Training and Injury Considerations in Female-Identifying Cyclists

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Alongside the growth of cycling has been a corresponding increase in the proportion of female-identifying cyclists on the roads and trails. Assumptions about anatomic differences have historically inspired specific equipment design for women cyclists, while most of the cycling research has included only male-identifying participants. More recently, the industry has shifted towards a more gender-inclusive design, in line with the heterogeneity seen in cyclists of any gender identity. There has been research into biomechanical and metabolic differences of female athletes, which can impact female cyclists' performance and injury risk. However, women cyclists are not defined solely by their anatomy or physiology. Their experiences, needs, access, and goals must be considered in developing strategies for prevention and rehabilitation of cycling-related injury, as well as training and performance.

INTRODUCTION

Cycling is an excellent activity for fitness as well as transportation, tremendously adaptable for musculoskeletal conditions and disabilities, making the population riding bicycles extremely heterogeneous. While some ride for fitness and spend many hours in the saddle, others ride for transportation, perhaps just across town. Owing to the repetitive nature of the pedal stroke, a properly adjusted bicycle is essential for comfort, prevention of overuse injury, as well as safety, such as the ability to properly steer and brake. While gender-specific anatomic and physiologic differences exist and have been studied in other contexts, riding style as well as anatomical and physiological variation among cyclists dictates the need for bicycle fit accommodations.[1-3]

In this article we aim to describe a variety of training and injury considerations for women cyclists, including hormonal and nutritional factors, bicycle fit and overuse injury mechanisms. To that end, and with an understanding of the heterogeneity of women cyclists, we will use the broadest and most inclusive definition of women in cycling. Many structural and anatomic characteristics including those associated with injury are not exclusive to women, and in turn, women cyclists are not defined by their anatomy. Not all topics discussed apply universally to cyclists, regardless of gender, and many issues may also apply to cyclists who do not define themselves as women or female. Prior research on women cyclists (as with other women athletes) is extremely limited, and studies vary with regard to their

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population and definition of study groups. Therefore, a combination of terms including "women," "female," and "female-identifying" will be used throughout.[4]

Participation

Although cycling has traditionally been a male-dominated activity, women's participation in both recreational and competitive cycling has been growing over recent years.[5-7] Numbers of commuter and recreational cyclists have increased, and software platforms including Strava and Zwift have likewise seen increases in women riders.[5] Competitive cycling has seen developments including the creation of a shorter women's race within the Tour de France, an increase in number of Union Cycliste Internationale (UCI) women's world teams and in the minimum salary for professional women cyclists.[6] However, there remains a persistent gender disparity in cycling, which is likely multifactorial.[8-11] A recent analysis has shown a positive association between the ratio of female : male cyclists and the presence of dedicated cycling infrastructure, indicating that perceived safety is a key factor related to gender disparity in cycling.[8] The increase in ridership during the COVID19 pandemic (associated with decreased car traffic) led to increases in women's cycling and use of bike share programs in cities such as New York.[12] Other factors include lack of availability of appropriate equipment, incompatibility of footwear or clothing with commuter cycling, as well as the inability to carry children or other passengers. When considering the disparities in cycling participation, it is important to consider all genders, as well as other intersecting identities such as age, race, ethnicity, income, and ability, all of which impact an individual's access, safety, and choice of transport modes.[9]

SYSTEMIC FACTORS AFFECTING INJURY RISK FOR WOMEN CYCLISTS

Athletes of all sex and gender identities are susceptible to injuries, which may result from muscular imbalance, degenerative change, insufficient nutrition and recovery, high training load and volume, as well as hormone- and/or anatomic-specific biomechanics.[13] Female athletes may be at higher risk, as evidenced by the higher rates of overuse injury in female Division 1 athletes compared to their male counterparts.[14] Both systemic factors (hormones, nutrition, physiologic effects of training load) and anatomical differences in joints and biomechanics may contribute.

