

# Cycling

## How to Move Well for Efficiency and Injury Prevention

### INTRODUCTION

Physiotherapists are perfectly placed to help the ever-growing cycling community to become better riders as well as to prevent pain and injury. Whilst there are a myriad of "bike set-up" protocols available, some more evidence based than others, very few "bike set-up" practitioners take into account the body and its neuromuscular and kinematic abilities.

There is no argument that understanding the geometry around optimal configuration is an important component for efficiency and injury prevention (Wisbey-Roth 2009), and some leading "Bike-Fit" proponents argue the neuromuscular perspective (Steve Hogg 2007). There are also endless references to optimal pedalling technique- "spinning the pedals", "elegant", "wipe the mud of the shoe", "like a duck swimming" or "smooth and continuous" (Colsen fr Brukner and Khan 2012), implying that optimising activation patterns has a distinct role in good pedaling technique.

Overuse injuries make up a large portion of injuries in aerobic sports that require long training sessions with a monotonous routine (eg, long-distance running, bicycling or cross-country skiing) (Bahr 2009). The greatest prevalence in overuse injuries in cycling is at the lumbar spine and knee, and efforts to prevent overuse injury should focus on these areas (Clarsen 2010).

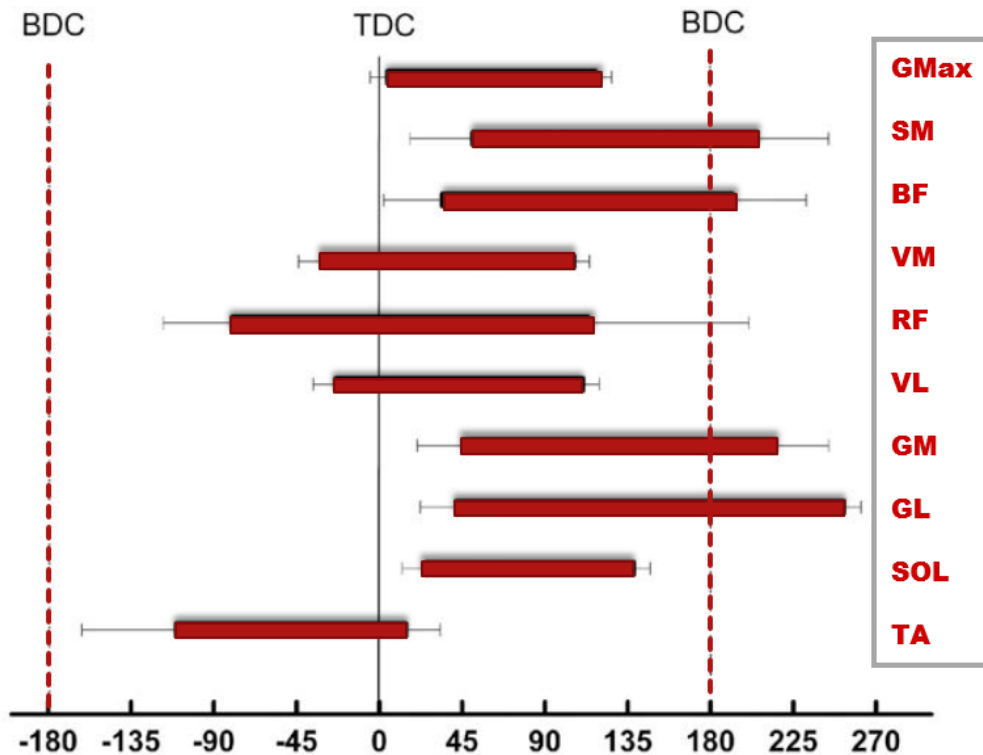
Maintaining or restoring precise movement of specific segments is the key to preventing or correcting musculoskeletal pain (Sahrmann 2002), and physiotherapists are clinically the best placed to be precise in the assessment and management of the movement patterns of the cyclist.

### PEDALLING TECHNIQUE and ACTIVATION

Historically the understanding of pedaling technique involved using the power muscles (gluteals/quadriceps) from 12-4 o'clock on the clockface, with the peak power phase at about 3 o'clock (Gregor 1996), the calf activating towards the end of the push phase (6 o'clock), the hamstrings and tibialis anterior pulling back and up, with the hip flexor (psoas), in the backstroke.

Top Dead Centre (TDC) is at 12 o'clock, and Bottom Dead Centre (BDC) is at 6 o'clock.

