

M/C as of 11/29/01

**Orthotics: A Correlation
To Spinal
Biomechanics**

Michael Tremba
Senior Research
Project

Abstract

Objective: To determine if any positive changes on spinal gravity lines can be detected after a trial of flexible orthotic devices on subjects who exhibit asymmetric flexible pes planus and spinal towering.

Methods: Anteroposterior full spine radiographs were obtained from both pre-trial and post-trial subjects. A spinal gravity line was constructed in both that ran from the apex of the odontoid process to the second sacral tubercle. The deviation that the odontoid displayed from the point of the second sacral tubercle was measured in all radiographs.

Results: The study found that six of the seven subjects involved moved in the direction of correction.

Discussion: Biomechanical faults in the pedal foundation may cause adverse affects such as towering of the spine.

Conclusion: This study supports the need for more research to be performed on the use of orthotic devices for the correction of spinal distortions.

Introduction

The Problem

Many healthcare professionals currently agree that the body acts as a closed kinematic chain, and that low back problems can be caused by a myriad of problems in that chain. ^{ref}

These problems are often addressed by use of full spine chiropractic manipulation, soft tissue therapy, physical therapy, lifts, and a variety of other pedal orthotics. ^{ref} One area in need of study is that of foot biomechanics and the role they play in spinal biomechanics.

A useful modality to study this subject is through the use of orthotics. However, the existing problem is that relatively little study has been done on the use of orthotics, and their effect on spinal biomechanics. This project is meant to study relationships that may or may not exist between the use of orthotics in spinal biomechanics.

Background

Because the human body has been said to act as a closed kinematic chain, steps were taken to investigate specific changes in that chain through the use of orthotics (10). One study found that an insertion of orthotics showed radiographic evidence of improved weight-bearing medial longitudinal arch angles in the involved subjects (17). Another study found that orthotics provided symptomatic relief to runners who previously had lower extremity complaints (4). Still, another author finds that as the foot pronates, the knee compensates by increasing the Q-angle of the corresponding foot to a biomechanically compromised state (11). If, indeed, a closed kinematic chain does exist between the foot and other parts of the body, then perhaps spinal measurements should be studied in their relation to talar biomechanics.

Solution

Based on the previous discussion, this experiment studied the effect of orthotics on spinal mensuration. A gravity line was constructed on the full spine radiograph to observe changes that may or may not have taken place after a trial period of orthotics in the involved subjects. The gravity line was drawn from a point that ran through the apex of the odontoid process, and straight down to the bottom of the film. A measurement was taken that compared how far the apex of the odontoid lies from the second sacral tubercle, and conclusions were drawn referring to the effectiveness of orthotics on that gravity line. Thus, the hypothesis for this experiment was as follows: a trial of orthotics in patients who exhibit asymmetric flexible pes planus would achieve statistically significant results in post trial spinal gravity lines as evidenced by full spine A-P radiographs.

Review of Literature

As previously mentioned, only a small amount of collected data exists that supports the effect of foot biomechanics has on the spine. However, research has been found that supports the idea that foot biomechanics influence other structures, and is useful in establishing impetus for spinal studies (3, 11-17).

The foot, when properly functioning, is a dynamic set of joints that allows for adaptation to a variety of surfaces, thus allowing maintenance of upright locomotion and forward ambulation (3). During the toe-off phase of gait, the tibia externally rotates, the calcaneus maximally inverts, and the head of the talus firmly situates itself in the head of the navicular (6). This mechanism helps maintain the medial arch of the foot, and is also known as the supination phase, and helps the foot act as a firm hinge type of lever during toe-off (6). Conversely, during the swing portion of gait, the tibia internally rotates, the calcaneus everts, and the subtalar joint maximally inverts, and the medial arch pronates, thus preventing excess stress to the ankle joint (6). These normal characteristics of the foot help maintain a proper gait cycle. This cycle helps to maintain proper subtalar joint angles, Q-angles of the knees, and absorb shock from the ground walked upon.

