SEXUAL MEDICINE ORIGINAL RESEARCH

BASIC SCIENCE

Effect of Oscillation on Perineal Pressure in Cyclists: Implications for Micro-Trauma

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ABSTRACT

Background: Genital numbness and erectile dysfunction in cyclists may result from repeated perineal impacts on the bicycle saddle (micro-trauma) that occur during routine cycling.

Aim: To evaluate the relationship between oscillation forces and perineal pressures among cyclists in a simulated laboratory setting.

Methods: Participants were fit to a study bicycle to ensure all cyclists had the same torso angle (60 ± 1 degree) and maximum knee angle (150 ± 1 degree). A lever system was used to generate oscillation events of 3 progressively increasing magnitudes. Perineal pressure was continuously measured using a pressure sensor on the bicycle saddle. This process was carried out in each of the following conditions: (1) stationary (not pedaling) with the standard seatpost, (2) pedaling with standard seatpost, (3) stationary with seatpost shock absorber, and (4) pedaling with seatpost shock absorber.

Outcomes: We compared perineal pressure changes during oscillation events in the stationary and pedaling states, with and without the seatpost shock absorber.

Results: A total of 39 individuals were recruited (29 men and 10 women). As the amount of oscillation increased from an average of 0.7*g* (acceleration due to Earth's gravity) to 1.3*g*, the perineal pressure increased from 10.3% over baseline to 19.4% over baseline. There was a strong linear relationship between the amount of oscillation and increase in pressure ($r^2 = 0.8$, $P < .001$). A seatpost shock absorber decreased the impact of oscillation by 53% in the stationary condition. Men and women absorbed the majority of shock in areas corresponding to pelvic bony landmarks.

Conclusion: This study represents one of the first characterizations of cycling-associated perineal micro-trauma in a laboratory setting. We found a strong linear relationship between oscillation magnitude and perineal pressure during cycling, which was mitigated by a seatpost shock absorber. The use of shock absorption in bicycle design may reduce perineal micro-trauma and potentially improve cycling-associated perineal numbness and erectile dysfunction. **Sanford T, Gadzinski AJ, Gaither T, et al. Effect of Oscillation on Perineal Pressure in Cyclists: Implications for Micro-Trauma. Sex Med 2018;6:239–247.**

Key Words: Perineum; Micro-Trauma; Cycling; Saddle

INTRODUCTION

Cycling is a form of physical activity that promotes health in numerous ways resulting in a reduction of all-cause mortality in individuals who cycle regularly.[1] Despite the known health benefits of cycling, overuse injuries are common, occurring in up to 85% of recreational cyclists.[2] The contact between the bicycle saddle and sensitive perineal structures results in genital numbness in 50–91% of cyclists and erectile dysfunction (ED) in 13–24% of men cyclists engaging in long-distance cycling events.[3,4] 2 Potential mechanisms have been proposed in the pathogenesis of these cycling-related urogenital disorders: decrease in blood flow to genital structures and pudendal nerve palsy from micro-trauma.[3]

The majority of the studies evaluating the mechanism of genito-urinary overuse injuries have focused on the effect of the bicycle saddle on perineal blood flow.[5–8] The palsy that occurs

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in the pudendal nerve distribution in cyclists is not as well-studied. This phenomenon has been termed the “Alcock syndrome” and is thought to be due to forces applied to the pudendal nerve within the Alcock canal.[9]

While static compression has been a proposed mechanism, the role of micro-trauma has also been postulated.[3] Micro-trauma refers to repeated low-intensity impact. The rationale for the deleterious effects of micro-trauma (as opposed to continuous compression) stems from a study utilizing a rat forelimb model in which the effect of a repetitive force of 2 N applied at a rate of 60−120 times per hour was compared with continuous pressure applied with the same force (2 N). The repetitive force condition resulted in nerve dysfunction whereas the continuous force condition did not produce nerve dysfunction.[10] Given most bicycles do not have an effective full suspension (front and rear shock absorbers), the forces created during cycling are transmitted directly to the perineum. Micro-trauma transmitted to the perineum may contribute to the genito-urinary overuse injuries including ED in men[11,12] and decreased perineal sensation in both men and women.[13,14]

In this study, we evaluated the effects of oscillation on perineal pressures in men and women in a controlled laboratory setting. We also evaluated a potential method to mitigate the effects of oscillation—a seatpost shock absorber. Our hypothesis is that with greater oscillation there is a corresponding increase in perineal pressure that would be dampened by a seatpost shock absorber. If proven correct, our hypothesis would provide a mechanism to reduce perineal micro-trauma experienced while cycling, and potentially alleviate cycling-associated ED and perineal numbness.

