TrySports Reference Guide: Bike Fit and Knee Pain in Road Cyclists

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Bike Fit and Knee Pain

Bike Fit and Knee Pain

- Knee pain is the most common lower-extremity overuse problem in cyclists. [1]
  - 42% - 65% of recreational long distance cyclists report overuse knee pain.

- Overuse injuries occur when a body structure accumulates damage caused by repetitive submaximal loading and does not have time between loading to heal.[1]

Bike Fit and Knee Pain

- **Bike Fit** is the process in which the bike is adjusted and modified to fit the rider in an optimal position for performance, comfort and to reduce the risk of injury. [2]

- Cycling is a repetitive activity.
  - 1 hour= ~5,400 pedal revolutions (3,600-7,200 per hour).[2]

- Incorrect bike fit that results in improper alignment and altered cycling mechanics can result in overuse injuries over time. [2]

Everyone is built differently so why would we fit everyone the same on a bike?

Individualized Bike Fit

Components of individualized bike fit: [1,2]

- Height: leg and trunk length
- Body alignment
- Flexibility
- Training schedule
- Cyclist's goals: competitive vs. recreational
- Static and dynamic fit.[4]
  - Dynamic: CompuTrainer assessment for power, cadence, heart rate, asymmetry and quality of movement.

Anatomy

Anatomy: Knee

http://www.osteoarthritisblog.com/category/knee-anatomy/

Knee joint:[5]

- 3 bones: femur, tibia and patella
- 2 joints make up the knee joint:
  - Patellofemoral
  - Tibiofemoral
- Primary motions of the knee:
  - Flexion
  - Extension
  - Rotation

Anatomy: Knee

- The muscles, tendons and ligaments are:[5]
  - The primary “movers” of the knee.
  - Provide stability to the knee.
- Primary knee structures related to cycling:
  - Quadriceps, hamstrings, Iliotibial band (ITB), patellar tendon and gastrocnemius (calves).
- When these structures are not functioning at their optimal length the movement and the amount of stress applied to the knee; as well as the amount of force that these muscle can produce are impacted. [1,5]
  - Increases the risk for knee pain and/or injury.

http://ohiodance.org/dance-education/dance-wellness/knee-anatomy/

Anatomy: Bike

3 interfaces between the bike and the rider: pedal, saddle and handlebars

http://www.njdsportsinjuries.co.uk/Bikefit.htm

Kinetic Chain

Kinetic Chain

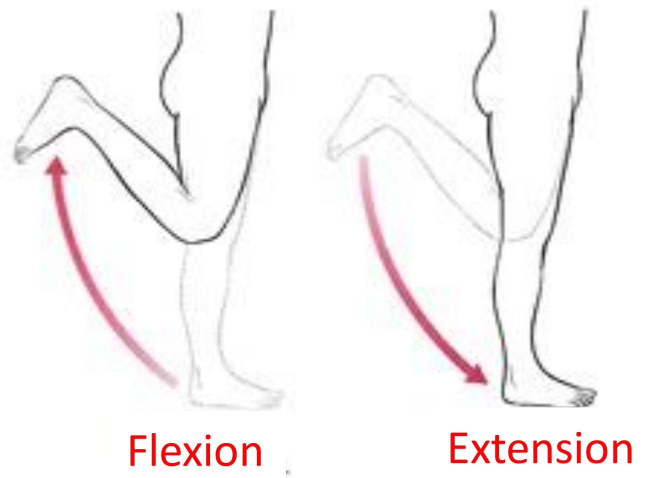
- The concept that all joints are connected to the joint above and below it and that motion at one joint causes motion at connected joints.
- Knee pain can be a caused by a problem anywhere above and below the knee.[6]
- Consequently, a comprehensive, individualized bike fit is necessary to help prevent knee pain in cyclists.

http://www.njdsportsinjuries.co.uk/Bikefit.htm

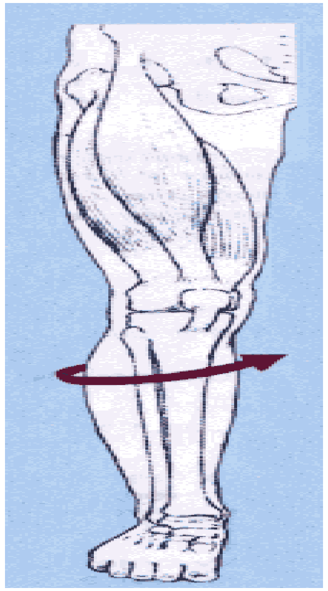
Bike Fit: Causes of Knee Pain

Bike Fit: Causes of Knee Pain

- The primary motions of the knee are flexion and extension with a little bit of rotation.
- There is an increased risk for knee injury when there is too much of these movements, these movements are restricted and/or if the knee undergoes motions that it is not built to do (side to side).[1,3,4,7]
- These abnormal motions and increased adjoining muscle activation can increase forces and stress at the knee leading to damage of the knee structures over time. [2,3]

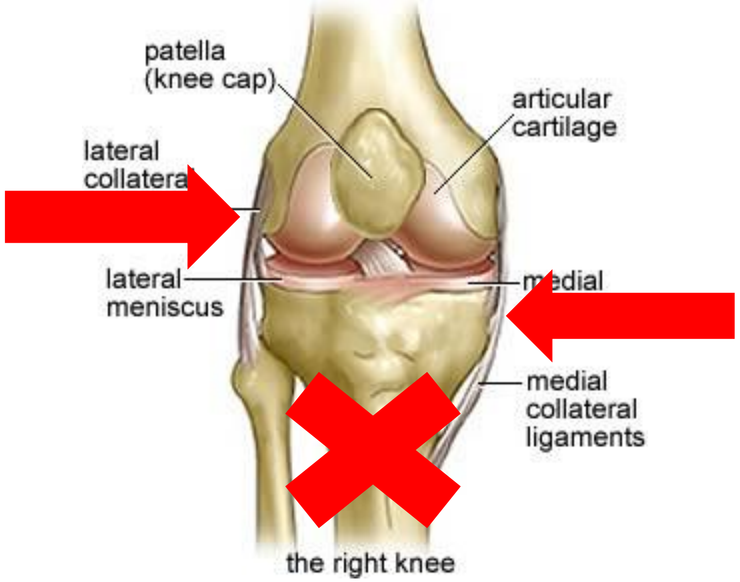


http://quizlet.com/6083574/kinesiology-knee-joint-soft-tissue-pathologies-special-tests-flash-cards/



Rotation

http://www.footankle.com/Knee-Pain.htm



Side to Side

http://www.aclsolutions.com/anatomy.php

Bike Fit: Causes of Knee Pain

- Increased knee flexion increases stress on the frontal knee structures (Figure 1).[1]
  - Compression of the patellofemoral joint. [1]

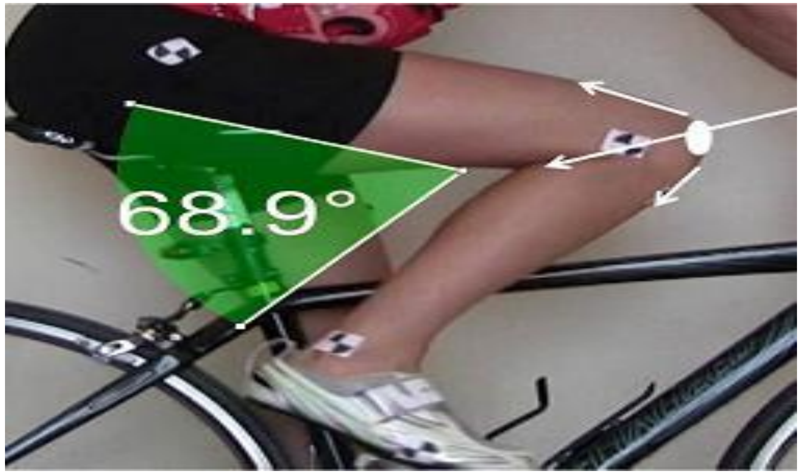


Figure 1

- Increased knee extension increases stress on the structures at the back of the knee (Figure 2). [1]
  - Hamstrings
  - ITB

