THE BENEFITS OF ANATOMICAL AND BIOMECHANICAL SCREENING OF COMPETITIVE CYCLISTS

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This article explains why competitive cyclists in search of marginal gains should be comprehensively screened for anatomical and biomechanical abnormalities before Bikefit or positional set-up. Efficient, injury-free cycling is reliant on pedalling symmetry, which is reliant on efficient lower-limb biomechanics, correct foot function, and a stable, level pelvis. The structure and function of the foot dictate how effectively pedal forces are transmitted via the foot/pedal interface down to the cranks, and potentially how deleterious forces are transmitted up the kinetic chain, creating pelvic disruption. Leg-length inequality must be clearly differentiated into anatomical and functional and then addressed appropriately to achieve a successful outcome. Biomechanical problems can be addressed successfully only if they are recognised and diagnosed. Ideally, the screening process should involve a sports medicine therapist with specialist knowledge of cycling biomechanics and foot function. In competition, marginal gains can represent the difference between success and failure.

THE GROWING POPULARITY OF CYCLING

Cycling is becoming one of the most popular sports in the world (1), offering an excellent alternative for people wishing to seek low-impact exercise (2) and reduced injury risk (3). For those who want a challenge, competitive cycling is arguably one of the most physiologically and psychologically demanding sports (4).

UNDISCOVERED MARGINAL GAINS

In competition, marginal gains can represent the difference between success and failure. As admirably described by Brailsford following British Cycling's supreme haul of eight gold medals in the 2008 Beijing Olympics, "The team's unprecedented success was achieved through an aggregate of marginal gains" (5). Despite this, little robust research exists on the benefits of cycling-specific varus wedges, and significantly less attention is afforded to the invaluable benefits of pre-screening the rider for anatomical or biomechanical abnormalities. This article attempts to explain these benefits and justify their inclusion with respect to reducing injury and enhancing cycling performance, thereby providing opportunity for marginal gains. Furthermore, areas of misapprehension and concern and shortfalls are identified.

RATIONALE

Efficient, injury-free cycling relies on rider symmetry throughout the pedal cycle. Symmetry represents a stable, level pelvis, with minimal pelvic motion throughout the frontal, transverse and sagittal planes. Similarly, sagittal plane deviation of the knees should be minimal (varus and valgus movement), as should tibial rotation throughout repetitive pedalling. The shoe/pedal interface is the mechanical link between the leg and the cycle and consequently the point at which asymmetry arises, usually as a result of excessive foot pronation.

Pronation

Pronation of the foot is a normal and necessary motion. However, excessive pronation often leads to pathological conditions and reduced performance. The most common causes of excessive pronation include forefoot varus, plantar flexed first ray, tibial varum and ankle equinus.

Pronation, which can be unilateral or bilateral, is where the foot tends to collapse inwardly and the medial column becomes parallel with the pedal platform. Pronation leads to internal tibial rotation and knee adduction. Abnormal stresses continue to travel

> "PRE-SCREENING THE CYCLIST SHOULD EXTEND BEYOND CYCLING ACTIVITIES"

up the kinetic chain, creating problems in the pelvic and low back regions.

The condition known as forefoot varus, described as a forefoot–rearfoot alignment problem (Figure 1), exaggerates the amount of foot pronation and therefore further compounds the problem. The key to success, and thus to acquiring marginal gains, is to identify and subsequently address those areas responsible for rider asymmetry.

Consequences of forefoot varus

During an hour of cycling, a rider may average up to 5000 pedal revolutions. The smallest amount of malalignment at the foot/pedal interface, whether anatomical, biomechanical or mechanical, can lead to overuse injury and impaired performance (2). Overuse injuries, particularly those relating to the knee, are frequently linked to the anatomical structure of the foot; this is because the structure and function of the foot dictate how effectively pedal forces are transmitted via the foot/pedal interface down to the cranks, and potentially how deleterious forces are transmitted up the kinetic chain. Studies have demonstrated that as power outputs increase, so does the amount of foot pronation (6–8). Consequently, excessive pronation can lead to greater knee misalignment, knee injury (2, 9–14) and power loss (15–17). Moreover, a recent study demonstrated that increasing amounts of power loss were significantly correlated ($P < 0.05$) with increasing amounts of forefoot varus (16).

