IMPROVED KNEE ALIGNMENT

IMMEDIATE CHANGES IN THE QUADRICEPS FEMORIS ANGLE AFTER INSERTION OF AN ORTHOTIC DEVICE

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INTRODUCTION

Hyperpronation of the foot causes many different stresses on the lower extremity joints and soft tissues.1 This changes the quadriceps femoris angle (Q-angle), which has been associated with chondromalacia patella and lateral displacement of the patella.1 The Q-angle has been defined as the angle formed by the line connecting the anterior superior iliac spine (ASIS) with the center of the patella and the line connecting the tibial tuberosity to the center of the patella.1,2

Normal mean values for the Q-angle are 13.5˚ ± 4.5˚ in healthy subjects between 18 and 35 years of age.1 Comparatively, women have a larger mean Q-angle of 15.8˚ ± 4.5˚ than men (11.2˚ ± 4.5˚).1

There have been a number of studies regarding the Q-angle and its relationship to anterior knee pain, standing and supine measurements, force on the patella in the frontal plane, shin splints, and others.2 However, we were unable to locate studies that examined the effects of a full-length, custom-made, flexible orthotic on the Q-angle, The purpose of this study was to evaluate the change in the Q-angle measurement in patients with bilateral hyperpronation of the foot after insertion of a custom-made orthotic.

METHODS

The study population was derived from a sample of male students enrolled at Logan College of Chiropractic and patients from the Montgomery Health Center, Inclusion criteria consisted of male subjects with bilateral hyperpronation who were asymptomatic and had no history of known ankle surgery, The selection of only male patients helped homogenize our study population and served to eliminate any confounding variables arising from different normal Q-angle values for men and women. A total of 40 men were included in the study population, and each subject read and signed a consent form which had been approved by the Logan College of Chiropractic Research Committee.

To determine whether subjects showed bilateral hyperpronation, the following examination protocol was used. The subjects were observed for any evidence of external rotation or toe-out during the plant phase of gait, their shoes were examined for excessive lateral wear, evaluation for Achilles tendon bowing was made, and observation of the height of the medial arch during non-weight-bearing and weightbearing conditions was made. The height of the arch was assessed in both weight bearing and non-weight bearing. The results were recorded in millimeters. This constitutes the navicular drop test, as described by Brody.3

An orthotic cast was made for both feet by using a standard Foot Levelers (Roanoke, Va) casting kit and standard casting protocol. The cast was made for a full-length, custom -made, flexible orthotic. The Q-angle was measured with a 12-inch goniometer with a 24-inch extension arm. The extension arm was made of clear plastic and was l/8-inch thick, 2 inches wide, and 24 inches long. The subjects' Q-angles were measured in a standing extended knee position in their daily footwear. One examiner was responsible for the measuring of the Q-angle. When the examiner achieved 2 identical measures, the Q-angle for that limb was recorded. The landmarks used to enhance accuracy of the Q-angle measure were as follows. A single dot was placed on the skin over the center of both patellae with a grease pencil, followed by the marking of this skin over the tibial tuberosity and the anterior superior iliac spine bilaterally. The center axis of the goniometer was placed over the patellar dot, with the short arm of the device directed toward the tibial tuberosity and the extended arm directed at the ASIS. Each subject was measured with and without the orthotics in place in the manner previously described. Because we were searching for an immediate effect on the Q-angle subsequent to the insertion of the orthotics, the order in which these measurements were obtained did not matter. Thus, the evaluator responsible for measuring the Q-angle was not informed about whether the exam was being performed with or without the orthotics in place. A separate investigator was responsible for the flow of subjects and recording the results in the appropriate category. The results were recorded in "before orthotic insertion" and "after orthotic insertion" categories. Each of these was done for the right and left limb. The data set was collected and assessed by using the t test program in Microsoft Excel (Redmond, Wash).

