Focus On Function In Custom Foot Orthotics

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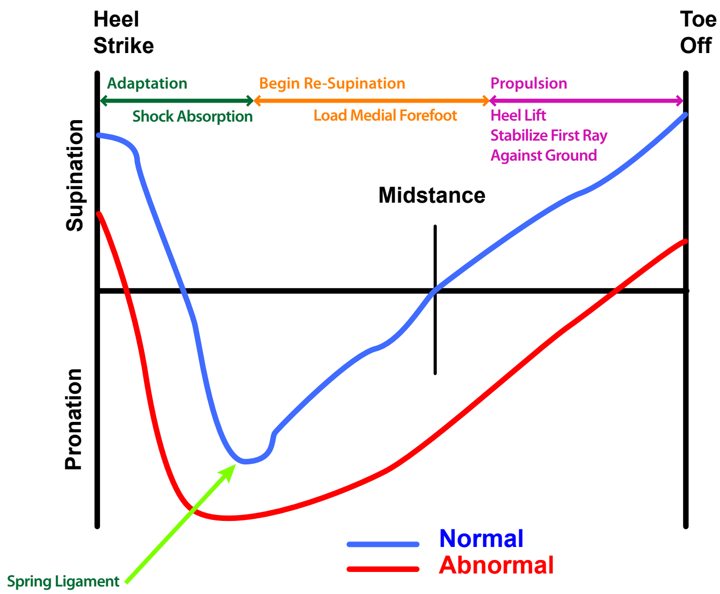
Re-Examining Neutral

Root described it as "Neither Pronated or Supinated"(1) . How is this position found, and what is the validity of this position? Not only has the validity of this position not been established in the literature, but the ability of clinicians to find this position is variable (2, 3). Should we palpate for talonavicular congruity? Although related in their function, the subtalar and talonavicular joints cannot be considered one and the same. In fact, fusion of the talonavicular joint will still allow some STJ motion (4).



Stance Phase Gait Cycle diagram

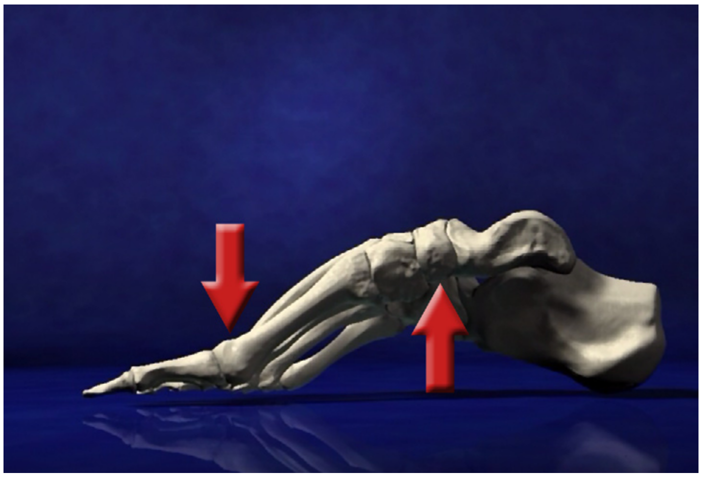
One of the earliest descriptions of the neutral position comes from Wright's work in 1964 in which he described what is now referred to as the relaxed calcaneal stance position (5). Root used Wright's limited data from 2 male subjects exclusively to define the ideal position of calcaneal inversion/ eversion relative to "subtalar neutral" during midstance.

