

Review

The Vicious Cycling: Bicycling Related Urogenital Disorders

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Abstract

Purpose: Bicycle riding is one of the most popular means of transportation, recreation, fitness and sports among millions of people of all ages who ride on road and off road, using a variety of bicycle types. It is also a readily available form of aerobic non-impact exercise with established cardiovascular beneficial effects. Bicycles are also a common source of significant injuries. This review focuses upon the specific bicycling related overuse injuries affecting the genitourinary tract.

Materials and Methods: MEDLINE search of the literature on bicycling and genitourinary disorders was performed using multiple subject headings and additional keywords. The search yielded overall 62 pertinent articles. We focused primarily on the most prevalent related disorders such as pudendal nerve entrapment, erectile dysfunction and infertility. The potential effect of bicycling on serum PSA level was also discussed in depth in view of its recognized clinical importance. Infrequent disorders, which were reported sporadically, were still addressed, despite their rarity, for the comprehensiveness of this review.

Results: The reported incidence of bicycling related urogenital symptoms varies considerably. The most common bicycling associated urogenital problems are nerve entrapment syndromes presenting as genitalia numbness, which is reported in 50–91% of the cyclists, followed by erectile dysfunction reported in 13–24%. Other less common symptoms include priapism, penile thrombosis, infertility, hematuria, torsion of spermatic cord, prostatitis, perineal nodular induration and elevated serum PSA, which are reported only sporadically.

Conclusions: Urologists should be aware that bicycling is a potential and not an infrequent cause of a variety of urological and andrological disorders caused by overuse injuries affecting the genitourinary system.

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1. Introduction

Bicycle riding is one of the most popular means of transportation, recreation, fitness and sports among millions of people of all ages who ride on road and off road, using a variety of bicycle types including mountain, touring, racing bicycles, stunt (BMX) bicycles and stationary exercise bicycles. Bicycling is a readily available, economical and efficient form of aerobic non-impact exercise with established cardiovascular beneficial effects. On the other hand,

bicycles are also a common source of significant injuries. Thompson and Rivara referring to bicycle related injuries cited 900 deaths, 23,000 hospital admission, 580,000 emergency department visits, and more than 1.2 million physician appointments resulting in an estimated cost of above \$8 billion per year, in the USA alone [1].

Bicycle related injuries are generally categorized into acute traumatic injuries which mostly involve the upper and lower extremities, head, face and abdomen, versus chronic overuse injuries which are especially common among regular bicycle riders and those involved in competitive racing [1,2]. The body regions most commonly involved by overuse injuries are the

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hand and wrist, neck, lower back, knee and buttocks/saddle region with reported incidence of symptoms consistent with overuse injuries of up to 35–90% [2]. Since biking related acute traumatic injuries, including those involving the genitourinary tract, do not generally differ from any other type of traumatic injuries sustained during other activities, this review focuses upon the specific bicycling related overuse injuries affecting the genitourinary tract. Urologists should be aware that bicycling is a possible and not an infrequent cause of a variety of urological and andrological disorders caused by overuse injuries affecting the genitourinary system.

2. Methods

MEDLINE search of the literature on bicycling and genitourinary disorders was performed using multiple subject headings and additional keywords. The search yielded overall 62 pertinent articles. We focused primarily on the most prevalent related disorders such as erectile dysfunction (ED) and pudendal nerve entrapment. The potential effect of bicycling on serum PSA level was also discussed in depth in view of its recognized clinical importance. Sporadic disorders, which were represented by a single reference, were still addressed, despite their rarity, for the comprehensiveness of this review.

3. Incidence

The reported incidence of bicycling related urogenital symptoms varies considerably. Some disorders are reported only as occasional case reports [3–8], while others, mainly those associated with perineal compression, are reported very frequently. Sommer et al. reported genital numbness in 61% and ED in 24% of 100 male cyclists, whose weekly training exceeded 400 km [9]. Similarly, Schwarzer et al. [10], in a large prospective cohort study conducted among 1786 amateur cycling club members, reported genital numbness in 58.3–70.3% of the riders. ED rate among the cyclists was 4%, while in a matched group of 155 active long distance swimmers the rate of ED was only 2% and none complained of genital numbness. 91% of 17 cycling patrol officers in the study conducted by Schrader et al. [11] experienced genital numbness but not ED according to the International Index of Erectile Function Questionnaire (IIEF-Q). Andersen and Bovim found penile numbness and ED in 21% and 13% of long-distance amateur cyclist respectively [12].