METHODS

Subjects

Healthy subjects with no known co-morbidities and no urinary/sexual dysfunction were recruited for participation. All subjects filled out a basic health questionnaire and demographics form. Informed consent was obtained for all subjects (University of California, San Francisco Institutional Review Board Number 14−14,946). Subjects were provided clean, fitted cycling shorts with no chamois for use during the study. All subjects wore athletic shoes. Subjects were given a $20 gift certificate for participation.

Laboratory Bicycle

The study bicycle (Tuono; Vilano, Elkton, FL) and associated equipment are shown in Supplemental Figure 1. Small, medium, and large sizes were available to fit cyclists of various sizes. The stem was replaced with a bicycle sizing stem (Purely Custom, Twin Falls, ID) to allow the bicycle to be fully adjustable. The rear wheel was removed and the bicycle was attached to a Kicker trainer (Wahoo Fitness, Atlanta, GA). The bicycle saddle model (Regal; Selle San Marco, Rossano Veneto, Italy) was chosen for its standard teardrop shape with minimal padding to allow for measurement of pressure throughout the perineum.

Pressure/Oscillation Measurement

Perineal pressure measurements were obtained using the F-Socket VersaTek 1-cuff system with a 9833E Large F-Socket Sensor (Tekscan, South Boston, MA). This system measures pressure via individual sensors embedded in a thin plastic sheet. To ensure appropriate sensor fit to the saddle, the F-Socket sensor was divided into strips that were secured to the saddle with double-sided tape and fine suture (Supplemental Figure 1). Accelerometer data were obtained using the application Vibration V3.53 (Diffraction Limited Design, Southington, CT) on an iPhone 5 (Apple Inc, Cupertino, CA). The iPhone was mounted to the seatpost using the BIKE+BAR mount (LifeProof, Fort Collins, CO). Oscillation was created using a custom-fabricated lever system attached to the trainer. 2 Seatposts were used—the stock Tuano aluminum seatpost and a seatpost suspension. For the seatpost suspension system, we utilized the SP12-NCX Suspension Travel Seatpost (27.2 × 350 mm) (SR Suntour, Madison, WI).

Position/Fit

Due to the known effects of cyclist position on perineal pressures,[15,16] the bicycle was adjusted such that all cyclists had a standardized torso and maximum knee angle (Supplemental Figure 2). Bicycle adjustments were made until each participant had a maximum knee angle of 150 degrees (±1 degree) and a torso angle of 60 degrees from horizontal (±1 degree). The Bike Fast Fit application (Double Dog Studios, Fort Myers, FL) was used to ensure these measurements were maintained while the cyclist pedaled (Supplemental Figure 2). Using software (Tekscan), we evaluated the pressure points associated with the ischial tuberosities (ITs) and ensured the distance between ITs was consistent with our measurements. We adjusted the saddle in the horizontal plane until the ITs of each cyclist were located within the rear portion of the saddle and confirmed this with visual examination of the pressure readings in real time. The saddle angle was set at 0 degrees for all participants.

Measurement of Perineal Pressure and Oscillation

To ensure consistent measurements between cyclists, the trainer was set at 100 W for all cyclists, which was maintained regardless of cadence or gear. Pressure sensors were calibrated for each cyclist during a 2-minute warm-up period. Oscillation was measured in the vertical plane in *g* (the average acceleration due to gravity at surface Earth, 9.8 m/s^2). The acquisition rate for pressure sensors and oscillation was set to 100 Hz.

There were 4 conditions tested: (1) stationary (not pedaling) with the standard seatpost, (2) pedaling with standard seatpost, (3) stationary with seatpost suspension, and (4) pedaling with seatpost suspension. Each condition lasted 40 seconds. The 40-second condition trial was split into 5-second intervals.

