

Effects of Workload on Seat Pressure While Cycling with Two Different Saddles

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ABSTRACT

Introduction. Seat pressure during cycling and its relationship to urological disorders have been discussed extensively in recently published literature. The effects of exercise configuration on seat pressure, however, still have not been fully investigated.

Aim. This study evaluates the effects of two different pedaling workloads and two saddle designs on saddle pressure in 22 (11 men and 11 women) recreational cyclists (bicycling <2 hours per week).

Methods. Seat pressure was measured in the saddle surface while pedaling at workloads of 150 and 300 W using a plain and a holed saddle model, both without any gel cushion characteristics. Analysis of variance was applied to compare seat pressure between situations.

Main Outcome Measure. Study the importance of bicycle saddle pressure.

Results. Mean seat pressure was not different between men and women. For the plain saddle, the men's average seat pressure increased as the workload increased. Using a holed saddle, the mean pressure increased as the workload increased, regardless of gender.

Conclusions. The increase of workload increased the seat pressure for the subjects, with the main effects dependent on workload. The use of a holed saddle was not directly related to lesser seat pressure during cycling. Our results support our understanding of a similarity between genders related to mean seat pressure, and suggest that different workload ranges may present different results for seat pressure. **Carpes FP, Dagnese F, Kleinpaul JF, de Assis Martins E, and Mota CB. Effects of workload on seat pressure while cycling with two different saddles. J Sex Med **;**:**_**.**

Key Words. Alcock's Syndrome; Pudendal Canal; Seat Pressure; Perineum; Erectile Dysfunction; Bicycle Saddle

Introduction

The relationship between cycling practice and erectile dysfunction (ED) has been studied widely. Numbness and ED are reported by bicyclists with a prevalence of 50–91 [1] and 13–24%, respectively [1,2]. In a former study considering a prolonged cycling tour (500 miles, 8 days), 45% of participants reported some episode of mild and transient perineal numbness, 10% severe, and 2% strong enough to temporally force the athlete out of the race [3]. Accordingly, the rate of ED after a prolonged cycling race (320 km) was 4.2 and 1.8%

for 1 week and 1 month after the race, respectively. Furthermore, penile numbness was reported by 31% of the cyclists participating in the race [4]. In association, only bicycling practice with a weekly volume higher than 3 hours was associated with manifestation of ED [5].

In some cases, impotence is experienced for longer durations than numbness [6]. It has been suggested that impotence is dependent on the repeated pressure on the perineal nerve within Alcock's canal, which decreases penile blood flow as well as penile oxygen pressure [7,8]. Ischemic events like this have been suggested as the

etiopathogenesis of Alcock's syndrome characterized by decreased glandular and penile sensitivity, and ED caused by compression of the pudendal nerve [6,7,9]. They have been described in male cyclists after prolonged compression of the pudendal nerve in the Alcock's canal against the saddle [10]. Recently, pudendal nerve compression in long-distance cyclists was hypothesized as resultant from irritation of the dorsal nerve of penis in a groove on the inferior ramus and anterior surface of pubis rather than irritation in pudendal canal [11]. This would support a dorsal nerve compression syndrome [11].

Pudendal nerve entrapment neuropathies are closely related to two critical sites, i.e., the proximal part between the sacrotuberous and sacrospinous ligament, and at the pudendal (Alcock) canal [12]. The nervus dorsalis penis is a sensory nerve fundamental for erectile and ejaculatory function. Its female counterpart is the nervus dorsalis clitoridis, which facilitates the sensory function of clitoris [13]. Perineal pain resultant from pudendal nerve entrapment can be aggravated by sitting, as well as a history of bicycle riding [14]. Additionally, the similarity in the course of dorsal nerve between genders [15] may support a similar mechanism of compression during cycling for men and women. It can result from repeated pressure against the saddle surface, especially the nose of the saddle, causing entrapment of the dorsal nerve of penis/clitoris in the ventromedial border of the ischiopubic ramus [11].