The considerable diversity in the reported incidences of perineal compression symptoms among the various studies may be related to differences in multiple variables which were shown to impact pre-

sentation of relevant symptoms i.e., genital numbness and ED. Such variables include age over 50 [13], body weight (correlates with the exerted pressure on perineum) [11], co-morbidity, more than 10 years of cycling history [13] and intensity of training (more than 3 hours of cycling per week which is equivalent to 39 miles per week) [14]. Furthermore, since perineal symptoms, genital numbness and especially ED may be still regarded as sensitive issues, the reported incidences of such symptoms, may underestimate the phenomenon [12].

4. Pudendal nerve entrapment syndromes

4.1. Anatomical considerations

The pudendal nerve derives from the sacral plexus, from S2–S4. It is a mixed nerve, transmitting somatosensory impulses from the genitalia and carrying motor fibers to the perineal muscles including the ischiocavernosus and bulbocavernosus muscles, which are crucial to achieve rigidity, as well as autonomic (parasympathetic and sympathetic) fibers. The major trunk of the pudendal nerve passes around the sacrospinal ligament, into the ischiorectal fossa and coursing through the Alcock (pudendal) canal, which allows smooth non-traumatic movements of the nerve. Subsequently, it emerges below the pubic bone and innervates the perineum and the genitalia. The internal pudendal arteries originate from the anterior trunk of the hypogastric arteries in the pelvis and accompany the pudendal nerves in their course through Alcock canal. After emerging from the pelvis they reach the base of the scrotum just medial to the inferior pubic ramus as the common penile arteries, where they divide to become the bulbourethral, dorsal and the cavernous penile arteries.

4.2. Mechanisms of pudendal nerve compression

The course of the pudendal nerve in pelvis and its anatomic relationships define several likely compression points. Pedaling while sitting on a slim hard saddle and being constantly subjected to repetitive impacts generates extreme perineal pressure, which indirectly compresses the pudendal nerves, and increases the friction within Alcock canal. The constant pressure and the consequent loss of the ability of smooth gliding movements of the nerves expose them to repetitive trauma. The importance of neural gliding and movement of the nerve has been recently emphasized in the clinical management of patients with multilevel nerve compression [15]. Another vulnerable location is outside the bony pelvis. Direct pressure of the nose of the

saddle against the perineum and the symphysis, further provoked by the forward leaning of the cyclist, pinch the pudendal nerves just where they emerge below the pubis. Additionally, the movements of the pedaling legs in the forward sitting position stretch the pudendal nerves over the sacrospinal and the scrototuberous ligaments, leading to strain of the nerves. The pathophysiological significance of nerve stretching is well established and it is the underlying principle of the neural tension test which is used to diagnose specific compression neuropathies [15].

4.3. Pathogenesis of pudendal nerve compression syndrome

The exact pathogenesis of pudendal nerve compression syndrome is not completely understood. Clinical presentation of pudendal strain is attributed either to ischemic neuropathy due to transient hypoxemia of the nerve caused by pressure on the neurovascular components, or to a primary neuropathic process due to mechanical pressure [15]. Recent experimental nerve compression studies revealed multiple changes in intraneural microcirculation, fiber structure, impairment of axonal transport, and increased vascular permeability, which added significantly to the understanding of the pathophysiology of compression neuropathy [15].

The distinction between these two pathophysiological pathways has significant clinical implications regarding the severity of the neuropathy, the expected duration of conduction recovery in the injured nerves and a considerable impact on the overall prognosis of the affected cyclists. The severity of the expected neural damage is dictated mainly by the duration of the pressure while the pressure amount is less important. Hence, the longer the duration of the pressure, the more substantial is the expected neural damage. Ischemic conduction blocks due to variable ischemia periods usually reverse rapidly, within hours to days or mostly several weeks, while recovery of a demyelinating block may take many months or even years [12].

4.4. Objective assessment of pudendal compression

Penile and perianal pudendal somatosensory evoked potentials (SSEP) are useful for the evaluation of pathology in the distal course of the pudendal nerve, especially the dorsal nerve of the penis [16]. Wolfgang [17] in 1998 described pathological SSEP of the pudendal nerve in a patient presenting with penile hypoesthesia following rectal surgery, compatible with compression pudendal neuropathy. Ricchiuti et al. [18] were the first to employ SSEP to document bicycling induced compression injury of the pudendal nerves by

electromyography. They performed pudendal nerve conduction studies in a 44 years old cyclist who suffered from recurrent transient genital numbness and mild ED and were able to demonstrate abnormal SSEP responses: prolonged nerve latency, low recruitment motor unit potentials, increased configuration amplitudes and either suppressed or absent bulbocavernosus response.