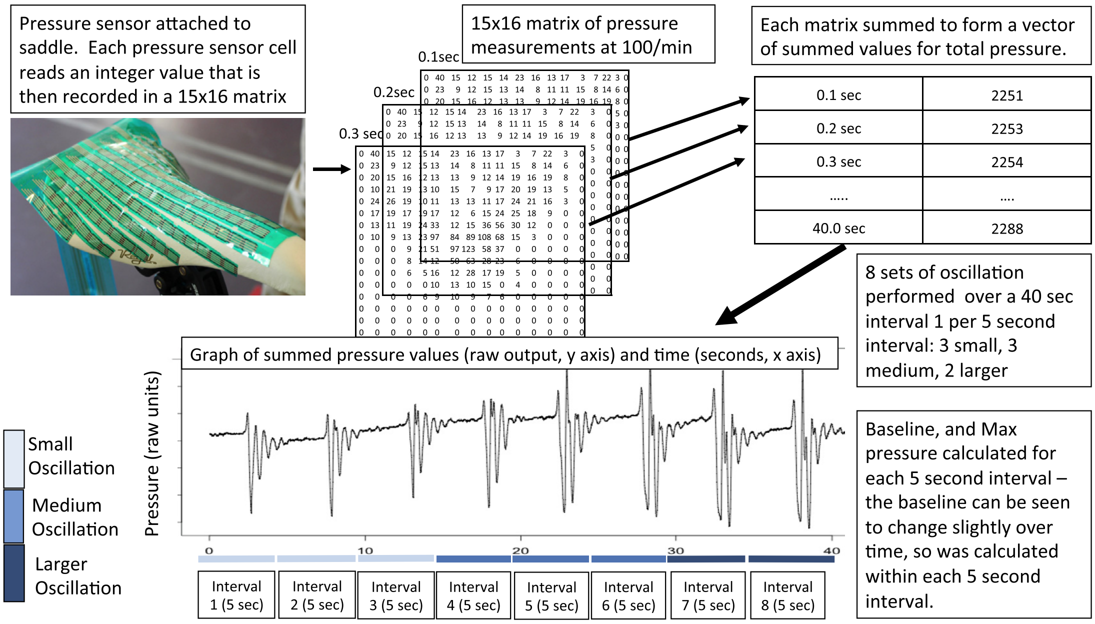


Figure 1. Experimental design. Pressure mat was cut into strips and attached to the bicycle saddle with double-sided tape and suture. The 15 × 16 matrix of integer values that was taken at 100 Hz was summed for the total pressure measurement. There was 1 oscillation event every 5 seconds. The maximum pressure change for each 5-second interval was defined as the maximum pressure value minus the baseline value for that 5 seconds. The baseline was defined as all the values that did not exceed 1 SD from the median value.

During each 5-second interval there was a single oscillation event where the back of the trainer was lifted between 0.5 and 2 cm off the ground and then released, allowing the rider to drop by gravity. The first 15 seconds had 3 small oscillations, the middle 15 seconds had 3 slightly larger oscillations, and the final 10 seconds had the 2 largest oscillations (Figure 1). The goal was to induce y-axis oscillation changes of $<1g$ in the small oscillation trial, between 1.0 and $1.5g$ in the medium oscillation trial, and between 1.5 and $2.0g$ in the large oscillation trial. Pedaling cadence was approximately 80 revolutions per minute, and during the stationary trial the subjects were instructed to hold the pedals parallel to the ground with the right foot forward.

Data Analysis: Calculation of Maximum vs Baseline Pressures

All statistical analyses were performed using R v3.2.1. Figure 1 summarizes the analysis workflow. The pressure sensor data were composed of frames representing a 15 × 16 matrix with integer values for the raw pressure measured at each point on the sensor. We chose to use raw pressure measurements (non-transformed, direct output from Tekscan) as these were more stable with our analyses than using values transformed into standard units (ie, kilopascal). The values within each matrix were added to produce a single pressure value for each frame. The summed pressure values were concatenated to produce a vector of integer pressure values representing the total pressure at each time point.

The absolute increase in pressure was calculated by the maximal pressure within a 5-second interval minus the baseline pressure. The percent increase in pressure was calculated as the maximal pressure within a 5-second interval divided by the baseline pressure. We multiplied the percent change in pressure by a correction factor to ensure variation in oscillation events was not influencing the outcome—this correction factor was the change in oscillation calculated as the maximum oscillation minus the minimum oscillation within each 5-second interval.