Hormones

Circulating sex hormone concentrations have significant effects on the neuromusculoskeletal system, and vary widely throughout a lifespan from puberty though menopause as well as throughout the menstrual cycle.[15] Female-identifying cyclists will have varying levels of sex hormones depending on their biological sex, presence (or lack) of menstrual cycle, and use of exogenous hormones (gender-affirming hormone therapy, hormone replacement therapy, doping). Effects of hormones on the musculoskeletal system are described in Table 1.[16-20] Of particular interest, estrogen and relaxin act synergistically and systemically to increase ligament laxity and decrease strength, while testosterone promotes stiffness and strength.[17-25] The relationship of cyclic hormonal fluctuations and traumatic injuries is still under exploration though emerging literature primarily on anterior cruciate ligament (ACL) injuries suggests risk may be increased during the follicular phase and decreased during luteal phase, while hormonal contraceptives may have a protective effect.[26-30]

Sex differences also exist in mitochondrial function, substrate utilization during exercise, insulin sensitivity, immune system responses, muscle and body composition, thermoregulation, endocrine function and other physiological functions in part due to hormonal differences.[31] Because hormonal impact on these functions is highly individual, tracking of the menstrual cycle versus training and recovery metrics may be useful to help tailor training and nutrition strategies for female athletes.[31] There is controversy regarding data and health privacy, gender bias and barriers to participation in sport that bear further consideration before implementing systematic menstrual cycle/status tracking.

Nutrition

A foundational nutrition focus is to ensure adequate energy availability (EA) to support training adaptation, performance, recovery, and the overall athlete health.[31,32] Low energy availability (LEA) refers to a lack of sufficient energy to support normal physiological functioning after accounting for exercise, leading to endocrine and metabolic changes, impaired sports performance,

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Table 1. Important sex hormone effects on the neuromusculoskeletal system for female-identifying cyclists

	Estrogen	*Progesterone*	*Relaxin*	*Testosterone*
Bone	- ↑ linear growth during puberty - ↑ growth plate closure during puberty	- Quickens bone formation during luteal phase	- ↑ osteoclasto-genesis (in vitro) - ↑ osteoblast differentiation (in vivo)	- ↑ calcium absorption and retention
Ligaments	- ↓ fibroblasts - ↑ laxity - ↓ load to failure	- ↓ estrogen suppression of fibroblasts	- ↑ collagen degradation - ↑ laxity	- ↑ fibroblast proliferation
Tendons	- ↑ collagen synthesis - ↓ stiffness	- ↑ collagen degradation by ↑ relaxin receptors	- ↓ stiffness throughout menstrual cycle[c]	- ↑ collagen maturation - ↓ relaxin effect
Muscle	- Undetermined influence on mass and strength - ↑ mass[a] - ↑ strength[a]	- May ↑ growth[b]	- ↑ healing at supraphysiologic doses	- ↑ mass
Nerves	- Excitatory	- Inhibitory	- Undetermined influence on spatial memory	- Excitatory - ↑ regeneration of motor neurons

[a] Evidence in animal model, [b] Evidence in postmenopausal women , [c] Evidence in patellar tendon

and the development of Relative Energy Deficiency in Sport (REDs), defined as "impairments of metabolic rate, menstrual function, bone health, immunity, protein synthesis and cardiovascular health."[31,33-37]

Female endurance athletes, including cyclists, are estimated to be at higher risk for LEA.[38] Risk factors for LEA are prevalent in cycling, including the emphasis on power-to-weight ratio, desire for lower body weight, tight fitting clothing, and the difficulty of eating during training and competition.[37,39,40] Low body mass has been correlated with better competition outcomes, and measures of world-class performance such as $VO2_{max}$ (mL/min/kg), or lactate threshold in (W/kg) are relative to mass.[41] Symptoms of LEA such as amenorrhea or oligomenorrhea, declining performance, extended recovery, or increased rating of perceived exertion (RPE) may be noted by athletes and/or coaches. In addition to objective performance metrics, an athlete's RPE is important to follow as perceptions of session difficulty may differ between athletes and coaches.[42] Nutritional considerations and recommendations for female athletes are highlighted in Table 2. However, athletes seeking to improve health, performance and avoid injury should consider a consultation with a sports dietician to ensure they are fueling appropriately.