Furthermore, 48% of the gait cycle is spent in the mid-swing phase (19). Based on this model, it is likely that alterations in the properly functioning foot can cause problems with many other structures involved in normal gait. In the case of pes planus, the foot loses its ability to properly lock itself in the 'hinge' type of position during toe-off, and causes abnormal stresses to be placed on the foot, as well as the structures in proximity to it (6,7).

One previous study looked at the relationship of pes planus in subjects as it related to bunions; the study finds that patients with flat feet are significantly more likely to experience bunions in their lifetime than subjects who have maintained medial longitudinal arches. Neither the cause or effect was specified in that study, but the correlation was confirmed nonetheless (1). Another study found a higher likelihood of calcaneal spurring in subjects who had a decrease in calcaneal pitch height (2). Moving up the kinetic chain, authors have shown that abnormal foot pronation is also associated with compensation in the limb above, which can be associated with injuries in the lower extremity such as patellar problems, and medial knee injuries. Orthotic devices have been indicated in patients to derotate the patella and femur while reducing the Q-angle in patients who exhibit pes planus (7,8). A study in 1991 found a statistically significant reduction in low back pain in individuals who used orthotics to correct aberrant gait patterns (14). Furthermore, an article published in 1993 described lumbar stress patterns to corresponding gait alterations; the article concluded that proper treatment of subjects with chronic low back pain was more effective than standard methods of care in alleviating

Based on the literature reviewed, it seems likely that excessive pronation of feet can be a plausible cause for alterations in spinal biomechanics as evidenced by radiographs. This study investigated spinal radiographs to observe that possibility, and conclusions were drawn from the data collected.

Materials and Methods

The subject group was a group of 20 trimester 1 students at Logan College of Chiropractic the fall of 2000. The group must have exhibited the following:

1. Ambulatory status
2. Maintained medial longitudinal arches while sitting
3. Asymmetric loss of medial longitudinal arches while standing
4. Pelvic unleveling evidenced by a full spine A-P radiograph
5. Willingness to sign a consent to participate in the study

Each student that fit this set of criterion was then fitted for orthotics based on the standard protocol of casting.

The initial radiograph was taken using a Bennett 100k Hz high frequency x-ray machine. 90 kVp was the potential with a large focal spot and MAS appropriate for the patient's A-P measurement at the central ray. The film used was Kodak 1200 speed, and the cassette was Kodak rare earth material, and a 12:1 grid was used at the bucky. The method used of obtaining the proper patient position is that of the full spine protocol as illustrated in Yochum and Rowe (18).

Each radiograph was then examined for pelvic unleveling as mentioned above. In the subjects that did show unleveling, they were then fitted for casts as also mentioned above. Orthotics were then ordered for each participant. The participants wore the orthotics for a trial of two weeks, and were radiographed again using the same method as mentioned

above. Both pre and post-trial radiographs were performed in the weight bearing position. Orthotics were in place for the post-trial radiographs. This provided the data specimens for this retrospective study.

The study observed the radiographs taken from the above-mentioned experiment. Dr. D. Robert Kuhn did all marking in a double-blind fashion. The notable observed feature was the deviation of the apex of the odontoid from the second sacral tubercle. A gravity line bisected the apex of the odontoid, and ran down the length of the film. This line compared how many millimeters the top measurement (apex of the odontoid) ^{varied} ~~lied~~ from the second sacral tubercle. This data was then collected, and that collection was analyzed using the t-test to note if a statistically significant change exists in the post-trial specimens.