Scharder et al., measured the pressure exerted on the buttocks and perineum that are in contact with the saddle, using a pressure measurement mat that was placed over the bicycle seat. They found trends of positive correlation between the rider's weight and saddle nose pressure and negative correlation with erectile function according to the IIEF-Q. The pressures that were applied on the perineum of the cyclists by the saddle nose were two folds above the threshold pressure known to cause ischemic injury [11].

4.5. Penile blood flow during cycling

Arterial insufficiency is another possible cause of genital numbness and impotence [19]. Cutaneous penile oxygen pressure, which is believed to correlate with penile blood flow, decreases significantly during cycling [9,20–22]. The extent of the decline in blood flow was correlated with the cycling position and the type of the saddle. Cycling in reclining position, in which the perineum is not compressed, did not alter penile perfusion. Conversely, cycling in the upright-seated position compresses the pudendal arteries in the perineum and consequently decreased penile blood flow by approximately 70% [21]. Standing up while cycling improved penile oxygenation back to its normal level before cycling [20]. Although cycling in the seated position invariably compromised penile perfusion, the type of the saddle significantly affected its extent. An ergonomic wide saddle with absent nose provided the maximum protection against penile hypoperfusion (20.3% decrease in comparison to 82.4% using a standard narrow saddle) [22]. Similarly, Broderick reported that sitting on a bike saddle decreases penile blood flow following intracavernous injection of PGE1 [23]. More recently, Jeong et al., employed an investigational, more accurate laser Doppler flowmetry technique, determined the effect of bicycle saddle shape, (either a narrow unpadded or wide unpadded saddle), on penile blood flow and concluded that the shape of the bicycle saddle clearly affects penile blood flow as cycling on the narrow saddle caused more prominent decline in penile blood flow [24]. Hypoxemia of the penis subsequently causes corporal connective tissue synthesis, apoptosis of trabecular smooth muscle cells and penile fibrosis which are induced by

the synthesis of transforming growth factor-beta 1. The loss of trabecular erectile tissue along with deposition of connective tissue result in impaired penile expandability which may cause permanent ED due to veno-occlusive dysfunction [25].

4.6. *The clinical spectrum of compression syndromes*

4.6.1. *Genital numbness*

Numbness in the perineum, penis, scrotum or the buttocks usually referred to, as “genital numbness” is probably the most common and the most recognized symptom of pudendal compression. Most of the times it is the only symptom or the earliest symptom that indicates the compression syndrome [26,27]. Genital numbness may occur unrelated to ED although cycling related ED is invariably associated with genital numbness [9], which may serve as a marker for the increased risk for erectile dysfunction [28]. Variable extent of compression at different points along the course of the pudendal nerves may predispose for various entrapment syndromes. Distal pinching of the pudendal nerves against the symphysis pubis involves merely the dorsal nerves of the penis, hence can cause mainly penile numbness. More proximal nerve strain, within Alcock canal or at the sacrospinal ligament, may present with mixed symptoms of penile, scrotal and/or perineal hypesthesia. With increasing levels of bicycle riding exposure, males are found to have significantly more urologic complaints, perineal pain or numbness. The most common symptoms are decreased sensation of the genitalia and moderate to severe impotence. However, other symptoms including difficulty to achieve orgasm, altered sensation of ejaculation, reduced sensation of defecation, and very rarely perineal pain, may occur. In accordance, micturition disturbances, symptoms of bladder outflow obstruction, hematuria, urinary incontinence and prostatitis are thought to be a result of compression of the proximal urethra, external urinary sphincter and prostate [29].

