Appendix K:

Rearfoot Motion Observations using a FootTrak Data Collection System.

Following is Pilot Study data collected in an effort to observe trends and assist in refining data collection protocols for larger scale studies.

Within this Appendix you will find the summary data provided by:

1) Rearfoot Kinematic Analysis of the Foot/Shank using a FootTrak motion capture device
    a. Objective: To observe hypothesized changes in rearfoot kinematics of the foot and shank associated with the use of the Barefoot Science insole product.
    b. Design: A Pilot Cohort study introducing the use of the Barefoot Science (aka DynaPro) insole technology as an independent variable.
    c. Participants: N=1 adult male aged 36 of medium activity level and non symptomatic for foot pathologies.
    d. Methods: Data was collected using a FootTrak motion analysis system. The test subject was asked to run on a treadmill at a speed determined by the subject to be a comfortable 5Km pace (10.5km/h) and data was collected in 5 different running shoes, with their original insoles and replaced with the Barefoot Science insole product using level 3 of the Barefoot Science progressive insole system.
    e. Outcome measures: Rear foot motion capture data was collected in the 10 combinations and the results were analyzed using elementary statistical analysis to observe trends.
    f. Results: When the FootTrak output data was analysed to compare rearfoot kinematic characteristics of the 5 shoes, tested with and without the Barefoot Science insoles, it was found that the average maximum pronation of the shoes in the original insole condition was 16.5^{o} compared to 9.1^{o} for the Barefoot Science condition, a reduction in maximum pronation of 7.4^{o} or 44.85%. The average total pronation of the shoes in the original insole condition was 11.7^{o} compared to 5.9^{o} for the Barefoot Science condition, a reduction in maximum pronation of 5.8^{o} or 49.57%. In the original insole condition the subject remained in pronation during propulsion displaying 8.3^{o} of pronation while in the Barefoot Science condition the subject assumed a supinated take off position with 3.4^{o} of supination
    g. Conclusions: The findings conclusively indicate that for the subject there was a definite reduction in the magnitude of pronation occurring during the stance phase when the Barefoot Science insole was introduced into the subject's shoe replacing the originally equipped insole. In addition the use of the Barefoot Sciences insole promoted a more efficient foot position for takeoff and propulsion
    h. Discussion: As pronation, and in particular excess pronation, is often cited as a factor contributing to gait related pathologies and as such reductions in this pronation have been presented by others as potentially reducing gait related injuries and pathology, the Barefoot Science insole demonstrates remarkable abilities in immediately reducing the potentially harmful pronation and also enhancing a less injurious and more efficient foot position for takeoff.

*- The Dynapro Insole was manufactured to the specification outlined in US Patent 5,404,659.

Barefoot Science Foot Trak Testing

The Foot Trak device is a simple diagnostic tool capable of measuring rear foot motion. Numerous studies have been done observing the role that rear foot motion, in particular excess pronation, has on the manifestation of injury. There is also a quantity of literature available drawing a direct correlation between specific injuries and the incidence of injuries, and excess pronation.

Studies in the realm of athletic footwear and orthotics suggest that controlling excess rear foot motion can have a profound effect on the prevention and symptomatic relief of excess pronation related pathologies.

As the foot excessively pronates a number of mechanical stresses are created:

- Shearing forces in the forefoot: As the forefoot excessively collapses and remains collapsed through out the stance phase it is often unable to re-supinate properly for toe off. During toe off the ideal location of the body's center of mass should be located somewhere dorsal to the 2nd and 3rd metatarsal heads. However in the excess pronated state characteristic of the weakened foot, the body's center of mass is medial to the first metatarsal thus introducing a medial to lateral shearing force on the large toe. This shearing force is a primary cause of bunion formation. This shearing force is also artificially introduced through narrow and pointy toe box shapes in footwear. Toe shape can thus also be observed as a likely contributor to bunion formation. By controlling excess pronation and enhancing the re-supination of the foot at toe off the shearing forces can be reduced and thus the predisposition and/or magnitude of the problems relating to the shearing forces can also logically be reduced or eliminated.
- Tensile and traction forces on the plantar fascia: The plantar fascia is a connective band linking the heel or calcaneus to the forefoot. The plantar fascia has limited elastic properties and serves to secure the base of the arch's dome structure in an effort to enhance the stabilization of the foot. Excess pronation has been shown to increase the tension on the plantar fascia resulting in a combination of two common foot ailments. These being the formation of heel spurs and the occurrence of plantar fasciitis. The reduction of excess pronation has been reported to have a tension reducing effect on the plantar fascia and thus can be attributed to the reduction in predisposition and/ or magnitude of problems associated with plantar fascia tension.
- Lower Leg Torsion: The lower leg, namely the tibia, interfaces with the ankle and subtalar joint through a mortise arrangement. The angle of this mortise joint has been likened to a torque converter. As the foot excessively pronates the calcaneus and talus are forced to internally rotate, because the talus and calcaneus help to form the mortise arrangement their internal rotation has a direct effect on the tibia. As the foot pronates the tibia is forced into internal rotation. It is well accepted that maximum pronation closely coincides with the midstance phase of the gait cycle. At this point the quadriceps and hamstring group are co-contracting to stabilize the knee and allow it act as a shock absorber. In most individuals, as is evidence by their externally rotated walking style, the lateral muscles of the hamstring and quadriceps group are much stronger forcing the upper leg and femur into external rotation. The resulting conflict between the internal rotation of the lower leg and external rotation of the upper leg exerts a rotary stress in the knee and

it's articulations. This conflict has been reported by experts to be one of the major causes of knee related pain such as retro patellar pain, chondramalacia patella and Ilio-tibial band syndrome.

- Hip and Lower Back Implications: It is speculated that the accompanying leg torsion of the lower leg that results from pronation draws the knee joint in a medial direction thus decreasing the absolute function leg length and forcing an associated plantar and anterior shifting of the associated hip. It has been suggested that the lower back and hip muscles are forced to stabilize this region for an excess amount of time and through excessive ranges of motion thus predisposing the muscles to premature fatigue and leaving the region suspect to chronic injury.

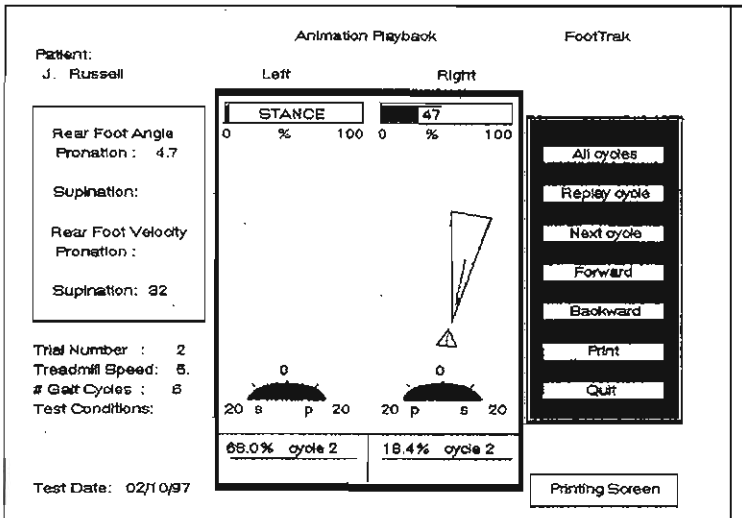
Barefoot Science Motion Control Implications:

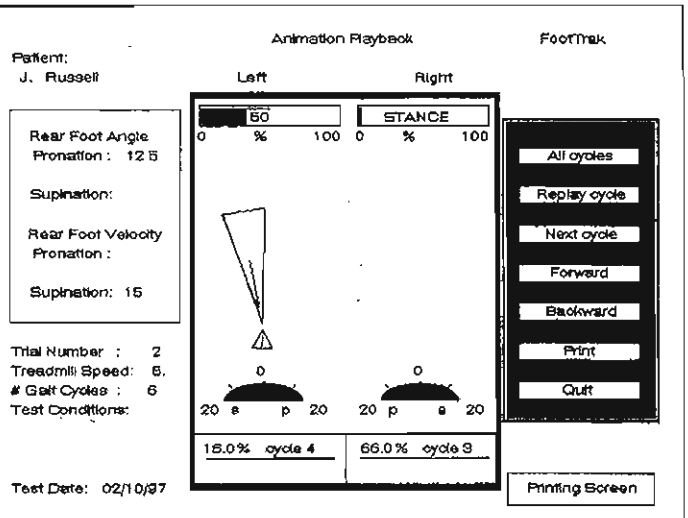
Logical dictates that the number and variety of pathologies related to excess pronation can be reduced if in fact the pronation can also be reduced. Three key measures in rearfoot motion analysis are generally observed. These are the maximum pronation (the maximum amount of pronation occurring measured relative to the neutral vertical plane), the amount of total pronation (the sum of the total motion from foot strike to maximum pronation and includes the initial supinatory position of the foot), and the toe off position of the foot. The latter may be either a pronation or a supination value depending on the foot's ability to achieve a desired biomechanical position. As mentioned previous the desired ideal is such that the foot has re-supinated from midstance through to toe off and that the body's center of mass be over the 2^{nd} and 3^{rd} metatarsal. With this occurring the toe off position is supinated.