Common symptoms involve decreased glandular and penile sensitivity accompanied by genital numbness and ED (for males), or decreased clitoral sensitivity and genital numbness (for females) [12,15]. The change in saddle orientation producing a trunk orientation shift forward elicits a lower pressure against the saddle for men [16], but alternatively it may pinch the pudendal nerve at the emergence point below the pubis [1]. Results of computer modeling demonstrate that wider bicycle saddles supporting the ischial tuberosities decrease pressure on the perineal area [17]. Additionally, it is widely recommended that cyclists pause frequently during long-term cycling to avoid ischemic damage of the nervus dorsalis penis and the development of ED [18].

As bicycle saddle manipulation may be an effective strategy to reduce nerve compression in cyclists, this has been extensively investigated in an attempt to identify the better geometry and design for comfort, and minimize pressure on the perineum while pedaling [19–21]. Considering

overall body posture, men would be more susceptible to changes in seat pressure when changing the saddle design or trunk inclination than women [16,22,23]. Controversially, specific saddle designs developed especially for men or women are unusual, which may be related to variability in the information of seat force and pressure. Recent investigations considering the normal reaction force in the saddle surface in experienced cyclists rather than pressure suggested women exhibit greater magnitudes of change in seat reaction force compared to men [21]. These differences were likely caused by the lower center of mass in women [23]. Subjects in that study were, however, experienced cyclists, and it remains uncertain if the findings would hold for recreational cyclists who may have not the same adaptation from such exercise as observed in athletes.

Our intention was to investigate the influence of saddle design and pedaling workload on seat pressure in healthy recreational cyclists (less than 2 hours of practice per week) instead of experienced trained athletes. Thus, seat pressure was measured while pedaling at two different pedaling workloads and using two different saddle designs usually chosen by recreational cyclists. We hypothesized that there would be a reduction in seat pressure with increases in workload and changes in seat pressure when using the holed saddle. It would occur specifically for men, because men present greater changes in seat pressure related to the saddle even when simply standing on a bicycle [16].

Methods

Participants

Eleven male and 11 female recreational cyclists (bicycling less than 2 hours per week) were recruited from our university population. All volunteered to participate in the experiments. The characteristics of the subjects are described in Table 1. The subjects provided informed consent for voluntary participation in agreement with the local Committee of Ethics on Research with Humans. All subjects included in the experiments had not been involved with bicycling exercise for more than 2 hours per week, and reported no perineal pain or muscular impairments.

Data Acquisition and Processing

The subjects were instructed to refrain from extensive activity for 1 day prior to the experiment.

Table 1 Individual and group characteristics for age, body mass, height, and body mass index (BMI)

	Subjects	Age (years)	Body mass (kg)	Height (m)	BMI (kg/m ²)
Men	1	24	71	1.69	25
	2	20	69	1.72	23
	3	23	65	1.74	21
	4	24	89	1.85	26
	5	19	74	1.73	25
	6	21	71	1.81	22
	7	25	68	1.83	20
	8	23	71	1.75	23
	9	21	87	1.77	28
	10	21	69	1.80	21
	11	24	78	1.80	24
Mean ± SD		22 ± 2	74 ± 8	1.77 ± 0.1	24 ± 2
Women	12	30	53	1.67	19
	13	24	63	1.63	24
	14	22	74	1.71	25
	15	22	65	1.75	21
	16	20	63	1.68	22
	17	20	54	1.55	22
	18	23	64	1.74	21
	19	21	55	1.64	20
	20	20	66	1.75	22
	21	21	54	1.64	20
	22	23	55	1.63	21
Mean ± SD		22 ± 3	61 ± 7*	1.67 ± 0.06*	22 ± 2*

*Statistically different of men (*t*-test, $P < 0.05$).

Results presented as mean and standard deviation (SD).