Data Analysis: Evaluation of Pressure Distribution Changes

We anticipated gender-specific differences in pressure distribution and therefore split the cohort into men and women participants. To evaluate the specific areas of maximal pressure at each point in the perineum, we determined the maximal value of each individual sensor point over every 5-second period during the trials. We then averaged the maximal pressures for each sensor point across subjects. The topographical distribution of mean maximal pressures was evaluated using the surface graphing function from the *plotly* R package. The location of the pressure sensors was then partitioned into 4 mutually exclusive areas containing important anatomic structures: the (1) right and (2) left ITs, the (3) posterior perineum (PP) between the 2 ITs, and (4) the anterior perineum (AP). The position of these partitions was the same for all subjects. The maximal pressures for each sensor within these anatomical areas was summed to produce a value for each area to be compared across the conditions.

Statistical Analysis

For the 3 conditions (small, medium, and large oscillation), a repeated measures analysis of variance was performed to evaluate

Table 1. Subject demographics

	Total, N = 39	Men, N = 29	Women, N = 10	Men vs women, P
Age, y, mean (range)	30 (18–44)	30 (18–44)	31 (28–35)	.77
Height, cm, mean (range)	175 (155–193)	178 (163–193)	165 (155–173)	<.01
Weight, kg, mean (range)	73.9 (45.4–111.1)	78.5 (56.7–111.1)	60.8 (45.4–78.0)	<.01
BMI, mean (range)	24.0 (17.7–31.3)	24.1 (18.8–31.3)	22.1 (17.7–29.5)	.06
Ischial tuberosity distance, cm, mean (range)	5.2 (4.2–7)	5.1 (4.2–7)	5.1 (4.5–6)	.98
Commute, N (%)	12 (31%)	8 (28%)	4 (40%)	.69
Commute, min, mean (range)	44 (15–180)	52 (20–180)	23 (15–40)	.20
Ride recreationally, N (%)	23 (59%)	15 (52%)	8 (80%)	.15
Median min/weekly recreational ride, mean (range)	110 (2–420)	101 (2–240)	126 (30–420)	.63

BMI = body mass index.

for differences in mean pressure (or change in pressure) among the 3 groups. t Tests were used to evaluate the differences in the mean values for the different trials (ie, shock absorber vs no-shock absorber). Paired t tests were used for comparisons from the same subjects evaluated in 2 conditions. Fisher exact test was used to evaluate categorical variables. A P value less than .05 was considered to be statistically significant.

RESULTS

Subject Characteristics

39 Healthy volunteers were recruited for study participation (29 men and 10 women). Demographics are listed in Table 1. The majority of subjects were recreational cyclists (59%), defined as individuals who cycled for any distance at least once per month. 12 Participants (31%) commuted at least weekly via bicycle. There were no significant differences in body mass index, age, or baseline ridership between genders (Table 1).

Pressure Changes—Relationship to Oscillation

As oscillation increased in magnitude, perineal pressure increased in every condition tested ($P < .01$) (Figure 2). Furthermore, there was a strong linear correlation between the average oscillation changes and the average perineal pressure changes ($r^2 = 0.82$, $P < .001$) (Figure 3). In the stationary condition at the smallest oscillation levels ($0.7g$, CI $0.6–0.9g$), there was a 10.3% (CI 7.8–12.8%) increase in perineal pressure over baseline (Table 2). As the oscillation increased to $1.3g$ (CI $1.1–1.5g$) in the large oscillation condition, the perineal pressure increased to 19.4% over baseline (CI 15.1–23.7%). Pressure changes while pedaling were higher for all magnitudes of oscillation compared with the stationary condition: 19.8% (CI 16.4–23.2%) over baseline in the small oscillation group, increasing to 26.9% (CI 22.8–31.0%) over baseline for large oscillations. To correct for the variation in oscillation, we then multiplied the percent pressure change by the oscillation correction factor, and found the same trends (Table 2).

The increase in pressure over baseline in the pedaling condition compared with the stationary condition was notable: in the stationary phase, small to large oscillations changed from 10.3–19.4% compared to the pedaling condition where pressure increased from 19.8–26.9%.

Pressure Changes—Impact of Shock Absorption

In the stationary condition, a seatpost shock absorber decreased the change in pressure associated with oscillation (Table 3). There was 57–59% decrease in pressure with the seatpost shock absorber, which was statistically significant in all levels of oscillation. This effect persisted after correction for variability in oscillation. In the pedaling condition, there were also decreases in the change in pressure, but these changes were not statistically significant.

