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Clinical Commentary

Hyperpronation in Cycling

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Abstract: Even with the best bike positioning, pre-existing excessive pronation (hyperpronation) or excessive navicular drop may be a contributing risk factor responsible for symptoms related to repetitive stress injuries incurred by the lower extremity. It has been theorized that a majority of the population has some degree of overpronation and are asymptomatic. However, with excessive repetitive compression to the medial longitudinal arch, associated with pedaling, symptoms may arise. To date, due to limited research, there has not been a strong correlation of hyperpronation to symptoms related to overuse injuries proximal in the lower extremity biomechanical chain. Over time, due to repetitious motion, even the slightest deviation in skeletal alignment or biomechanics may result in injury, dysfunction, or reduced performance. The foot, specifically the medial longitudinal arch, forms the foundation for the skeletal system making it responsible for the skeletal systems static and mechanical alignment. For decades, despite the publications of Tiberio, Powers and Neumann, the medical community still researches and treats the possible focal effects of excessive pronation without evaluating the regional biomechanics of the lower extremity. The running community has recognized the adverse effects of pronation and now manufactures shoes to limit or prevent it. The cycling community has limited research pertaining to the biomechanics and pathomechanics of the foot, specifically the medial longitudinal arch, during pedaling. Meanwhile, medical professionals continue to treat cyclists with syndromes such as Plantar Fasciitis, Achilles Tendinopathy, Patellofemoral Pain, and Iliotibial Band with mixed results. These overuse injuries have been associated with overpronation in runners. When experienced by cyclists these complaints are commonly treated by changing equipment, saddle and/or shoe position, thereby altering lower extremity biomechanics. The intent of this paper is to provide biomechanical evidence linking excessive pronation to commonly treated syndromes. By addressing this factor, an improvement in long term outcomes and injury prevention may be achieved.

Keywords: Overpronation, Hyperpronation, Pronation Distortion Syndrome, Patellofemoral Pain Syndrome, Iliotibial Band Syndrome, Plantar Fasciitis, Achilles Tendinopathy

1. Introduction

Hyperpronation, excessive pronation from medial longitudinal arch (MLA) collapse or navicular drop, is perhaps the most overlooked and therefore undiagnosed risk factor, which may be responsible for lower extremity overuse or repetitive stress injury (RSI) sustained by cyclists. As there is no consensus as to its pathogenesis, biomechanical effects, or treatment, hyperpronation continues to be a controversial topic. What is agreed upon is that overpronation has been linked to improper lower extremity biomechanics, which in turn may lead to a lower extremity musculoskeletal disorder (MSD) (Dodelin, 2020). One proposed theory, Posterior Tibial Tendon Dysfunction Syndrome (TPDS) (Burba, 2015) results in navicular drop or MLA dysfunction, the precursor to pes planus or a flat foot. Hyperpronation is typically asymptomatic (Stovitz, 2004), therefore, is commonly not included in the differential diagnosis list in the evaluation of the possible numerous better known symptomatic secondary syndromes such as; Plantar Fasciitis, Achilles Tendinopathy, Patellofemoral Pain, and Iliotibial Band.

When the musculoskeletal system is exposed to excessive repetitive stress, such as sustained with pedaling, its accumulation over prolonged periods of time, months to even years, may result in an RSI. Take into consideration the average amateur road cyclist with a cadence of 90 revolutions per minute may approximate 5000-6000 lower extremity biomechanical interactions per hour. Over the course of a three-hour ride this may approach 18,000 times. The pre-existing dysfunction overpronation, a precursor for pathomechanical motion within the lower extremity (Francis, 1986), will also be repeated 18,000 times. De Bernardo (2012) reported 53% of the injuries to top level cyclists were overuse in nature, of those, 68.5% were to the lower extremity. Thus, proper foot/ankle biomechanics may be an essential first step to minimizing or treating an overuse injury to other links within the lower extremity biomechanical chain.