4.6.2. *Erectile dysfunction*

One of the early reports that connected ED with bicycling described a 55 years old physician who developed penile numbness and progressive ED, which developed gradually as a consequence of a daily, 20 minutes, vigorous bicycling exercise. Penile numbness resolved following adjustment of the saddle but recovery of erectile function required a whole month of complete cessation of bicycling [8]. Following that report, the association of ED with bicycling was investigated in multiple studies, which repeatedly demon-

strated increased risk of ED in cyclists [9,10,12,14,19–22,24,28,30]. In contrast to most studies, which focused on elite long-distance racers who ride 100–400 miles per week, the analysis of the results of Massachusetts Male Aging Study (MMAS) by Marceau et al., investigated the incidence of ED in the general-population cyclists from a variety of riding categories including recreation or transportation, as well as sport riders. In this study, cyclists were categorized according to intensity of cycling as moderate cyclists (cycling less than 3 hours per week) or sport cyclists (cycling more than 3 hours, equal to 39 miles per week). The frequency of ED in non-cyclists, moderate cyclists and sport cyclists was 21%, 11% and 17% respectively. Logistic regression analysis, unadjusted to covariates (e.g., age, chronic illnesses, smoking), showed a possible protective effect of bicycling in view of the fact that moderate as well as sport cyclists were less likely to have ED in comparison to those who do not ride bicycles (odds ratio 0.48 and 0.82 respectively). When logistic regression analysis was controlled for those covariates, moderate cyclists were still less likely to have ED (odds ratio 0.61) in comparison to sport cyclists (odds ratio 1.72). The authors discussed the statistical weaknesses of their study, which due to insufficient sample size lacks the desired power. Nevertheless, they conclude that moderate physical activity, including bicycling, may have a protective effect against ED. Hence, although ED may be a serious concern in elite or even sport cyclists this cannot be generalized to the average cyclists who actually have reduced likelihood to develop ED [14]. Moreover, a recent survey conducted over the internet among 688 cyclists did not find a significant correlation between erectile dysfunction and several cycling related variables [13].

Nocturnal penile tumescence (NPT) tests, in 17 cycling patrol officers with normal erectile function according to IIEF-Q, showed decreased erectile quality manifested by a significant shortening of the erection sleeping time, as well as (insignificant) trends towards lower RAU (rigidity activity units) and TAU (tumescence activity units) of both penile base and tip. These findings were accompanied by typical complaints of transient numbness in the buttocks, scrotum and penis [11]. The significance of the pathological NPT findings in the presence of normal erectile function is not clear. However, it may predict potential pending development of cycling associated ED if cycling strain persists.

Lehmann et al. [31] proposed that subclinical perineal vascular trauma may account for ED in young men with otherwise unexplained ED. They hypothesized that if subclinical perineal trauma is linked to the

etiology of ED, the affected men should have hemodynamically significant, non-atherosclerotic, occlusive lesions in the pudendal and penile arteries in the predefined injury-prone locations along their course in Alcock canal and below the symphysis pubis. In order to confirm this assumption, they performed selective pudendal angiography in 91 men with ED. 20/91 men formed a distinct group characterized by significantly younger age of ED onset (35 as compared to 53 in the atherosclerotic group), with angiograms demonstrating typical focal occlusive lesion in the vulnerable portions of the pudendal-penile arterial tree prone to blunt perineal injury. 6/20 men also reported history of remote blunt perineal trauma, either direct minor trauma or chronic repetitive perineal strain such as this associated with cycling. In summary, subclinical direct or chronic strain type perineal injury may cause vasculogenic ED in young men.

4.7. Management and prevention of pudendal neurovascular compression syndromes

The optimal prevention scheme is comprised of two strategies: changing the riding style and schedules as well as modifying the design of the saddle and its positioning. Both aim to minimize the strain upon the neurovascular structures in the perineum during vigorous cycling and as a consequence reduce nerve injury and penile hypoxemia. The type of the bicycle was reported to influence the risk of erectile dysfunction. Mountain bicycles are linked with higher risk than road bicycles partly due to the more upright postures characteristic to the mountain bicycle riding which exerts more of the body weight on the buttocks [28]. The increasing numbers of ergonomic saddles in the market offer a whole variety of bike seats, designed to shift the weight bearing from the perineum and distribute the pressure over a wider area of the buttocks and the ischial tuberosities, the so called “sit-bones”. Overall, the optimal saddle seems to be a wide, heavily padded with a flexible or absent nose. These “urologist-approved” models include the two-cheek saddle, the V-groove saddle, split saddle design, central cutout seat with a hole in the middle, seats with an inflatable air cushion and seats that conform the individual rider’s anatomy. Such experimental and industrial saddles, were shown to decrease the pressure distributed in the perineum [32], reduce genital-area numbness [27] and prevent decrease of penile blood flow [22,24]. More than others, heavier riders who appear to be at higher risk, because of the greater pressure being placed on the perineum, seem to benefit from such wider saddles with extra padding [11]. Conversely, Dettori et al. found increased risk of erectile

dysfunction mainly in those who cycled with a cutout saddle, specially designed to prevent numbness and erectile dysfunction, and experienced perineal numbness. They suggested that such riders are characterized by a unusual vulnerable perineal anatomy and hence the edges of the cutout or the overall decreased surface area of the saddle exerts greater pressure against the pudendal structures instead of relieving it [28].