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Table 2. Female athlete nutrition considerations and recommendations

	Current nutrition considerations and recommendations*
Energy availability (EA)	Defined as the difference in energy intake (EI) and exercise energy expenditure (EEE) relative to fat free mass (FFM).[34] Target optimal EA at 45 kcals/FFM/day
Carbohydrate (CHO)	- Preferred fuel for moderate-to-high intensity exercise, and important for an athlete's health, performance and bone health, though research specifically on female athletes is limited.[43-45] - Align overall carbohydrate intake to activity level and goals.[31] Ingesting ~30g of CHO prior to high intensity exercise lasting an hour may confer a performance benefit.[31] - Target 30-60g of CHO per hour for exercise longer than an hour.[31] - Following longer sessions, replenish glycogen stores with at least 1.2g/kg of CHO.[31] - Gastrointestinal symptoms during exercise are prevalent among female athletes, and as glucose kinetics change throughout the menstrual cycle, tracking CHO intake, cycle and symptoms may be useful.[31]
Protein	- Protein helps to repair and rebuild muscle and replenish losses of amino acids oxidized during exercise.[31] - Target 1.8g – 2.2g/kg/day spaced evenly throughout the day.[31] - Rapidly consume 0.32-0.38 g/kg of a quality protein source immediately before and/or after exercise, including ~10g of essential amino acids for peri- and post-menopausal athletes.[31]
Hydration	- Female athletes are at greater risk for hyponatremia relative to men as sex hormones impact fluid regulation and electrolyte balance, and thermoregulation may be impacted at lower levels of dehydration, increasing the importance of a tailored hydration strategy.[31] - The dietary reference intakes (DRI) for women are 2.2L/day of water and 2.7L/day of water containing beverages and food.[46] Athletes need more than the DRI and can benefit from sweat testing to customize individual hydration and electrolyte needs.
Supplements	- Caffeine, creatine and iron have the most evidence supporting use in female athletes.[31]

Transgender Athletes	- Nutrition assessments utilize sex-specific reference information which can vary significantly, including estimated energy expenditure, recommended dietary intakes and biomarker reference ranges.[47]
	- Current guidelines include:
	  - Using reference ranges based on sex at birth for those not medically transitioned.
	  - Select reference ranges for the nutrition assessment based on the status of the medical transition.
	  - Using a range between listed male & female values.[47]

* These nutritional considerations and recommendations will continue to shift with more targeted research on female athletes.

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BIKE FIT AND INJURY

Bike fit is the process of adjusting a bicycle to the precise measurements needed to position a rider for optimal comfort, efficiency, and power. While optimization of cycling biomechanics is widely researched, the majority of studies are comprised of men and there is relatively little research on how the non-male-identifying body interacts with the bicycle, instead relying on experience and anecdotal evidence.[48-50] Historically, the approach to bicycle design for women was known as "shrink and pink," based on assumptions regarding female proportions seen in standing. However, newer anthropometric data obtained in the cycling position suggests that bike fit differences between genders are not nearly as clear as previously thought, and are comparable to the heterogeneity within an all-female or all-male population.[51] As such, the industry is trending towards a more gender-inclusive design, focusing on individual variations between body types which exist regardless of gender, as well as considering experience, skill, and goals of riding.[51,52]

While a variety of positions may be tolerable based on volume and type of riding, several basic relationships exist on the bike. The appropriate position of a rider is described in Figure 1, and basic bicycle anatomy is shown in Figure 2.[50,53-55] The three contact points of the rider and bicycle are the pedals, saddle, and handlebars. A bike fit typically starts at the feet to ensure proper positioning on the pedal, then saddle position, and finally the bars. Every small adjustment has an effect along the kinetic chain. Starting at the foot, factors including improper cleat position, lack of support, excessive rotation on the pedal ("float"), or flexible shoe impair the ability of the foot to serve as a rigid lever for power transfer, and can cause inefficiency and alter biomechanics further up the kinetic chain.[56-58] During pedaling, the foot traces a circle dictated by the length of the crank arm, which also determines maximum knee and hip flexion. Similarly, moving the saddle affects not only the knee but the upper body and reach to the handlebars.[55] Fit can then be further "dialed" through adjustment or substitution of components to improve comfort, optimize performance, and accommodate injury. Small changes at several areas may be better tolerated than a single large adjustment.[49] For example, saddle position may be raised to a knee angle of approximately 25° for optimal performance, but this may not be tolerated by a rider due to limited hamstring flexibility, resulting in lumbopelvic flexion, excessive knee extension and plantarflexion to reach the pedals, and lateral pelvic rocking, potentially leading to injury throughout the kinetic chain.[50,59-64]

