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Biomechanical Factors Associated with Knee Pain in Cyclists: A Systematic Review of the Literature

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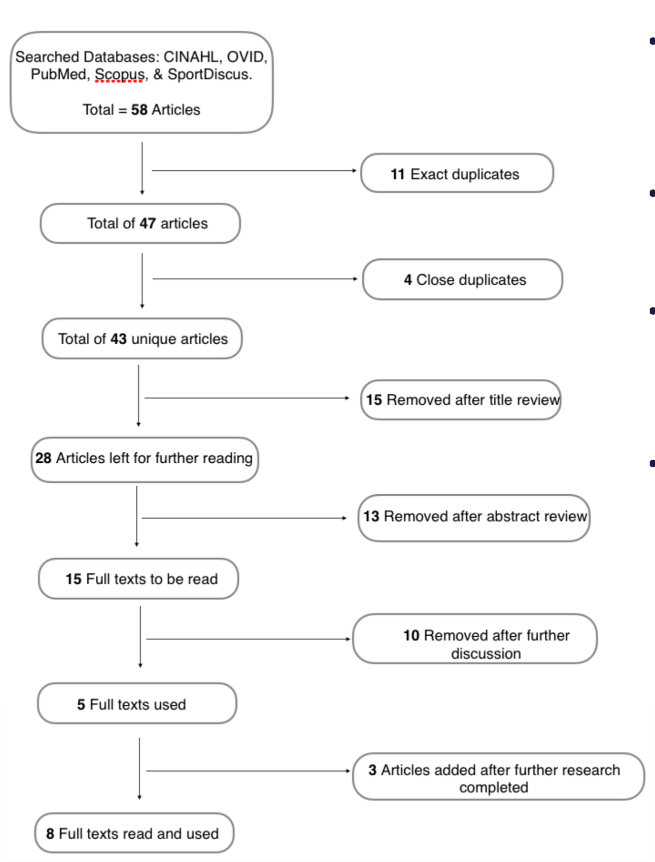
Purpose

- This systematic review will focus on literature related to positioning on, and configuration of the bicycle that can influence forces acting on the knee and their potential effects on injury. This review also serves to present recommendations for rehabilitation and injury prevention based on the findings in current literature. The goal of this research was to develop an algorithm that can be used in guiding decision making for the sports medicine practitioner.

Clinical Relevance

- Roughly thirty-three million United States residents ride a bicycle an average of 6 days/month for an average of >1 hour/day
- Knee pain is the most common overuse injury in cycling
- Elite professionals: 38% traumatic injuries and 62% overuse injuries
- Anterior knee pain is the most common complaint among cyclists seeking medical care, and accounts for 25% of overuse injuries in cycling
- The iliotibial band (ITB) is the most common cause of lateral knee pain in cyclists.
  - Hills can cause repetitive forceful shearing at the knee
  - Toes pointing inward
  - Saddle too high or too far forward
- Medial knee pain can also be experienced by cyclists
  - Pes anserine syndrome
  - Medial plica syndrome
  - Medial meniscus tear is least common reason
- The high demand of pressure during the downstroke is the proposed mechanism for the development of PFS or "biker's knee"
  - More common in females
  - High Q angle predisposes individual to condition
  - Incorrect saddle position has a negative effect on knee biomechanics

Methods



- Review Protocol
  - Based on Preferred Reporting Items for Systematic Reviews and Meta-Analsys (PRISMA) guidelines
- Search Terms
  - knee injuries, knee pain, cycling, cyclist, and overuse.
- Data Extraction
  - Knee pain, cycling parameters, number of subjects, gender, EMG activity, bike fit, and limitations
- Grading the Evidence
  - Downs and Black Questionnaire was used
  - Consultation between all 4 researchers and faculty advisor to resolve discrepancies
  - Risk of bias include lack of randomization and lack of level 1 evidence.