RESULTS

Forty subjects had a mean Q-angle of 12.1˚ ± 2.6˚ on the left and 11.8˚ ± 2.4˚ on the right, with a range of 8˚ to 19˚. After insertion of the orthotics, subjects had a mean Q-angle of 9.6˚ ± 25˚ on the left and 9.5˚ ± 2.2˚ on the right, with a range of 5° to 18°. This represents a significant mean reduction of the Q-angle by 2.5˚ [2-tailed, matched sample, $t (39) = -7.31$, $P < .01$] on the left and 2.3˚ and 2-tailed matched sample, [$t (39) = -9.25$, $P < .01$)] on the right (Tables 1, 2, and 3).

Before orthotic insertion, there was a 2.3° mean asymmetry between the left and right Q-angle within subjects. After orthotic insertion, there was a 1.4° mean asymmetry between Q-angles. This resulted in a significant decrease of .9˚ [1-tailed, matched sample, $t (39) = -3.26$, P < .OJ in the left and right asymmetry of the Q-angles within the population. Furthermore, the population with a Q-angle asymmetry greater than 4° (n = 8) realized a larger reduction in Q-angle asymmetry after orthotic insertion (mean before, 4.9˚; mean after, 2.1˚). A larger sample size is necessary to establish statistical significance. We feel this trend may be important •for individuals experiencing altered lower extremity function associated with a large asymmetry in right and left Q-angle measurements.

DISCUSSION

An increase in the Q-angle can occur as a result of internal femoral torsion and excessive foot pronation, which may cause genu valgum or coxa vera. Hyperpronation leads to internal tibial rotation, followed by compensatory internal rotation of the femur, resulting in an increase in the lateral tracking of the patella.4 ,5 This excessive tibial rotation transmits abnormal forces upward to the knee, changing the force vectors of the quadriceps muscle, and causes lateral displacement of the patella.4, 5 As the patella displaces laterally, the Q-angle is subsequently increased. As the patella tracks over the femoral condyles, erosion of tbe patellar and femoral cartilage can occur. In addition, the hyperpronated foot may produce a preloading stress on the anterior cruciate ligament, thus rendering it susceptible to injury.5 Asymmetrical pronation patterns have been shown to produce faulty pelvic biomechanics.6

Subject	Q-Angle1	(Q-Angle1)²	Q-Angle2	(Q-Angle2)²	Q-AngleΔ	(Q-AngleΔ)²	
1	8	64	12	144	4	16	
2	14	196	13	169-	-1	1	0 888
3	18	324	13	169-	-5	25	0 9
4	10	100	11	121	1	1	1 000000
5	16	256	13	169-	-3	9	1 11111
6	11	121	10	100	-1	1	1 222222222222
7	10	100	10	100	0	0	1 33
8	8	64	5	25	-3	9	1 444
9	8	64	8	64	0	0	1 55
10	12	144	10	100	-2	4	1 666
11	12	144	7	49	-5	25	1
12	15	225	9	81	-6	36	1 8
13	13	169	9	81	-4	16	1 9
14	13	169	10	100	-3	9	
15	14	196	9	81	-5	25	0 5
16	11	121	8	64	-3	9	0 6
17	12	144	8	64	-4	16	0 7777
18	10	100	8	64-	-2	4	0 8888888888
19	12	144	8	64	-4	16	0 99999
20	11	121	9	81-	-2	4	1 00000000
21	16	256	13	169	-3	9	1 1111
22	12	144	8	64	-4	16	1 2
23	12	144	8	64	-4	16	1 3333
24	12	144	10	100	-2	4	1 4
25	12	144	9	81	-3	9	1
26	10	100	10	100	0	0	1
27	12	144	7	49	-5	25	1
28	12	144	11	121	-1	1	1 8
29	11	121	8	64	-3	9	
30	12	144	7	49	-5	25	
31	10	100	6	36	-4	16	
32	15	225	10	100	-5	25	
33	12	144	11	121	-1	1	
34	10	100	10	100	0	0	
35	10	100	8	64	-2	4	
36	16	256	14	196	-2	4	
37	9	81	8	64	-1	1	
38	14	196	7	49	-7	49	
39	11	121	11	121	0	0	
40	19	361	18	324	-1	1	
41	19	361	18	324	-1	1	
SUM	485	6135	384	3926	-101	441	t = -7.31
MEAN	12.13		9.60		-2.53		P < .01
SD	2.55		2.48		2.18		