The concept of subtalar neutral fails to have a logical relation to the goals of podiatric biomechanics which the current authors propose as:

1. Sufficient re-supination of the foot occurs after midstance to stabilize or "lock" the tarsus in the sagittal plane to allow for efficient propulsion.
2. The forefoot contacts the ground without imposed abnormal compensatory motion proximally or in the transverse, sagittal or frontal planes
3. The first metatarsal is stably plantarflexed against the ground during forefoot loading
4. The first metatarsal accepts 60% of forefoot loading force
5. The first metatarsophalangeal (MTP) joint is free to dorsiflex sufficiently to avoid compensations in foot or lower extremity posture that would otherwise be necessary to allow sufficient dorsiflexion or forward gait progression

A more appropriate definition of "neutral position" might be the resting position, off weight bearing, of the foot at the end of development at approximately 5.5 years of age. This position is characterized by talonavicular congruity and approximately one third of the total ROM from maximal supination. Simple observation confirms that the calcaneus (and often the forefoot) is generally, as Root et al. described (1977), in a varus orientation in the frontal plane in relation to a bisection of the leg. It may be plausible that such an inverted normal resting position, especially if somewhat rigid, might require over-pronation to enable full medial forefoot loading.

"Neutral position", in this sense, could be regarded as a problem instead of a solution. It is this common occurrence of incomplete frontal plane rotational development that may be an etiological factor for excessive pronation in a majority of the population. Over-pronation is also likely prevalent due to the prolonged effects of gravity, hard and flat surfaces and sedentary lifestyles –all of which could likely cause progressive ligamentous laxity. This calls into question the logic of casting the foot in "neutral" or in any semi-pronated position if the problem is over-pronation. The current authors propose that instead it would be better to decide what is the proper re-supinated position for end-stage stance function and cast to that. The support would also have to offer sufficient flexibility to allow adequate pronation for shock absorption



MASS position: Maximal Arch Subtalar Supination with lowered head of first, rearfoot and forefoot flush to floor

and surface adaptation.

Another problem with casting to neutral becomes clear when one considers the graph of STJ motion during stance phase: "If the foot ideally heel-strikes in a supinated position, why would we allow the foot to drop to "neutral" before beginning to correct it? Moreover, it is conventional to effectively pronate the cast further by means of arch fill during lab processing.

An Alternative Paradigm

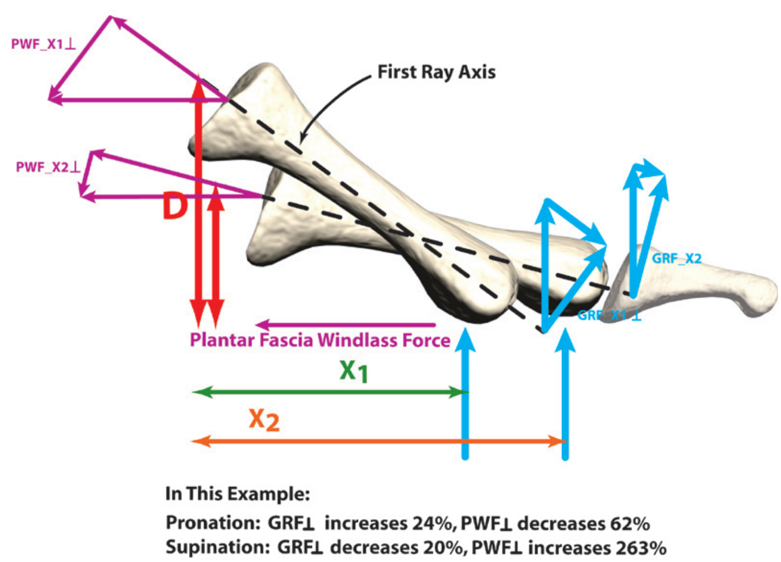
Cast the foot in the maximum amount of closed-chain, midstance supination easily achieved by an individual's anatomy. This is done by passing weight through the foot in the normal progression of stance phase. This creates a default position of supination that both aggressively controls pronation and firmly assists re-supination as the heel leaves the ground. The authors propose to call this MASS (Maximum Arch Subtalar Stabilization) position in order to define a corrected position that is distinct from neutral.

