Vertical Facial Dimensions Linked to Abnormal Foot Motion

Brian A. Rothbart, DPM, PhD*

Background: Twenty-two children from Juetepec, Mexico, were studied to determine whether a correlation exists among foot motion, the position of the innominates, and vertical facial dimensions (ie, the distances between the outer corners of the eyes [the exocanthions] and the ipsilateral outer margins of the lips).

Methods: Three null hypotheses were constructed and tested using the one-sample *t* test. Hypothesis A: there is no relationship between abnormal foot pronation and hip position; Hypothesis B: there is no relationship between hip position and vertical facial dimensions; and Hypothesis C: there is no relationship between abnormal foot pronation and vertical facial dimensions.

Results: The three null hypotheses were rejected.

Conclusions: An ascending foot cranial model was theorized to explain the findings generated from this study: 1) due to the action of gravity on the body, abnormal foot pronation (inward, forward, and downward rotation) displaces the innominates anteriorly (forward) and downward, with the more anteriorly rotated innominate corresponding to the more pronated foot; 2) anterior rotation of the innominates draws the temporal bones into anterior (internal) rotation, with the more anteriorly rotated temporal bone being ipsilateral to the more anteriorly rotated innominate bone; 3) the more anteriorly rotated temporal bone is linked to an ipsilateral inferior cant of the sphenoid and superior cant of the maxilla, resulting in a relative loss of vertical facial dimensions; and 4) the relative loss of vertical facial dimensions is on the same side as the more pronated foot. (J Am Podiatr Med Assoc 98(3): xxx-xxx, 2008)

Changes in meningeal, muscle, and facial tensions; cerebrospinal and blood pressures; cardiac rhythms; and dental or occlusal pathomechanics have all been linked to misalignments in the cranial bones.[1-9] These cranial misalignments can result in imbalances in the topography (appearance) of the face. An example is the imbalance in the vertical dimensions of the face (VFD); that is, the linear distances between the exocanthions (outer orbit of the eyes) and the ipsilateral outer margins of the lips (Fig. 1). The left side is measurably shorter than the right side (>3 mm).

Changes in weight distribution in the feet are linked to dysfunctions in the stomatognathic system: clenching shifts the body's weight distribution anteriorly, and asymmetrical loss of an occlusal supporting zone shifts the body's weight laterally.[10] In controlled studies, occlusal interferences (eg, overbites and cross bites) were linked to dysfunctions in the upper cervical spine (C1-C3) and sacroiliac joints[11] and to postural distortions in the sagittal and frontal planes of the trunk of the body.[12] A positive correlation was found between skeletal facial patterns (craniofacial morphology) and pelvic inclinations.[13] The previous studies are examples of descending postural distortion patterns.

*GRD BioMed Inc, R&D Biomechanics, 468 Main St, Safety Harbor, FL 34695. (E-mail: rothbartsfoot@yahoo.com)

During the past 35 years, I have consistently observed VFD imbalances in patients whose pronation patterns were abnormal and asymmetrical. These observations raised the following questions: 1) Are facial imbalances the result of abnormal foot pronation (eg, an ascending postural distortion pattern)? 2) If so, is there a discernible pattern? The purpose of this study was to answer these questions.

The following three research hypotheses were constructed: Hypothesis A, there is a significant positive correlation between abnormal (dynamic) foot pronation and hip position[14]; Hypothesis B, there is a significant positive correlation between hip position and VFD; and Hypothesis C, there is a significant positive correlation between abnormal foot pronation and VFD.