However, even as far back as 1996, Gregor in his review paper, showed EMG graphs with activation of the gluteals and quadriceps initiating at approx 11 o'clock, with the hamstrings highly active from 2 o'clock and through the power phase to Bottom Dead Centre (BDC). The gastrocnemius was active from 2-9 o'clock, peaking also through the power phase. So a more contemporary view of the pattern of muscle activation in pedaling looks like this:



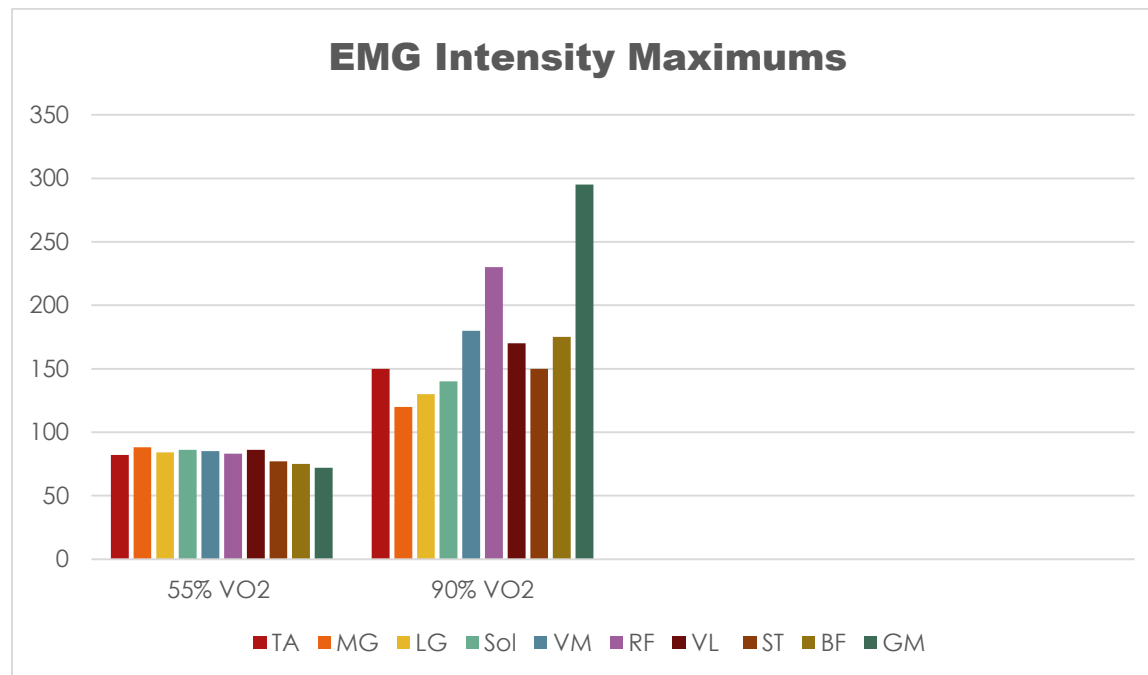
Note the extensive range of hamstring activation, as well as the calf, especially in the power phase, in an agonist/antagonist relationship to control the pedal stroke. Also the activation of tibialis anterior, and vastus lateralis and medialis, at the end of the recovery to prepare to push over the top of the pedal stroke.

The most efficient pedaling needs to maintain power at the top and bottom of the pedal stroke (Dead Centres – Leirdal 2011). Given that the peak of power is at 3 o'clock on the clock-face, maintaining power at the Top Dead Centre (TDC) and Bottom Dead Centre (BDC) becomes a challenge of co-ordination/activation.

### CO-ORDINATION

Blake (2012) looked at muscle co-ordination patterns in cycling, finding that peak efficiency occurred at 55% VO<sub>2</sub> max, with efficiency being the relationship between power output and metabolic cost. At optimal efficiency there was an even spread of activation levels between the muscle groups, but as the workload increases, there

was a greater emphasis upon the power muscles (GMx, VL, VM), and less efficiency (least at 90% VO2 Max), with a higher level of variation in the timing of the co-ordination muscles (Hamstrings, RF, Gastrocnemius).



Blake showed the GMx and VL/VM are the power muscles acting vertically, but with the VL/VM activating earlier in the pedal stroke at higher workloads, and GMx increasing the most relatively, as workload increases. An increase in the work done by the power muscles relative to the co-ordination muscles is a common theme with increased workload and fatigue states (Dingwell 2008, Bini 2010).

Periods of high workload (hills/powering) and fatigue have a relationship with the clinical presentation of pain in the cycling community. Rarely does pain present in "easy" riding.

The GMx has the greatest potential for increased power as it functions at low MVC at maximum efficiency. One can imagine it, and the VL/VM being the gears, and the co-ordination muscles the clutch, allowing for synchronous change in gears and timing of activation. So the "gears/power muscles" increase their activation level significantly with increased workload, whilst the co-ordination muscles don't increase their activation for power, but they function for smooth transmission of the power, especially in the TDC/BDC positions.

The idea that the hamstrings and calf muscles work synergistically with the power muscles to co-ordinate the fast and powerful moments of hip, knee and ankle extension resonates well from a movement analysis perspective, with early activation of quadriceps and tibialis anterior at TDC to gain a good angle for the horizontal vector component, also a notion that makes sense. Add the strong and smooth transmission of force to the pedal through ball of foot contact and good foot and ankle range and position, and the proposed model of power and co-ordination presented by Blake is highly usable for the physiotherapist in optimising efficiency and injury prevention in cycling.

