tissue (eg, fascia), from a colloid "gel" (semisolid) phase to a "sol" (liquidlike) phase. On the molecular level, several authors have proposed that the glycoprotein structure of connective tissue's ground substance breaks down with the addition of heat (eg, from mechanical pressure or electrical stimulation).^{33,35-38} When pressure is removed, the ground substance "reshapes" and returns to a "transformed and hydrated" gel phase.^{4,35} An investigation that would lend further plausibility to this mechanism would involve measuring the connective tissue temperature during soft tissue manipulation and comparing this finding to the temperature needed to produce a phase transition in the ground substance.

The other possible mechanism involves changes in tone of flexor-internal rotator and extensor-external rotator muscle groups that attach to the pelvic girdle. Hunt and Massey conducted an electromyographic analysis of six basic movements before and after 10 sessions of the Roling method.³⁹ For the group receiving the soft tissue manipulation, the posttest measurements demonstrated decreased EMG activity in the antagonist muscles of several agonist-antagonist pairs, including the iliopsoas-hamstring and gluteus medius muscles and the gluteus minimus-deep lateral hip rotator muscles. Similar shifts in EMG patterns between agonist and antagonist pelvic muscle groups may account in part for the reduction in SPT angle found in our study.

Parasympathetic activity. Most theories concerning pelvic mobilization's effects on autonomic function have

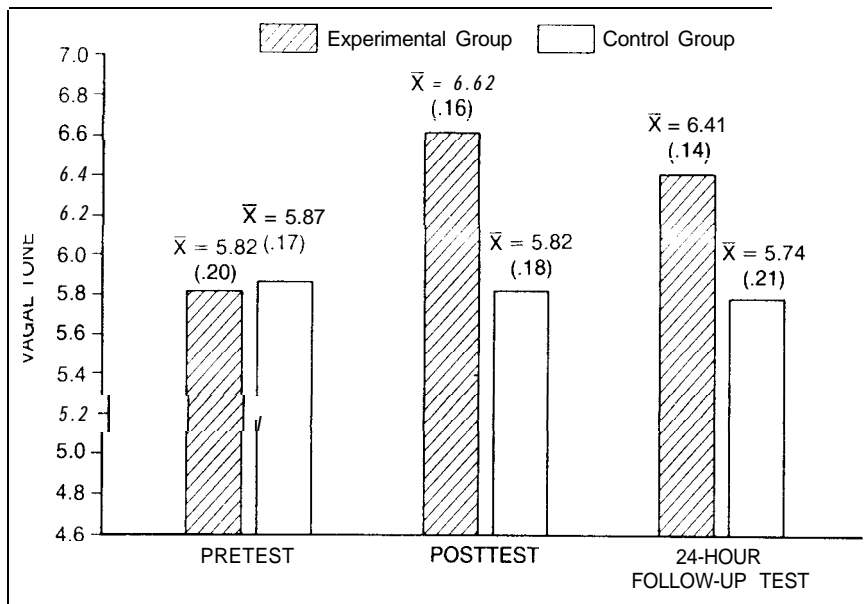


Fig. 4. Mean vagal tone (with associated standard error in parentheses) as a function of the test trials for the Experimental Group (Roling pelvic manipulation) and Control Group (no manipulation).

TABLE 3
Analysis of Variance Results for Effects of Group Classification and Trial on Heart Rate

Source	df	ss	MS	F
Between subjects				
Group	1	30.86	30.86	0.18
Error	28	4696.70	167.74	
Within subjects				
Trial	2	54.15	27.07	3.26*
Group x trial	2	59.23	29.62	3.57*
Error	56	465.00	a.30	

* $p < .05$

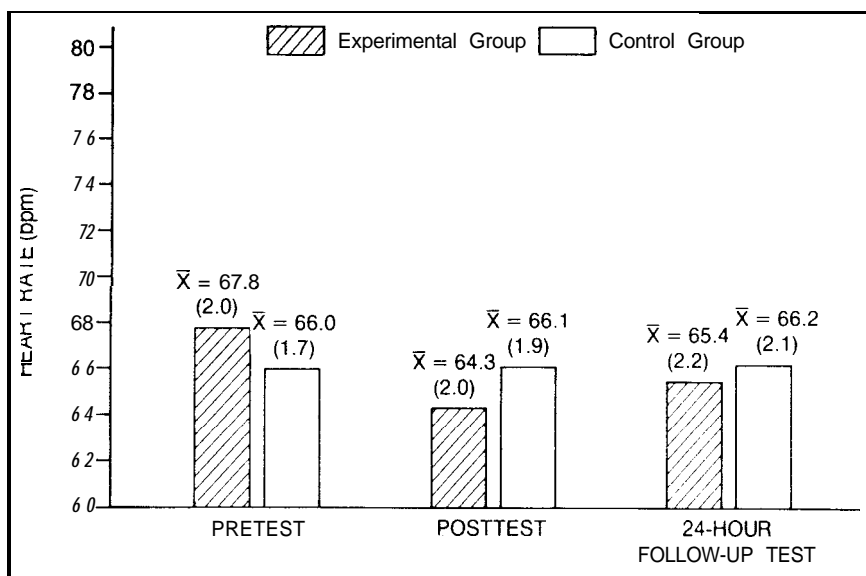


Fig. 5. Mean heart rate (with associated standard error in parentheses) as a function of the test trials for Experimental Group (Roling pelvic manipulation) and Control Group (no manipulation).