Methods

Foot pronation was graded according to the Foot Posture Index[15] in a modified stance position.[14] Hip patterns were determined by comparing the relative

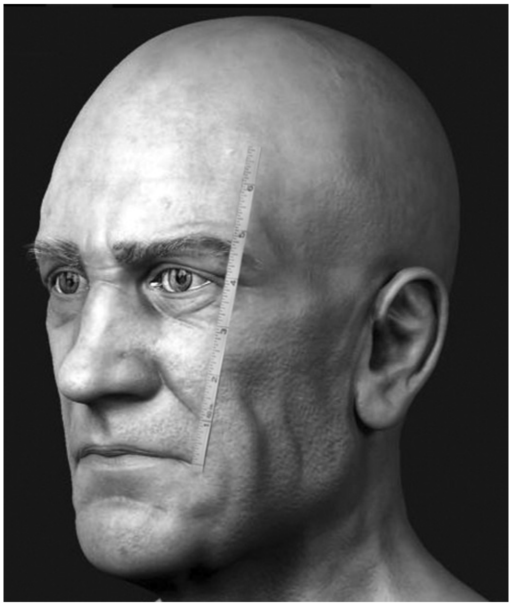

Figure 1. Vertical facial dimension. Linear distance between the outer orbit of the eye and the ipsilateral outer margin of the lip, left side of the face.

positions of the posterior superior iliac spines (standing barefoot). The VFDs were obtained by directly measuring the distance from the outer corner of the eye to the outer corner of the lip. All of the measurements were taken by the same podiatric physician (B.R.) with more than 35 years of clinical and research experience.

The following potential sources of error were identified and controlled for: 1) foot measurements required quiet standing for up to 5 min, and fatigue could impact the position of the foot (all of the subjects tolerated this measurement without fatigue); 2) subjects with excess body fat could impact the accuracy of locating body landmarks (these subjects were excluded from this study); and 3) individual differences between subjects could generate random errors (all of the subjects were taken from a genotypically homogenous population).

A physical examination was completed on each adolescent. The inclusion criteria included a Foot Posture Index greater than 2 (defined in the “Foot Position” subsection), Foot Posture Index asymmetry (between the paired feet) greater than 2, asymmetrical sagittal plane positioning of the posterior superior iliac spines, asymmetrical VFD greater than 3 mm (defined in the “Vertical Facial Dimensions” subsection), cesarean delivery births (vaginal births have been implicated as a major cause of cranial [sphenobasilar and temporal] misalignments[16]), and no orthodontic or dental interventions (iatrogenic dental work has also been linked to cranial misalignments[9, 16-19]).

One hundred sixty three indigenous Mexican children and teenagers living in Juetepec were screened. Twenty-two (17 girls and 5 boys) met the inclusion criteria and participated in this study. Their ages varied from 7 to 17 years, with a mean age of 12 years. Weights ranged from 23 to 54 kg, with a mean weight of 38 kg. Heights ranged from 1.16 to 1.65 m, with a mean height of 1.45 m (Table 1). All of the measurements were taken between August 1 and December 31, 2003, by the same podiatric physician (B.R.). Because this study did not entail any type of intervention, ethical approval was not required, or requested, by the regional Mexican government. However, parental approval was obtained before initiation of this study.

Operational Techniques

Foot Position

Abnormal pronation patterns were quantified with the Foot Posture Index (version 1.0) in a modified stance position: arms extended, forward lean against a wall, knees sufficiently bent to load the forefoot (Fig. 2). Eight criteria were graded (on a scale from –2 to +2), compiled, and summated on each pair of feet: 1) talar head position, 2) lateral malleolar curva-

Table 1. Vital Statistics of the 22 Study Patients

Subject No.	Sex	Age (y)	Weight (kg)	Height (cm)
2	F	13	41	152
3	F	10	35	142
5	F	10	30	132
6	F	9	24	127
8	F	17	51	156
16	F	12	40	152
17	F	11	37	149
18	F	13	44	154
19	F	15	46	158
23	F	16	48	155
24	F	17	50	157
31	F	12	41	153
40	F	10	34	135
41	F	8	28	127
42	F	14	47	154
43	M	10	39	153
44	M	11	45	161
45	M	15	54	165
56	M	9	30	129
57	M	10	33	131
83	F	7	23	116
95	F	8	26	125

