Changes in Spinal Height After Manual Axial Traction or Side Lying: A Clinical Measure of Intervertebral Disc Hydration Using Stadiometry

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Abstract

Objectives: The purpose of this study was to determine the immediate effects of a manual therapy technique consisting of axial traction compared with side lying on increased spine height after sustained loading.
Methods: Twenty-one asymptomatic participants were included. Participants either received manual therapy technique consisting of manual axial traction force for 2 consecutive rounds of 3 minutes or sustained side lying for 10 minutes. Spine height was measured using a commercially available stadiometer. Spinal height change was determined from measurements taken after loaded walking and measurements taken after manual therapy. A paired *t* test was performed to determine if a manual therapy technique consisting of axial traction increased spinal height after a period of spinal loading.
Results: A significant increase in height was found after both manual therapy technique and sustained side lying ($P < .0001$). The mean height gain was 8.60 mm using 3-dimensional axial separation.
Conclusion: This study is an initial attempt at evaluating the biomechanical effects of manual therapy technique consisting of axial traction. Both manual axial traction force and sustained side-lying position were equally effective for short-term change in spine height after a loaded walking protocol among healthy asymptomatic individuals. This study protocol may help to inform future studies that evaluate spine height after loading. (J Manipulative Physiol Ther 2019;42:187-194)
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Introduction

Low back pain has a major impact on our society. Eighty-four percent of the population will experience an acute episode of back pain.[1] According to a systematic review, the global prevalence of low back pain lasting more than 1 day is 11.9%, prevalence of low back pain of 1 month is 23.2%, prevalence of low back pain of 1 year is 38.0%, and lifetime prevalence is 39.9%.[1] The most commonly reported cause of work disability for working-age US adults between 2011 and 2013 was back and neck problems (30.3%).[2] This is important when considering that in 2013, $87.6 billion was spent treating neck and low back pain.[3]

There seems to be an association between lumbar intervertebral disc degeneration and loss of intervertebral disc height where reduced fluid exchange appears to accelerate degeneration.[4,5] Loss of intervertebral disc hydration capacity results in decreased intervertebral disc height. The result of this excess loss in intervertebral disc height may lead to decreased mechanical energy dissipation, radial intervertebral disc bulging, and increased zygapophyseal joint loading.[6] Cinotti et al hypothesized that loss in foraminal height and buckling of the ligamentum flavum, as a result of lumbar intervertebral disc degeneration, could cause the symptoms of neurogenic claudication associated with lumbar stenosis.[7] Zhao et al proposed intervertebral disc dehydration, and the resulting loss in segmental height, as being one of the possible causes of pain in degenerated discs.[5] Methods of accurately and precisely assessing the intervertebral disc capacity for imbibing and losing fluid would be helpful.

Throughout the course of the day, the spinal intervertebral discs display viscoelastic creep properties that determine an individual's overall stature.[8-10] Tyrrell et al used in vivo stadiometry measurements to detect 19.3-mm (1.1% of stature) variation in height between first arising and the end of the day.[8] Zhu et al used magnetic resonance imaging (MRI) to determine that the distance between L1 and S1 was significantly decreased (2.1%) after daily activities when comparing

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morning and evening measurements.[11] An additional study reported that the volume of intervertebral disc increased by 10.6%, attributed to a 0.9 cm^3 increase in volume, during at least 8 hours of overnight bed rest.[12] The diurnal changes in spine height could be attributed to fluid diffusion in and out of the intervertebral disc as a result of loading (decreased spine height) and unloading (increased spine height).[12-14] Contributions to the total diurnal stature loss from structures other than the intervertebral disc are minimal.[15,16]

The 2 primary methods of measuring spine height changes are MRI and stadiometry. Stadiometry has been shown to be a valid[17,18] and reliable[19,20] tool to assess spinal height compared with objectifiable measures made from MRI. Stadiometry assessment has advantages over MRI in costs, use in clinical setting, and the ability to measure participants who simultaneously sustain compressive loads of the trunk.