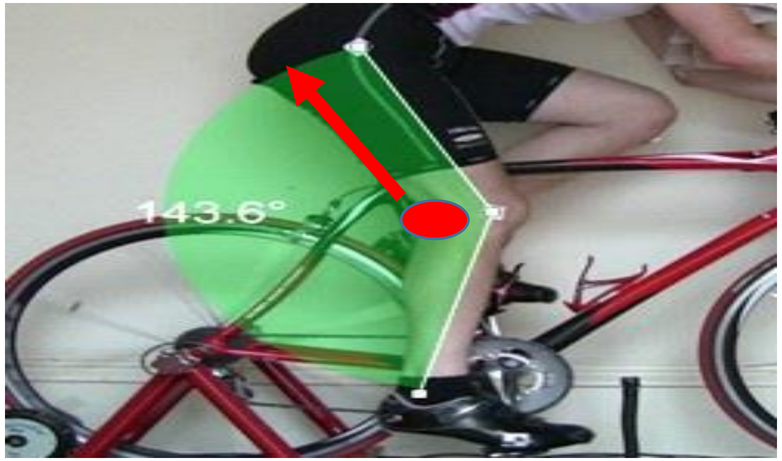


Figure 2

http://bikedynamics.co.uk/guidelines.htm

Bike Fit: Causes of Knee Pain

- Increased rotational and side to side knee movements.
  - Wear and tear of the knee structures: cartilage, ligaments, menisci and muscles.[1-3,6]

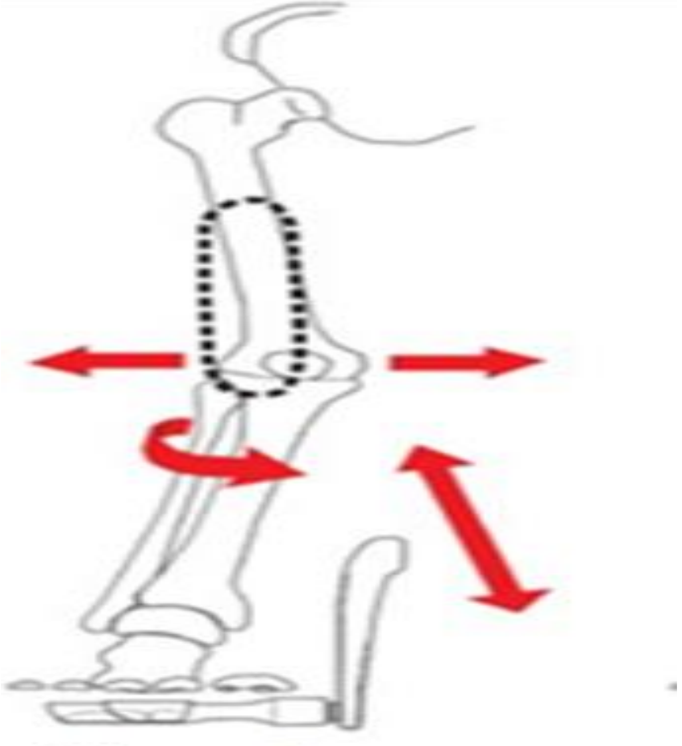


Figure 2a

http://www.trainingwithtracy.net/2013/03/alignment-alliance-part-1-of-5-knees.html

http://www.njdsportsinjuries.co.uk/Bikefit.htm

Components of Bike Fit and Knee Pain

Components of Bike Fit and Knee Pain

- Shoe-Cleat-Pedal Interface

- Pelvis-Saddle Interface

- Hands-Handlebar Interface

Shoe-Cleat-Pedal Interface

Shoe-Cleat-Pedal Interface

- Float
- Motions of the foot
- Forwards or backwards positioning
- Angular positioning (toed in and toed out)
- Q-factor
- Crank arm length
- Leg length difference

Pedal Interface: Float

- Fixed clipless and toe-strap pedals result in greater stress on the knee.[10,11]
  - Increases rotational and side to side loads imposed on the knee during cycling (Figure 1). [10]
- Increasing movement or float at the shoe-pedal interface improves the quality of knee motion and reduces stress at the knee (Figure 2). [10,12]
  - Float should have side to side movement and rotational movement. [10]
  - For the majority of individuals 5-10° of float is adequate. [1,10]

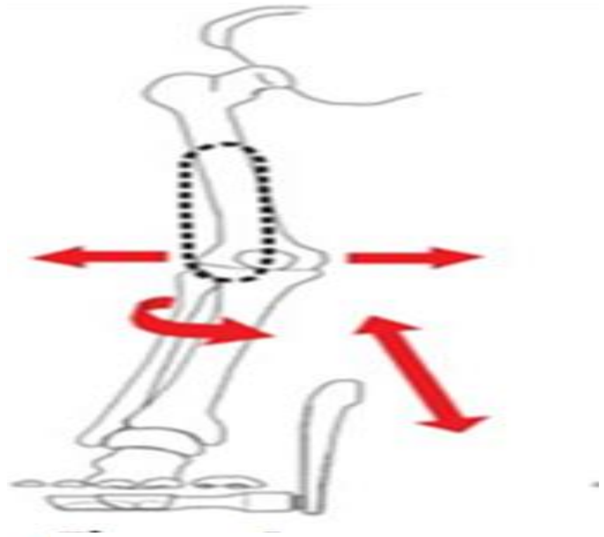


Figure 1

http://www.njdsportsinjuries.co.uk/Bikefit.htm

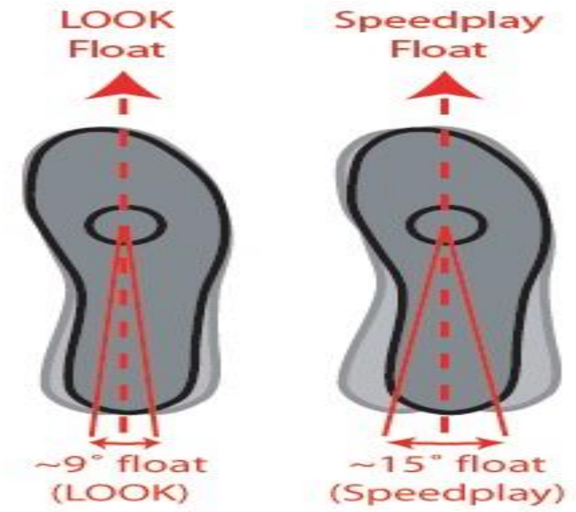


Figure 2

http://www.probikekit.co.uk/blog/pedals-and-cleats-buying-guide/2012/

Pedal Interface: Float

- Increasing float beyond 5-10 ° can have a negative impact and actually increase the risk of a lower extremity injury. [10]
- Too much float causes increased motion at the joints in the leg during cycling (Figure 1). [10]
  - This can result in poor cycling mechanics and increased stress at the knee which can lead to knee injury and pain over time. [1,12]
- However, some cyclists may need more float than others. [10,12]
- 5-10° of float does not result in a reduction in power. [10]

Figure 1

http://www.footfactor.com/cycling.html

Pedal Interface: Motions of the Foot

Pronation and supination are natural movements that occur at the foot during cycling (Figure 1). [2,13]

- Pronation is most prominent during the powerstroke.
- Supination is most prominent during the upstroke.