Researchers have examined the foot's posture, biomechanics and pathomechanics when static, walking and running with regards to how these may be predictors and correlate to better known MSD. Unfortunately, little attention has been given to foot/ankle biomechanics and the ensuing pathomechanics when pedaling when the foot overpronates. Excessive pronation has been linked to overuse lower extremity MSD in runners, which may also similarly have affected cyclists experiencing similar symptoms.

The medical community considers cycling a low weight bearing, minimal impact activity. Because of this, the stationary bike is frequently utilized as a form of rehabilitation for the lower extremities. Yet, the force generated by the lower extremity of a recreational cyclist when transmitted through the ankle/foot/shoe interface on its way to the pedal, may equal approximately half the cyclists' body weight while seated and up to three times body weight when standing (Hennig, 1995; Sanner, 2000). While the magnitude of the force transmitted through the MLA may not be responsible for its compromise, the accumulation of the repetitive plantar compression of pedaling may lead to its eventual dysfunction, and to an already compromised MLA, may be responsible for the pathomechanics causing other MSD.

The biomechanics of pedaling involves the transfer of force generated by the musculature from the lower extremity via the ankle/foot complex, through the shoe to the pedal. The interface between the foot/shoe is the only link between the rider and the bicycle where force may be lost, thus, an efficient transfer of force through the ankle/foot complex to the shoe/pedal is of utmost importance. Researchers have studied various aspects of forces experienced at the hip (Ericson, 1986), knee (Ericson, 1986, 1987), ankle (Ericson, 1985) and pedal (Hoes, 1968; Davis, 1981; Lafortune, 1983; Lafortune, 1983; Broker, 1990; Sanderson, 1991). No comprehensive research has been conducted on the forces incurred by a healthy and hyperpronated MLA while pedaling. Bousie (2012) reported an increase in mid-foot pressure on the plantar surface when contoured inner soles were used. The link between foot posture and lower extremity MSD may have been made by Francis (1988) and Davis (1981).

2. Pronation Distortion Syndrome

Hamill (2003) defined foot pronation as the combination of rearfoot eversion, midfoot abduction and talocrural dorsiflexion. In a healthy individual, pronation is a necessary biomechanical triplanar movement required for ground force attenuation and adaptation to terrain variations. Hyperpronation, however, is a pathomechanical movement that initiates a cascade of adaptive events in the lower extremity known as Pronation Distortion Syndrome (PDS). This theory, described by Tiberio (1987) and Powers (2003), has been growing in acceptance. PDS is the lower extremity's structural adaptation arising from the unilateral or bilateral loss in the MLA's height. This loss in height at the first link, whether caused by a collapse in the MLA or "flat foot" when standing or hyperpronation with ambulation, results in eversion of the ankle. A pathomechanical domino effect progressing proximally in the lower extremity eventually affecting the pelvis ensues. The tibia displaces and rotates medially, the femur adducts and medially rotates. The pelvis anteriorly rotates due to the anteversion of the femoroacetabular joint (Khamis, 2007). The femur's adduction displaces the hip musculature's lines of force (Neumann, 2010). Pathomechanical stress may affect various structures in the lower extremity resulting in their RSI (Francis, 1986), which may include any of the following; Plantar Fasciitis, Achilles Tendinosis, Patellofemoral Pain Syndrome, Iliotibial Band Syndrome. This structural misalignment of the lower extremity and pelvis may carry over to the cyclist's riding position.

3. Foot Pathomechanics

The structures which comprise and support the foot are some of the most important and biomechanically complex in the body. These structures are responsible for converting the foot from a flexible shock absorber instantaneously into a rigid lever, enabling force transmission generated from the lower extremity (Donatelli, 1996; Levangie, 2001; Perry, 1992; Myerson, 1996) to the ground enabling ambulation. Equally, foot rigidity is crucial in cycling as the force produced from the lower extremity must be efficiently transferred from the lower extremity through the ankle/foot to the shoe/pedal interface.

Research has shown proper foot alignment and biomechanics plays a critical role in pedalling, influencing rider's comfort and performance (Callaghan, 2005; Bini, 2011; Zinn, 2004; Burke, 1986, Fong 2008), unfortunately, there is limited research investigating how the biomechanics of the lower extremity are affected when the foot overpronates. Asplund (2004) stated, "Even the smallest amount of malalignment, whether anatomical or biomechanical, may result in injury, dysfunction or reduced performance."