A variety of manual therapy techniques have been described as being effective for treating nonspecific low back pain, particularly when treatment-based classification models are applied to patients.[21-23] Despite these findings, some researchers have described inconsistencies with the application of treatment-based classification models in outcomes for patients with nonspecific low back pain.[24] Therefore, an increased understanding of the biomechanical and neurologic mechanisms that result in effective manual therapy management of nonspecific low back pain is needed.

The lumbar intervertebral disc is considered a possible source of low back pain.[25-27] Clinicians frequently use manual therapy mobilization techniques that include axial traction force for the treatment of low back pain.[28,29] These manual therapy techniques are suggested as a treatment for low back pain originating from the intervertebral disc. For example, increased spine height has been reported after high-velocity, low-amplitude thrust manipulation in low back pain patients with degenerative lumbar disc disease.[30] To our knowledge, no researchers have assessed the effects of manual therapy techniques that target the intervertebral disc through the use of manual axial traction force.

The purpose of this study was to determine whether a manual therapy technique consisting of sustained axial traction force could increase spine height.[28,29] We hypothesized that (1) a manual therapy technique consisting of a sustained axial traction force would produce an increase in spine height, and (2) sustained axial traction force would produce a greater increase in spine height than sustained side lying.

Methods

Design

A pretest, posttest crossover design was used to evaluate the effects of manual therapy technique consisting of axial traction force and sustained side-lying position on spine height change after a period of sustained loading.

Apparatus

Spine height was measured using a commercially available stadiometer (235 Heightronic Digital Stadiometer, Measurement Concepts, Quick Medical, Snoqualmie, Washington). The stadiometer was mounted to a wooden frame.

Participants

Approval for this research project was granted by the Hampton University institutional review board. A sample of convenience was used. Thirty-six participants were sampled from Hampton University's Graduate School. Participants were healthy individuals who reported neither current spine-related symptoms nor any history of spinal pain that requires consultation by a physician or hospitalization. Participants were excluded if they were unable to sit or lie for a minimum of 10 minutes without pain or discomfort, unable to carry 15 lbs, reported current upper respiratory symptoms or neurologic disorders, or had uncorrectable visual impairments. A diagnosis of spinal deformity such as scoliosis or Scheuermann's disease was excluded secondary to increased potential for anatomical intervertebral disc abnormality.

Stadiometer Measurement Protocol

All measurements were taken with participants sitting on a wooden chair, which was securely fixed to a frame. The hip, knee, and ankle were positioned according to previously published protocol.[18] The cervical spine was supported with an inflated sphygmomanometer for comfort and to assist participants with maintaining consistent body positioning. Hip and shoulder support boards were placed on the lateral most portion of the left hip and left shoulder to provide tactile cues to assist participants with maintaining consistent body position. Safety glasses with a laser pointer attached to the lateral side of the frame were worn by each participant during measurements. Participants were instructed to maintain the laser point directly on a square to maintain a consistent head position during measurements. Once the participants were correctly positioned, the head caliper was lowered and spine height readings were recorded (Fig 1).

Familiarization

Participants completed a questionnaire that included pertinent demographic and medical history information. Each participant's standing height and weight was measured. The stadiometer was calibrated according to the manufacturer's instructions before testing.

Fig 1. *Position for measuring spine height using the stadiometer.*

Fig 2. *Demonstration of manual axial traction force.*

All participants underwent a familiarization session to be trained on positioning themselves in the stadiometer. The participants positioned themselves in the stadiometer and a measurement was taken. Participants then exited the stadiometer and walked 2 laps around the room. Participants then repositioned themselves in the stadiometer and a measurement was recorded. This sequence was repeated for 10 trials. The practice session was repeated until participants were able to reposition in the stadiometer with a standard deviation (SD) of 1.3 mm or less for 5 consecutive trials.[18,31] Additional practice trials were completed until this SD was achieved.