Forefoot inversion (varus) and eversion (valgus) are components of pronation and supination. [13]

- Definition: Angling of the forefoot on a stable rearfoot (Figure 2).
- Cyclists propel the bike using the forefoot; therefore forefoot alignment is critical during cycling. [13]

Figure 1

http://markhamchiro.ca/_www2/pages/services/orthotics.php

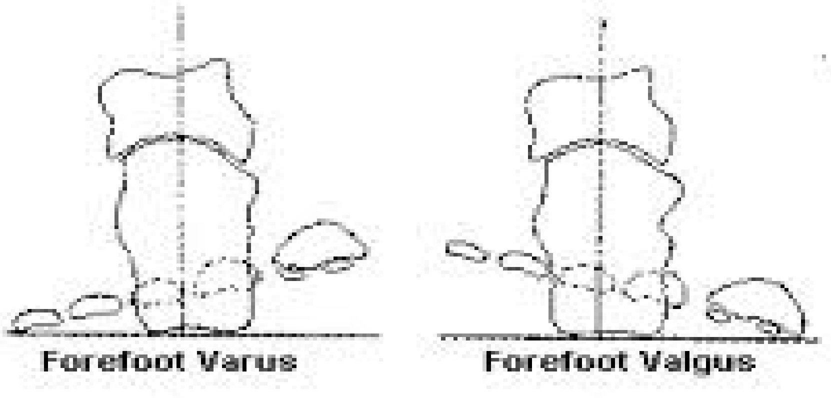


Figure 2

http://bikedynamics.co.uk/fit01.htm

Pedal Interface: Motions of the Foot

Excessive pronation, supination and/or forefoot inversion and eversion can increase the risk for knee pain and injury during cycling.[3,14,15]

- Excessive supination and/or forefoot inversion causes greater knee displacement away from the bike. [3,14,15]
  - Creating a bow-legged riding position (Figure 1)

- Excessive pronation and/or forefoot eversion causes the knee to “cave-in” towards the bike. [3,14,15]
  - Creating a knock-kneed riding position (Figure 2)

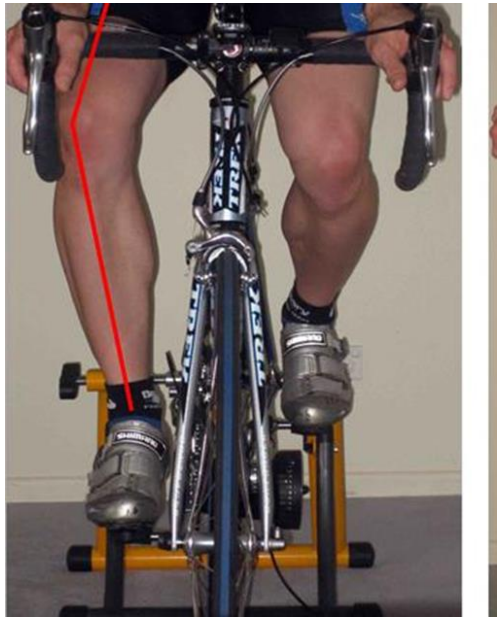


Figure 1

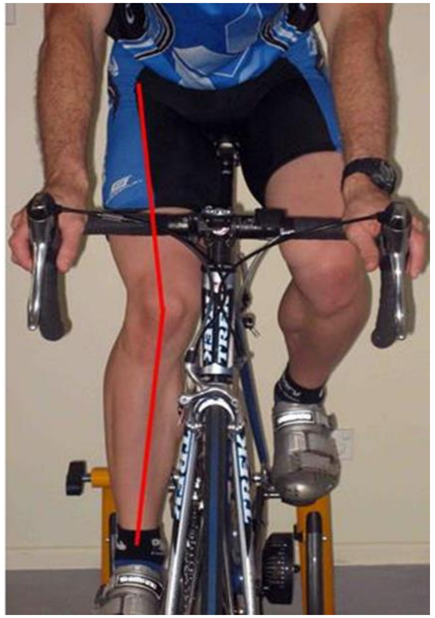


Figure 2

http://www.trainingwithtracy.net/2013/03/alignment-alliance-part-1-of-5-knees.html

Pedal Interface: Motions of the Foot

Excessive pronation and or supination

- Cleat wedging can be used to reduce foot and subsequent knee motion (Figure 1).

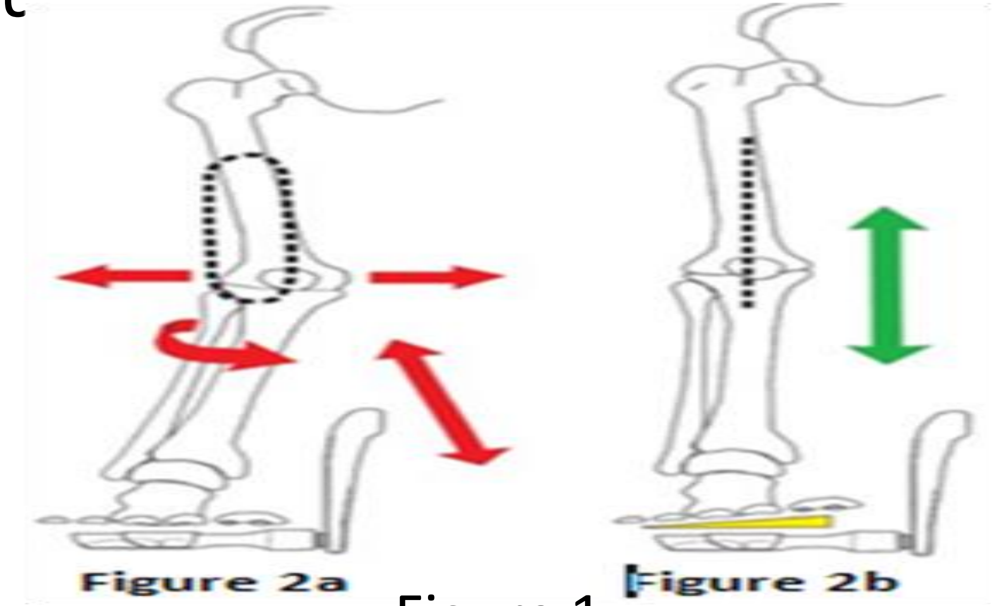


Figure 1

tenerife-training.net

Forefoot inversion and eversion

- Typically requires specialized cycling insoles (Figure 2). [13]
- Cleat wedging can also be used. [13]

Figure 2

http://www.footdisc.co.uk/cycle-insoles.php

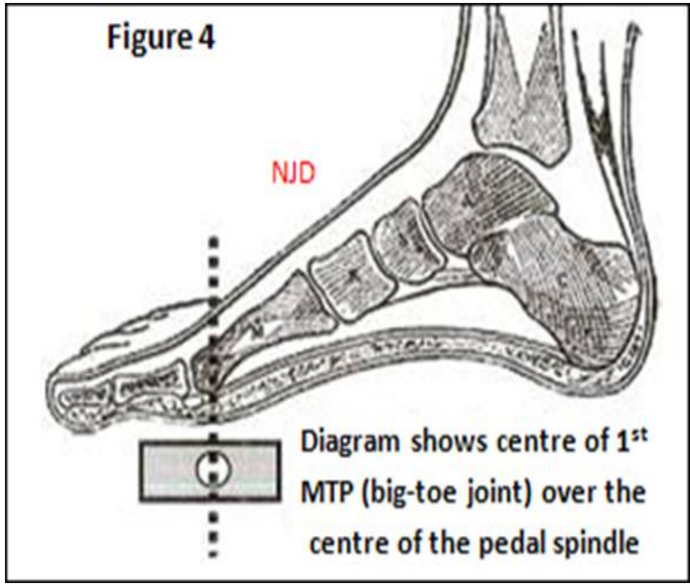
- At least 10° wedges are required. [3,14,15]
- Not all cyclists respond the same way to wedging/insoles. [3]
- Cyclists will need time to accommodate to wedging/insoles. [3]