Issues leading to lower extremity pathomechanics and repetitive stress injuries may originate with pedal and road cycling shoe design/construction (Hull, 1995). The soles are rigid, only providing support to the contact areas, the forefoot and heel (Hennig, 1995). They may have improper or no MLA support (Francis, 1986). Additionally, the shoes' rigidity also inhibits the foot's ability to contort in the dissipation of forces involved in pedalling (Francis, 1986). Road shoes are commonly manufactured with approximately 10 degrees of posterior inclination (the heel higher than the toe), thus forcing the talocrural and talocalcaneal joints into plantarflexion. At approximately 10 degrees of plantarflexion the talocrural and MLA joints are in an open packed and unstable posture. This plantarflexion of the ankle is seen throughout a majority of the power phase of the pedal revolution (Burke, 1986; Fonda, 2010; Ericson, 2019). Francis (1986) noted, when the foot is plantarflexed it slightly adducts, thus as the force from the lower extremity is transmitted, it is diverted through the medial aspect of the foot causing the MLA to flatten. His findings were reflected in later published research. Sanderson (1991, 2000) reported an increased medial plantar surface pressure with an increased cadence. Both Hannaford (1986) and Hennig (1995) published that an increase in power output was accompanied by an increase in medial forefoot pressure as the foot collapsed allowing for the knee to deviate from the vertical axis. With the talonavicular joint being in an open packed position, combined with the morphology of the talonavicular joint, the anterior face of the talus being convex and the posterior aspect of the navicular concave, a medial shift and rotation in the talus occurs from the downward force from the lower extremity (Bonnel, 2010). As the force may not always be significant, the shear repetition of pedalling at approximately 90 revolutions per minute, without proper support, may gradually deteriorate and weaken the MLAs ligamentous structures. The greatest impact to the MLA/ankle complex occurs at bottom dead centre (BDC) resulting in foot pronation (Franics, 1986, Franics, 1988; Sanner, 2000; Hannaford, 1986; Hennig, 1995), adduction of the knee and an increased Q Angle (Francis, 1986; Francis, 1988; Sanner, 2000; Eng, 1993; Ruby, 1992). Snook (2001) reported a loss and delay of propulsive forces in the overpronated foot.

4. Plantar Fasciitis

Plantar fasciitis (PF), the chronic inflammatory condition affecting the plantar fascia and perifascial tissue (Kwong, 1988), typically arises from the inefficient foot biomechanics that has been linked to medial longitudinal arch laxity or excessive foot pronation. This leads to an increase in stress to the soft tissue structures through plantar fascial elongation (Arangio, 1998; Whiting, 1998; Cornwall, 1999). Researchers have also reported PF may be the result of the longevity of the pathomechanical movement (Cornwall, 2000; Chandler, 1993; Kwong, 1988).

5. Achilles Tendinopathy

Achilles Tendinopathy (AT) has been the topic of extensive research, yet it continues to be unclear as to what risk factors predispose athletes to this injury. Although AT is one of the lesser occurring and medically reported RSIs sustained by cyclists (Barrios, 2015), it is responsible for significant performance reduction and time off the bike Clarsen (2010). While Althunyan (2021) theorized AT may be the result of "ankling", when the cyclist actively contracts the gastrocnemius throughout the power phase plantarflexing the ankle. AT may arise when the active plantarflexion of the gastrocnemius is abruptly stopped by the resistance from the crank arm/pedal achieving BDC, resulting in a stretching the Achilles Tendon.

A flat foot and foot pathomechanics were earlier cited in research as risk factors for this condition (Baker, 1998; Pruitt, 2006). In the healthy foot the AT inserts midline on the posterior surface of the calcaneus. In the flat foot or the foot that excessively pronates, the calcaneus everts stretching the medial aspect of the gastrocnemius and medially displacing Achilles Tendon's line of pull. The primary function of the gastrocnemius is plantarflexion of the foot, it may also become a powerful supinator or pronator of the talocalcaneal joint depending on the mechanical orientation of the fibres (Subotnick, 1989). Research in runners revealed the AT undergoes up to 12.5 times the runner's body weight (Komi, 1990, 1992), however, to date there is limited data measuring the stresses the AT endures when cycling.