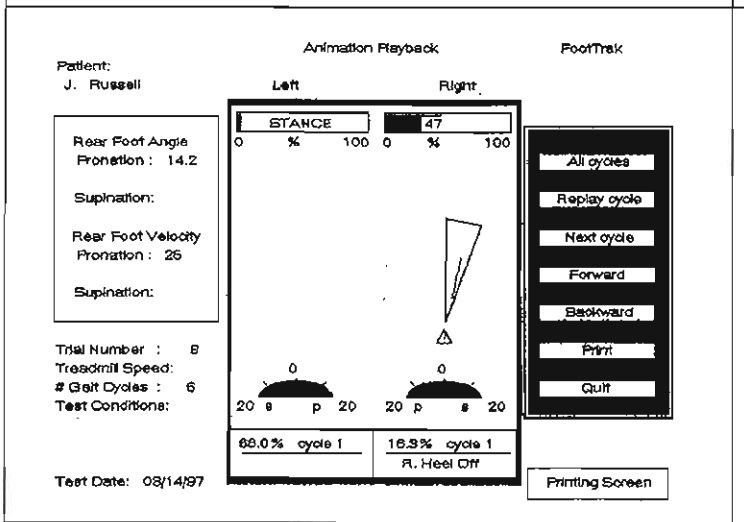
The following diagrams illustrate the effectiveness of the Barefoot Science prototype (Dynapro) on motion control during gait. Subjects were asked to walk at a speed that they perceived to be comfortable but brisk. Rearfoot measures were taken with the subjects normal footwear, with and with out the Dynapro insole. The following table shows the results with respcect to total and maximum pronation and toe off position.

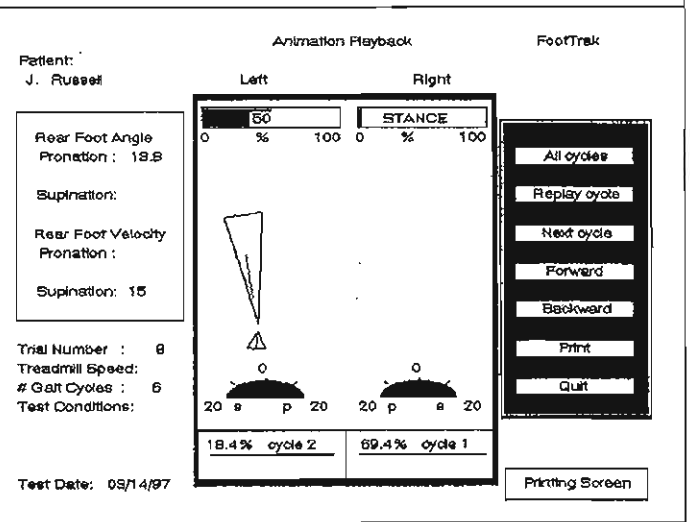
Of interest is the immediate effect that the Dynapro product had on the reduction of pronation, both total and maximum as well as the dramatic encouragement of the foot to assume a more biomechanical ideal position for toe off.