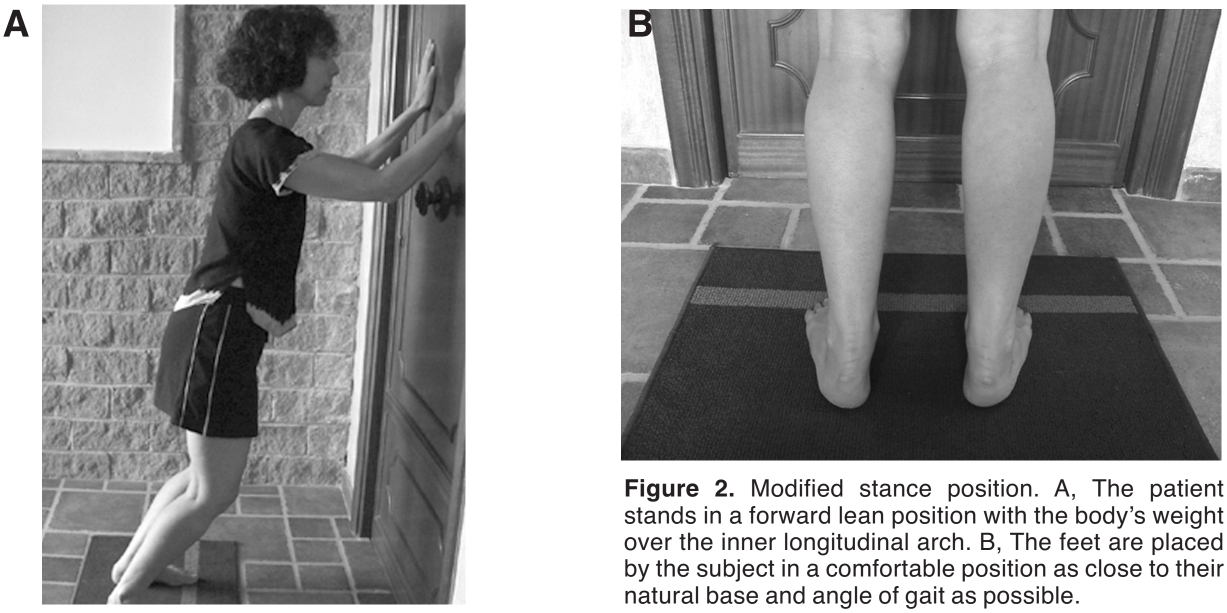

Figure 2. Modified stance position. A, The patient stands in a forward lean position with the body's weight over the inner longitudinal arch. B, The feet are placed by the subject in a comfortable position as close to their natural base and angle of gait as possible.

tures, 3) Helbing's sign, 4) calcaneal position, 5) congruency of the talonavicular joint, 6) contour and height of the inner longitudinal arch, 7) congruency of the lateral arch, and 8) position of the forefoot relative to the rearfoot. (A score of +16 identified a maximally pronated foot, and a score of –16 identified a maximally supinated foot.) Foot Posture Index scores were compared between paired feet, with the more pronated foot noted and recorded.

Redmond et al[15] investigated the overall accuracy of the Foot Posture Index by using the Cronbach α reliability coefficient. All of the components of the Foot Posture Index proved to be acceptable predictors of the total Foot Posture Index score. This provided a quantitative assessment of which foot was more pronated.

Dynamic foot motion is defined in terms of hip rotation; that is, in a closed kinetic state, internal hip rotation drives the ipsilateral (same side) foot to pronate (Fig. 3).[20] Any foot pronation occurring when the ipsilateral hip is externally rotating is, by definition, abnormal pronation.[21]

In this study, the foot pronation pattern was evaluated in a modified stance position. This modified stance position was chosen because it places the body's weight directly over the inner medial longitudinal arch. It is in this position that asymmetrical pronation patterns are most easily discernable.[22]

Hip Position

Hip position was assessed by comparing the relative positions of the posterior superior iliac spines. With the subject standing relaxed, unshod, and facing forward, the posterior superior iliac spines were located by palpation (Fig. 4). Anterior rotation of the innominates displaces the posterior superior iliac spines cephalad (upwards). Because the innominate bones rotate independently around the sacrum,[23-25] the more superiorly displaced posterior superior iliac spine identifies the more anteriorly rotated innominate bone.