The experimental testing was conducted on a road bicycle that was mounted on a cycle simulator (Computrainer *PROLAB 3D*, Racermate, Inc., Seattle, WA, USA). The saddle and handlebar height and horizontal positioning of the bicycle were adjusted for each subject prior to data collection according to the proper biomechanical positioning for bicycling [24], and kept constant for each subject for the duration of the experiment. Seat pressure was measured using two piezo-resistive instrumented F-Scan insoles with spatial resolution of four sensors/cm² and thinness of 0.15 mm (Tekscan Inc., South Boston, VA, USA). The insoles were adapted to cover the overall saddle surface and adjusted to maintain the same position during the evaluation [25]. The position of the insoles was verified by one of the investigators during the rest intervals.

The insoles placed over the saddle were calibrated every time that a different subject was evaluated. The calibration was done with each subject seated on the bicycle saddle, and considering a load correspondent to 60% of an individual's body weight. We decided to use a load correspondent to 60% of the total body weight because it has been reported as the real load applied on the saddle during bicycling [24]. We checked the reliability of this method with part of the sample by means of the bicycle placed over two three-dimensional biomechanical force plates embedded

at the floor level (OR6 Advanced Mechanical Technology, Inc., Watertown, MA, USA) while the weight over each wheel was measured (one wheel over each force plate).

Saddle pressure was measured while pedaling at two different workloads (power outputs) and with two different saddle designs that are commonly used by cyclists. The plain saddle had a flat surface, whereas the holed (cutoff) saddle had a full-length center recess with a hole through the nose designed in an attempt to relieve discomfort. After a 5-minute warm-up, the subjects pedaled for 5 minutes at the test workload and then the seat pressure was recorded continuously during 5-second intervals at a sampling rate of 30 Hz. The subjects were instructed to use nonpadded shorts, without seams or buttons. During the trials, the subjects kept their trunk positioned 60° forward related to the horizontal taken from goniometric measurement, with this position sustained by means of feedback from the researchers and by not changing the handlebar position (top). The saddle pressure measurements were conducted in the following (randomized) situations for the two saddle designs: (i) seat pressure measured during static posture on the bicycle with trunk positioned shift forward 60° related to the horizontal in order to pressure's system calibration; (ii) seat pressure measured during pedaling at a workload of 150 W; (iii) rest period of 5 minutes

Table 2 Results for mean and peak normalized seat pressure (Pa/kg) considering saddle design (plain and holed), workload (150 and 300 W), and gender (men and women)

Saddle design	Subjects	Workload (W)	Mean pressure (Pa/kg)	Peak pressure (Pa/kg)
Plain	Men (N = 11)	150	2.04 ± 0.5	2.51 ± 0.6
		300	2.81 ± 1.3**	3.32 ± 1.5**
	Women (N = 11)	150	2.54 ± 0.7	2.54 ± 0.8
		300	3.12 ± 1.7***	3.07 ± 1.1**
Holed	Men (N = 11)	150	2.09 ± 0.5	3.38 ± 1.1
		300	2.88 ± 1.3**	4.42 ± 2.3
	Women (N = 11)	150	2.95 ± 0.5	3.96 ± 1.1*
		300	4.59 ± 2.0**	4.31 ± 1.7

*Significant statistical difference ($P < 0.05$) between saddle designs within genders; **significant statistical difference ($P < 0.05$) between workloads; ***significant statistical difference ($P < 0.05$) between gender. Statistical significant outcomes are indicated.

out of the bicycle; and (iv) seat pressure measured during pedaling at a workload of 300 W.

Workloads were randomized, and the subjects were asked to keep a pedal rate of 90 rpm based on the information from the cycle simulator cadence indicator.

Statistical Procedures

The raw data for mean and peak seat pressure were averaged from right and left sides of the saddle surface because of the use of two independent F-Scan insoles over each saddle hemisphere. This procedure was accomplished using custom codes developed in a MATLAB environment (MATLAB 5.3, Mathworks, Inc., Novi, MI, USA). The seat pressure distribution was analyzed using Tekscan's software and MATLAB environment to identify the places of higher pressures over the saddle surface while pedaling. The locations of highest peak of pressure were visually analyzed. Values were organized for mean and standard deviation. Data normality was confirmed by means of Shapiro–Wilk's test. Age, body mass, height, and body mass index were compared between the groups employing independent Student's t -test. Seat pressure was normalized by individual body mass and then compared between workloads and saddle designs by means of analysis of variance for repeated measures. Where main effects or interactions were found, Student's t -test was selected as post hoc. Statistical power averaged 96% considering this sample size. The statistical package used was SPSS 12.0 for Windows (SPSS, Inc., Chicago, IL, USA). A significant level of 0.05 was considered for all statistical procedures.