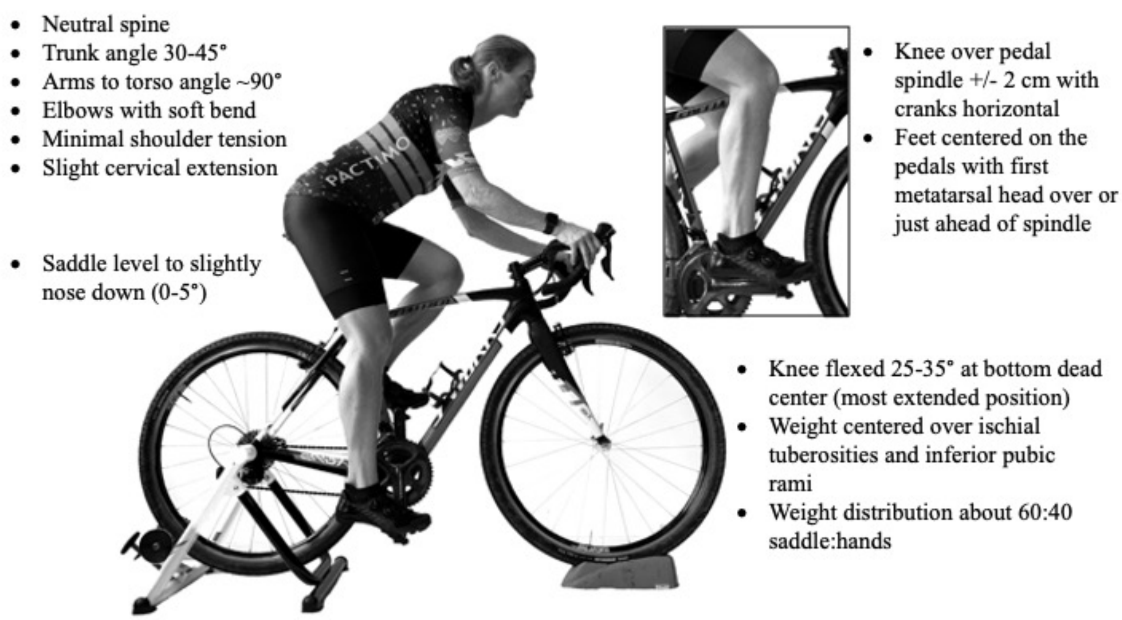

Figure 1. Appropriate bicycle position

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Figure 2. Selected bicycle anatomy and components

The understanding of bike fit is variable among both cyclists and coaches. The need for bike fit modifications may present itself as muscle or joint pain that persists for more than a few days, in spite of reduced training intensity and volume including when acute injury is not apparent. An inappropriate position on one bike that causes excessive fatigue in a muscle group can also increase the RPE for a workout, even for similar heart rate and power as performed on another bike with more optimized fit.[65] The appearance may be similar to the decoupling of power, heart rate, and RPE when seen in injury and illness.[66] Bike fit should also be considered with metabolic testing. Small changes in bike fit, such as raising or lowering saddle height by 2%, can change gross efficiency, in that the work performed and power output are different for the same rate of oxygen consumption.[67] One cyclist may ride multiple bicycles in order to compete or train in several disciplines (i.e. road, triathlon, gravel), making evaluation of bike fit contributors to overuse injury challenging.

Injuries of Cyclists

Cycling injury must be approached with an understanding of anatomy, biomechanics, and bicycle fit.[56] Lower extremity overuse injuries including low back pain and anterior knee pain are prevalent and often related to inappropriate bicycle fit, but there is a wide spectrum of injury reflective of the many moving parts of the kinetic chain, the many types of riding, long hours spent in the saddle, and the repetitive nature of the pedal stroke.[68,69]

Knee

Cycling involves dynamic flexion at the ankle, knee, and hip joints, predominantly in the sagittal plane, similar to the position of squatting or landing from jumps, which have established sex-based kinematic differences.[56] Compared to men, women demonstrate increased pelvic rotation, hip adduction and internal rotation, and mediolateral knee motion in a single-leg squat and larger knee valgus peak joint displacement when landing from a jump.[3,70] A correlation was found between hip abductor strength and hip flexion and adduction and knee valgus in women but not men.[70]