Research has suggested overpronation is correlated with impaired proprioceptive feedback. Aberrant lower extremity biomechanics alters postural reflexes, causing the patient to rely on visual input to control postural stability.7 Furthermore, abnormal mechanoreceptor activity of muscles, tendons, and ligaments has been found to affect dynamic equilibrium as well as visceral function.8

Previous and current research suggests that the hyperpronated foot is an etiologic factor in many lower extremity complaints. These include foot pain, knee pain, hip pain, and low back pain.6 Because of the dynamic nature of bone, abnormal stress results in hypertrophic changes in the osseous structures.9 It has been shown that abnormal pedal mechanics results in bone marrow edema observed with magnetic resonance imaging in the weight-bearing bones of the lower extremity.10 This study by Schweitzer and White showed early evidence of physiologic change in the bones when abnormal biomechanics were induced. Furthermore, when a portion of their sample population was scanned after returning to normal lower extremity functional status, there

Subject	Q-Angle1	(Q-Angle1)²	Q-Angle2	(Q-Angle2)²	Q-AngleΔ	(Q-AngleΔ)²	
1	15	225	12	144	-3	9	
2	12	144	11	121	-1	1	0 888
3	16	256	15	225	-1	1	0 9999
4	14	196	12	144	-2	4	1 000000
5	16	256	14	196	-2	4	1 1111111
6	16	256	12	144	-4	16	1 222222
7	8	64	10	100	2	4	1 33333
8	12	144	9	81	-3	9	1 444
9	10	100	7	49	-3	9	1 55
10	15	225	14	196	-1	1	1 666
11	10	100	8	64	-2	4	1 7
12	12	144	8	64	-4	16	
13	12	144	10	100	-2	4	
14	11	121	10	100	-1	1	0 6
15	12	169	10	100	-3	9	0 77777
16	11	121	9	81	-2	4	0 888888888
17	14	196	8	64	-6	36	0 999999999
18	11	121	7	49	-4	16	1
19	8	64	7	49	-1	1	1 1
20	9	81	6	36	-3	9	1 222
21	12	144	10	100	-2	4	1
22	10	100	9	81	-1	1	1 44
23	13	169	9	81	-4	16	1 55
24	11	121	9	81	-2	4	
25	13	169	8	64	-5	25	
26	9	81	10	100	1	1	
27	9	81	7	49	-2	4	
28	14	196	10	100	-4	16	
29	10	100	8	64	-2	4	
30	11	121	8	64	-3	9	
31	8	64	8	64	0	0	
32	13	169	9	81	-4	16	
33	13	169	9	81	-4	16	
34	11	121	9	81	-2	4	
35	12	144	10	100	-2	4	
36	10	100	9	81	-1	1	
37	11	121	7	49	-4	16	
38	10	100	8	64	-2	4	
39	9	81	8	64	-1	1	
40	17	289	15	225	-2	4	
SUM	471	5767	379	3781	-92	308	t = -9.25
MEAN	11.78		9.48		-2.30		P < .01
SD	2.38		2.21		1.57		

was evidence of normal bone marrow signal, with no evidence of edema. The assessment of lower extremity biomechanical dysfunction therefore requires a complete examination of the entire kinetic chain in both static and motion analysis, with close inspection of the foot-ankle complex. The use of custom-made flexible orthotics can stabilize the pes planus foot and restore the optimal degree of pronation. Reduction of pronation thereby decreases the amount of internal rotation of the tibia and femur, with a subsequent reduction in the Q-angle.