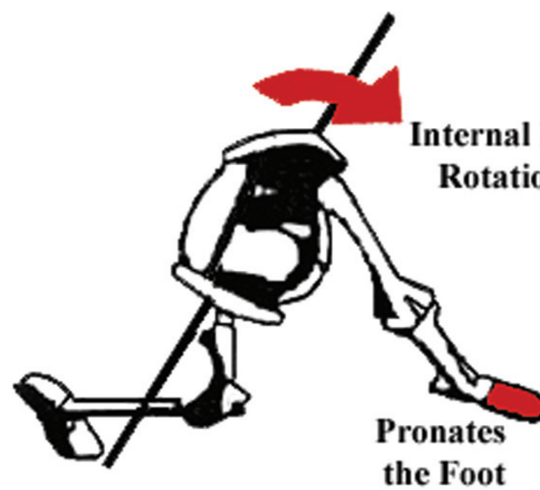

Figure 3. Hip-directed pronation (hip drive). In a closed kinetic chain, internal rotation of the left hip pronating the left foot is shown.

Figure 4. Palpation of the posterior superior iliac spines to determine the relative anterior rotation pattern of the innominates.

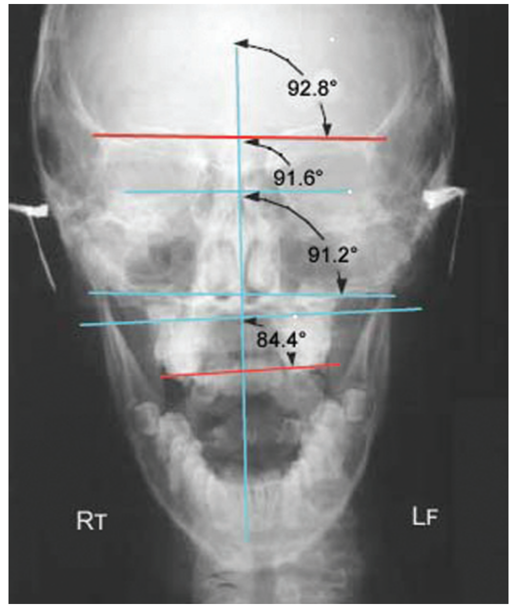

Figure 5. Dental orthogonal radiographic analysis visualizing a cranial imbalance. An inferior cant of the sphenoid (cephalad red sphenoid line) concurrent with a superior cant of the maxilla (caudal red malar line) can result in a relative loss of vertical facial dimension. This author suggests that the cant in the sphenoid and maxilla bones results from an anterior (internal) rotation of the temporal bone. The petrous acts as the axis of rotation of the temporal bone. As a point of reference, internal rotation of the temporal bone is defined as a relative medial, anterior displacement of its squama; external rotation as a relative lateral, posterior displacement of its squama. The sphenoid line is the horizontal line through the two points where the sphenoid contacts the outer rim of the orbit, and the malar line is the horizontal line through the two lowest points on the inferior border of the malar bone. (Reprinted with permission from Smith.[8])

Vertical Facial Dimensions

Asymmetry in VFD was determined by means of direct measurement. The distance between the outer orbit of the right eye and the outer margin of the right lip (the VFD) was measured three consecutive times with a tape ruler. The average was reported as the right VFD. This procedure was repeated on the left side of the face. Right and left VFDs were compared to determine the side with the "relative" shorter VFD.

Comparing anteroposterior facial radiographs with facial photographs, I noted a correlation between the VFDs and cants ("unleveling") in the sphenoid and maxilla bones (Fig. 5). Specifically, the side with the collapsed VFD frequently correlates with an ipsilateral inferior cant of the sphenoid and a superior cant of the maxilla.[26] Based on these observations, I suggest that asymmetry of the VFD (>3 mm) can be used as an indicator of imbalances in the cranial bones. This suggested paradigm is consistent with a radiographic study[27] that demonstrated cranial bone mobility.

The following null hypotheses were constructed: Hypothesis A, there is no relationship between abnormal (dynamic) foot pronation and hip position; Hypothesis B, there is no relationship between hip position and VFD; and Hypothesis C, there is no relationship between abnormal foot pronation and VFD. The one-sample *t* test (Analyse-it, version 1.73; Analyse-it Software Ltd, Leeds, England) was applied to the dichotomous variables: greatest Foot Posture Index value (left or right), highest posterior superior iliac spine (left or right), and shorter VFD (left or right). A $P < .05$ gives a high level of confidence that there is a positive correlation between the variables not attributable to chance occurrence alone.