The repetitive sagittal motion and force across the anterior knee may lead to patellofemoral pain syndrome (PFPS), pain in the patella or surrounding soft tissues.[71] In the general population PFPS is described as affecting predominantly young females, and is likely multifactorial including patellar maltracking, dynamic valgus due to decreased strength of the hip abductors or foot pronation, vastus medialis weakness.[72,73] On the bicycle, excessive medial or

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lateral knee deviation (Figure 3) during pedaling may predispose cyclists to PFPS, and can occur due for several reasons.[63,73] Lateral deviation may due to reduced hip range of motion or hip impingement, particularly if the crank length of the bicycle is long enough to force excessive hip flexion at the top of the pedal stroke. Inadequate foot support allowing pronation may lead to medial knee deviation during the downward (power) phase of the pedal stroke.

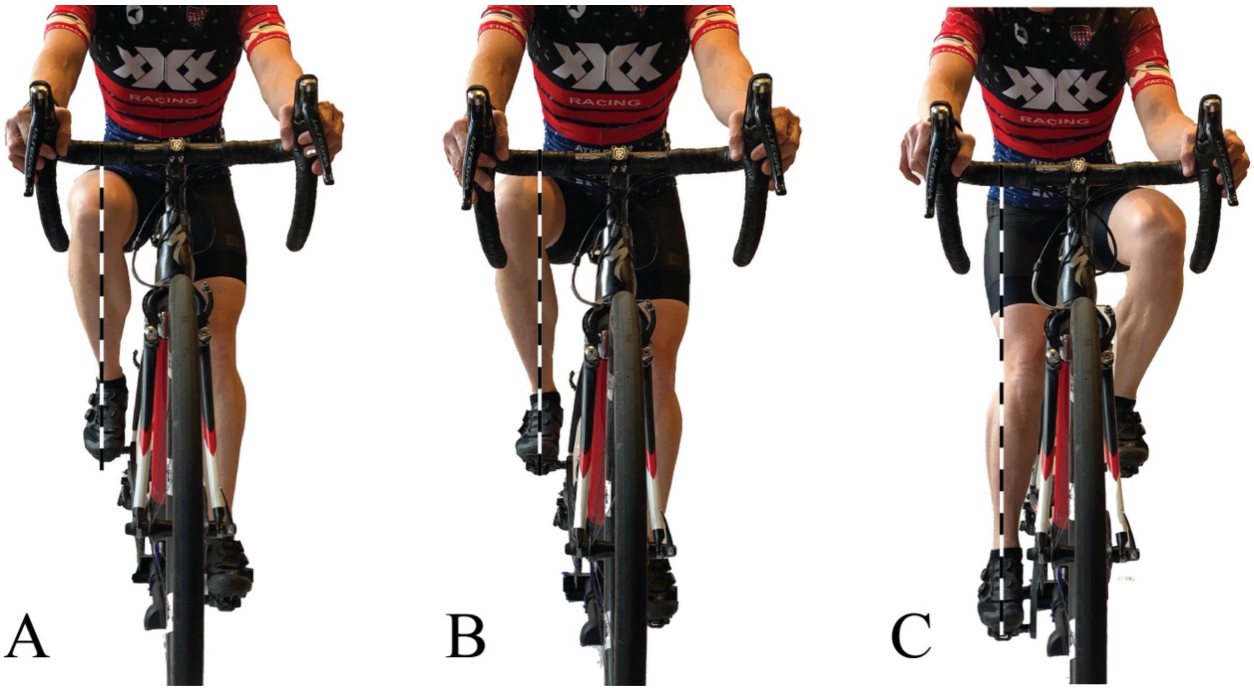

Figure 3. Medial-lateral knee deviations while pedaling. A: Relatively neutral, B: Right knee laterally deviated at the top of the pedal stroke, C: Right knee medially deviated at the bottom of the pedal stroke

As bicycles are a fixed width, and unlike humans, do not get proportionally wider as the size increases, the stance width of a taller rider (of any gender) will likely place the feet medial to the ASIS, causing stress on the lateral hip and knee. This may explain why a sex-based difference in PFPS has not been observed in cyclists, whereas PFPS has been reported at higher rates in females in the general population and in runners.[74-77] This can be corrected with bike fit modifications to the cleat position or pedal spindle.