Pedal Interface: Motions of the Foot

Practical application

- Cyclists with knock-knees and knee pain during cycling may benefit from wedging under the arch of the foot that prevents excessive pronation. [14,15]
- Cyclists with bow-legs and knee pain during cycling may benefit from wedging under the outside of the foot to prevent excessive supination. [14,15]
- Cyclists with excessive forefoot motion that results in abnormal motions of the knee (bow-legged or knock-kneed) during cycling may benefit from specialized cycling insoles. [13]

Pedal Interface: Forwards and Backwards Positioning



Forwards and backwards positioning

- Place the cleat or shoe with the center of the big toe over the center of the pedal axis. [4]

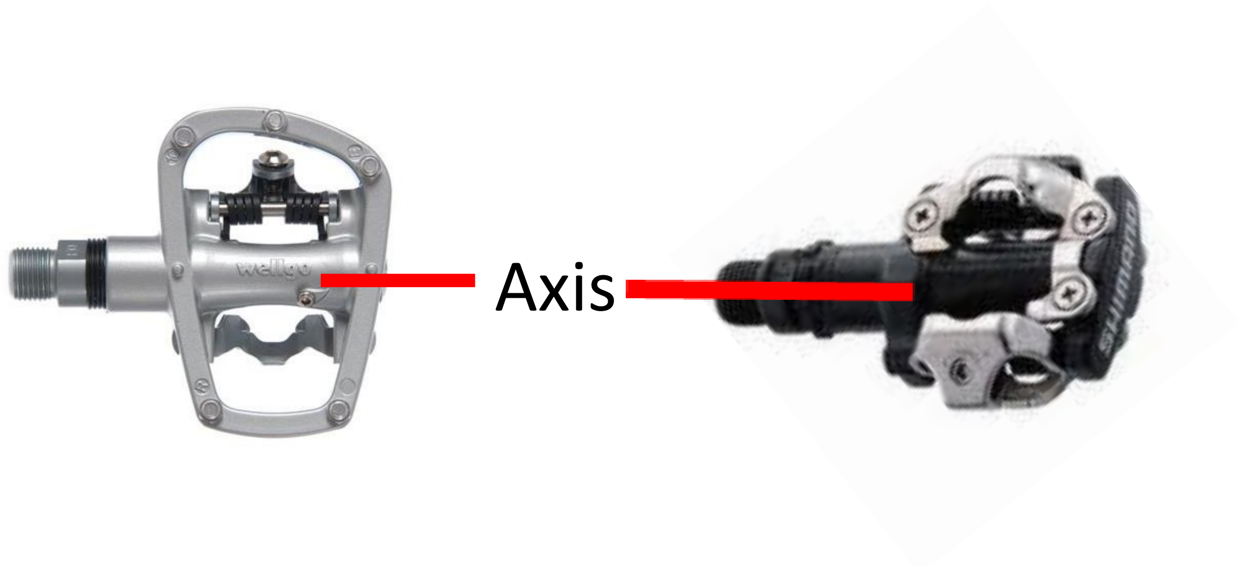
Moving the cleat or shoe forwards and backwards (10cm) can impact the knee and ankle joint. [16]

- A more forward position increases tension on structures at the back of the knee and increases calf activation. [16]
- A more backward position increases knee flexion and quadriceps activation. [16]

http://www.njdsportsinjuries.co.uk/Bikefit.htm

Pedal Interface: Forwards and Backwards Positioning

- A quantitative method has been developed for optimal cleat placement such that the bottom of the big toe is positioned directly over the pedal axis.[17] For optimal placement:[17]
  - Measuring from the heel of the shoe place the base of the cleat at 43% of the total length of the shoe (Figure 2).
  - This will place the base of the cleat 3.6cm from the pedal axis.



http://sports365blog.com/

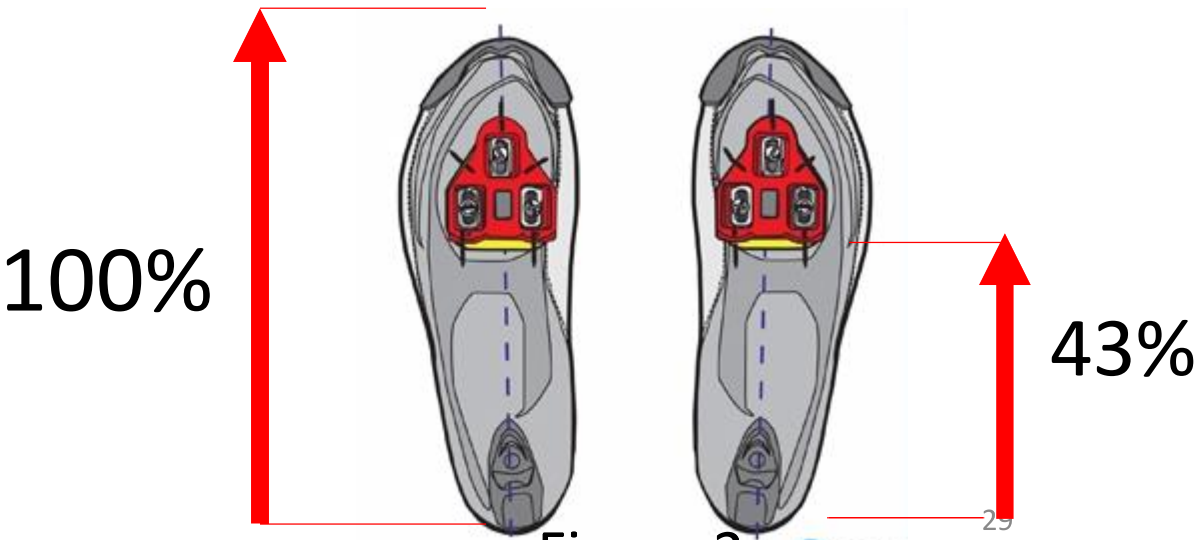


Figure 2

http://www.bikefit.com/

Pedal Interface: Forwards and Backwards Positioning

Practical application

- If a cyclist wants to limit the amount of calf activation on the bike, such as triathletes, or has tight hamstring and they are having related symptoms try placing their cleat or shoe in a more backward position on the pedal.

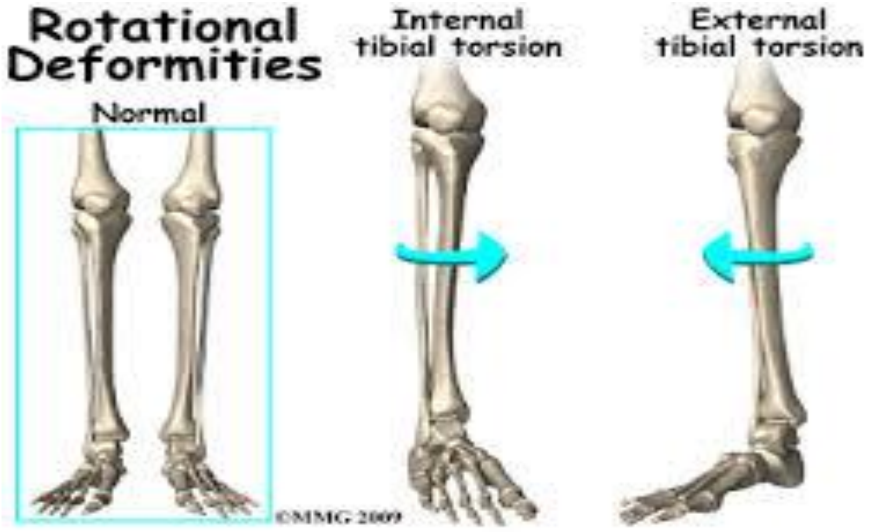
- If a cyclist has difficulty bending their knee and is having related symptoms try moving the cleat or shoe forward on the pedal.