Results

Hypothesis A (Hoa) was that there is no relationship between abnormal foot pronation and hip position. The relationship was characterized as the greatest Foot Posture Index value relative to the highest posterior superior iliac spine (2-tailed $P \leq .0001$). The pronation pattern of right greater than left occurred in 7 of 22 children (32%). The pronation pattern left greater than right occurred in 15 of 22 children (68%). The right innominate was rotated more anteriorly, relative to the left innominate, in 7 of 22 children (32%). The left innominate was rotated more anteriorly, relative to the right innominate, in 15 of 22 children (68%). This correlates fairly closely to the observation of Zink and Lawson[28] of predominant left anterior innominate rotation in approximately 75% of his tested population.

Hypothesis B (Hob) was that there is no relationship between relative hip position and relative loss of VFD (2-tailed $P \leq .0001$). Hypothesis C (Hoc) was that there is no relationship between the relative loss of VFD and the more pronated foot (2-tailed $P \leq .0001$). The three null hypotheses (Hoa, Hob, and Hoc) were rejected.

The following positive correlations were noted: 1) the more pronated foot was ipsilateral to the more anteriorly rotated innominate (Table 2), 2) the more anteriorly rotated innominate was ipsilateral to the side with the smaller VFD (Table 3), and 3) the more pronated foot was ipsilateral to the side with the smaller VFD (Table 4).

Discussion

The results of this study suggest that imbalances in the pelvis and face (VFD) can result from abnormal,

Table 3. Relationship Between Relative Hip Position and Relative Loss of VFD

Subject No.	Highest PSIS	Shorter VFD
2	Right	Right
3	Right	Right
5	Left	Left
6	Left	Left
8[a]	Left	Right
16	Left	Left
17	Left	Left
18	Left	Left
19	Left	Left
23	Left	Left
24[a]	Right	Left
31	Right	Right
40	Left	Left
41	Right	Right
42[a]	Right	Left
43	Right	Right
44	Left	Left
45	Right	Right
56	Left	Left
57	Left	Left
83	Left	Left
95	Left	Left

Abbreviations: PSIS, posterior superior iliac spine; VFD, vertical facial dimension.

[a]Not ipsilateral.

Table 2. Relationship Between the More Pronated Foot and Hip Position

Subject No.	Greatest FPI	Highest PSIS
2	Right	Right
3	Right	Right
5	Left	Left
6	Left	Left
8	Left	Left
16	Left	Left
17	Left	Left
18	Left	Left
19	Left	Left
23	Left	Left
24[a]	Left	Right
31	Right	Right
40	Left	Left
41	Right	Right
42[a]	Right	Left
43	Right	Right
44	Left	Left
45	Right	Right
56	Left	Left
57	Left	Left
83	Left	Left
95	Left	Left

Abbreviations: FPI, Foot Posture Index; PSIS, posterior superior iliac spine.

[a]Not ipsilateral.

Table 4. Relationship Between the More Pronated Foot and the Relative Loss of VFD

Subject No.	Greatest FPI	Shorter VFD
2	Right	Right
3	Right	Right
5	Left	Left
6	Left	Left
8[a]	Left	Right
16	Left	Left
17	Left	Left
18	Left	Left
19	Left	Left
23	Left	Left
24	Left	Left
31	Right	Right
40	Left	Left
41	Right	Right
42[a]	Right	Left
43	Right	Right
44	Left	Left
45	Right	Right
56	Left	Left
57	Left	Left
83	Left	Left
95	Left	Left

Abbreviations: FPI, Foot Posture Index; VFD, vertical facial dimension.

[a]Not ipsilateral.

asymmetrical pronation patterns in the feet. However, not all pelvic imbalance patterns are ascending in nature. For instance, prior studies have reported sacral imbalances developing from cranial imbalances (eg, descending patterns).[29-32] Thus, pelvic or VFD imbalances can be the result of abnormal foot pronation (ascending) or cranial imbalances (descending).