Importantly, training habits involving increased resistance from harder efforts, hill climbing, or lower-cadence riding increase patellar pressures. A low saddle height or forward saddle position likewise increases forces across the anterior knee, causes relative overuse of the quadriceps, and can lead to or exacerbate PFPS.[78] Muscle activation and kinematics change with fatigue and may exacerbate maladaptive positions including increased motion in the frontal plane, resulting in decreased power output and increased risk of injury.[56,79,80]

Cervical Spine and Upper Extremity

To maintain forward gaze in a flexed posture, the cervical spine is in relative extension, which is further increased in the presence of exaggerated thoracic kyphosis or posterior pelvic tilt. The cervical extensors are activated to maintain this position, which may result in pain or soreness, and frequently improves with time and training. Aggressive road or triathlon-specific geometry, excessive reach or a low handlebar position increases cervical extension, often accompanied by cervical protraction and thoracic kyphosis. This position, in combination with cervical spondylosis or core weakness, may result in neck pain, radicular pain or paresthesias.

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While recent studies have found no meaningful sex differences in the prevalence of chronic neck pain, the smaller cross sectional area of the neck, smaller vertebral size, and increased spinal mobility in females may relate to the increased risk of whiplash injury, a frequently seen traumatic head/neck injury in cyclists.[81-83] Both female sex and whiplash symptoms are associated with prolonged recovery from concussion injuries.[84,85] In the case of neck pain or radiculopathy, modification of the riding position to elevate the stem and handlebars and decrease cervical extension may be helpful in the short term, though must be done with caution as it can affect handling of the bicycle.

Neurologic symptoms in the hands including numbness and/or weakness may originate from compression or irritation of cervical nerve roots, or from nerve compression in the thoracic outlet, cubital triangle, carpal tunnel, Guyon's canal or hand.[86] Gender-specific considerations include the increased prevalence of carpal tunnel syndrome in women, potentially related to their narrower carpal arch, as well as the increased incidence of electrophysiologically-confirmed thoracic outlet syndrome which may be attributable to higher rates of a cervical rib and/or the presence of a scalenus minimus muscle.[87-90] Ulnar and median neuropathies are both common in cyclists, secondary to weightbearing on the extended wrists, road vibration, and prolonged grip pressures on the handlebars.[91,92] A study of cyclists after a multi-day bicycle tour found prolonged latencies of the ulnar palmar branch to the first dorsal interosseous muscle (FDI). Further prolongation of median nerve latency was also seen in those with baseline carpal tunnel syndrome.[93] While neuropathic hand symptoms, or "cyclist palsy," are common in cycling, they are not necessarily correlated to EMG abnormalities, suggesting a neuropraxia without axonal or myelin loss.[91,93]

Frequent hand position changes help to alleviate prolonged pressure on nerves and are likely to improve comfort. Excess pressure in the hands frequently results from saddle discomfort, excessive reach, or low handlebar position. Bicycle handlebars come in many shapes, styles, and widths, some allowing for multiple hand positions. However, the standard handlebar size supplied on a new bicycle may be too wide for a woman rider of a given height and cannot always be exchanged without a cost. For riders with smaller hands, brake levers and shifters must be adjusted to ensure ease of braking and shifting, both for safety and comfort.

Hip and Lumbar Spine

The hips and lumbar spine must be considered together, as they both contribute to the overall range of motion needed to assume the cycling position. Restricted hip range of motion, therefore, will necessitate increased lumbar flexion to maintain contact with the saddle and reach the handlebars.[94] A properly positioned rider achieves the appropriate spinal posture and pattern of muscle recruitment without exceeding the structural limits of the hip joint.[95]

While cycling is usually well tolerated in the case of intra-articular hip pathology including arthritis and femoroacetabular impingement (FAI), excessive flexion or forced rotation may provoke symptoms.[96] Excessive hip flexion occurs with low or posterior saddle position, or if the crank arm length produces a pedal stroke too large for the individual's degree of allowable hip flexion. Long reach or low handlebar position will also result in closure of the hip angle. If hip range of motion is not available, excessive lumbar flexion, lateral knee deviation, or pelvic rocking will occur with pedaling. Bike fit accommodations for hip dysfunction include raising the saddle height, moving the saddle anteriorly to open the hip angle. Shorter cranks (165 mm) reduce the maximum hip flexion angle of pedal stroke without sacrificing average power, and pedals with sufficient float to allow external rotation of the foot can also decrease hip impingement and pain.[97]