Pedal Interface: Angular Positioning

- Angular foot positioning, toeing in or out, can be caused by:
  - Rotation of the tibia and femur, forefoot motion and/or increased tightness of the hip muscles.[18]

- Most people generally have 5-10° of toeing out. [19]

- HTTP://WWW.BRAMPTONFOOTCLINIC.COM/TREATMENTS/LIST-OF-TREATMENTS/INTOEING-OUTTOEING.HTM



http://www.eorthopod.com/content/rotational-deformities-in-children

Pedal Interface: Angular positioning

Practical application

- Cyclists with approximately 5-10° of toeing out should position their cleats and/or shoes in neutral (toes pointing straight ahead) with 5-10° of float. [9]

- This permits natural movement of the leg during cycling which can prevent and manage knee pain.[9]

- Positioning these cyclists' cleats and/or shoes in:[20]
    - Toeing out position results in a knock-kneed riding strategy and increases the risk for pain on the inner side of the knee.[20]
    - Toeing in position results in a bow-legged riding strategy and increases the risk for the development of ITB syndrome. [20]

Pedal Interface: Angular positioning

Practical application continued

- Cyclists that naturally have *excessive* amounts of toeing in or out should position their cleats and/or shoes to match their body's natural alignment (Figure 1). [9,20]
- A more complex quantitative method has been developed to assist with optimal angular positioning of the cleat based upon an individual's lower limb alignment. [20]
- Sometimes you just have to fit the pedal interface for comfort. [9]

http://bikedynamics.co.uk/fit02.htm

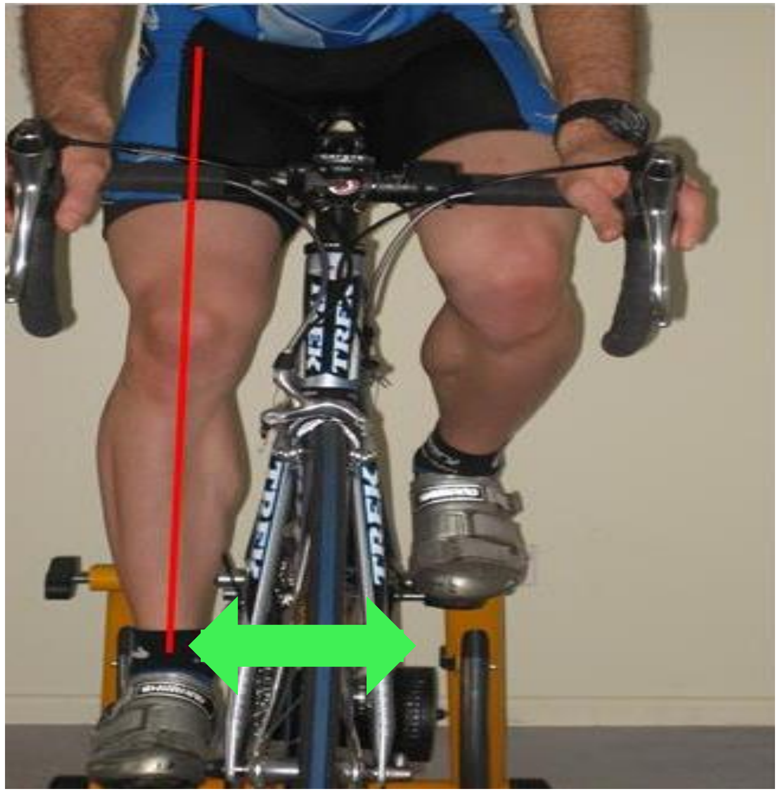
Figure 1

Pedal Interface: Q-factor

Q-factor: the distance between the bike and pedals.

- An ideal q-factor would result in a straight line drawn through the thigh, knee and ankle and be fitted for cyclist's comfort.[21,22]

- There is a recent trend to decrease q-factor to mimic normal standing and walking and to improve efficiency of power translation from the rider to the pedal.[21]



http://bikedynamics.co.uk/fit02.htm

Ideal

Pedal Interface: Q-Factor

- **Issue**: Q-factor has been standardized:[21]
  - Wider hips and too narrow of a q-factor will result in bow-legged riding position (left).[21]
  - Narrow hips and too wide of a q-factor will result in knock-kneed riding position (right).[21]
  - There is limited research suggesting that a q-factor that more closely mimics a cyclist's natural body alignment may result in less muscle activation and therefore reduce fatigue and improve cycling performance.[21,22]
  - Pedal spacers can be used to adjust q-factor

Too narrow Ideal Too wide

http://bikedynamics.co.uk/fit02.htm

Pedal Interface: Q-factor

Practical application

- Q-factor should be tailored to fit the individual cyclist such that a straight line can be drawn through the center of the thigh, knee and ankle and cyclist’s comfort is maximized. [21,22]

Pedal Interface: Crank Arm Length

- Changes in crank arm length (CAL) result in changes of range of motion requirements of the hip, knee and ankle during cycling. [23,24]
- Increasing CAL by 35 mm:[23,24]
  - Increases the total amount of knee extension.
  - Does not significantly affect maximal knee flexion angles.
  - Increases total knee range of motion during a pedal cycle.

Crank arm

http://www.aliexpress.com/

Pedal Interface: Crank Arm Length

Practical application

- CAL is generally standardized and therefore is not always a good fit for smaller or taller cyclists or for those with a large discrepancy between their leg and trunk lengths.
  - Example: For a smaller cyclist with shorter legs a standard CAL will be too long and will cause increased knee extension at the bottom dead center of the pedal cycle and increased total knee range of motion during cycling. This will increase the cyclist's risk for a knee overuse injury.

- Crank arms are costly to replace, so this may be a last consideration during bike fitting.

Pedal Interface: Leg Length Difference

- Two types: anatomical (true) vs functional (apparent).
- A true leg length discrepancy greater than 6mm is significant.[4]
    - Correct 1/3 to ½ of the discrepancy. [4]
- Cleat shim (Figure 2) vs. fitting the bike to the longer leg [13]
    - Fitting the longer leg can negatively impact the kinetic chain. (Figure 1)