Results

Author, Year	Research Design	Downs & Black Score	Methods	Results	Conclusions
Bailey et al., 2003	Observational	13	24 experienced male cyclists, 10 with a history of knee pain Coronal and sagittal plane kinetics measured at 90 rpm and 200±10W	Cyclists with knee pain experienced greater DF and knee valgus throughout revolution No differences in knee flexion angle between pain and no pain groups Previously injured group demonstrated 2.3° more DF at maximum 3.8° difference in minimum DF at DBC between cyclists with and without injury Anterior knee pain related to phases of pedal cycle when knee extensors active	More medial knee position adopted by previously injured cyclists not conclusively attributed to a cause and effect of injury Greater DF seen in previously injured cyclists, no strong relationship to anterior knee pain or patellar tendinitis No support in relating excessive knee flexion from low saddle height and overuse knee injuries Increased valgus (Q angle) likely disrupts knee extensor mechanism
Bini et al., 2013	Observational	9	21 competitive cyclists (cycling or triathlon) Cyclists rode 1 min with 90 rpm pedaling cadence maximal power output from the incremental test in their preferred saddle position, then at a workload set to the second ventilatory threshold in three saddle positions: preferred, most forward and most backward Forces applied on the right and right lower limb kinematics recorded for last 20 s during conditions using 2D pedal dynamometer and high speed camera	Substantial differences in position between preferred/forward/backward positions Large reductions in tibiofemoral anterior shear forces in forward saddle position Large increases in knee flexion angle when comparing forward to backward saddle positions Neither forward or backward positions affected patellofemoral compressive and tibiofemoral compressive forces	Tibiofemoral anterior shear force greater for backward position compared to forward and preferred Small increases in knee flexion angle for a constant workload level may explain differences in patellofemoral and tibiofemoral compressive forces Tibiofemoral anterior shear force more sensitive to changes in knee joint angle than other knee force components
Bini and Hume, 2014	Observational	9	12 cyclists (more cycling training volume) and 12 triathletes with competitive experience Athlete's vertical and horizontal position of handlebars measured Stationary cycle ergometer set at "preferred height" Four sub-maximal 2-min cycling trials completed at preferred, low, high and an advocated optimal saddle height for cycling efficiency Right pedal forces measured via instrumented pedal Lower limb kinematics observed via high speed camera, recorded for each saddle height	No changes observed in total pedal force or index of effectiveness when saddle height changed or comparing cyclists vs. triathletes Large decreases in ankle ROM and mechanical work observed for triathletes at low saddle height Increased knee mean angles and decreased hip mean angles observed for both groups at low and preferred compared to high and optimal heights Smaller hip mean angle and greater hip ROM at preferred saddle height in triathletes	Changes in saddle height up to 5% of preferred saddle height for cyclists and 7% for triathletes affected hip and knee angles High saddle height resulted in smaller knee angle and greater ROM and hip mean angle Cyclists demonstrated improved index of effectiveness, triathletes presented with greater ankle work and ROM with optimal saddle height Greater adaptation of triathletes to changes in saddle height compared to cyclists
Dieter et al., 2014	Observational	10	10 healthy cyclists (6 women and 4 men) and 7 cyclists with PFPS (1 women and 6 men) 10 minute cycling trial conducted, measuring EMG activity in VM/VL.BF/ST Pedaled at RPE scale score of 14 for consistency	No significant difference found in VM/VL on time between groups Significant difference found in VM/VL off time, with VL occurring longer in the PFPS group Significant difference found in BF/ST on time, with BF occurring first in PFPS group (opposite found in CTL group) During knee flexion movement, ST was not contracted in PFPS, where CTL group had contraction Significant difference found in BF/ST off time, where PFPS group had BF contract after ST was shut off (opposite found in CTL group)	Onset of quadriceps activation not correlated to PFPS Differences in offset of the quadriceps activity not likely to be a contributor in altering joint mechanics but may contribute to pain Temporal activation differences in BF/ST in these groups, co-activation of quadriceps may suggest changes in PFJ kinematics and kinetics Further research recommended to see if changes are causal or compensatory