6. Patellofemoral Pain Syndrome

Patellofemoral Pain Syndrome (PFPS) is the most common complaint among cyclists. It has come to be a generalized descriptor for pain anywhere in the vicinity of the knee. Bini (2011) found that 50% of questioned elite cyclists reported having experienced anterior knee pain at some time. While the medical and cycling communities are unable to arrive upon a consensus as to its aetiology, terminology or treatment, cyclists continue to be afflicted with this RSI. What is agreed on, is that PFPS arises from the combination of structural misalignment (Powers, 2003; Tiberio, 1987; Barton, 2009, 2010; Waryasz, 2008), pathomechanics (Eng, 1993; James, 1978; Muller, 1983; Witvrouw, 2000; Piva, 2005) and repetition (Juhn, 1999).

Foot alignment and foot overpronation were cited as possible risk factors responsible for PFPS. (Francis, 1986; Powell, 1986; Pruitt, 1988, 2006)

7. Iliotibial Band Syndrome

Whilst ITBS is more common among runner's, it may be the second most common RSI reported by cyclists (Holmes, 1994 Baker, 1998). Nath (2015) reported over 22% of cyclists reported having experienced symptoms. ITBS has been linked to saddle position (Bini, 2011, Pruitt, 2006) and faulty foot/ankle mechanics (Bini, 2011; Holmes; 1994). However, no definitive aetiology nor pathomechanics of ITBS has been forthcoming. Holmes (1994) believed repetitive friction from fibres from the posterior distal aspect of the iliotibial band against the lateral femoral condyle may be responsible. What is known is that it is the result of biomechanical problems. Hyperpronation or flat feet in runners has been shown to be a major contributor (Dodelin, 2018). Damien (2018) reported correcting overpronation in runners aided in the resolution of the condition.

Burke (1986), Pruitt (2006) and Zinn (2004) cited foot pronation as a potential risk factor.

8. Piriformis Syndrome/ Deep Gluteal Pain

True Piriformis Syndrome (PS) is the condition whereby the piriformis muscle has spasmed or shortened, irritating the sciatic nerve. However, the lay community has come to use PS as a generalized descriptor for pain in the gluteal region. The medical community has recognized that due to the layers of musculature and multitude of structures in the buttock region, a definitive identification of the involved structure may not be possible. Therefore, an alternative term was presented by McCory and Bell (1999), "Deep Gluteal Pain Syndrome" (DGPS) (Martin, 2015; Park 2020), which encompassed several other syndromes whose symptoms included; deep buttock ache with or without sciatica.

As with the aetiology of the other pathomechanical conditions of the lower extremity, DGPS has not been confirmed. Research has linked PS/DGP to prolonged poor body mechanics leading this to being a chronic condition (Huang, 2018). One such theory involves foot overpronation causing a malalignment of the lower extremity with adduction of the femoroacetabular joint (Rothbart, 1988). In this anatomic position the gluteal/piriformis complex musculature becomes overtaxed (Reynolds, 2007).

Bini (2011) reported that 43% of competitive cyclists in his survey complained of buttock/hip pain.

9. Femoroacetabular Impingement

Over the past few decades with an increased awareness in personal physical fitness, cycling has boomed. As a result, Femoroacetabular Impingement Syndrome (FAIS) has become more commonly diagnosed among cyclists who experience anterior hip pain. Frank (2018) Lajam (2012) Stone (2016).

Pre-existing lower extremity misalignment arising from hyperpronation causes the pelvis to assume an anteriorly rotated position (Khamis, 2007). This in combination the quadratus femoris' increase in strength and hypertrophy from pedaling (Jorge, 1984), FAIS may ensue.