Not all abnormal, asymmetrical pronators demonstrate asymmetrical VFDs. In the screening process, 47 pronators were excluded from this study because they exhibited no VFD imbalances: 28 had sacroiliac imbalances, 11 had pelvic and cervical imbalances, and eight had no discernable imbalance patterns. Apparently abnormal foot motion can, and does, impact different patients at different levels. Herein, all 22 children had the primus metatarsus supinatus foot type.[22]

A gravitational model, referred to as the ascending foot cranial model,[33] was theorized to explain the correlations among the feet, the pelvis, and VFD (Fig. 6): 1) due to the action of gravity on the body, abnormal foot pronation (inward, forward, and downward rotation) displaces the innominates anteriorly (forward) and downward, with the more anteriorly rotated innominate corresponding to the more pronated foot[14]; 2) anterior rotation of the innominates draws the temporal bones into anterior (internal) rotation, with the more anteriorly rotated temporal bone being ipsilateral to the more anteriorly rotated innominate bone; 3) a relatively more anteriorly rotated right temporal bone is linked to a right inferior cant of the sphenoid and right superior cant of the maxilla, which results in a relative loss of VFD on the right side of the face; 4) a relatively more anteriorly rotated left temporal bone is linked to a left inferior cant of the sphenoid and a left superior cant of the maxilla, which results in a relative loss of VFD on the left side of the face; and 5) the relative loss of VFD is on the same side as the more pronated foot.

Many authors[28, 34-38] have suggested a more detailed explanation of the pathomechanics linking the pelvis to the cranial misalignments. However, none of these studies were statistically based or looked at foot mechanics.

Conclusion

Twenty-two Mexican children participated in a study to determine whether a positive correlation exists among foot pronation, innominate rotation, and VFD. All of the subjects were evaluated for pronation patterns (which foot was more pronated), hip positions (which posterior superior iliac spine was higher), and VFD (which side was smaller). Plausible null premises (Hoa, Hob, and Hoc) were constructed and tested

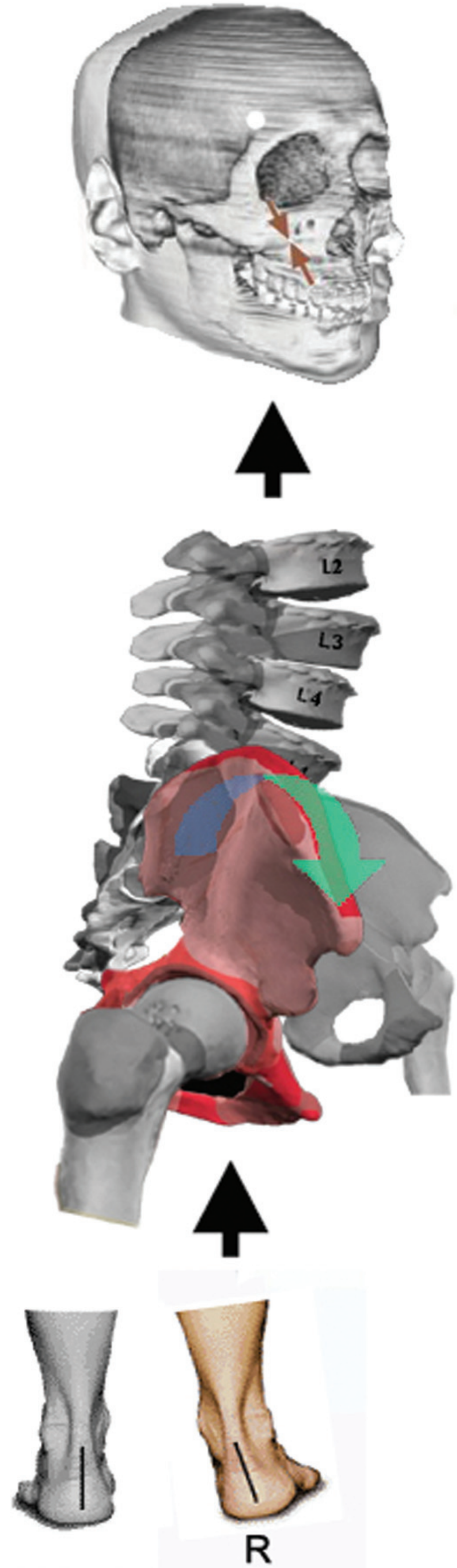

Figure 6. Ascending foot cranial model. The right foot is more pronated, the right innominate is more anteriorly rotated, and the vertical facial dimension is smaller on the right side of the face (red arrows).