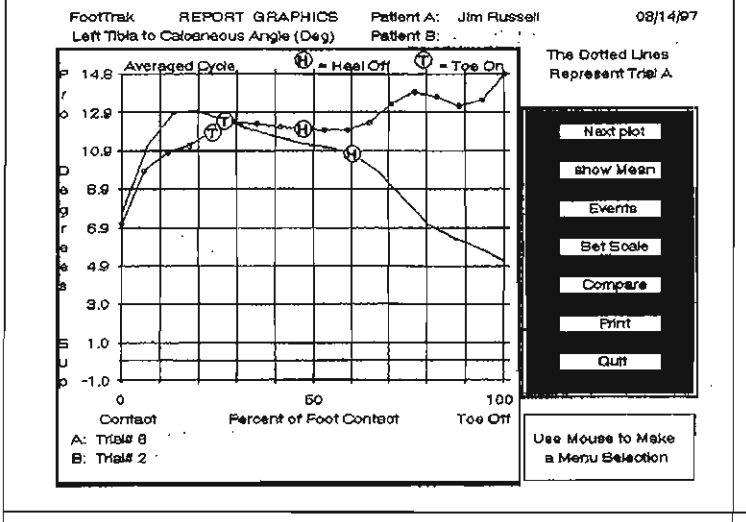
Attached are the details of the data collected.

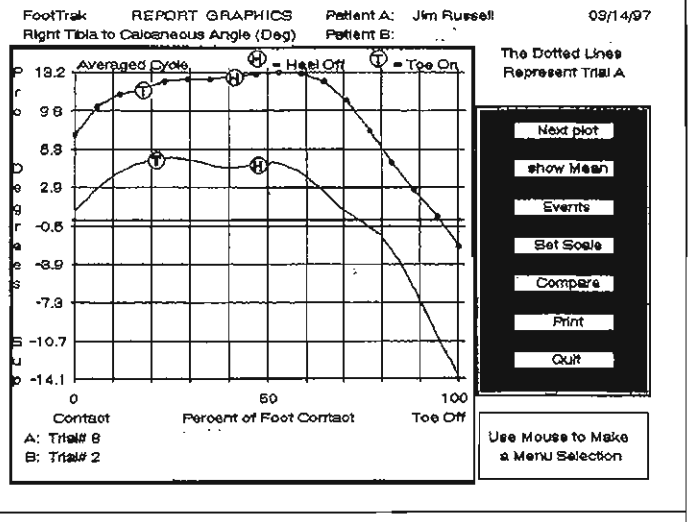

Animation Playback
FootTrak
Patient:
J. Russell
Left
Right
Rear Foot Angle
Pronation : 4.7
Supination:
Rear Foot Velocity
Pronation :
Supination: 32
STANCE
47
0 % 100
All cycles
Replay cycle
Next cycle
Forward
Backward
Print
Quit
Trial Number : 2
Treadmill Speed: 5.
Gait Cycles : 6
Test Conditions:
68.0% cycle 2
18.4% cycle 2
Test Date: 02/10/97
Printing Screen


Animation Playback
FootTrak
Patient:
J. Russell
Left
Right
Rear Foot Angle
Pronation : 12.5
Supination:
Rear Foot Velocity
Pronation :
Supination: 15
50
STANCE
0 % 100
All cycles
Replay cycle
Next cycle
Forward
Backward
Print
Quit
Trial Number : 2
Treadmill Speed: 5.
Gait Cycles : 6
Test Conditions:
15.0% cycle 4
66.0% cycle 3
Test Date: 02/10/97
Printing Screen


Animation Playback
FootTrak
Patient:
J. Russell
Left
Right
Rear Foot Angle
Pronation : 14.2
Supination:
Rear Foot Velocity
Pronation : 25
Supination:
STANCE
47
0 % 100
All cycles
Replay cycle
Next cycle
Forward
Backward
Print
Quit
Trial Number : 8
Treadmill Speed:
Gait Cycles : 6
Test Conditions:
68.0% cycle 1
16.9% cycle 1
R. Heel Off
Test Date: 03/14/97
Printing Screen