In addition to the structural design of the saddle, its positioning is particularly important. Downward tilt of the nose of the saddle and a limited height difference between the seat and the top of the handlebar, despite potential aerodynamic compromise due to the resulting higher profile of the cyclist, are crucial to prevent putting vigorous pressure directly on the vulnerable perineum. Setting the height of the saddle is also important to allow slightly flexed legs at the lowest point of the pedal spin as this improves supporting the cyclist weight [9,28].

For cyclists who suffer from prolonged refractory pudendal compression syndrome, refraining temporarily from cycling may be the most efficient way to make a full recovery from the genital numbness and ED, and to restore normal genital sensation and regain erectile function. Ignoring pudendal strain and continuation of vigorous cycling, in spite of obvious early pudendal entrapment symptoms, may cause irreversible damages. However, in most cases compression symptoms are transient and occur during active cycling and last for a limited time period of days or a week following long distance races. For these cyclists and those who wish to avoid potential pudendal compression, judicious changes of riding style are recommended. Taking frequent breaks during long drives, regularly alternating between riding in seating position and riding in standing position especially in rough bumpy terrain [9,22,27]. Silbert et al. reported the efficiency of such measures in 2 men with bicycling induced pudendal nerve pressure neuropathy. Both improved owing to adjustment of the saddle and change of riding style [26].

5. Priapism

Bicycling related priapism is typically a high flow type [5,33–36] which is caused by unregulated cavernous arterial inflow. The most common etiology of this condition is a vascular trauma that results in formation of arterial-venous fistula or shunt, which feeds the cavernous sinusoids directly in an uncontrolled manner [37]. Riding in a straddle position predisposes the cyclist to repeated significant blunt perineal injuries.

The entire weight of the cyclist generates a strong force that strikes into the small profile of the saddle or the top tube of the bicycle, resulting in a powerful impact that violently compresses the perineal structures between the pubic bone and the above mentioned parts of the bicycle and may lacerate branches of the cavernous arteries. Severe laceration of the cavernous artery followed by continuation of cycling activity may result in formation of arterial-venous fistula or shunt and consequent immediate penile tumescence. In contrast, minor vascular damage and a break in the riding activity may allow initial formation of a clot that delays the creation of the fistula until later, when physiological increase in cavernous blood flow removes the clot and allows delayed presentation of priapism. If not removed by a sudden increase in cavernous blood flow, the temporary clot may organize and partially occlude the cavernous branches. The recurring nature of cycling associated perineal trauma may gradually lead to significant occlusion of the cavernous arteries and cause vasculogenic ED. Following Doppler sonography or arteriography that establishes the diagnosis the management of high flow cycling-related priapism is similar to the standard guideline recommendations i.e., observation, selective arterial embolization or surgery [37].

Machtens et al. [38] reported a case of partial priapism presenting a day after a prolonged bicycle ride. Partial segmental priapism is a very rare condition, nearly invariably idiopathic, caused by partial unilateral thrombosis of the proximal corpus cavernosum [39]. The delayed presentation after bicycle ride, brings to mind the likelihood of vascular trauma as the underlying mechanism. A possible sequence of events initiated by cavernous artery injury, followed by formation of a clot at the site of laceration and ultimately, progression to limited thrombosis that may advance to segmental occlusion of the cavernous branches.

6. Infertility

Specific alteration in sperm morphology but not in other sperm characteristics was demonstrated in sperm analysis of long distance competitive cyclists. These changes included significantly lower percentage of spermatozoa with normal morphology and a significantly higher proportion of morphologically abnormal tapered forms [40]. The regulatory role of the scrotum in maintaining the core temperature of the testicles is achieved through the collective function of the cremasteric and dartos muscles as well as the blood vessels of the spermatic cord and the scrotum, which