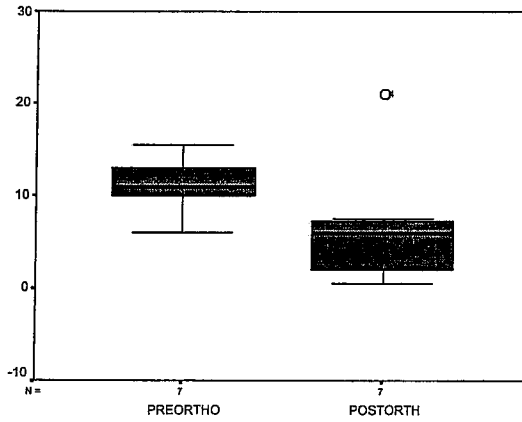
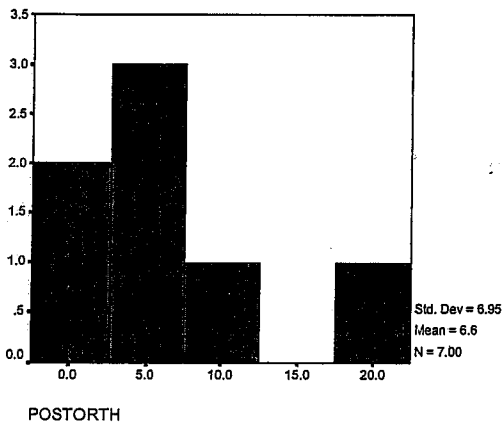
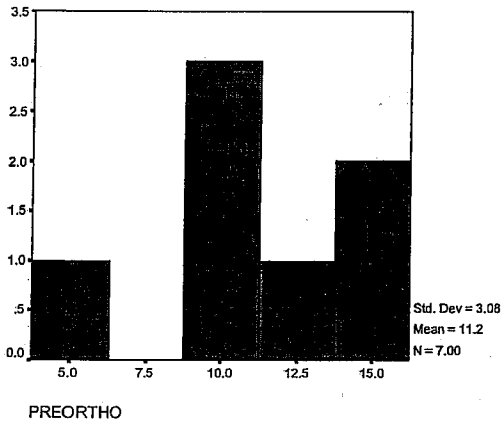
There are limitations to address in this experiment, however. Among them include patient compliance; if the subjects did not wear the orthotics, the experimenters had no way to change the study appropriately, except for exclusion of that subject. Another limitation is radiographic positioning; involuntary positioning artifacts produced by patient could have potentially distorted data. Another limitation was the interexaminer reliability of measuring each patient for pes planus using the protocol as mentioned above.

Results

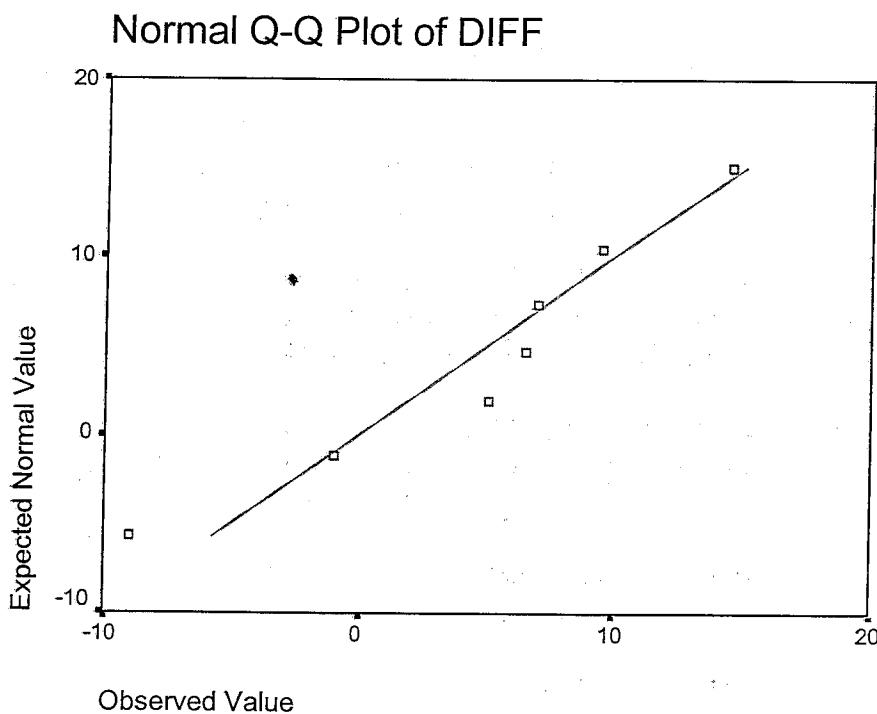
Subject	Delta Pre-Tx(mm)	Delta Post-Tx(mm)
2	R-10.0	R-3.0
4	L-14.0	L-7.5
5	L-11.0	L-6.0
7	L-12.0	L-21.0
8	R-10.0	L-0.5
9	R-6.0	L-7.0
10	L-15.5	R-1.0