Farrell et al., 2003	Observational	8	10 total participants (6 M and 4 F) without ITBFS Ramped cycling up to 80-90 RPM, data collected at 5 minute intervals Foot/pedal force analyzed at each revolution using electrical markers Goal to see if knee flexion or pedal force production would cause more injury to the ITB compared to running	Increase in knee flexion moment at dead bottom center, attributed to lateral pelvic tilting Ground reaction force was 17-19% when compared to aggressive jogging Runners spent 75ms in impingement zone, cyclists spent only 38ms Cyclists spent 30-40% more repetitions in the impingement zone than runners Runners spent more time overall in the impingement zone	Force pedal not seen as an important role to attribute to ITBFS due to small fraction of ground reaction force vs. running Cycling, ITB spends less per cycle time in impingement zone Repetition, anatomical differences, improper bike set-up, and improper training more important roles
Gardner et al., 2015	Randomized Control Trial	13	13 subjects with OA and 11 healthy subjects 35-65 years old (male and female) Motion analysis system and custom instrumented pedal used to obtain 3D kinematics and kinetics during cycling 5 pedal cycles obtained: One neutral (0°) and two toe-in conditions (5° and 10°) Conditions were collected at 60 RPM and 80W.	Greater pronation increases internal tibial rotation, which increases valgus forces at knee. Cycling seated, using both 5° and 10° toe-in foot progression angles effective in reducing knee adduction angles in knee OA and healthy subjects. No decrease knee abduction moments (KAM) or decreased knee pain found	For individuals who cycle with increased knee adduction angles, Decreasing foot progression angle beneficial for reducing the risk of overuse knee injuries during cycling Frontal plane knee alignment closer to a neutral position.
Gregersen et al, 2006	Observational	3	15 competitive cyclists18-30 years, no overuse injuries Pedaled at five randomly assigned inversion/eversion angles (10°and 5° everted/inverted and neutral) on mounted racing bike Non-driving intersegmental knee moments throughout crank cycle computed VMO, VL, and TFL forces measured with surface EMG	Greater pronation increases internal tibial rotation, which increases valgus forces at knee. At 10° everted position, peak varus moment decreased 55% and peak internal axial moment decreased 53% during power stroke	Everting the foot beneficial in preventing or ameliorating patellofemoral pain syndrome while cycling
Tamborindeguy et al, 2011	Observational	10	9 uninjured male non-cyclists aged 22-36 Saddle height calculated for 3 trials: 100%, 103%, and 97% of trochanteric height At each height pedaling cadence and workload set at 70 rpm and 70 W, 1 min of cycling Changes in saddle height achieved within 30s following random selected order	No significant difference in saddle height effects on maximal peak tibiofemoral compressive/anterior shear components No significant difference in saddle height effects on maximal peak patellofemoral compressive/anterior shear components No significant difference in knee angle compressive forces from saddle height differences Significantly higher knee flexion angle at low saddle height compared to normal and high saddle height	No significant effects on joint load in uninjured subjects with small changes in saddle height (low workload) Significant changes in joint kinematics unrelated to changes in joint forces Knee flexion angle sensitive to changes in saddle height, gold standard method for setting bicycle configuration Increased saddle height may create increased plantarflexion