using the one-sample t test. The null premises were rejected. A positive correlation was found linking the relatively more pronated foot to the relatively more anteriorly rotated innominate and to the shorter VFD. A theoretical ascending foot cranial model was constructed to explain these findings.

The sample size used in this study (N = 22) was too small to be definitive; hence, there is a need for more statistical studies with larger samples. Also, this study would have been improved if the foot, hip, and facial measurements were repeated by two or more investigators using a double-blind protocol, and the pronation patterns were evaluated dynamically instead of statically. However, at this time, no future studies are planned.

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Conflict of Interest: None reported.

References

1. Tettambel M, Cicora A, Lay E: Recording of the cranial rhythmic impulse. J Am Osteopath Assoc **78:** 149, 1978.
2. Upledger JE, Retzlaff EW, Vredevood MFA: Diagnosis and treatment of temporoparietal suture head pain. Osteopath Med **(July):** 19, 1978.
3. Babler WJ, Persing JA: "Experimental Alteration of Cranial Suture Growth: Effects on the Neurocranium, Basic Cranium, and Midface," in *Factors and Mechanisms Influencing Bone Growth*, p 333, Alan R Liss Inc, New York, 1982.
4. Retzlaff EW, Upledger JE, Mitchell FL Jr, et al: Aging of cranial sutures in humans [abstract]. Anat Rec **193:** 663, 1979.
5. Foley WJ, Kokich VG: The effects of mechanical immobilization on sutural development in the growing rabbit. J Neurosurg **53:** 794, 1980.
6. Blum C: Biodynamics of the cranium: a survey. Cranio **3:** 164, 1985.
7. Behrents RG, Carlson DS, Abdelnour T: In vivo analysis of bone strain about the sagittal suture in macatta mulatta during masticatory movements. J Dent Res **57:** 904, 1978.
8. Smith G: Craniodontics: new technology of the twenty-first Century. ICNR Web site. http://www.icnr.com/articles/craniodontics.html. Updated 2005. Accessed March 31, 2008.
9. Gelb H, Gelb M: "An Orthopedic Approach to the Diagnosis and Treatment of Craniocervical Mandibular Disorders," in *New Concepts in Craniomandibular and Chronic Pain Management*, ed by H Gelb, p 215, Mosby-Wolf, London, 1994.
10. Yoshino G, Higashi K, Nakamura T: Changes in weight distribution at the feet due to occlusal supporting zone loss during clenching. Cranio **21:** 271, 2003.
11. Fink M, Wahling K, Stiesch-Scholz M, et al: The functional relationship between the craniomandibular system, cervical spine and sacroiliac joint: a preliminary study. Cranio **21:** 202, 2003.
12. Nicolakis P, Nicolakis M, Piehslinger E, et al: Relationship between craniomandibular disorders and poor posture. Cranio **18:** 106, 2000.
13. Lippold C, Danesh G, Schilgen M, et al: Relationship between thoracic, lordotic and pelvic inclination and craniofacial morphology in adults. Angle Orthod **76:** 779, 2006.
14. Rothbart BA: Relationship of functional leg-length discrepancy to abnormal pronation. JAPMA **96:** 499, 2006.
15. Redmond A, Burns J, Ouvrier R, et al: An initial appraisal of the validity of a criterion based, observational clinical rating system for foot posture. J Orthop Sports Phys Ther **31:** 160, 2001.
16. Frymann V: Relation of disturbances of craniosacral mechanisms to symptomatology of the newborn: study of 1,250 infants. J Am Osteopath Assoc **65:** 1059, 1966.