Delta= mm difference the apex of the odontoid lies in relation to the second sacral tubercle

In viewing the descriptive statistics for both the pre-orthotic measurements and that of the post-orthotic measurements, one can see that there is a bimodal distribution for each. In addition, the mean amount of millimeters away from the origin point is higher before orthotic inserts are introduced.



In order to ascertain whether there is a statistical difference between the pre and post orthotic groups, it is first necessary to check for the normality of the differences. This is achieved by looking at the results of a Q-Q plot and the significance values arrived at by running a Shapiro-Wilk test. These tests show that the differences in measurement between pre orthotic use and post orthotic use are normally distributed, which suggests that the paired samples t-test is the appropriate statistical test to employ.



Tests of Normality

	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
DIFF	.233	7	.200*	.944	7	.642

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

The outcome of the paired-samples t-test show a non-significant result ($p=.16$). This allows one to conclude that there is not statistically significant evidence to suggest that there is a difference between the pre and post orthotic measurements. However, since the measurements were drawn from a limited number of subjects ($n=7$) there is a possibility that this conclusion is in error. With such a small sample size, it is plausible that even large differences could be not be detected.

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	POSTORTH- PREORTHO	-4.6429	7.6142	2.8779	-11.6848	2.3991	-1.613	6	.158

Conclusion

Based on the above research, it is clear that six out of the seven subjects involved moved in the direction of overall spinal correction, while showing a 2-tailed paired samples test with a significance of .158. Therefore, possibilities are opened through this experiment that ^{and} should be subject for further study. ^{is warranted}

One point of further study is that concerning sample size. In this experiment, the population sample was so small that a relatively small number of subjects could possibly distort the outcome to a considerable amount. Although the measurements once again showed improvement in this study, they may have been more accurately measured with more subjects. In a larger sample, a more valid argument might be made for or against the efficacy of orthotics to correct spinal distortions.

Another point to consider is that concerning the disqualification of radiographic positioning error; this particular study lacked a group to observe the possibility that positioning artifacts may or may not occur in the observed subjects. A further study should include a group to observe the accuracy of performing full spine A-P radiographs for the purpose of mensuration.

The fact that this improvement in six out of the seven subjects in this experiment gives the grounds that further studies should be performed. As this study earlier stated, little research has been done to support or refute the use of orthotics for the use of spinal correction. The author believes that more research needs to be performed on this subject.