Testing Sequence

Before initial stature measurement, participants assumed a supine position with hands resting on stomach and legs supported by a pillow for 10 minutes to normalize spine height. The investigators then recorded a stadiometer measurement. Participants completed a loading phase that was adopted from Simmerman et al: participants walked at a comfortable pace for 3 minutes with no load, then walked with a loaded backpack of 5 pounds for 3 minutes, then walked with a loaded backpack of 10 pounds for 3 minutes, followed by walking with a loaded backpack of 15 lbs for 3 minutes, for a total of 12 minutes of walking.[32] The backpack was securely fastened around the participants' shoulders to ensure uniformed weight distribution along their spine without support from the hips.

Participants were randomly assigned to 1 of 2 interventions: manual therapy technique consisting of manual axial traction force for 2 consecutive rounds of 3 minutes or sustained side lying for 10 minutes. The first eligible participant was randomly assigned to intervention via coin flip. The following eligible participant was assigned the alternative intervention. This process was repeated until all participants had been assigned an intervention. The testing sequence is summarized in Figure 2.

Participants performed sustained side lying for 10 minutes on their left side with their arms crossed, a pillow under their head, and a pillow between the knees. The participant's hip and knees were prepositioned in 45° of flexion.

A certified manual therapist performed a manual therapy technique consisting of manual axial traction force as described by Winkel et al.[29] Participants were positioned in left side-lying position, with the right hip in 45° of flexion and the right forefoot hooked behind the left leg. The participant's spine was aligned with the table break midway between T8 and L5. The participant's lumbar spine was placed in 10° of left lateral flexion by elevating the table break. This measurement was confirmed by the therapist using a goniometer to measure the angle formed by a line connecting the posterior superior iliac spines and a line connecting the midpoint of this line and the L1 spinous process. The participant's trunk was rotated to the right until the left scapula was in full contact with the table. The right arm was placed in a relaxed position with the forearm against the side of the participant's body. The left arm was placed in a relaxed position with the forearm in front of the participant.

To standardize the amount of force the therapist applied to each participant, the table height was adjusted to the level

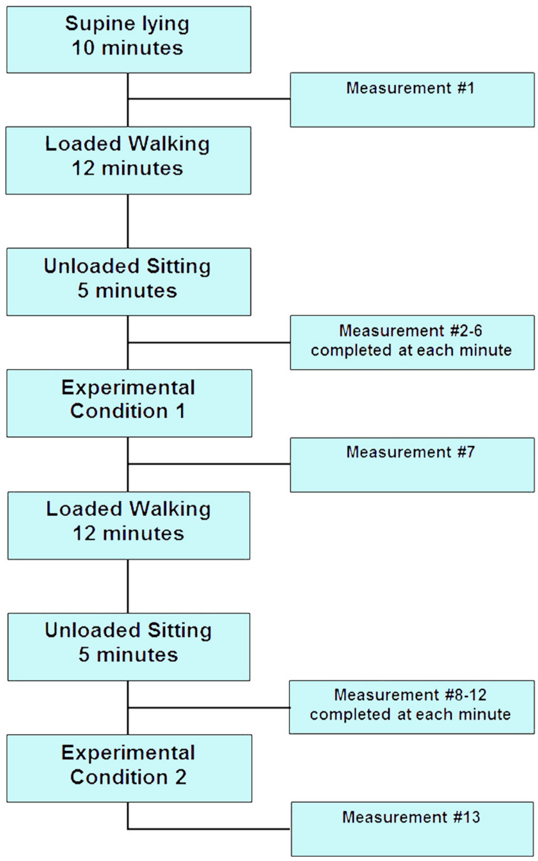

Fig 3. *Measurement sequence flow chart.*

where the participant's right greater trochanter was 100 mm above the floor. A straight line was extended from the right greater trochanter in line with the spine and onto the floor for 95 mm. The therapist placed his left anterior iliac spine 95 mm from the line extended from the greater trochanter. This allowed the therapist to stand at a consistent distance from the greater trochanter for each manual therapy trial. The therapist provided the manual axial traction mobilization force by stabilizing the participant's right shoulder while simultaneously applying an axial directed force through the right greater trochanter (Fig 3).[29]