17. Wheaton C: "Mandibular Rest Position: Relationship to Occlusion, Posture and Muscle Activity," in *New Concepts in Craniomandibular and Chronic Pain Management*, p 163, Mosby-Wolf, London, 1994.
18. Rocabado M, Johnston BE Jr, Blakney MG: Physical therapy and dentistry: an overview. J Craniomandibular Pract **1:** 46, 1983.
19. Huggare J, Pirttiniemi P, Serlo W: Head posture and dentofacial morphology in subjects treated for scoliosis. Proc Finn Dent Soc **87:** 151, 1991.
20. Inman VT, Mann RA: "Biomechanics of the Foot and Ankle," in *DuVries' Surgery of the Foot*, ed by VT Inman, 3rd Ed, p 3, CV Mosby, St Louis, 1973.
21. Rothbart BA, Estabrook L: Excessive pronation: a major biomechanical determinant in the development of chondromalacia and pelvic lists. J Manipulative Physiol Ther **11:** 373, 1988.
22. Rothbart BA: Medial column foot systems: an innovative tool for improving posture. J Bodyworks and Movement Ther **6:** 37, 2002.
23. Mitchell F Jr, Mitchell P: "Evaluation and Treatment of the Pelvis and Sacrum," in *The Muscle Energy Manual*, Vol 3, p 94, MET Press, East Lansing, MI, 1999.
24. Denslow J, Chace I: Mechanical stresses in the human lumbar spine and pelvis. J Am Osteopath Assoc **61:** 705, 1962.
25. Rothbart BA: Postural distortions: the foot connection. Online Journal of Sports Medicine. 2004. http://www.sportmedicina.com/postural_imbalances.htm. Accessed September 1, 2004.
26. Rothbart BA: Ascending and descending patterns. Proprioceptive Stimulation: An Effective Therapeutic Tool in Resolving Chronic Pain by Correcting Postural Distortions (Poor Posture): Prof/Dr Rothbart's Site for Health Care Researchers. http://www.rothbartsfoot.info/BiteToPelvis.html. Accessed March 7, 2006.
27. Oleski SL, Smith G, Crow WT: Radiographic evidence of cranial bone mobility. Cranio **20:** 34, 2002.
28. Zink G, Lawson W: An osteopathic structural examination and functional interpretation of the soma. Osteopath Ann 7: 12, 1979.
29. Gregory TM: Temporomandibular disorder associated with sacroiliac sprain. J Manipulative Physiol Ther **16:** 256, 1993.
30. Blum C: Chiropractic and dentistry in the 21st century. Cranio **22:** 1, 2004.
31. Denton DG: From head to foot. Basal Facts **8:** 203, 1986.
32. Fink M, Wahling K, Stiesch-Scholz M, et al: The functional relationship between the craniomandibular sys-

tem, cervical spine and the sacroiliac joint: a preliminary investigation. Cranio **21:** 202, 2003.
33. Rothbart BA: Ascending foot cranial model. Proprioceptive Stimulation: An Effective Therapeutic Tool in Resolving Chronic Pain by Correcting Postural Distortions (Poor Posture): Prof/Dr Rothbart's Site for Health Care Researchers. http://www.rothbartsfoot.info/AFCM.html. Accessed October 5, 2006.
34. Kuchera W, Kuchera M: *Osteopathic Principles in Practice*, Rev, 2nd Ed, p 336, Greyden Press, Columbus, OH, 1993.
35. McManus I, Bryden M: Geschwind's theory of cerebral lateralization: developing a formal, causal model. Psychol Bull **110:** 237, 1991.
36. Rea W, Casner VH, Denslow JS, et al: A progressive structural study of school children: an 8 year study of children in the rural areas of Adair County, Missouri. J Am Osteopath Assoc **51:** 155, 1951.
37. Strachan F, Robinson M: Short leg linked to malocclusion. Osteopathic News **(April):** 1965.
38. Milani R, De Periere DD, Lapeyre L, et al: Relationship between dental occlusion and posture. Cranio **18:** 127, 2000.