Results

The body mass presented statistically significant different between men and women ($P < 0.05$). In

an attempt to avoid the effects of body mass on the statistical procedures and compare the values considering gender, the seat pressure (mean and peak) was normalized by individual body mass. The values for mean and peak normalized seat pressure are described in Table 2.

For normalized mean seat pressure, there was no statistically significant difference between saddle design, regardless of gender (plain vs. holed saddle for 150 W in men, $P = 0.79$; plain vs. holed saddle for 150 W in women, $P = 0.25$; plain vs. holed saddle for 300 W in men, $P = 0.89$; plain vs. holed saddle for 300 W in women, $P = 0.06$). The increase in pedaling workload elicited by increase of power output was related to statistically significant increase of the mean seat pressure for both saddle designs in men ($P = 0.020$ for plain saddle, and $P = 0.028$ for holed). Alternatively, for women, the increase in workload statistical significance increased mean seat pressure only for the holed saddle ($P = 0.284$ for plain saddle, and $P = 0.007$ for holed). A comparison between men and women showed statistically significant difference for mean seat pressure only for the workload of 150 W using the plain saddle ($P = 0.006$). When considering peak seat pressure, saddle design statistically significantly influenced seat pressure only for women at workload of 150 W ($P = 0.01$). Effects of workload on seat pressure were observed for the plain saddle for both genders, i.e., the increase of workload statistically significantly increased peak seat pressure using plain saddle design ($P = 0.022$ for men, and $P = 0.048$ for women). The peak seat pressure did not change statistically significantly when workload increased using the holed saddle. The statistical significant of peak seat pressure did not differ between men and women ($P > 0.05$). An analysis of pressure distribution suggested the locations of highest pressure depending on the saddle design, but not on

the pedaling workload or gender. The plain saddle elicited a pattern of distribution over the whole saddle, including perineal area and tendency of peaks of pressure concentrated over ischial tuberosities. On the other hand, the holed design had the pressure distribution predominantly concentrated on the posterior saddle over the ischial tuberosity, with only low pressure values for other points of the saddle.

Discussion

The purpose of this study was to evaluate the effects of two different workloads and two saddle designs on seat pressure for healthy men and women recreational cyclists. We did not use a specific system to measure saddle pressure in bicycle saddles, which was the main limitation of the investigation because a proper comparison between different parts of the saddle could not be performed. Instead, we used a method previously described as suitable [22,23]. The main findings in the present study were that there was no statistically significant difference between men and women for most variables investigated, and the statistically significant effect of workload on seat pressure during pedaling, especially for men. The saddle design had little effect on seat pressure with the only statistically significant difference found when peak pressure was compared between hole and plain saddles in women while pedaling at a workload of 150 W. In this regard, it is important to consider that the holed saddle has edges in the hole that may increase pressure caused by the contact of small surface areas under an elevated compressive load [1].

The plain saddle presented a profile of pressure distribution spread throughout the saddle surface, whereas the holed saddle was consistent with points of higher pressure located over the ischial region. It is consistent with the support of the body weight over the ischial bones and the reduction of pressure over the perineum while using cutoff models [21]. Indeed, the similar patterns between subjects suggest a universal impingement zone that limits blood flow to the penis [26]. It leads to ED in men, decreased clitoral sensitivity in women, and numbness in both [12,15].

Regarding seat force, a recent investigation illustrated differences between genders in the saddle reaction force and their correlated variables when pedaling workload was changed from 100 to 200 W [21]. Our seat pressure results showed statistically significant differences between genders only for the lowest workload tested (i.e., 150 W).