Flexion-based lumbar pain suggests pathology of anterior structures, including discogenic pain from annular tear, disc herniation, or disc degeneration, as flexion such as that on a bicycle tends to increase intradiscal pressure.[98-101] A primary complaint of those suffering discogenic pain is sitting intolerance, which can certainly limit cycling, while extension-based pain (such as from facet joints or stenosis) is often well tolerated on the bike. Research evaluating cyclists with flexion-based low back pain has demonstrated greater lower lumbar flexion, loss of multifidus co-contraction, and a related increase in pain during cycling, pointing to a potential underlying maladaptive motor control pattern.[102-104] Compared to other activities however, the overall mechanical load on the lumbar spine in cycling is less, as some of the load is shifted to the upper limbs.[101]

Excessive lumbopelvic flexion also frequently results from saddle discomfort, including upward tilt of the saddle; the rider shifts their weight posteriorly on the ischial tuberosities to decrease

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pressure on the perineum. A similar strategy is adopted to open the hip angle in the case of hip impingement or pain. As such, bike fit accommodations typically include modification to the saddle shape and position to improve comfort and allow positioning on the ischial tuberosities, neutralization of the spine, and appropriate hip range of motion. Physical therapy intervention for hip and back dysfunction can improve joint range of motion, dynamic core and hip girdle stability, and reduce muscular (hamstring) tightness which can exacerbate posterior pelvic tilt.

Pelvis

The spectrum of pelvic disorders in cyclists includes a wide range of skin, soft tissue, nerve, and vascular issues for riders of all gender identities. There is both sex-dependent and race-dependent variability in soft tissue and bony structures in the pelvis, but importantly, common anatomical features are present, and are often the source of pelvic or perineal pain.[105] A detailed study comparing pelvis size and shape in male and female participants found that overall pelvis size correlates to height, but not to sex. While this study and others consistently show that females have a wider angle between the inferior pelvic rami (android versus gynecoid pelvic shapes), leading to potentially larger inter-ischial distances, this angle also depends on height and race.[106,107]

The urogenital triangle is bordered by the inferior pubic symphysis and the ischial tuberosities, which along with the ischiopubic rami are the major contact points of a saddle. The bulbocavernosus muscle runs down the center of the urogenital triangle, with portions on either side of the vaginal canal and deep to the vulva tissue, or deep to the scrotum and posterior to the penis if these structures are present. In gender-affirming penile inversion vaginoplasty surgery, this muscle may be completely removed.[108] In all cases, soft tissue structures of the perineum remain relatively fixed and in contact with the saddle (Figure 4).

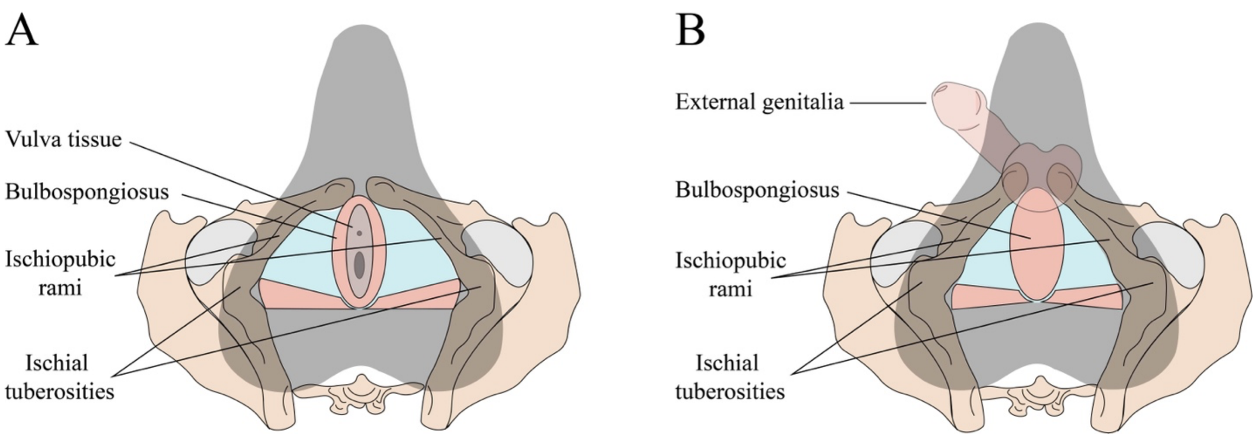

Figure 4. Position of pelvic anatomic structures relative to a bicycle saddle. A. Gynecoid pelvic shape with vulva tissue centrally located. B. Android pelvic shape showing the position of external genitalia relative to the saddle.