The force being applied by the therapist was determined to be consistent based on the results of 10 consecutive manual axial traction techniques with a handheld force dynamometer. The average amount of force for the 10 trials was 9.36 kg (20.64 pounds) with SD of 0.30 kg (0.663 pounds). The therapist was able to apply a consistent force using the procedures described earlier. This was based on the relatively low coefficient of variation score for the 10 trials of 3.2%. Once data collection began, the therapist performed 2 manual axial traction techniques on each participant for 3 minutes with a 30-second rest break in between.

The investigator performing the measurements was blinded to the intervention before stadiometry measurement to prevent any potential tester bias. Spine height change as a result of intervention was calculated from the difference between the measurement after intervention and the measurement performed postloaded phase.

Statistical Analysis

Our estimated sample size was based on previously reported change in spine with side lying mean 5.8 mm and SD 4.4 mm, and spinal manual therapy mean 3.98 and SD 1.46 mm.[30,31] The effect size based on these previously reported data was 0.49. Our sample estimate was 38 participants based on a 2-tailed α level of 0.05 and a power of 0.80.[32] We were unable to reach our estimated sample size. Recruitment limitations we faced were time, space availability, and positioning criteria. We initially had 36 participants enrolled in the study, but 15 were unable to achieve correct positioning criteria during the familiarization period. Being able to reposition oneself 5× consecutively with a SD of 1.3 mm was the largest limitation.

Descriptive statistics were compiled for participants' age, height, weight, and body mass index (BMI). Independent *t* test was used for comparison of sex differences in age, height, weight, and BMI. Two separate paired *t* tests were used to evaluate if sustained manual axial traction force and sustained side lying demonstrated an increase in spinal height compared with the preceding seated loaded positions. A paired *t* test was performed to determine if significant differences existed between the changes in trunk height after 2 consecutive 3-minute trials of manual therapy consisting of a sustained axial traction force and 10 minutes of sustained side lying. Statistical analysis was performed using the Statistical Program for the Social Sciences, version 13.0 (SPSS, Chicago, Illinois). For all inferential statistics, an α level of .05 was used to determine statistical significance.

Results

Before data collection, all participants were evaluated for consistency of positioning in the stadiometer and achieved height measurement variations of 1.3 mm SD or less for 5 consecutive measurements. Of the 36 participants, 10 participants were able to achieve below 1.3 mm SD with 5 trials. Six participants were able to achieve the desired SD after 6 trials. One participant was able to achieve the desired SD after 7 trials. Two participants required 8 trials, 1 participant required 9 trials, and 1 participant required 12 trials. Fifteen participants were excluded owing to inability to achieve the desired SD within reasonable amount of trials. The mean SD for all successfully completed training sessions was 0.98 mm.

Table 1. *Summary of Demographic Information*

Variables	All Participants (n = 21)	Female (n = 14)	Male (n = 7)	*P* Values
Age (y)	25.6 (1.88)	26.1 (2.34)	25.9 (2.12)	.628
Height (m)	1.70 (0.09)	1.67 (0.09)	1.79 (5.06)	.001 [a]
Weight (kg)	75.1 (14.0)	71.2 (11.22)	86.9 (6.68)	.001 [a]
Body mass index	25.7 (3.16)	25.3 (2.45)	27.0 (1.45)	.072

[a] Statistically significant difference between groups.

Twenty-one participants (14 female and 7 male) with a mean age of 25.6 years (SD, 1.88 years) were included in the data analysis. The mean BMI was 25.2 (SD, 3.16 kg/m^2), height 1.70 m (SD, 0.09 m), and weight 75.1 kg (SD 14.0 kg). Participant characteristics are summarized in Table 1.