It suggests that pedaling at a workload higher than previously tested will see the differences between genders disappear or at least decrease significantly. It is stated because we found statistically significant differences between gender only with workload comprehended by that workload range investigated in Potter et al.'s study [21], and not for higher workloads (from 100 to 200 W, Potter et al.'s study showed statistically significant differences between genders; the present study showed statistically significant differences between gender only at 150 W and not while pedaling at 300 W; see Table 2). Even though not tested in our experiments, we could hypothesize that different workloads lead to different effects on seat pressure for cyclists. It could be related to changes in propulsive force applied on the pedals or even by alterations in pedaling technique that changes in exercise configuration can elicit [27].

Regardless of workload, women riding with the hole saddle were less susceptible to changes in seat pressure. It was also reported that consideration of a static posture on the bicycle, when a posture of trunk shift forward, did not significantly influence seat pressure in women [16]. Our results reinforce the susceptibility of men to urological impairments caused by pressure and friction on the contact with the saddle, which will affect the dorsal nerve of penis in particular [11]. When considering possible effects of pressure, the main factor in safeguarding penile perfusion resultant from perineal arteries compression [6] is the use of a saddle design that avoids compression on these tissues [28]. The seat pressure can lacerate branches of cavernous arteries and pudendal nerves because of friction and leads to decreases, or cessation, of blood supply to the region because of entrapment of the dorsal nerve of penis/clitoris [11]. This contributes to numbness in both the genders [1,6,29]. Furthermore, bicycle seat pressure below the pubic symphysis limits the blood flow in the penile region [26].

The workload previously suggested as a factor influencing seat pressure for both genders [23] in the present study was more remarked for men. The changes in seat pressure support the use of a partial cutout design more comfortable than a standard plain saddle or with complete cutout design [30]. On the other hand, a few changes in seat pressure while riding may support the fewer cases of abnormality in women. However, these results do not mean that female cyclists are not subject to genital disorders [31]. For instance, competitive female cyclists are subject to unilateral

vulval enlargement resulting from increased unilateral loads or similar lymphoscintigraphic abnormalities in their pelvis and ipsilateral leg [32,33].

Additionally, unilateral vulval enlargement in competitive female cyclists may result from biomechanical factors related to asymmetries, such as muscle strength imbalances influencing asymmetric load on one side [33]. It brings into the discussion variables frequently neglected, such as lower limb bilateral strength differences. Differences of force between limbs should be considered in further studies, because the lower limb inequalities affect the strength capacity and contributes to low back pain [34]. Low back pain was reported as a negative factor for normal pelvis movement [35], which was reported as affecting seat pressure during cycling [17,36].

Because investigations frequently report conflicting evidence regarding the best saddle design, mainly because of the high variability of models and materials, the adoption of rest intervals during prolonged distance cycling events could be suggested as a satisfactory strategy to minimize disorders [6]. An additional question is whether in a situation of misalignment of the handlebar position or seat height, the outcome of the study can change dramatically. It is an effect possible not only in the present study, but also for all investigations conducted at a similar experimental design. Here, a proper positioning for cycling was considered. Despite the factors influencing saddle design improvement for seat pressure [37–40], further investigation could also consider the incorrect body adjustments in cycling, which is frequently observed mainly for recreational cyclists. Indeed, we suggest seat pressure is also dependent on the experience of the cyclists, which means that highly trained cyclists could present characteristics concerning seat pressure that may be developed with the improvement of body positioning and ability to select equipment, such as saddles, according to the perception of pain and comfort.

Conclusion

Our results suggest that different saddle designs tested do not perform a fundamental role for a reduction in seat pressure in recreational cyclists. Hole saddle design seems to play a higher protective role for women in some situations because lesser effects of changing workload were observed for women. Higher power output might elicit different responses for seat pressure between men and women. The differences elicited by studies

considering experienced cyclists suggest riding experience as a plausible consideration for affecting seat pressure. Further investigations should consider a larger range of workloads, which seem to significantly influence seat pressure, as well as distinguish and compare pressure load and distribution in particular in saddle regions such as the anterior and posterior saddle parts, which might add important knowledge to the understanding of Alcock's syndrome etiopathogenesis.

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Statement of Authorship

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