Saddles come in a variety of shapes and widths to fit the rider's pelvis. Those with a central "cutout" have been marketed on their ability to alleviate soft tissue pressure in the genital area, but this has not been borne out by research; saddle shape is ultimately a matter of personal preference not determined by a measurement or algorithm.[109,110] Research on female cyclists' position has demonstrated a greater increase in anterior pressure compared to male cyclists when in a more flexed position, as well as increased dynamic pelvic obliquity and internal rotation with increased power production.[106,111] Handlebar height positioned below the saddle exacerbates this motion and has been demonstrated to increase perineum saddle pressures as well as reduce genital sensation.[112]

A common pelvic problem among cyclists is "saddle sores," or skin irritation, breakdown, and folliculitis, often the result of pressure and friction

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combined with repetitive pedaling.[113,114] Hypertrophic changes may develop with repeated pressure on perineal tissue, referred to as perineal nodular induration (PNI, or the "cyclist's nodule"). These may occur in the labia or perineum, and consist of a non-neoplastic proliferation of atypical fibroblasts resulting from sustained pressure on pelvic soft tissue.[115]

Vulva tissue is relatively fixed in the central portion of the saddle contact area and is subject to pressure and friction (Figure 4). There is considerable diversity in the size and appearance of vulval tissue that is clinically classifiable as normal.[116] Chronic inflammation related to friction and compression of the inguinal lymphatic vessels may result in vulvar or labial hypertrophy, with associated pain, irritation, and swelling.[117] To mitigate symptoms, athletes may position or tuck their labia for comfort.[63] If vulvar care, reduction of riding volume, and modification of bike fit does not improve the symptoms, labiaplasty can be considered to reduce the size of the labia for comfort, after careful screening for body dysmorphic disorder, as this may be a confounding factor prompting a cyclist to seek definitive treatment. Following this surgery, a period of 8-12 weeks off the bicycle is recommended to avoid postoperative complications. Other pelvic surgeries will have similar time course regarding return to cycling, including vaginoplasty as a component of gender-affirming surgery.[118]

The ischiocavernosus muscle, pudendal nerve, pudendal artery and vein run along the ischiopubic rami in the pudendal canal. These structures are anterior to the ischial tuberosities and are vulnerable in a forward-flexed, aerodynamic position on the bicycle. Prolonged pressure on these structures may be associated with pain, paresthesias in the soft tissue structures that are supplied by the pudendal nerve and artery (scrotum/penis and vulva/clitoris), as well as sexual dysfunction. A study of 2774 male cyclists found that 54% had experienced penile numbness, without sexual dysfunction, while a study of 178 female cyclists found that 58% had experienced genital numbness, which along with urogenital pain, positively correlated with sexual dysfunction for the female cyclists.[119,120]

There is little evidence-based treatment for pelvic pain in cyclists, but general guidance involves ensuring that a bicycle is properly fit with an appropriate width and shape saddle, wearing properly fitting cycling shorts (chamois) directly over the skin (without undergarments), with appropriate lubrication to reduce friction (including antifungal and antibacterial chamois creams).[113] For lingering problems, a period of time off the bicycle may be necessary. There is no "one size fits all" clothing or saddle solution for pelvic pain in cyclists, and the wide array of options that the industry provides is likely helpful.

CONCLUSION

As the population of cyclists becomes increasingly more diverse, the relevance of the literature focused primarily on male-identifying cyclists is called into question. We are as diverse within genders as we are across genders, and as such must pursue equipment design to fit all body types and encourage participation in cycling. A larger number of cyclists on the roads improves safety for all cyclists, regardless of gender. Women's participation in cycling is subject to different social pressures which also impact training, competition, and satisfaction. Continued investment in research on female athletes is essential, including further study of cycling biomechanics, cycling injury, LEA and REDs in non-male-identifying cyclists to improve the education of cyclists, coaches, cycling teams, and the medical community to help prevent injury and enhance athlete recovery.

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Conflict of Interest Statement

The authors report no conflict of interest with the contents of this manuscript.

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