operate as a thermoregulatory system. In response to changes in environmental temperature, this apparatus can regulate the inflow and outflow of blood in the scrotum as well as influence radiant heat loss by relaxation or contraction of the dartos and the cremasteric muscles. Since elevated scrotal temperature may cause atrophy of the testicular germinal epithelium and spermatogenesis arrest, anomalous thermoregulation may have a significant role in various conditions of infertility or sub-fertility, such as cryptorchidism and varicocele [41]. Similarly, injurious effect of exercise on spermatogenesis was attributed to increased scrotal temperature rather than to changes in the hypothalamic-pituitary-testicular hormonal axis [42,43] as the intense exercise associated with pro-cycling causes prolonged increase in core scrotal temperature. Moreover, the special settings associated with pro-cycling, such as regular wearing of tight supportive clothing, for instance Lycra race suits, and compression of the scrotum against the saddle, further promote the harmful effect because they oppose the thermoregulatory protective mechanisms which cannot respond orderly to the change in environmental temperature.

7. Hormonal effects of strenuous cycling

Several studies reported changes in stress and sex hormones during intense cycling. Additionally, professional cycling was shown to affect the Insulin-like Growth Factor (IGF) axis demonstrating significant increase in IGF-1 and IGF-binding protein-1 [44]. Fernandez-Garcia et al. reported decrease in testosterone and cortisol levels but not in LH, FSH and prolactin levels, during continuous intense cycling competition [45]. Similarly, Hoogeveen and Zonderland reported decreased post exercise testosterone levels with concomitant increased cortisol levels in 10 professional cyclists [46]. In contrast, Lucia et al. who studied the reproductive function in athletes did not find exercise to adversely affect the hypothalamic-pituitary-testicular hormonal axis in cyclists or other groups of athletes. Nevertheless, they noted decreased sperm motility exclusively in cyclists during racing periods probably due to local factors such as testicular mini trauma and higher testicular temperature rather than hormonal influence [43]. The etiology of such hormonal changes is not completely understood, however, Maynar et al. suggested that physical activity may increase the urinary elimination of androgenic hormones and decrease the synthesis of their binding proteins [47].

8. Effect of bicycling on serum PSA concentration

Bicycle riding, combines strenuous physical activity and direct pressure on the perineum and prostate. These factors are believed to uniformly affect PSA concentrations by false elevation of its serum level and thus compromise accuracy of PSA screening. Possible mechanisms by which bicycling may affect serum PSA concentrations include systemic factors related to the hormonal effects of strenuous physical activity [44,48] and local factors. These involve mechanical stress of the prostate caused by movement of the pelvic muscles [49], or direct perineal pressure produced by the saddle with a significant massage effect on the prostate [50]. Additionally, temporary interference with the flow in the dorsal vein complex due to increased pelvic pressure during exercise, may lead to a subsequent capillary washout of PSA into the circulation [49]. Rana and Chisholm [50], in an intriguing short article reported on marked elevation of PSA level due to everyday use of an exercise bike in a T3 prostate cancer patient. In this patient, total discontinuation of pedaling and selling the bicycle resulted in a striking decrease in PSA concentration from 3244 to 5.9 ng/ml. Similarly, Oremek and Seiffert [49], observed twofold to threefold increases in serum PSA, and a lesser elevation of prostatic acid phosphatase, immediately after standardized exercise test on a bicycle ergometer. On the other hand, Crawford et al. [51], based upon their overall data, concluded that there was no statistically or clinically significant change in PSA levels following a 4 day 250-mile bicycle ride. Nevertheless, the clinical implications of this conclusion should be looked at carefully since according to subset analysis of this study population, patients 50 years and older or men with initially elevated PSA level may present with either statistically or clinically significant, increase in PSA, respectively. Also, in a recent study in men participating in a 13-mile bicycle tour, Luboldt et al. did not find a significant diagnostic alteration in the pre-cycling and post-cycling total PSA, free PSA, and free to total PSA ratio and hence declared that “normal PSA values remained normal, and abnormal PSA values remained abnormal” regardless of cycling [52]. In view of the discrepancy between the results of these studies, the influence of bicycle riding remains inconclusive. Therefore, avoiding avid cycling before blood sampling for diagnostic and screening purposes cannot be unequivocally recommended. However, prostate cancer patients, patients with initially elevated PSA levels and most probably also men 50 years and older, should

be advised regarding the potential impact of strenuous cycling on the results of PSA testing.