Distribution of Pressure Change in the Perineum

When the maximum pressure at each point in the perineum was averaged across subjects (stratified by gender), much of the total pressure was concentrated in small areas of high pressure (Figure 4 and Supplemental Figures 3–6). This effect was particularly notable for women with much of the pressure being concentrated in areas corresponding with the ITs and the symphysis pubis. In men, the maximal pressure was distributed throughout the location of the pubic rami. We found significant differences in most areas of the perineum between the stationary condition and the pedaling condition (Supplemental Table 1). In women, the AP was relatively spared from increases in maximal pressure during pedaling (Supplemental Figure 4 and Supplemental Table 1). In both men and women, the increases in PP pressures between the stationary and pedaling conditions were higher than for increases in AP pressures.

When comparing non-oscillation to oscillation in the stationary condition, there were increases in pressure throughout the perineum (Supplemental Table 1). However, the effects were particularly pronounced in the AP in both men and women. In both men and women, the addition of a seatpost shock absorber significantly decreased the maximal pressure in the perineum. It should be noted that the higher pressures seen in the right IT in the stationary condition were likely due to position—subjects

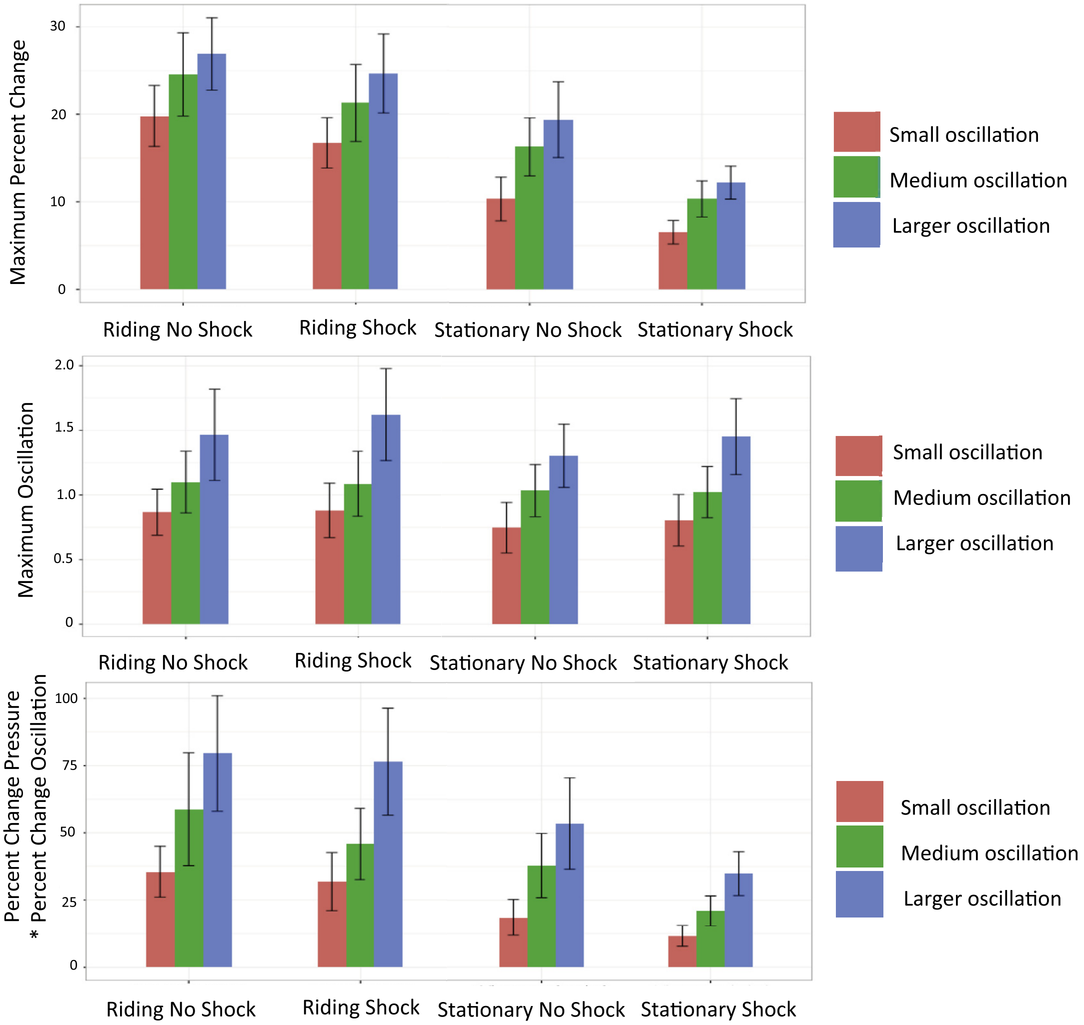


Figure 2. Average of maximal changes. There was an increase in perineal pressure as the amount of oscillation increased from 0.8–1.5*g*. This pressure was mitigated by the presence of a shock absorber in the stationary group. The shock absorber had less of an effect in the riding group. The trends remained after correcting the amount of pressure by the oscillation.

were instructed to keep their right foot forward during this portion of the study.

DISCUSSION