In this position, the foot does not reach the end range of pronation so that tissue and joint stresses are maintained within healthy limits. Anatomical structures can then function safely in the manner for which they were designed. Since "form follows function", the foot can avoid many of the common painful deformities over the long term. This is in contrast to the otherwise all too common scenario of treating symptoms while leaving the root disease.

Examine the Forces

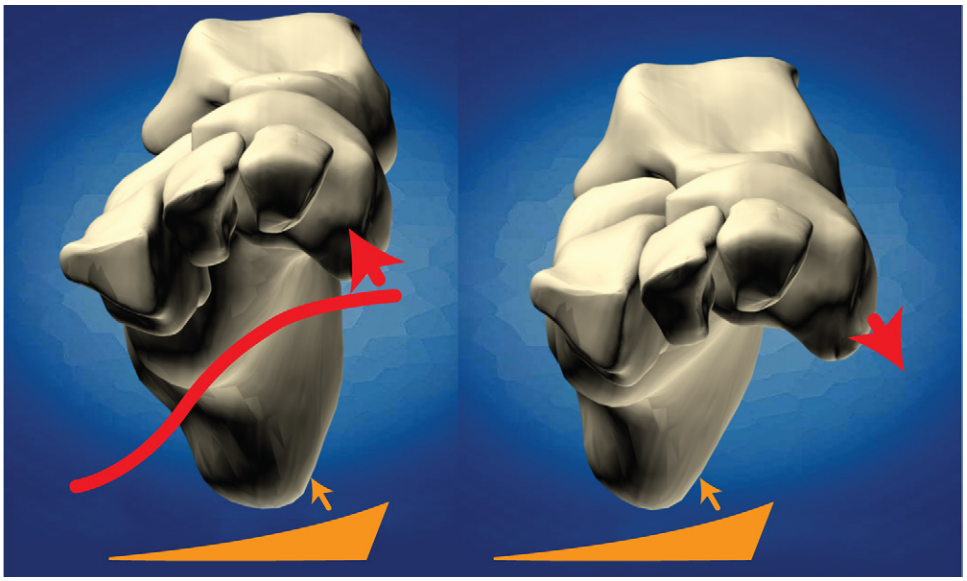
There are three main forces during midstance that are pertinent to achieving re-supination for push-off: 1) The ground reactive force in the pronated foot has a greater lever arm to cause further pronation. 2) The re-supination torque of the windlass effect has a greater lever arm to facilitate supination. 3) Leg external rotation, the re-supination force of which is facilitated by starting from a less pronated position.

Craig Payne quantified something called "supination resistance" which is the frontal plane, inversion resistance of the foot measured by a force meter attached to a one inch band of nylon pull-



Change in pronating (GRF) forces vs. supinating forces (PWF) with an arbitrary increase in first metatarsal declination angle.

ing upward in the arch (6). It is further interesting to note that this technique assesses the force required to supinate the foot by means of the leverage applied at the midfoot rather than the calcaneus. This appears to correlate with the MASS position approach of exerting primary corrective force through the midfoot rather than under the calcaneus.



Frontal plane section through midfoot showing relative mechanical advantage of direct support into arch apex (red contour line of MASS orthosis) compared with post under heel (orange wedge). Note the more medial position of the MASS shell leverage point compared with that of the rearfoot post. On the left the tarsus is supported in MASS (supinated) position with nested state of bones giving additional tarsal resistance to pronation. On the right the foot is already significantly pronated as in Neutral Position with the only force resisting further pronation coming from the typical medial rearfoot post at a point only slightly medial to the pivot point of the everting calcaneus. Consider too, that after heel lift (when the heel is off the ground), very little supination assistance is provided by a rearfoot post

A simple way to think about this is that the supination resistance is less when the foot is less pronated and increases dramatically when it is in full pronation. The determination of how much supinatory force is required is central to the decision making process in the prescription of custom foot orthoses. It is probable that orthoses cast in less supination (or a more neutral position) may only facilitate enough re-supination to cover a symptom.