Excessive foot pronation generates excessive aberrant pelvic motion in the frontal (Figure 2a) and transverse (Figure 2b) planes. Although not well documented in the cycling literature, forefoot varus is a common cause of pelvic, sacroiliac joint (SIJ) and low back dysfunction among cyclists (18, 19). Localised soft tissue structures and surrounding joints often become

> "87% OF CYCLISTS PRESENT WITH FOREFOOT VARUS"

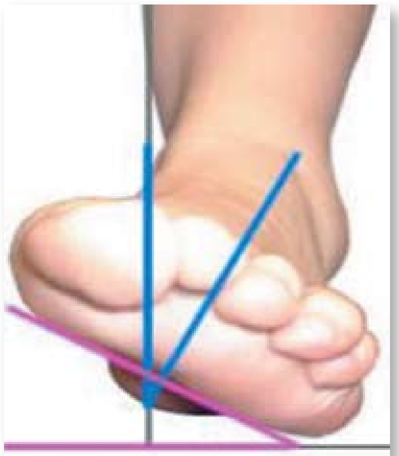


Figure 1: Forefoot varus

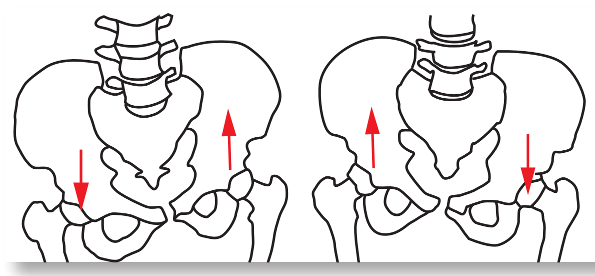
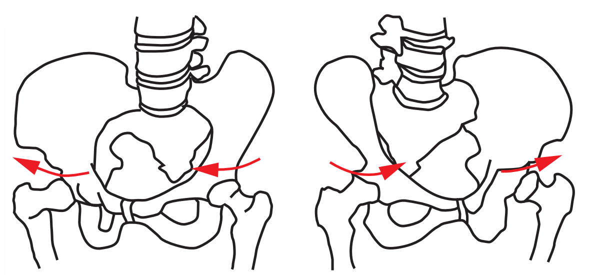


Figure 2: Excessive pelvic motion in the (a, above) frontal and (b, below) transverse planes



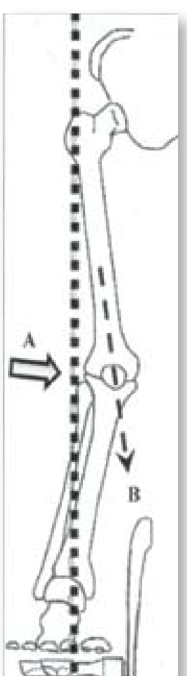
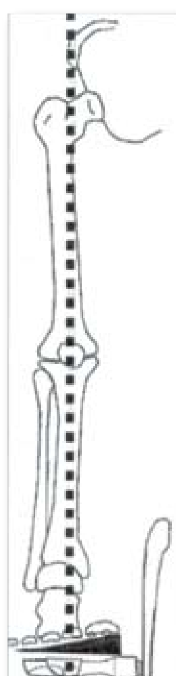


Figure 3 (a left) Effects of pronation caused by forefoot varus; (b right) correcting effect of varus in-shoe inserts (see text for details)



> "IN COMPETITION, MARGINAL GAINS CAN REPRESENT THE DIFFERENCE BETWEEN SUCCESS AND FAILURE"

overworked and inflamed due to excessive pelvic motion. Furthermore, recent studies have demonstrated that high levels of forefoot varus lead to pelvic and postural instability (20, 21).