In this study, we found a strong correlation between the amount of oscillation and perineal pressure. When the amount of oscillation was approximately 1.5*g* in the *y*-axis, the perineal pressure increased 19.4% over baseline in the stationary condition and 26.9% over baseline in the pedaling condition. The implication of this change in pressure is that a 160-lb cyclist who carries 50% of body weight on the perineum will have an increase of 16–21 lb of additional pressure applied to the perineum during every oscillation of 1.5*g*. We cycled under real-world road conditions with the oscillometer recording (Supplemental Methods), and found that the increase in oscillation over just about every type of common road irregularity exceeded 1.5*g* (Supplemental Figures 7 and 8). Thus, cycling over rough road will likely generate a changing repetitive force of the type associated with nerve dysfunction in animal models,[10] and in human beings could incur pudendal nerve palsies hypothesized to cause genital numbness in cyclists.[17]

Using a standardized position and saddle pressure mapping, we demonstrated specific areas where most subjects have increases in pressure. The distribution of these pressure changes in the perineum during the stationary condition is consistent with prior reports demonstrating a specific focus of elevated pressure in the AP in women.[16] However, during oscillation conditions, there were relatively small areas that absorbed a disproportionate amount of force, which appeared to correspond with known bony landmarks (Supplemental Figures 3–6) in both men and women. These areas of maximal pressure have implications for the genito-urinary maladies that affect both men and women cyclists. For both men and women, the pudendal nerve will be impacted as it courses through Alcock canal during increases in pressure, which may explain the perineal numbness that is shared

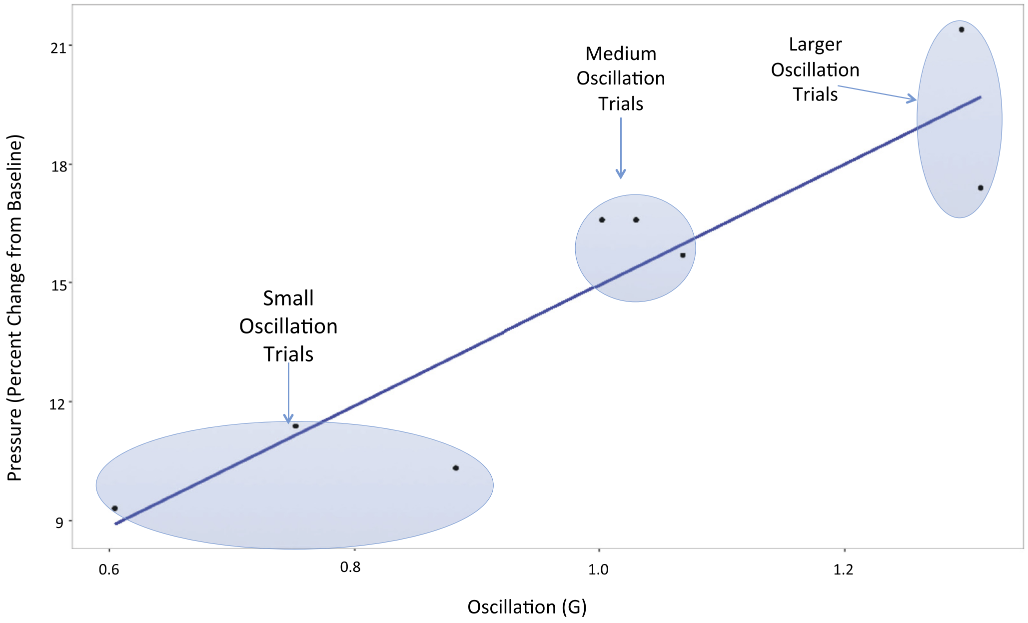


Figure 3. Relationship between pressure and oscillation. There is a linear direct relationship among small, medium, and large oscillation events with r^2 of 0.8.