Figure 2

http://www.bikefit.com/p-22-1-pack-3mm-universal-leg-length-shim.aspx

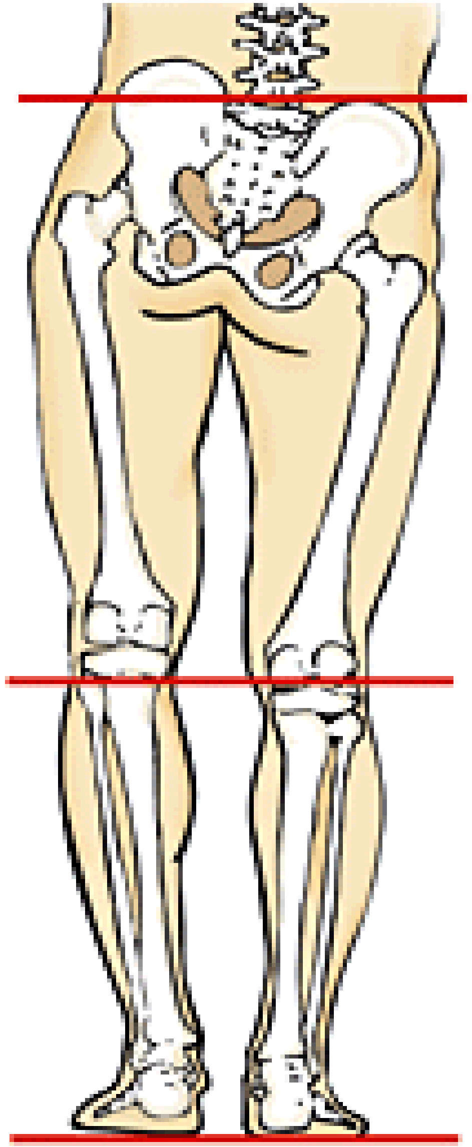


Figure 1

http://erikdalton.com/media/published-articles/short-leg-syndrome-part-2/

Pelvis-Saddle Interface

Pelvis-Saddle Interface

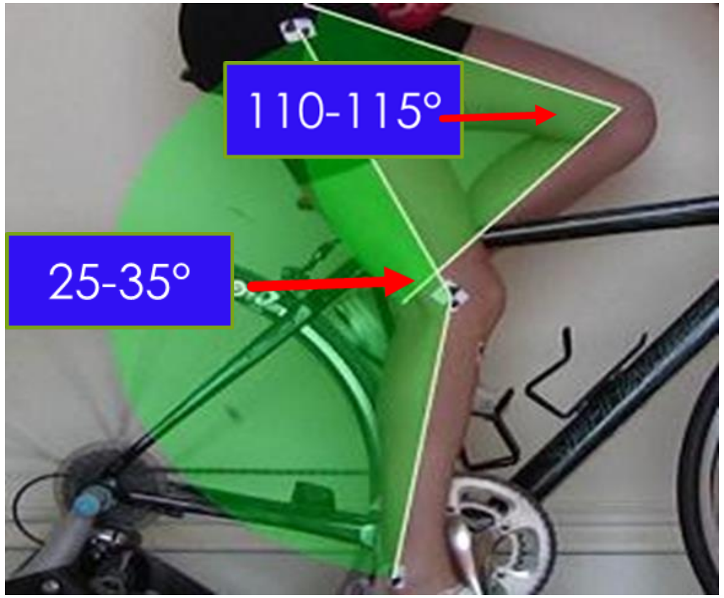
- Establishing saddle height

- Saddle height
  - Knee range of motion
  - Patellofemoral joint forces
  - Tibiofemoral joint forces

- Saddle position
  - Forward and backward

Pelvis-Saddle Interface: Establishing Saddle Height

- There are a variety of different methods for establishing the ideal static saddle height. [25]
- To prevent knee pain and optimize performance during cycling the best method for establishing saddle height is: [25]
  - When the cyclist is seated and the pedal is at the bottom dead center of the pedal cycle there should be 25-30° of knee flexion.
    - 25-30° of knee flexion may be more optimal to limit pain and injury in cyclists with pain at the front of the knee.[1]
    - 30-35° of knee flexion may be more optimal to limit pain and injury in cyclists with ITB syndrome. [1]
- At the top of the pedal cycle there should not be more than 110-115° of knee flexion. [1,4]



http://bikedynamics.co.uk/fit02.htm

Pelvis-Saddle Interface: Establishing Saddle Height

Dynamic: assessing bike fit while the cyclist is riding on a trainer.

- A study comparing a static versus dynamic method for establishing saddle height. [26]
    - Found that static saddle height measurements do not always correlate with dynamic measurements.
    - Knee motion during cycling is impacted by motions at the ankle and hips; as well as lower extremity flexibility and pedaling techniques. [26]

Pelvis-Saddle Interface: Establishing Saddle Height

Practical application

- Aim for a static knee flexion angle between 25-30° at the bottom dead center of the pedal cycle. If possible, perform a dynamic evaluation assessing for excessive changes in knee movement, the quality and symmetry of motion, power, cadence, heart rate and cyclist comfort.

http://www.jacksbikes.com/contents/en-us/d42_Custom_Bicycle_Fitting.html

Pelvis-Saddle Interface: Saddle Height-Knee Range of Motion

Saddle height affects hip, ankle and knee movements during cycling. [25]

- 4-5% change in saddle height results in a 25% change in total knee range of motion and a 40% change in knee joint angle when the pedal is at the bottom dead center of the pedal cycle. [25]

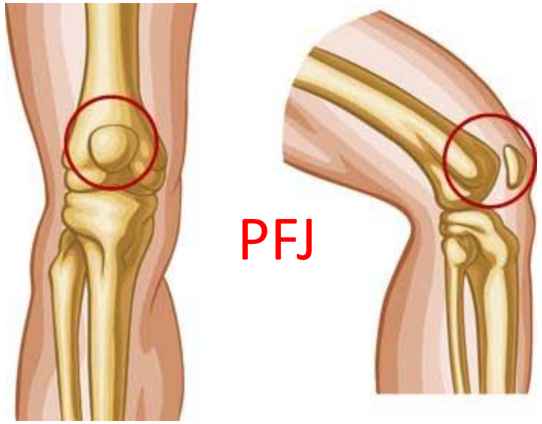
Changes in knee joint range of motion can result in injury:

- Over stretching of muscles and tendons. [3,25]
- Increased stress applied to the knee. [3,25]
- More wear and tear on the structures of the knee. [3]

Pelvis-Saddle Interface: Saddle Height-Patellofemoral Joint Forces

Increased knee flexion during cycling increases forces or stress at the patellofemoral joint (PFJ). [27]

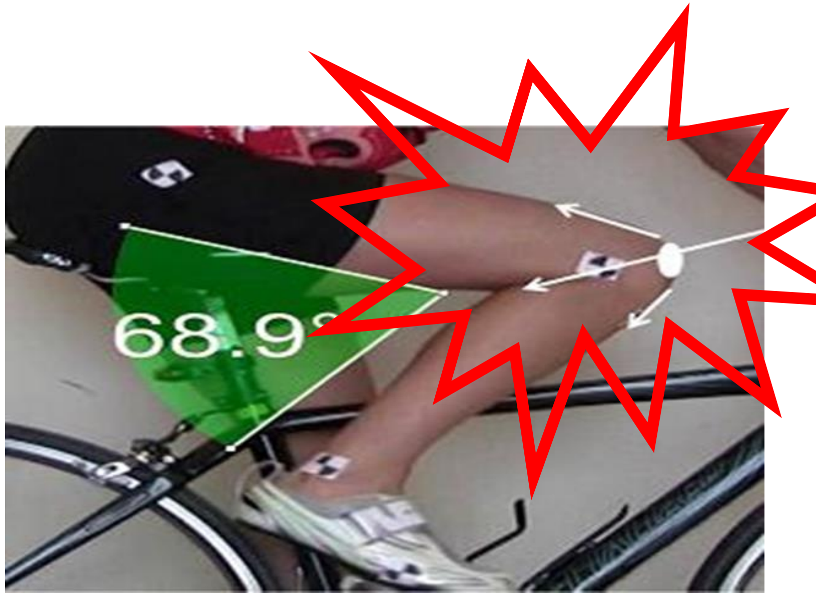
- Increasing saddle height, decreases PF forces. [27]
- Decreasing saddle height, increases PF forces. [27]



http://thewellnessdigest.com/knee-pain-patellofemoral-pain-syndrome-symptoms-and-cau

- Maximal forces observed at the PFJ during cycling. [25]
  - 800N (75 W , 70 rpm)
  - 1500 N (157 W, 80 rpm)

- PFJ forces of 1500N are greater than normal and can result in damage to the structures of the knee over time. [25]



http://bikedynamics.co.uk/fit02.htm

Pelvis-Saddle Interface: Saddle Height-Tibiofemoral Joint Forces.