Figure 3a shows the effects of pronation caused by forefoot varus, while Figure 3b shows the correcting effect of varus in-shoe inserts. During the pedal downstroke, the forefoot tends to collapse inwards, allowing the forefoot to become parallel with the pedal. Consequently, foot pronation, internal tibial rotation and knee adduction increase (Figure 3a, arrow A). This causes the applied resultant force to be lower (Figure 3a, arrow B). Varus wedges support the medial column of the forefoot, thereby preventing the foot from collapsing (Figure 3b).

Studies suggest that increasing pedal forces result in increasing amounts of pronation, which in turn lead to increasing power losses (15, 17), whereby lower pedal forces associated with steady-state cycling may not be sufficient to elicit detectable changes. Dinsdale and Williams demonstrated that increasing amounts of power loss were significantly correlated with increasing amounts of forefoot varus (16). Furthermore, cyclists with high levels of forefoot varus demonstrated a 10% increase in mean anaerobic power output when wearing varus in-shoe inserts compared with not wearing in-shoe inserts. Testing involved two 30-second Wingate anaerobic tests on a Monark 824E cycle ergometer.

Prevalence of forefoot varus

In a study to examine different foot types, Garbalosa and colleagues found that 87% of the sample population had forefoot varus unilaterally or bilaterally, 9% had forefoot valgus and 4% had a neutral forefoot–rearfoot relationship (22). Conventional or standard pedal systems are designed for the cyclist to be positioned on the pedal flat-footed and are therefore ideally suited to only

4% of the cycling population (23). The high prevalence of forefoot varus and the associated implications clearly highlight the need for a comprehensive clinical approach to pre-screening of the rider. Thereafter, the correct amount of cycling-specific wedges should be prescribed to address any varus or valgus condition. Dr Andy Pruitt of the renowned Boulder Center for Sports Medicine, USA, used the findings of Garbalosa and colleagues (22) in the development of the Specialized Body Geometry (BG) shoes, footbeds and wedges.

EXTENDING PRE-SCREENING BEYOND CYCLING ACTIVITIES

Although various Bikefit companies offer some degree of pre-screening before bike position set-up, many appear to fall short of what can be considered to be an appropriate comprehensive clinical approach. The consequence of failing to identify important anatomical and biomechanical abnormalities means problems often get taken on to the bike. This will often compromise the optimum bike position, which can lead to rider asymmetry, potential injury and reduced cycling performance. For example, the screening process should consider foot function when involved in both cycling and gait activities; if this is not done, although both the correct shoe wedging and ideal rider set-up may have been achieved, abnormal pronation during gait (walking) can subsequently cause pelvic and SIJ dysfunction. Pelvic and SIJ dysfunction can lead to functional leg-length differences, which then lead to asymmetry. Unknowingly, the rider then takes the gait-created problems on to the bike and must compensate by adopting an asymmetrical riding position. Therefore, the authors strongly believe that the pre-screening process should include a suitably trained sports medicine clinician or therapist.

Key areas for consideration when pre-screening

Evidently, the cyclist must be screened for the main causes of pronation, namely forefoot varus, plantar flexed first ray, excessive tibial varum and ankle equinus. Thereafter, the ankles, knees and hips should be checked for normal range of motion. Emphasis should be placed on the hip and pelvic regions for restrictions commonly associated with pelvic muscle imbalance. Strength and balance in the muscles situated in and around the pelvis are prerequisite to symmetry and paramount for efficient cycling, whether this involves road, track or mountain biking (24). Hypotonic muscles, typically the piriformis, tensor lata fascia/ilio-tibial band, psoas and adductors, should receive manual therapy and stretching to restore normality. Leg length should be checked for inequality using a battery of suitable tests (25–27). It is essential to differentiate any leg-length inequality into three groups: anatomical (actual), functional (apparent) or a combination of both. Studies have demonstrated the prevalence of anatomical leg-length inequality to be about 90% of the population. Although this is near universal, the mean magnitude is small and not likely to be clinically significant (28, 29). Functional leg-length inequality associated with SIJ dysfunction is common and recurrent, especially if the underlying cause is not addressed adequately. Anatomical leg-length inequality is often mistaken for functional leg-length inequality, and unfortunately compensatory packing shims are fitted to the cycling shoe unnecessarily, further exacerbating the problem. Hence, this single problem highlights the importance of undertaking a reliable comprehensive assessment.