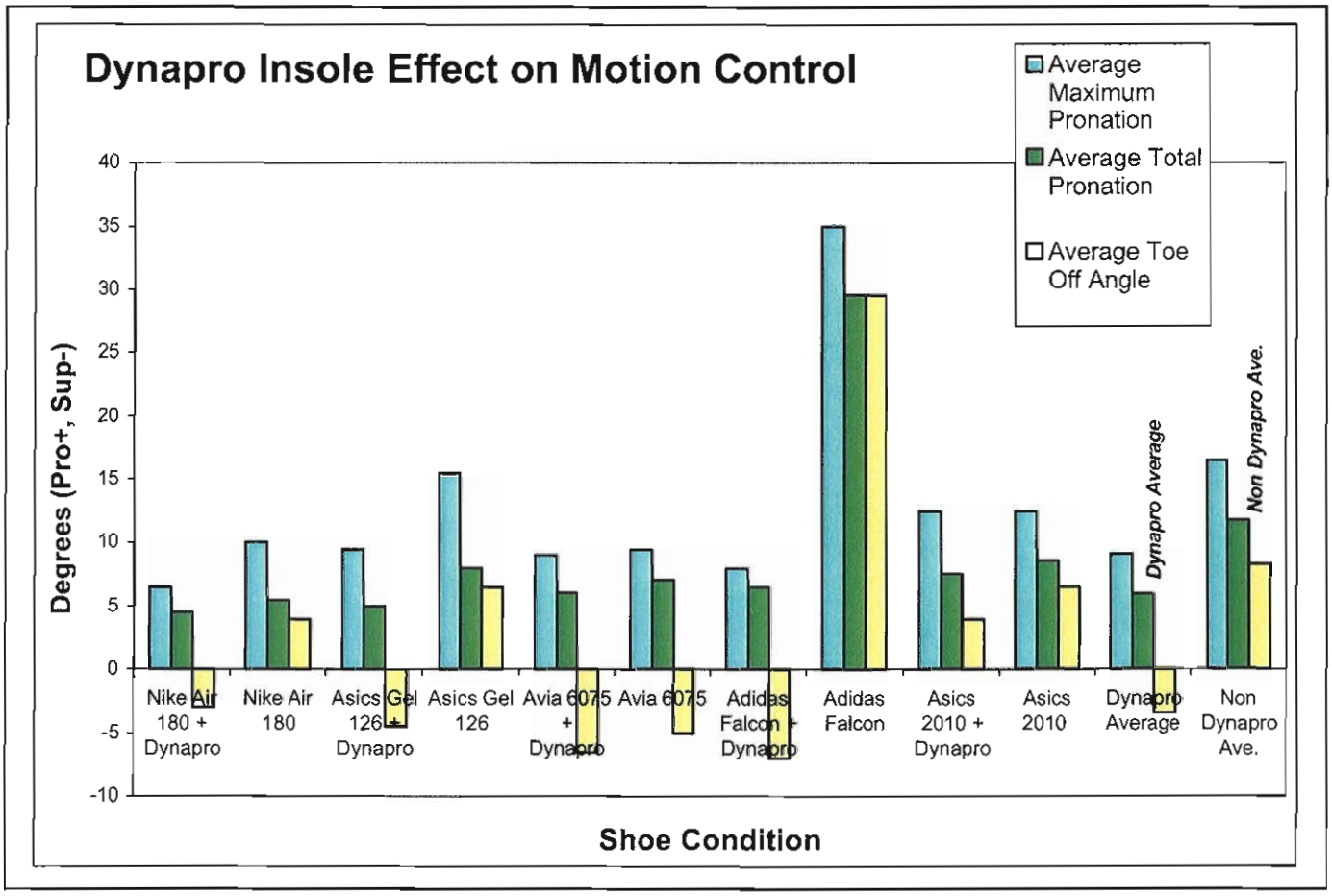

Animation Playback
FootTrak
Patient:
J. Russell
Left
Right
Rear Foot Angle
Pronation : 18.8
Supination:
Rear Foot Velocity
Pronation :
Supination: 15
50
STANCE
0 % 100
All cycles
Replay cycle
Next cycle
Forward
Backward
Print
Quit
Trial Number : 8
Treadmill Speed:
Gait Cycles : 6
Test Conditions:
18.4% cycle 2
69.4% cycle 1
Test Date: 03/14/97
Printing Screen