Fig. 1: Cycle Diagram

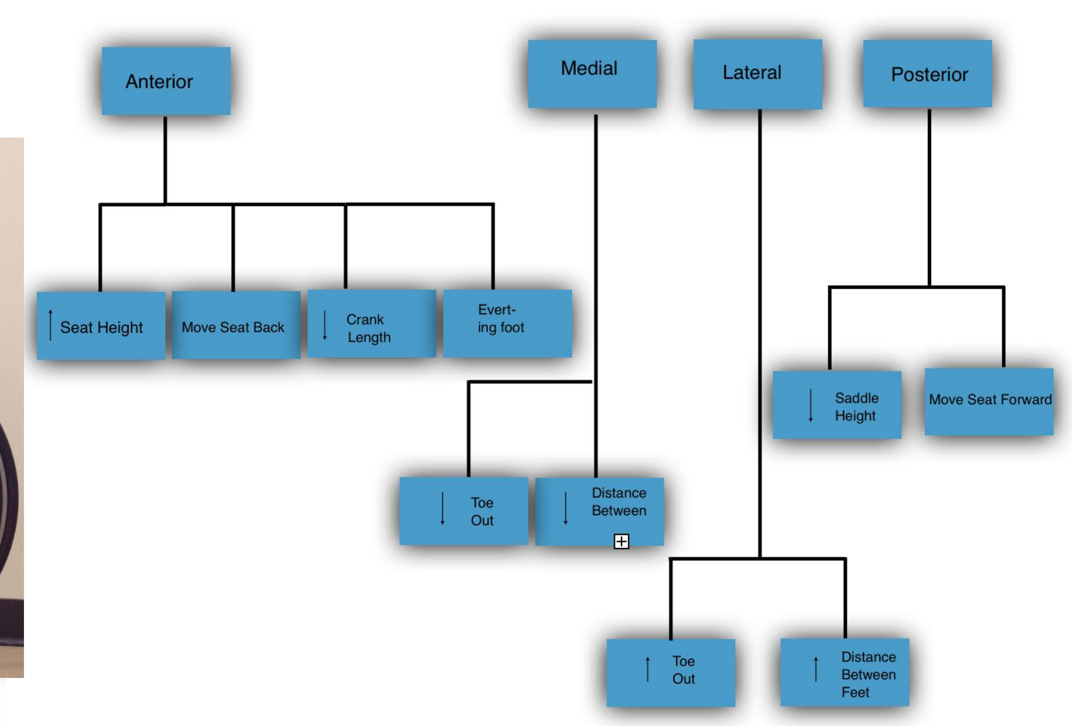


Fig. 2: Algorithm for Alleviating Knee Pain during Cycling

Discussion

- Difference between cyclists with and without knee pain
  - Cyclists with prior history of injury may adapt a more medial knee position which reduces stress on the extensor mechanism
  - Greater dorsiflexion observed in cyclists with history of injury during phase of pedal cycle where a knee flexor moment is found
- Effects of different saddle and foot position
  - Saddle
    - Backward saddle positions increases tibiofemoral anterior shear force
      - Compressive forces are more sensitive to knee flexion angles
      - Compressive forces relate to increased patellofemoral knee pain
    - Low saddle height may contribute to anterior knee pain
    - Knee flexion angle appears to be sensitive to changes in saddle height, low saddle height produces significantly higher knee flexion angle
    - High saddle height relates to lateral knee pain (ITBS) due to increased time within the knee impingement zone
  - Foot position
    - Increased eversion may reduce patellofemoral pain syndrome
      - Due to changes in muscle activation and potential reduction in lateral patellar tracking
      - Increased pronation leads to increased tibial rotation and increased values forces at the knee
      - Peak virus forces decrease with 10 degrees of eversion of the foot
    - A more neutral foot and knee position is beneficial for reducing overuse knee injuries
    - No ideal foot position noted in the literature to prevent most knee injuries
    - Alterations in foot position may alleviate pain in cyclists with knee pain

Limitations

- Limited experimental studies comparing cyclists with and without knee pain. Studies containing data on cyclists with knee pain but limited research regarding preventative measures in those without knee pain
- Few randomized control trials across the literature on the topic
- Low to moderate evidenced per Downs and Black grading scale
- Little research regarding effects of positioning in cyclists with posterior or medial knee pain

Conclusions

- "Optimal" bike fit inconsistent across the literature
  - No single configuration shown to decrease or prevent knee pain
- Inconclusive data regarding biomechanical differences in cyclists with and without knee pain
- Recommendation for further experimental research in manipulating various bicycle components to determine an optimal configuration to prevent or alleviate knee pain in cyclists

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