Mixed results

- Some evidence suggests that changes in saddle height does not impact tibiofemoral joint (TFJ) compressive forces. [28,29]

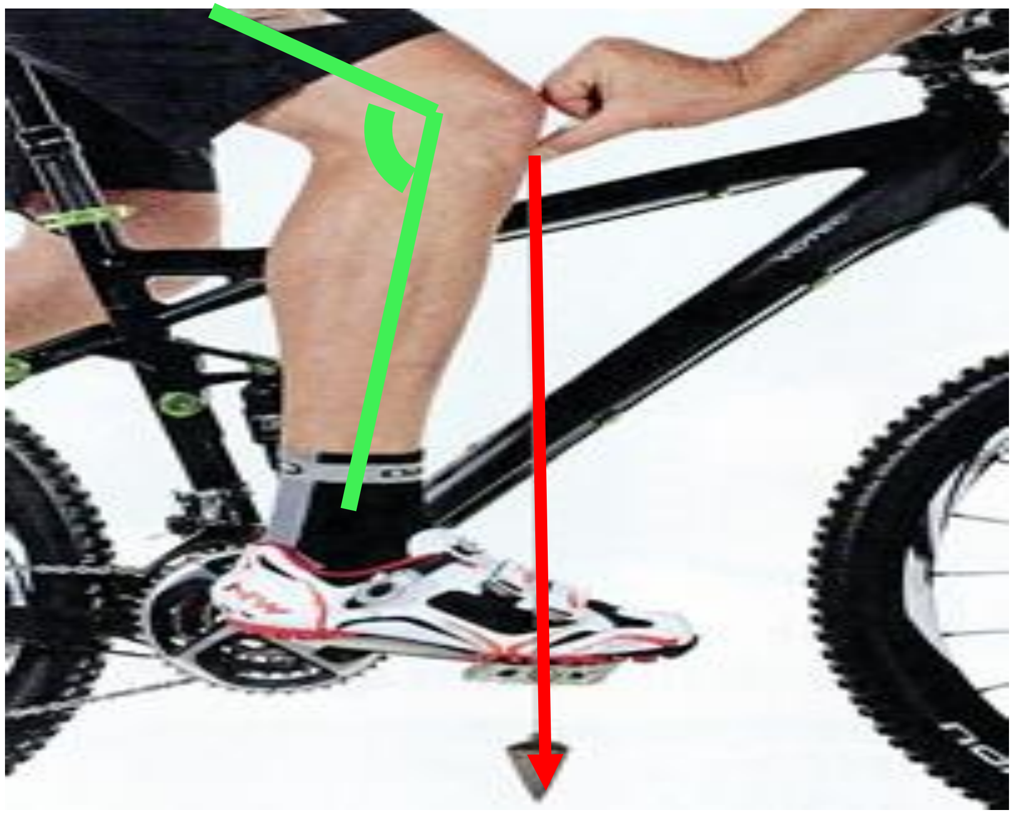
- Other evidence suggests that decreasing saddle height increases TFJ compressive forces and increasing saddle height decreases TFJ compressive forces.[16]

http://kinetichealthcalgary.blogspot.com/2011/01/treating-and-preventing-meniscus.html

Pelvis-Saddle Interface: Saddle Position

Forward and backward saddle position

- At the 3 o’clock position in the pedal cycle a line dropped straight down from the bottom of the kneecap should bisect the pedal axis. [4] (Figure 1)
- A more forward saddle position or moving a rider’s bottom forward on the saddle increases the knee flexion angle at the 3 o’clock position.[4,8]
- A more backward saddle position or moving a rider’s bottom backwards on the saddle decreases the knee flexion angle at the 3 o’clock position.[4,8]



http://www.singaporebikehash.com/hints_n_tips.html

Figure 1

Pelvis-Saddle Interface

Practical application

- If a cyclist has pain at the front of their knee while cycling and a low saddle height and/or forward saddle position with increased knee flexion angles then:
    - Increase the saddle height to achieve 25-30° of knee flexion at the bottom dead center of the pedal cycle. [16,25-29]
    - And/or move the saddle position backwards so that in the 3 o'clock position of the pedal cycle the kneecap is over the pedal axis. [4,8]
- If a cyclist has pain at the back of their knee while cycling, a high saddle height and/or a more backward saddle position with decreased knee flexion angles then:
    - Decrease the saddle height to achieve 25-30° of knee flexion at the bottom dead center of the pedal cycle. [16,25-29]
    - And/or move the saddle forwards so that in the 3 o'clock position of the pedal cycle the kneecap is over the pedal axis. [4,8]

Hands-Handlebar Interface

Hands-Handlebar Interface

- Limited research assessing the impact of the hands-handlebar interface directly on knee pain and injury in cycling.

- What can we look at?
    - Trunk orientation and postures during cycling.[30,31]

http://thefixedgear.wordpress.com/tag/velodrome/page/5/

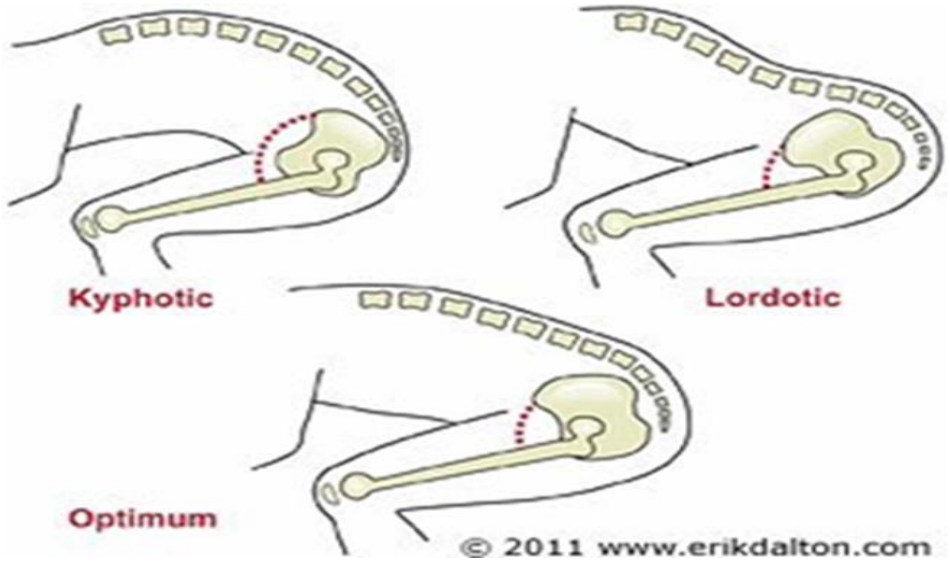
Hands-Handlebar Interface: Trunk Orientation

Trunk postures and orientation during cycling [30,31]

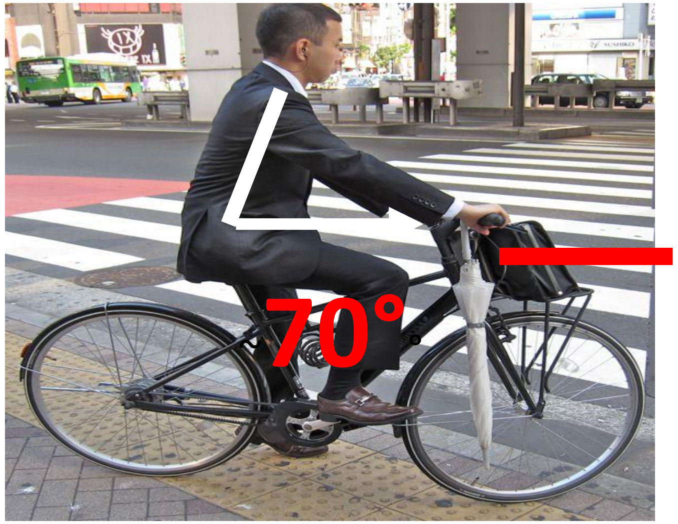
- Changes trunk and hip angles

Examples:

- Kyphotic, lordotic and optimum postures.
- Upright (brake hoods), dropped and aero position.