Patients (and insurance companies) expect foot doctors to make changes in the gait cycle that are greater than what they can achieve with OTC devices. The outcomes of the research done on the efficacy of orthoses varies considerably. There is a considerable amount of research that is inconclusive or refutes the effect of custom made devices (7). It could be argued that the advantage of standard podiatric "custom" orthoses is minimal or negligible because both do quite well in relieving symptoms. Both do this by means of an incomplete arch support. This has always been thought a "safe" strategy because patients may experience some discomfort with more aggressive arch contact. As Podiatrists, in order to be significantly more effective with our intervention and justify the expense of our expertise, we need to raise the bar. If we are to distinguish ourselves from prefabs, we will have to do more. We should be giving the patient the maximum amount of correction in their gait cycle that is comfortable.

Full Contact

No change in the gait cycle is possible without applying a force. One cannot apply a force to the foot without touching it. Custom orthoses do not commonly attempt aggressive supination by means of full arch contact. There is usually a significant space between the orthotic and the midfoot. This space is the distance the foot has to travel into closed chain pronation before the orthotic touches the arch. By the time the foot is in reasonable contact with the orthotic, the foot is deeply into closed chain pronation where the most tissue stress is likely to occur. The end range tissue stresses may be reduced, but the authors suggest that this amounts to incomplete correction.

Full contact correction is commonly avoided because the amount of force applied directly to the foot is not well understood: should the orthosis be rigid or flexible. Some orthoses are made extremely rigid like rohadur, graphite, fiberglass, carbon fiber etc. while others are made flexible like plastizote, EVA, "rubber-butter", etc. A key concept in delivering a significant force comfortably is that of force per unit area. Unless the orthosis distributes the corrective force evenly over the entire plantar surface, thus reducing the force per unit area, adequate corrective force may not be tolerated. The problem may additionally be posed as follows: If a curved piece of material is placed on a flat surface, how much average upward vertical force does the material need to apply to the foot to achieve proper re-supination without blocking too much pronation or being subject to progressive collapse over time? There is certainly a range of right answers.

A Full Contact design orthosis with a calibrated thermosplastic shell. The shell allows very limited pronation for shock absorption, terrain adaptation and proprioception and then assists re-supination as load transfers to the forefoot.

Calibration

To achieve the proper balance of rigidity and flex, we need a way to measure or calibrate the properties of the supportive shell. The authors use a device created to apply a force equally over the whole surface of the orthosis while simultaneous measurements are taken matching pressure to vertical displacement. From this data a force curve can be generated.The slope of this curve correlates to the supination resistance. A scatter graph was created using thousands of measurements to determine a "trendline". This enables each orthosis to be tuned to the correct flexibility according to this trendline. Body weight and foot flexibility are used with the trendline to determine proper shell properties. Calibration is not a method of accurately delivering an equal and opposite force to the foot in all positions, activities and phases of the gait cycle. It is rather a method of bringing the flexibility of the orthotic into a clinically acceptable range where adequate control is delivered to facilitate re-supination without intolerable rigidity or excessive flexibility.

Conclusion

A new paradigm must replace standard thinking about "neutral" position as the corrected or desired position of the foot: the authors submit the MASS position as an alternative. It is fortunate that there is a common denominator in terms of positioning the foot to affect more ideal gait. The authors propose that a new standard be placed on biomechanical treatment, namely achieving proper re-supination, raising the bar from simply masking symptoms to making a significant positive effect on gait function. Further, the authors postulate a theoretical explanation as to why supination resistance increases in direct relation to degree of pronation of the foot. It is hypothesized that control of the foot requires the application of a force which is best distributed over as great a surface area as possible, thus reducing the force per unit area (pressure) of the orthoses making greater correction possible with smaller pressures. This would logically be accomplished by full contact. Finally, full contact is facilitated by calibration to deliver a customized force. These are the factors that must be addressed in order to create a more effective custom orthosis.

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