Bibliography

1. Kalen, V., and Brecher, A. Relationship Between Adolescent Bunions and Flatfeet. *Foot and Ankle* Vol. 8, No.6 June 1988, pp. 331-336.
2. Prichasuk, S., and Subhadrabandhu, T. The Relationship of Pes Planus and Calcaneal Spur to Plantar Heel Pain. No. 306, pp. 192-196.
3. Gross, M., Davlin, L., Evanski, P. Effectiveness of Orthotic Shoe Inserts in the Long Distance Runner. *American J or Sports Medicine*, Vol. 19, No. 4, pp. 409-412.
4. Huang, C., Kitaoka, H., An, K., Chao, E. Biomechanical Evaluation of Longitudinal Arch Stability. *Foot and Ankle*. Vol. 14, No.6 July 1993, pp. 353-357.
5. Franco, A., Pes Cavus and Pes Planus. *Physical Therapy*. Vol. 67 No. 5 May 1997, pp.688-694.
6. Reigler, H., Orthotic Devices for the Foot. *Orthopaedic Review*, Vol 16, No. 5, May 1997 pp.293-303.
7. Bates, B., Osternig, L., Mason, B., James, L. Foot Orthotic Devices to Modify Selected Aspects of Lower Extremity Mechanics. *Am J Sports Medicine*. Vol.7 No.6, 1979. Pp.338-342.
8. Dahle, LO., Mueller, M., Delitto, A., Diamond, J., Visual Assessment of Foot type and Relationship of Foot Type to Lower Extremity Injury. *JOSPT* Vol. 14, No. 2 Aug. 1991. pp.70-74.
9. Bennett, P., Duplock, L., Pressure Distribution Beneath the Human Foot. *J.Am Pod.Med Assn*. Vol. 83, No.12, Dec.1993.pp.674-678.
10. Hyland, J. Weightbearing Casting: Why It's Best and How to Do It. *Foot Levelers, Inc. Bulletin* No.527.
11. Moss, R., Devita, P., Dawson, M., A Biomechanical Analysis of Patellofemoral Stress Syndrome. *J.Athletic Training*. Vol.27 No.1. 1992. pp.64-68.
12. Steadman, J. Nonoperative Measures For Patellofemoral Problems. *Am J Sports Med*. Vol.7, No.6. 1979. pp.374-375.
13. Lutter, L. The Knee and Running. *Clinics in Sports Medicine*. Vol. 4 No. 4, Oct. 1985. pp. 685-698.

14. Danaberg, H. Gait-Related Stress Leads to Chronic Low Back Pain. *Biomechanics*, July, 1998. pp.43-49.
15. Cornwall, M. Three-Dimensional Movement of the Foot During the Stance Phase of Walking. *J Am Podiatric Medical Assn.* Vol. 89. No. 2. Feb 1999. pp. 56-66.
16. Dananberg, H., Guiliano, M.I Chronic Low-Back Pain and Its Response to Custom-Made Foot Orthoses. *J Am Podiatric Assn.* Vol.89. No.3 March 1999. pp.109-117.
17. Kuhn, R., Shibley, N., Austin, W., Yochum, T., Radiographic Evaluation of Weight-Bearing Orthotics and Their Effect on Flexible Pes Planus. *JMPT.* Vol.22 No.4 May 1999. pp. 221-225.
18. Yochum, T., Rowe, L., *Essentials of Skeletal Radiology.* Vol. 2, 1996. pp. 58-59.
19. Danaberg, H. Biomechanical Management of Patellofemoral Pain and Dysfunction with Foot orthotic Devices. Ch. 13. pp. 177-223.

Orthotics Project

Informed Consent Form

I have been asked by Dr Robert R Kuhn, principle investigator, or by Michael Tremba, Senior intern to participate in the Foot Leveler's Research Project at Logan College of chiropractic. The purpose of this study is to evaluate the possible mechanisms through which orthotics may provide benefits in the area of spinal correction.

I understand that my participation in this project is voluntary and that my refusal to participate or withdraw from participation at any time will in no way result in penalty or loss of care for which I am otherwise entitled.

I understand that because of the nature of this study, I will be randomly assigned to a treatment group. Upon completion of my treatment, I will be re-evaluated, and told my results, and advised as to the options of my future care.

My participation in this project will be limited to a gait analysis, questionnaire, foot measurement, orthotic trial, and radiographic examination. I will be asked to wear the custom made orthotic devices in my shoes during daily activities for a period of two weeks. After that time, I will be re-evaluated through radiographic exam.

I understand that my participation in this project may produce no benefit to me. Furthermore, I understand that I may experience discomfort and/or bruising through the use of the orthotic devices. Last, I understand that I will be exposed to ionizing radiation in the form of X-rays that I would not otherwise experience if it were not for this study.

I also understand that my participation in this study will be held in the confidence of Dr. Robert Kuhn and senior intern Michael Tremba.

Date

Signature of subject

Print name of subject

I certify that I have explained to the above subject the nature and the purpose, the potential benefits and possible risks associated with participation in this research study, and have answered any questions that have been asked.

Date

Signature of investigator