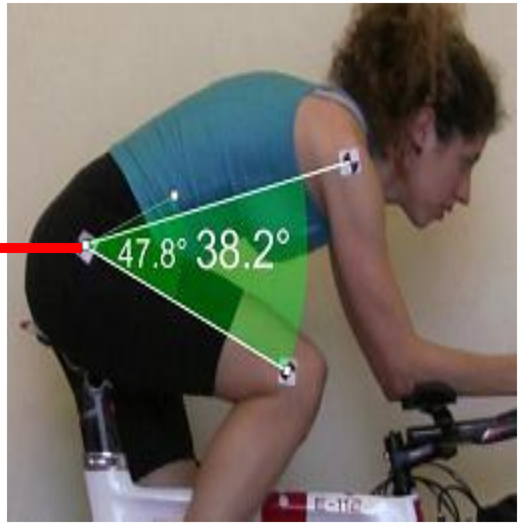


http://erikdalton.com/bad-bodies-or-bad-bike



Trunk angle

Hip angle



http://jnyyz.wordpress.com/2010/06/05/bike-sights-in-tokyo

http://bikedynamics.co.uk/fit02.htm

http://bikedynamics.co.uk/fit02.htm

Hands-Handlebar Interface: Trunk Orientation

Changes in trunk and hip angles during cycling impacts: [7,30,31,33,34]

- Length of the muscles and structures of the lower extremity.
    - Specifically, the quadriceps, hamstrings, hip flexors and ITB that attach onto both the hip and knee.
    - When the hip moves the knee is impacted by changes in the length of these structures.

http://bodybuilding24x7.com/archives/1516

Changes in lower extremity muscle and structure length during cycling impacts:

- Lower extremity muscle activation
- Lower extremity joint motion
- Cycling mechanics

→ Increased risk for knee overuse injury

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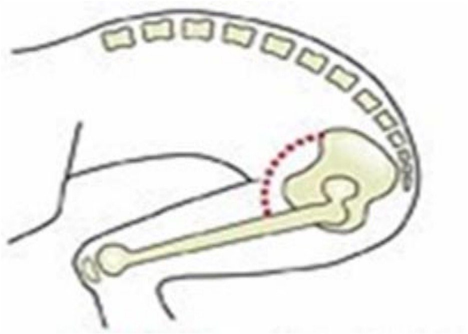
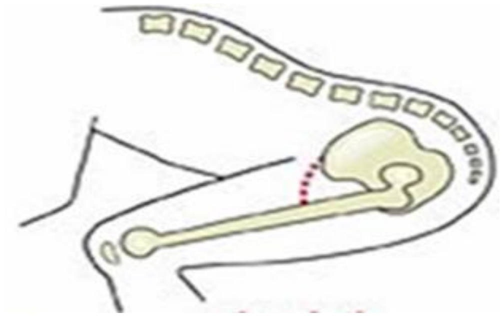
Trunk orientation and adjustments:



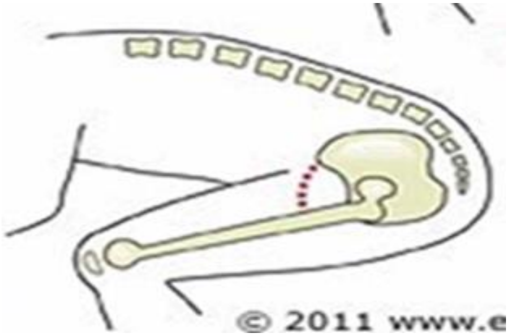
Kyphotic posture

- Short top tube and/or stem length[4]



Lordotic posture

- Long top tube and/or stem length[4]
- Handlebars tilted down [4]



Optimum position

- Hands on brake hoods: 45° trunk angle [4]
- Hands on drop bars: 60° trunk angle[4]
- Top of stem should be 1-3 in. below the level of the seat. [4]

http://erikdalton.com/bad-bodies-or-bad-bike

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Practical application

- Orientation and postures of the trunk impact the motion and muscle activation of the lower extremities during cycling and are critical components of a comprehensive bike fit for a cyclist with knee pain from cycling.

Examples:

- If a cyclist is over extended on the bike and in a lordotic position this can increase tension in the hamstring muscles and result in pain on the backside of the knee.
- If a cyclist is in a kyphotic position this can increase tension in the hip flexor muscles and can result in pain or injury to the front of the knee.

General *Guidelines* for Bike Fit Adjustments for Knee Pain

These are only guidelines and are not applicable for all individuals.

Knee pain[1]	Causes	Bicycle Adjustment
Anterior (front-side)	Saddle too low Saddle too far forward Crank arm too long Cleat/shoe too far backward Kyphotic posture Climbing too much Big gears and low rpm	Raise saddle (25-30° knee flexion) Move saddle back Shorten crank arm length Move cleat/shoe forward Increase top tube and/or stem length Reduce climbing (get out of saddle) Reduce gears, increase rpms.
Medial (Inner)	Cleats and/or toes pointing out during cycling No float or excessive float Excessive pronation Forefoot eversion Feet too far apart	Modify cleat position to neutral with 5-10° of float. Limit float to 5-10° 10° wedging to limit excessive motion. Cycling insoles to limit motion Decrease q-factor (take out spacers)
Lateral (Outside)	Cleats and/or toes pointing in during cycling No float or excessive float Excessive supination Forefoot inversion Feet too narrow	Modify cleat to neutral with 5-10° of float. Limit float to 5-10° 10° wedging to limit excessive motion. Cycling insoles to limit motion. Increase q-factor (add spacers)
Posterior (backside)	Saddle too high Saddle too far back Crank arm too long Cleat/shoe too far forward Lordotic posture	Lower saddle (25-30° knee flexion) Move saddle forward Shorten crank arm length Move cleat/shoe backward Reduce top tube and/or stem length

When do you fit a cyclist into a neutral position versus their natural body alignment?

- For most cyclists a neutral set up with 5-10° of float at the pedal interface is appropriate. [1]

Some practical suggestions:

- If a cyclist is having knee pain as a result of cycling first assess their bike fit, static and dynamic, and look for any components of their bike fit that are not adjusted properly. If adjustments need to be made make one adjustment at a time and allow time in between adjustments to assess the affects on the cyclist.[2]
  - Example: If a cyclist has knee pain from cycling and after assessing their bike fit you realize their saddle is too low then adjust their saddle appropriately and send them away to test out the adjustment for a week or two before making other adjustments.

- If a cyclist has a diagnosed or observable alignment issue in standing or walking and is having knee pain in a standard bike set-up/neutral position with 5-10° of float then it may be necessary to bias their bike set-up towards their body's natural alignment.
  - Example: A cyclist with excessive toeing out during standing and walking that is riding with their shoes and/or cleats positioned in neutral (toes straight ahead) and is having knee pain may benefit from placing their shoes and/or cleats in a more toed out position.

- Trial and error

Conclusions

- All cyclists can benefit from an individualized bike fit.
- Individualized bike fits can reduce the risk of injury, improve comfort on the bike, enhance performance, and optimize enjoyment while cycling.
- The kinetic chain is a critical component of an individualized bike fit. The knee can be impacted by all motions and postures occurring above and below the knee.
- There are three primary interfaces where the cyclist and the bike meet; the pedal, saddle and handlebars. Adjustments can be made at each of these interfaces to improve alignment, comfort and reduce the risk of knee pain and injury.
- Most cyclists require a bike fit that puts them in a neutral alignment with 5-10° of float at the pedal interface.
- Some cyclists may require a bike fit that is biased towards their body’s natural alignment.

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