A significant increase in spine height was recorded between measurements taken after 12 minutes of loaded walking (mean, 877.61 mm; SD, 42.42 mm) and 2 consecutive 3-minute sessions of manual therapy technique consisting of a sustained axial traction force (mean, 886.21 mm; SD, 41.98 mm) ($P < .0001$). A significant difference was also reported between loaded walking (mean, 876.78 mm; SD, 43.73 mm) and 10 minutes of sustained side lying (mean, 885.48 mm; SD, 41.83 mm) ($P < .0001$). Of the 21 participants, 20 demonstrated increased spine height after sustained axial traction force, and 20 of 21 participants demonstrated increased spine height after 10 minutes of sustained side lying.

The mean height gain with manual therapy technique consisting of a sustained axial traction force was 8.60 mm (SD, 5.44 mm) and 8.70 mm (SD, 4.87 mm) after 10 minutes of side lying. Spine height change after unloaded sitting at 1-minute intervals, after 2 consecutive 3-minute sessions of manual therapy technique consisting of a sustained axial traction force (Fig 4), and 10 minutes of side lying seen in figures (Fig 5). The results of the paired *t* test for changes in spine height after 2 consecutive 3-minute sessions of manual therapy technique consisting of a sustained axial traction force and 10 minutes of sustained side lying showed no significant difference in spine height change ($P = .907$).

Discussion

To our knowledge, this is the first investigation to assess the immediate effects of manual therapy technique consisting of a sustained axial traction force on spine height using a stadiometer measurement protocol. Our reported change in spine height is larger than other studies that have examined spine height change with a stadiometer. We believe this may be due to differences in our spine loading protocol. Owens et al described only a 3.24-mm (SD, 3.02 mm) decrease in spine height after their seated loading phase.[18] Gerke et al described only a 3.3-mm (SD, 3.00 mm) decrease in spine height after a seated loading phase.[30] Deursen et al completed a study describing the relationship between everyday activities and spinal shrinkage and found that after 1 hour of walking, the spine height had decreased 7.9 mm (SD, 0.5 mm) using a stadiometer.[33] This decrease in spine height after 1 hour of walking is comparable to our 8.65-mm decrease in spine height after our loaded walking protocol. This suggests that our loaded walking protocol represents normal spine response to functional tasks performed throughout the day.

Both sustained axial traction force and sustained side lying demonstrated full spine height recovery after loaded walking. Gerke et al also described the same sustained side-lying position having the ability to fully recover lost spine height after a loaded seated position.[30] Simmerman described positive spine height recovery findings with both land and aquatic-based traction techniques similar to the spine height recovered after sustained axial traction force, a manual traction technique provided by a physical therapist.[34]

Decreased spine height has been attributed to loss of hydration of the intervertebral disc. Beattie et al described that the diurnal changes in spine height can be attributed to fluid diffusion in and out of the intervertebral disc through loading and unloading of the tissue.[14] Manual therapy consisting of a sustained axial traction force and sustained side lying both unload the intervertebral disc and allows for fluid to diffuse back into the tissue to increase spine height. However, our results showed that only 6 minutes of axial traction force equated to the same height recovered compared with 10 minutes of sustained side lying.

Further research is needed on manual therapy and its effects on intervertebral disc rehydration and pain perception of patients experiencing low back pain. Areas of further research should include alteration in the length of time that manual therapy consisting of a sustained axial traction force is applied, and also the amount of force applied to participants. As mentioned previously, there is a 19.3-mm loss in stature when comparing first arising and the end of the day (Tyrell et al[35]). This loss in stature can be attributed