by both genders. For women, it may also describe the source of skin breakdown that tends to occur in the labia creating hyperplastic nodules.[18] Furthermore, given that pudendal neuropathy has been shown to contribute to ED,[12] and cyclists have had documented nerve-conduction delays,[13] pudendal neuropathy may contribute to the ED seen in recreational cyclists after long-distance events.[19,20]

Our findings also carry implications for bicycle saddle design. Although there was an increase in pressures in the PP in both men and women, the majority of the force increase sustained during oscillation did not occur in this location—this is the part of the perineum that would be spared with a "cutout" saddle design. Despite a relatively small increase in recorded pressure in this area, any saddle changes resulting in a re-distribution of this pressure may contribute to increases in genital numbness and associated ED noted in men using cutout saddles.[17,20] It also has implications for saddle angle and body position. A relatively upright position was used for this study; given the known

Table 2. Changes in perineal pressure above baseline with standard saddle

Percent pressure change Stationary		Percent pressure change Riding	
Size oscillation	Percent change pressure (95% CI)	Size oscillation	Percent change pressure (95% CI)
Small	10.3 (7.7–12.7)	Small	19.8 (16.4–23.2)
Medium	16.3 (12.9–19.5)	Medium	24.6 (19.8–29.4)
Large	19.4 (15.1–23.7)	Large	26.9 (22.8–31.0)
P value ANOVA	<.01	*P* value ANOVA	<.01
Percent change pressure * correction factor Stationary		Percent change pressure * correction factor Riding	
Size oscillation	Percent change pressure (95% CI)	Size oscillation	Percent change pressure (95% CI)
Small	18.6 (11.9–25.3)	Small	35.5 (26.1–44.9)
Medium	37.9 (26.0–49.8)	Medium	58.7 (37.7–79.7)
Large	53.6 (36.7–70.5)	Large	79.5 (58.0–101.0)
P value ANOVA	<.01	*P* value ANOVA	<.01

ANOVA = analysis of variance.

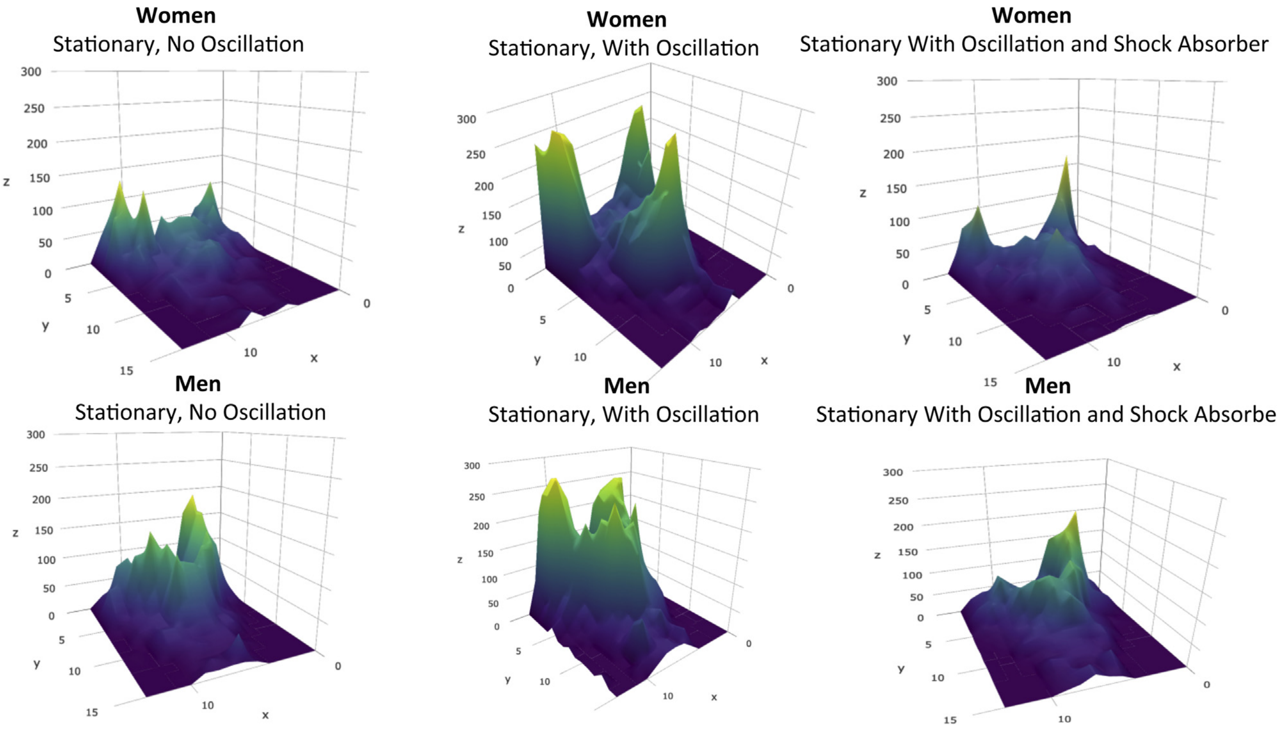
Table 3. Changes in perineal pressure above baseline with addition of seatpost shock absorber