9. Testis cancer

Coldman et al., in a case control study, investigated the relationship between the risk of testis cancer and various sports activities among 133 men with testicular seminoma. After controlling for known risk factors such as cryptorchidism and after stratification for age, they found a significant increase in risk of testicular seminoma in men with history of regular bicycling (odds ratio 1.99), horse riding (odds ratio 3.31) or both (odds ratio 4.56). They suggested that persistent repetitive trauma to the scrotal contents, as well as contact exposure to potential dyes and chemicals present in the leather saddles, may be the underlying cause in the development of testicular cancer in riders [53]. The relationship between exercise and the risk of testicular cancer was also addressed by Forman et al., who found that the risk of testicular cancer decreased with increased amount of exercise and increased with increased sedentary [54]. Therefore, although cycling per-se may be associated with increased risk of testicular cancer in a direct mechanism, the protective effect of exercise against testicular cancer may reduce this risk or cancel it completely [30].

10. Perineal soft tissue lesions

Repeated chronic microtrauma of the perineum is the result of continuous contact with the saddle and bumping of the perineum against it. These repetitively contuse the perineal structures and may cause a variety of soft tissue lesions including calluses that form over the ischial tuberosities, chafing that may result in saddle sores and ulcerations. The combination of chafing, sweating and tight biker's suits can cause skin irritation, perineal folliculitis and furuncles [1,55]. Perhaps the most definite lesion is perineal nodular induration. This lesion also named perineal nodular induration of the cyclist, ischiatic hygroma, accessory testicles, third testicle or biker's nodule, almost invariably affects cyclists. Perineal nodular indurations are believed to result from pressure applied to the soft tissues caught between the saddle and the ischial tuberosities and friction of the perineal fascia against the pelvic bones which induce collagen degeneration, myxoid changes and pseudocyst formation. Accordingly, histologically, this nodule is characterized by a dense fibrous capsule surrounding a central pseudo-

cyst. Clinically, perineal nodular indurations usually present as elastic, bilateral, 2–3 cm perineal nodules, on each side of the midline. The nodules are usually fixed to the underlying deep soft tissues and are covered by normal skin. The common management of these lesions usually consists of reducing the riding time and surgical excision if required [55]. Another unusual observation, the bicyclist's vulva is characterized by unilateral lymphedema of the labia majora which is attributed to the combination of chronic inflammation and damaged lymphatic flow due to repetitive trauma to the vulvoperineal and inguinal lymphatic vessels [56].

11. Hematuria

Sports hematuria is a benign well known phenomenon that commonly occurs following nearly any, contact and noncontact, sports activity. One possible mechanism of sport-related hematuria may be traumatic due to repeated impact on the kidneys or the bladder. Nontraumatic mechanisms of sports hematuria are attributed to various degrees of vasoconstriction of the renal vessels that increase filtration pressure and glomerular permeability, and thus favor hematuria. Sports hematuria may be related to the duration of exercise and its intensity [57,58]. Both reports of bicycling related hematuria attributed the occurrence of hematuria to bouncing and vigorous repeated collisions of the perineum with the saddle during acrobatic or bumpy rides, hence referred to as bicycle-seat hematuria. Abandoning cycling in one case, and adjustment of the saddle position along with rising off the saddle before crossing bumps in the second, prevented any recurrences of hematuria [7,59].

12. Torsion of spermatic cord

The association between torsion of the spermatic cord and bicycle riding is controversial. Jackson and Craft [60] reported on 5 cases of young boys who presented with torsion beginning abruptly during, or shortly after a bike ride and argued that cycling may be a significant cause of torsion of the spermatic cord. Potential mechanisms of bicycling-related torsion were suggested, including twisting of the testis between the thigh and the saddle by the up and down movements of the legs, and vigorous contraction of the cremasteric muscles caused by strenuous effort or exaggerated cremasteric reflex resulting from the cold air penetration during fast cycling [4,60].

13. Scrotal ultrasound findings

Repetitive microtrauma to the scrotum during bicycling may cause structural alterations in the contents of the scrotum, which can be detected by Ultrasonography. Frauscher et al., compared the prevalence of ultrasonographic scrotal abnormalities in 85 off road bikers and 31 nonbikers, and found a significantly higher prevalence of such findings in bikers compared with nonbikers (94% vs. 16%, respectively). The most common scrotal abnormalities among bikers were scrotal calculi (found in 81%), followed by epididymal cysts, epididymal calcifications, testicular calcifications, hydroceles, varicoceles and testicular micro-lithiasis. On the other hand, only epididymal cysts were found among nonbikers. Scrotum related symptoms were always associated with pathologic ultrasonographic findings though ultrasonographic findings were asymptomatic in nearly half of the cases [55].