emphasized how the mechanical stimulation of local, peripheral nerves and plexuses elicit spinal and segmental autonomic reflexes.^{2-4,19}

In this study, however, the enhanced PNS activity was still apparent 24 hours after the experimental treatment. Thus, the autonomic shifts demonstrated cannot be explained entirely in terms of transient, regional somatovisceral reflexes. Instead, a sustained, systemic shift in PNS outflow appears to be modulated from supraspinal levels. Gellhorn demonstrated similar autonomic shifting, or "tuning," in animal investigations involving mechanical stimulation of afferent receptors (eg, carotid sinus) and direct electrical stimulation of higher neural centers (eg, hypothalamus).⁷ Prolonged stimulation produced autonomic changes in the direction of dominance for one autonomic branch with concurrent suppression in the other branch (law of reciprocity).^{22,40,41} Other investigators have similarly produced PNS and SNS dominance in animals through electrical stimulation of the limbic system (eg, amygdala).^{40,41}

The vagal tone data from this study provide further support for Gellhorn's construct of autonomic tuning.⁴⁰ Because vagal tone is mediated by central nervous system mechanisms²⁴⁻²⁸ and because in our study soft tissue pelvic manipulation was shown to significantly increase vagal tone levels for at least 24 hours, these pelvic manipulations apparently also produced a shift in CNS modulation of PNS activity. Thus, the mechanism possibly involves an afferent-efferent feedback loop that would include the following components: 1) stimulation of somatic and visceral afferents in the pelvic region, 2) conduction of this information up the spinal cord to supraspinal centers (eg, brain stem and hypothalamus), and 3) supraspinal modulation of peripheral auto-

nomic output (eg, cardiac vagal outflow) that in turn modifies the subsequent sensory input.^{2,41}

Clinical Implications

The results of this investigation suggest two possible clinical applications of the Rolting method of soft tissue manipulation. First, the finding that Rolting pelvic manipulation evoked a significant reduction in anterior pelvic tilt supports its use in treating certain low back problems (ie, low back dysfunction associated with anterior tilt of the sacral base and ASISs and depression of the pubic symphysis).^{6,10,42}

A second clinical implication concerns the use of the Rolting method in the treatment of certain autonomic stress disorders. The vagal tone assessments of this investigation clearly demonstrated that soft tissue pelvic mobilization produced a strong and sustained increase in vagal tone, presumably with a concurrent decrease in SNS activity. This repatterning of autonomic outflow implies a reduction of chronic SNS arousal responses and a shift toward a relaxed, attentive physiological state associated with enhanced vagal activity. Vagal tone (RSA amplitude) appears to be an index of overall CNS function as well as PNS tone and has been used to assess newborns' neurological status,³¹ attention disorders,⁴³ clinical depth of general anesthesia,⁴⁴ and autonomic stress.^{16,45} Thus, the Rolting technique may be an appropriate treatment for musculoskeletal disorders that are related to autonomic dysfunction, including myofascial pain syndromes (ie, primary fibromyalgia), restricted breathing patterns, and certain hyperactive behaviors.^{2,17,18}

This study demonstrated that soft tissue pelvic mobilization produced a 24-

hour shift in SPT angle and PNS tone in healthy young adults. The longevity of these results and the relative contribution of component manipulations in producing them, however, remains unknown. From a clinical viewpoint, these factors are extremely important in further defining appropriate therapeutic use of this modality.

CONCLUSION

A group of young healthy men, preselected for exhibiting an anteriorly tilted pelvis, were randomly assigned to either an Experimental Group (n = 16) or a Control Group (n = 16). The Experimental Group received a 45-minute Rolling soft tissue pelvic mobilization session, and the Control Group received no manipulation. In comparisons of a pretest assessment with immediate posttest and 24-hour follow-up assessments, the Experimental Group showed a significant decrease in SPT angle and a significant increase in PNS activity. The Control Group did not demonstrate significant changes in pelvic angle or PNS tone. Possible physiological mechanisms underlying these findings were discussed. The reduction in anterior pelvic tilt produced by Rolting pelvic manipulation supports its clinical use as a treatment for certain types of low back disorders. Likewise, the sustained increases in PNS (vagal) tone that followed the manipulative procedure support the Rolting technique's use in musculoskeletal dysfunctions associated with autonomic stress and characterized by excessive SNS tone and reduced PNS activity.

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