The co-ordination correlate on the bike is high cadence pedaling (100RPM+), with riders who struggle with their co-ordinative muscle activation finding it difficult to maintain a smooth pedal stroke and "bouncing" around on the seat. Practice of high cadence pedaling is common in well-trained cyclists - therefore the practice of optimising co-ordinative patterns exists.

So the higher the workload, the more dominant the power muscles become, with a less efficient and more vertical pedal stroke. If the power muscles are deficient other muscles must fill the gap as workload and fatigue increase. Riders with poorer co-ordination will use the power muscles more at lower loads, with earlier fatigue, less efficiency and greater potential for adverse kinematics.

## ASSESSMENT

In the clinic one can extrapolate the pedal stroke, essentially a concentric contraction with the foot moving forward and down, to aspects of closed kinetic chain (CKC) deficit. CKC theory has its basis in sequential segmental shared loading of the joints and muscle groups, and detailed assessment is essential, especially addressing aspects of gluteal function, areas of fatigue/overload and general co-ordination.

**If the gluteal bulk is deficient in timing of activation, strength or endurance**, there is likely a compensation with increased work done by the Adductor Longus (AL), Psoas or TFL (Lewis and Sahrmann 2009), but especially the quadriceps and medial hamstrings(MH)/adductor magnus(AM) bulk (Leighton 2006). Regardless of efficiency of pedal stroke a similar power output per pedal stroke is recorded with differing activation patterns at similar workloads (Blake 2012). Hence, a gluteal deficit might be compensated for by the quadriceps working harder (a common pattern in the recreational cyclist), which of course is less efficient and loads the quadriceps excessively. The higher the quadriceps force, the higher the patello-femoral joint compression forces (McLean 1993), the greater the risk of patella-femoral pain syndrome (PFPS), the most debilitating injury in cycling (Clarsen 2010).

Conversely, a **decrease in quadriceps force generation** ability has been linked to PFPS (Langhorst 2012).

If the **MH and AM overwork**, local fatigue, proximal hamstring tendinopathy and sciatic nerve related symptoms can occur.

With **poor co-ordination** generally, the power muscle groups will both overwork, giving rise to local overuse and fatigue, or similar overuse and fatigue in the muscles which compensate for the power muscles to extend the hip and knee ie: TFL/MH/AM. Further, poor co-ordination is likely to cause kinematic disturbance such as dynamic knee valgus and lateral pelvic tilt, with likely sequelae of patellofemoral pain syndrome (PFPS) (Souza and Powers 2009) and lumbar pain.

## MANAGEMENT

Epidemiological research regarding cycling overuse injuries is almost non-existent (Clarsen 2009), and there is no evidence of cause and effect regarding closed kinetic chain deficits in activation and strength and cycling injuries. A lack of evidence should not exclude optimising the CKC as a management strategy - in cycling there is little evidence underpinning most theories regarding bike set-up and pedaling technique. However, it has been shown that land-based strength exercises enhance earlier activation of Biceps Femoris (BF) and Rectus Femoris (RF) (Bieuzen 2007), and that elite level cyclists have purer activation patterns than novice cyclists and elite triathletes (Chapman 2008).

**One can change activation patterns in cyclists!!**

Therefore, improving strength, improving endurance, improving activation and co-ordination generally, and specific to the pedal stroke mechanics, will improve cycling efficiency and prevent injury!

Logically, management is based upon assessment findings, and could initially involve lower limb strength, especially of the power muscles the gluteals and quadriceps. Optimising activation and co-ordination in a functional way is the ultimate goal. Cycling as stated is essentially a concentric activity of the lower limb with relative up and forward movement of the pelvis (down and backwards movement of the foot), with pedal interface force through the ball of the foot (Gregor 1996) and knee angles 30-110 degrees and hip angles 55-90 degrees. A 'monkey squat' type single leg step up with progression onto the toes, might be the most functional on-ground activation exercise for cycling. Adding speed is an obvious inclusion. On-bike exercises for strength and speed are essential, but one might emphasise gluteal activation, top and bottom dead centre momentum, calf and ankle activity, and smooth pedal stroking with good posture and kinematics.

## **CONCLUSION**

In the relationship between the body and the bike, given that bicycle geometry is adequate, optimising the body for cycling can give great improvement in mechanical efficiency and injury prevention. This can be achieved on and off the bike, and requires an understanding of the neuromuscular and kinematic variables of cycling and the load mastery components of the closed kinetic chain.

***Paul Visentini FACP** is a Specialist Sports Physiotherapist and a director of Physiosports Brighton. He has a special interest in Cycling and Closed Kinetic Chain mechanics, and will be presenting Load Mastery theory in the SPA course 'Integrated Rehabilitation of the Sporting Pelvis and Lower Limb' (Melbourne Aug 11th), as well as 'The Science of Cycling' in Melbourne Nov 29<sup>th</sup> and 30<sup>th</sup> 2013 with Rob Brown (Orica Greenedge Physiotherapist).*