14. Women too . . .

Sexual and urinary symptoms associated with bicycle riding exist also in female bicyclists. The anatomical course of the pudendal artery and nerve within Alcock canal and its orientation medial to the pubis is homologous in males and females. Hence, similar types of sexual and urinary dysfunction may occur when these structures are compressed during bicycling. LaSalle et al. reported that approximately a third of 282 female members of a bicycling club had experience of perineal trauma, 19% of which were associated with hematuria or dysuria, and 34% with perineal numbness. The frequency and the severity of these symptoms were related to bicycling exposure as measured in weekly cycling hours and miles, and lifetime cycling hours and miles [61]. Also Doursounian et al., reported that female cyclists have significantly more urological complaints including difficulty in achieving orgasm, difficult urination, hematuria, perineal numbness, and chronic perineal pain [29]. The bicyclist's vulva which was described above, is another typical lesion characteristic of female high level cycling competitors and is correlated with more intense and longer training [56].

15. Conclusions

Bicycle riding, the most popular means of transportation, recreation, fitness and sports among millions of people of all ages is also a common source of acute

traumatic injuries as well as overuse injuries, many of them directly affect the genitourinary tract causing genital numbness, ED, priapism, infertility, hematuria and influence serum PSA levels. Urologists should thus be aware that bicycling is a possible and not an infrequent cause of a variety of such urological

and andrological disorders. Nevertheless, bicycling is also an ideal form of aerobic non-impact exercise with established cardiovascular protective effects and beneficial influence on the risk of hypertension, diabetes and stroke which may outweigh its hazards [62].

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Editorial Comment

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The field of erectile dysfunction (ED) is an evolving one. Great strides in our understanding of the underlying pathophysiology of erection have led to new therapeutic approaches to treat men with a broad range of erectile difficulties. The recent recognition that erectile dysfunction may be an early marker for systemic arterial disease has added a new wrinkle into how ED is perceived by internists and primary care physicians. Exciting developments in medications directed at therapy for rapid ejaculation coupled with the global acceptance that normal sexual functioning is an important component of quality of life, have led to growth in the field of male health.

Although still in its infancy, in my view, male health is a valid concept. The ability to train healthcare professionals able to diagnose and treat men's health issues such as voiding dysfunction, vascular disease, sexual dysfunction and andropause is important. It may allow for the development of a more unified or holistic approach towards men's cardiovascular, urological and sexual wellbeing.

In this report the authors provide a detailed summary of the potential risks associated with cycling. They

carefully document reports that associate cycling and a wide array of clinical conditions linked to perineal compression syndromes. While they provide a valuable service to urologists world-wide by highlighting these often rare events as described in small isolated case reports and clinical series, I believe it is vital to put perspective on the likelihood these events will occur in any one individual patient. In fact, urologists should balance the risk benefit ratio of cycling as they would any intervention in medicine. In essence, is the potential risk of any of the described events in this report greater than the likely cardiovascular benefit from this low impact form of aerobic exercise to a particular individual? If yes, then cycling should not be recommended.

Additionally, the reader should be aware of recent strategies described in the medical literature to minimize potential adverse effects of cycling which include rising from the saddle for a brief time periodically or alternatively using a modified seat with a shortened nose extension. Use of a recumbent cycle has also been shown to produce a smaller decrease in genital oxygen tension.

Exercise in general and non-impact aerobic-cardiovascular exercise in particular have extensive support in the medical literature over a period of greater than 5 decades. As initially described by Morris in the *Lancet* in 1953, London bus drivers who were sedentary had significantly higher rates of coronary disease compared

to an age matched group of drivers who worked the double decker buses where they were required to climb up and down. Exercise such as cycling induces a plethora of systemic effects in the host including upregulation of nitric oxide synthase (the putative neurotransmitter of erection), increased arterial wall compliance, increased HDL cholesterol, lowered LDL cholesterol, reduces the rise in insulin in response to a glucose load, reduced blood pressure and improved endothelial function among other effects. Recently the beneficial effects of exercise on endothelial function have been clearly defined in a study by Esposito where 110 men with obesity were placed into an exercise program and obtained weight loss. Thirty percent of these men had their ED resolve.

In summary, while I strongly applaud the authors for their comprehensive review of the potential risks of cycling, until an article is published that demonstrates improved longevity or lower general morbidity of noncyclist sedentary individuals compared to an age matched control group of recreational cyclists, I will continue to advocate cycling to my patients as a safe form of cardiovascular exercise.

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