10. Discussion

The intent of this clinical commentary was to elucidate and theorize how the overlooked pre-existing condition, hyperpronation, when placed under the excessive repetitive stress of pedalling, may accelerate or be a precursor to lower extremity overuse injuries.

Despite well documented evidence linking excessive pronation to numerous overuse injuries incurred by runners (Holmes, 1994; Mellion, 1991; Schwellnus, 1996; Brukner, 2008), the cycling community has not adequately researched for similar correlations. The running community has tomes of research investigating the interaction of forces, postural imbalances and how abnormal structures may result in improper biomechanics that may increase the risk for an overuse injury to the MLA (Clement, 1981; Gross, 1992; Hamill, 1992; McClay, 1996; Subotnick, 1985) as a result from increased tissue stress (Kwong, 1988, Whiting 1998). Compromises to the MLA height and overpronation among runners have been linked to numerous lower extremity RSIs including; Plantar Fasciitis (Pohl, 2009; Wearing, 2006), Achilles Tendinopathy (Lorimer, 2014; McCrory, 1999), Medial Tibial Stress Syndrome (Kudo, 2015; Bandholm, 2008; Noh, 2015), Patellofemoral Pain Syndrome (Alberti, 2011; Eng, 1994; Duffey, 2000), Iliotibial Band Syndrome (Burke, 1986; Pruitt, 2006; Holmes; 1994), Piriformis Syndrome (Huang, 2018) and Femoroacetabular Impingement Syndrome (Levine, 2007). Subsequently, running shoe companies have engineered and now manufacture shoes designed to limit or prevent excessive pronation.

Some early cycling research pioneers were aware of the biomechanical complications associated with flat feet or excessive pronation and cycling. Francis (1986) detailed how under normal biomechanical conditions; forces may be focused medially affecting the MLA. He then overviewed the detrimental pathomechanical effect the overpronated foot has on the lower extremity, utilizing high-speed videos and films. Francis states, “Excessive Pronation: This particular problem may be the cause of more injuries than any other structural abnormality seen in cyclists, and those injuries may appear in any one or more of several anatomical locations.”. He went on to refer to overpronation as a potentially devastating problem. Francis suggested the usage of in-shoe orthotics for cyclists who have pre-existing flat feet or overpronation to realign the structure of the foot, to “create a “neutral” foot, which is not subject to excessive arch flattening”.

Pruitt (2006) stated that a flat foot may be a risk factor for PFPS, ITBS and Pes Anserine Tendonitis. He suggested the use of orthotics may be beneficial in the treatment of these conditions.

For decades bike fitters have been addressing these RSIs through an alteration in lower extremity biomechanics via changing saddle height (Bini, 2001; Burke, 1986; Pruitt, 2006, Zinn, 2004), saddle forward/aft position (Bini, 2001; Francis, 1988; Pruitt, 2006, Zinn, 2004), cleat placement and at one time wedging the forefoot of the shoe (Bini, 2001; Francis, 1988; Pruitt, 2006, Zinn, 2004). The medical community approach has been through rehabilitative exercise, focusing on the thigh and buttock musculature to control femoral adduction. Studies have shown when foot overpronation in cyclists has been addressed with foot orthotics, supporting the MLA, they may have; reduced plantar pain (Francis, 1986; Baker, 1998; Pruitt, 2006; Millour, 2016), postural stability (Francis, 1986; Baker, 1998; Zinn, 2004; Pruitt, 2006), and improved pressure distribution across the foot’s plantar surface (Hodgson, 2006) and improve biomechanics (Baker, 1998; Zinn, 2004; Wanich, 2007). While long-range studies have been performed to verify their efficacy as an invention for MSD in runners, limited research exists for cyclists.

11. Conclusions

Research has provided us with ample data when cyclists are in healthy biomechanical alignment and research thus far conducted on cyclists with a lower extremity RSI has been of a focal not regional perspective. Tiberio (1987) stated, "physical therapists must evaluate the structure and function of the STJ in all their patients with patellofemoral dysfunction. Otherwise, an unnecessary surgical procedure may be performed because the "whole" patient was not evaluated."

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