Figure 4** (a above) **In-shoe insert (wedges);** (b below) **yellow cleat wedges as fitted

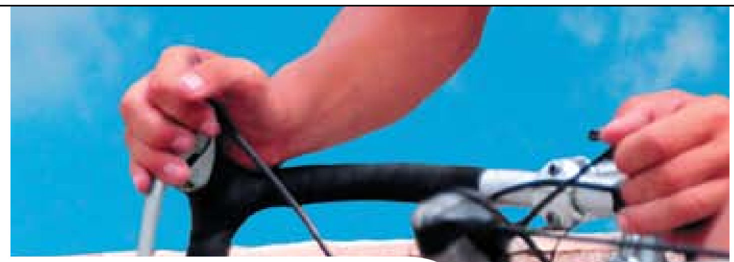
CHOOSING AND FITTING INSERTS AND WEDGES

Wedges can be used to address both varus and valgus foot positions. However, owing to the high prevalence of cyclists presenting with forefoot varus, this article concentrates on the varus foot.

Wedges are commercially available as forefoot in-shoe inserts, which fit into the shoe (Figure 4a), and as cleat wedges, which fit externally between shoe and cleat (Figure 4b). Both wedge shim designs provide approximately 1.5 degrees of varus or valgus tilt and are manufactured from non-compressible plastic.

There appears to be some confusion over when best to use the different wedge options. Ideally, in-shoe inserts should be used to address forefoot varus. Generally, cleat wedges should be used to address excessive tibial varum. The in-shoe insert is designed to correct only the forefoot, as in the case of forefoot varus, whereas the cleat wedge cants the whole foot (forefoot and rearfoot) and is best suited when compensating for excessive tibial varum. Many clinics offer biomechanical assessments before prescribing cycling inserts. However, caveat emptor applies – buyer beware! Some allied sports clinics fail to acknowledge the difference between gait and cycling requirements; consequently, assessments and the ensuing custom inserts/orthotics are based on rearfoot gait analysis (applicable to running) rather than analysis of the forefoot (applicable to cycling), and therefore

> "MALALIGNMENT AT THE FOOT/PEDAL INTERFACE CAN LEAD TO OVERUSE INJURY"



"LEG LENGTH SHOULD BE CHECKED FOR INEQUALITY"

are not necessarily appropriate for competitive cycling.

CONCLUSION

This article highlights the benefits of undergoing a comprehensive anatomical and biomechanical screening process before a Bikefit or positional set-up. Efficient, injury-free cycling is reliant on pedalling symmetry, among other things. The deleterious effects of excessive pronation on pedalling symmetry, and its far-reaching consequences throughout the kinetic chain, can be addressed effectively by using appropriate wedging devices. Considering the high prevalence of forefoot varus among the population, many cyclists have real opportunity to gain. Furthermore, those presenting with higher levels of forefoot varus potentially have the most to gain.

FURTHER INFORMATION

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TEST YOUR LEARNING

- **Why should leg-length inequality be diagnosed and subsequently differentiated into two groups – anatomical and functional?**
- **Why should foot pronation be addressed differently in cycling compared with gait?**

THE AUTHORS
Graduate sports therapists Nick Dinsdale and his daughter Nicola run NJD Sports Injury Clinic in Clitheroe. The family clinic is recognised for its strong evidence-based approach to the management of musculoskeletal conditions and ongoing professional development. Nick has a keen interest in lower limb biomechanics with respect to gait, and more specifically cycling. He often delivers private workshops and presents at conferences. Nick has served on the Executive Committee of the Society of Sports Therapists and has worked with the GB cycling teams. Nicola graduated from Teesside University with a BSc (Hons) in sports therapy and is the official sports therapist for Blackburn RUFC.