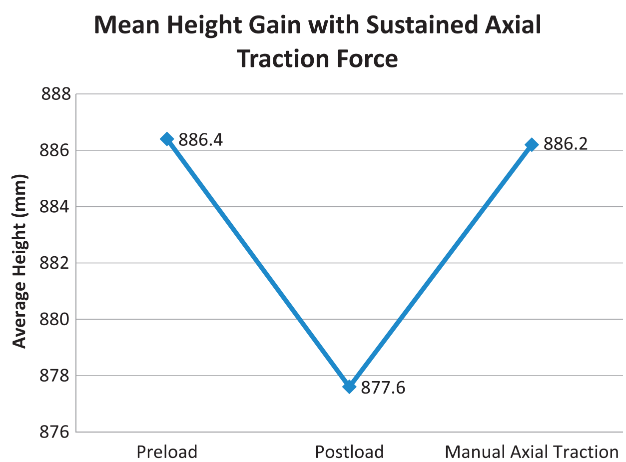

Fig 4. *Mean height gained with sustained axial traction force.*

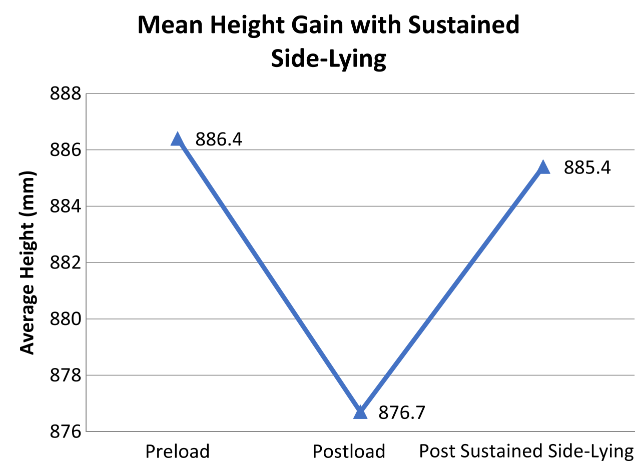

Fig 5. *Mean height gained with sustained side-lying.*

to decreased disc hydration from increased load on the spine throughout the course of the day. Further research should include manual therapy consisting of a sustained axial traction at the end of the day to determine the magnitude of the treatment effect on recovering spine height.

Limitations

The use of asymptomatic participants of a narrow age range (23-31 years) reduces the generalizability of our results to the larger population, and no inferences can be made for low back pain patient populations. Also, spinal height measurements of the participants in this study were not compared to MRI or a gold standard. Although stadiometers have been proven to be a reliable and valid tool to measure spine height, numerous manual adjustments to components of the stadiometer were required while recording data, which could potentially lead to human error while collecting data. Despite the use of a healthy population younger than 31 years, the potential for significant disc degeneration or some other undiagnosed spine pathology may have had an impact on spine height measurements. The measurements in this study were for short-term findings, thus the long-term effects of sustained axial traction force on spine height are unknown.

Conclusion

This study is an initial attempt at evaluating the biomechanical effects of manual therapy and its effect on the intervertebral disc of the lumbar spine. A manual therapy technique consisting of a sustained axial traction force and sustained side-lying position were equally effective for recovery of spine height after a loaded walking protocol among healthy asymptomatic individuals. This study protocol may help to inform future studies that evaluate spine height after loading.

Funding Sources and Conflicts of Interest

No funding sources or conflicts of interest were reported for this study.

Contributorship Information

Concept development (provided idea for the research): D.M.R., V.K., J.D., S.C.O.
Design (planned the methods to generate the results): D.M.R., V.K., J.D., S.C.O.
Supervision (provided oversight, responsible for organization and implementation, writing of the manuscript): D.M.R.
Data collection/processing (responsible for experiments, patient management, organization, or reporting data): D.M.R., V.K., J.D.
Analysis/interpretation (responsible for statistical analysis, evaluation, and presentation of the results): S.C.O.
Literature search (performed the literature search): D.M.R., V.K., J.D., S.C.O.
Writing (responsible for writing a substantive part of the manuscript): D.M.R., V.K., S.C.O.
Critical review (revised manuscript for intellectual content, this does not relate to spelling and grammar checking): D.M.R., S.C.O.

Practical Applications

- The findings of this study show the relationship of spine height change with loaded and unloaded positions of the spine.
- Both manual axial traction force and sustained side-lying position were equally effective for short-term change in spine height after a loaded walking protocol among healthy asymptomatic individuals.
- This study protocol may help to inform future studies that evaluate spine height after loading.

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