D' Amico and Rubin11 demonstrated an average reduction of 6˚ in the quadriceps angle with the use of orthotic devices. Similar findings were obtained in this study. The use of full-length, custom-made, flexible orthotics showed a 2.4˚ average reduction in Q-angle bilaterally and a .9˚ average reduction in Q-angle asymmetry in the examined

Subject	∆R&L1	$(\Delta R\&L1)^2$	∆R&L2	$(\Delta R\&L2)^2$	∆R&L∆	$(\Delta R\&L\Delta)^2$	
1	7	49	0	0	-7	49	
2	2	4	2	4	0	0	
3	2	4	2	4	0	0	
4	4	16	1	1	-3	9	
5	0	0	1	1	1	1	
6	5	25	2	4	-3	9	
7	2	4	0	0	-2	4	
8	4	16	4	16	0	0	
9	2	4	1	1	-1	1	
10	3	9	4	16	1	1	
11	2	4	1	1	-1	1	
12	3	9	1	1	-2	4	
13	1	1	1	1	0	0	
14	2	4	0	0	-2	4	
15	1	1	1	1	0	0	
16	0	0	1	1	1	1	
17	2	4	0	0	-2	4	
18	1	1	1	11	0	0	
19	4	16	1	9	-3	9	
20	2	4	3	9	1	1	
21	4	16	3	1	-1	1	
22	2	4	1	1	-1	1	
23	1	1	1	1	0	0	
24	1	1	1	1	0	0	
25	1	1	1	1	0	0	
26	1	1	0	0	-1	1	
27	3	9	0	0	-3	9	
28	2	4	1	1	-1	1	
29	1	1	0	0	-1	1	
30	1	1	1	1	0	0	
31	2	4	2	4	0	0	
32	2	4	1	1	-1	1	
33	1	1	2	4	1	1	
34	1	1	1	1	0	0	
35	2	4	2	4	0	0	
36	6	36	5	25	-1	1	
37	2	4	1	1	-1	1	
38	4	16	1	1	-3	9	
39	2	4	3	9	1	1	
40	2	4	3	9	-1	1	
SUM	90	292	57	137	-33	127	t = 3.26

MEAN	2.25		1.43		-0.83		P < .01
SD	1.51		1.20		1.60		

population. with the greatest reductions in asymmetry in the population with the largest discrepancy in right and left Q-angle measurements.

CONCLUSION

The insertion of a full-length. custom-made, flexible orthotic device significantly changes the Q-angle in asymptomatic pronating male subjects. Excessive pronation in Q-angle asymmetries can be effectively controlled or corrected by using orthotic devices. Further research examining the long-term effects of orthotic use on lower extremity biomechanics and determining whether these biomechanical changes are maintained after a course of orthotic use is suggested. Functional analysis of the interrelationship gait, Q-angle, and hyperpronation is recommended.

REFERENCES

1. Horton MG, Hall TL. Quadriceps femoris angle: normal values and relationships with gender and selected skeletal measures. Phys Ther 1989;69:897-901.
2. Caylor D, Fites R, Worrell T. The relationship between quadriceps angle and anterior knee pain syndrome. J Orthop Sports Phys Ther 1993;17:11-6.
3. Brody D. Techniques in the evaluation and treatment of the injured runner. Orthop in North Am 1982;13:542-58.
4'. Tibero D, The effect of excessive subtalar joint pronation on patellofemoral mechanics: a theoretical model J Orthop Sports Phys Ther 1987;9:160-5.
5. Beckett ME, Massie DL, Bowers KD, Stoll DA Incidence of hyperpronation in the ACL injured knee: a clinical perspective.) Athl Train 1992;27;58•62.
6. Rothbart. BA, Estabrook L Excessive pronation: a major biomechanical determinant in the development of chondromalacia and pelvic lists, J Manipulative Physiol Ther 1988;11: 373•9.
7, Kandel E, Schwartz J, JesseU T. Principles of neural science. 3rd ed. Norwalk (CT); Appleton & Lange; 1991.
8. Walther D. Applied kinesiology synopsis. Pueblo (CO); Sys• terns DC; 1988.
9. Yochum TR, Barry MS. Bone marrow edema caused by altered pedal biomechanics. J Manipulative Physiol Ther 1997;20;56•9.
10. Schweitzer ME, White LM. Does altered biomechanics cause marrow edema? Radiology 1996;198;851•3.
11. D' Arnica IC, Rubin M. The influence of foot orthoses on the quadriceps angle. J Am Pod Med Assoc 1986;76;337-40.