FootTrak REPORT GRAPHICS
Patient A: Jim Russell
03/14/97
Left Tibia to Calcaneous Angle (Deg)
Patient B:
Averaged Cycle
H = Heel Off
T = Toe On
The Dotted Lines Represent Trial A
Degrees
14.8
12.9
10.9
8.9
6.9
4.9
3.0
1.0
-1.0
0
50
100
Contact
Percent of Foot Contact
Toe Off
A: Trial# 8
B: Trial# 2
Next plot
show Mean
Events
Set Scale
Compare
Print
Quit
Use Mouse to Make a Menu Selection


FootTrak REPORT GRAPHICS
Patient A: Jim Russell
03/14/97
Right Tibia to Calcaneous Angle (Deg)
Patient B:
Averaged Cycle
H = Heel Off
T = Toe On
The Dotted Lines Represent Trial A
Degrees
19.2
9.8
6.8
2.9
-0.5
-3.9
-7.9
-10.7
-14.1
0
50
100
Contact
Percent of Foot Contact
Toe Off
A: Trial# 8
B: Trial# 2
Next plot
show Mean
Events
Set Scale
Compare
Print
Quit
Use Mouse to Make a Menu Selection

Shoe	Left Maximum	Right Maximum	Left Total Pronation	Right Total Pronation	Left Toe Off Angle	Right Toe Off Angle
Nike Air 180 + Dynapro	7	6	4	5	-2	-4
Nike Air 180	11	9	5	6	9	-1
Asics Gel 126 + Dynapro	13	6	5	5	5	-14
Asics Gel 126	17	14	10	6	15	-2
Avia 6075 + Dynapro	14	4	5	7	9	-22
Avia 6075	13	6	9	5	1	-11
Adidas Falcon + Dynapro	6	10	6	7	-13	-1
Adidas Falcon	58	12	55	4	58	1
Asics 2010 + Dynapro	14	11	8	7	12	-4
Asics 2010	12	13	9	8	12	1

Shoe	Average Maximum Pronation	Average Total Pronation	Average Toe Off Angle
Nike Air 180 + Dynapro	6.5	4.5	-3
Nike Air 180	10	5.5	4
Asics Gel 126 + Dynapro	9.5	5	-4.5
Asics Gel 126	15.5	8	6.5
Avia 6075 + Dynapro	9	6	-6.5
Avia 6075	9.5	7	-5
Adidas Falcon + Dynapro	8	6.5	-7
Adidas Falcon	35	29.5	29.5
Asics 2010 + Dynapro	12.5	7.5	4
Asics 2010	12.5	8.5	6.5
Dynapro Average	9.1	5.9	-3.4
Non Dynapro Ave.	16.5	11.7	8.3



Shoe	Left Maximum	Right Maximum	Left Total Pronation	Right Total Pronation	Left Toe Off Angle	Right Toe Off Angle
Nike Air 180 + Dynapro	7	6	4	5	-2	-4
Asics Gel 126 + Dynapro	13	6	5	5	5	-14
Avia 6075 + Dynapro	14	4	5	7	9	-22
Adidas Falcon + Dynapro	6	10	6	7	-13	-1
Asics 2010 + Dynapro	14	11	8	7	12	-4

Shoe	Average Maximum Pronation	Average Total Pronation	Average Toe Off Angle
Nike Air 180 + Dynapro	6.5	4.5	-3
Asics Gel 126 + Dynapro	9.5	5	-4.5
Avia 6075 + Dynapro	9	6	-6.5
Adidas Falcon + Dynapro	8	6.5	-7
Asics 2010 + Dynapro	12.5	7.5	4
	9.1	5.9	-3.4

Shoe	Left Maximum	Right Maximum	Left Total Pronation	Right Total Pronation	Left Toe Off Angle	Right Toe Off Angle
Nike Air 180	11	9	5	6	9	-1
Asics Gel 126	17	14	10	6	15	-2
Avia 6075	13	6	9	5	1	-11
Adidas Falcon	58	12	55	4	58	1
Asics 2010	12	13	9	8	12	1

Shoe	Average Maximum Pronation	Average Total Pronation	Average Toe Off Angle
Nike Air 180	10	5.5	4
Asics Gel 126	15.5	8	6.5
Avia 6075	9.5	7	-5
Adidas Falcon	35	29.5	29.5
Asics 2010	12.5	8.5	6.5
	16.5	11.7	8.3
% change	44.85%	49.57%	140.96%