	Condition	Size oscillation	No shock	Shock	Decrease	*P* value
% Change pressure	Stationary	Small	10.3	6.5	58%	<.01
	Stationary	Medium	16.3	10.4	57%	<.01
	Stationary	Large	19.4	12.2	59%	<.01
	Riding	Small	19.8	16.8	18%	.11
	Riding	Medium	24.6	21.3	15%	.23
	Riding	Large	26.9	24.6	9%	.41
% Change pressure * Correction factor	Stationary	Small	18.6	11.6	60%	<.01
	Stationary	Medium	37.9	21.1	80%	<.01
	Stationary	Large	53.6	34.9	53%	<.01
	Riding	Small	35.5	31.8	12%	.62
	Riding	Medium	58.7	45.8	28%	.24
	Riding	Large	79.5	76.4	4.0%	.81

relationship between forward tilt and pressure on the AP,[16] we postulate a more forward-leaning position (in both genders) may increase the pressure on the AP during oscillation.

Although the seatpost shock absorber utilized a relatively simple spring-based design, we found that it substantially reduced the amount of pressure the perineum received in the stationary condition. There were also decreases in the riding condition, although the magnitude was less and the decreases did not reach statistical significance. Given the substantial increase in perineal pressures with even small oscillation events and the reduction in perineal pressure found with shock absorber use, we believe this study provides a significant rationale for future investigations assessing whether the use of a seatpost shock absorber in real-world cycling conditions produces a clinically measurable reduction in perineal numbness and ED.

We took great care to design the study in such a way as to standardize potential cofounders that would influence perineal pressures. For example, all participants were given standard form-fitting shorts without a chamois, all subjects rode the same saddle model with the tilt set at 0, and all cyclists were fitted to the bicycle using a standardized method that was verified with video analysis. Despite this, there are limitations to our study. There was variability within each oscillation size due to the mechanical nature of our lever system. Thus, we corrected the


Women Stationary, No Oscillation

Women Stationary, With Oscillation

Women Stationary With Oscillation and Shock Absorber

Men Stationary, No Oscillation

Men Stationary, With Oscillation

Men Stationary With Oscillation and Shock Absorbe

Figure 4. Points of maximal pressure in men and women. For men and women, the distribution of the maximum pressure averaged across all participants. The increases in pressure were absorbed by relatively small areas corresponding to known bony landmarks.

pressure for the oscillation measurements to ensure the trends we observed were not confounded by variability in oscillation. Additionally, our seatpost shock absorber should was not tuned to each individual's body weight. However, since there is no standardized way to do this, we used a tension we believed would work best for all subjects. Tuning this parameter may improve the results from shock absorption, particularly while cycling.

The role of micro-trauma while cycling has long been postulated to contribute to perineal numbness in both men and women cyclists and potentially to ED in men cyclists. In this study, we demonstrate a strong correlation between oscillation and increases in perineal pressure over baseline. We also show an absolute pressure increase of 27% over baseline when pedaling and of 19% over baseline when not pedaling with 1.5*g* of oscillation. In both men and women, small anatomical areas corresponding to bony landmarks received a disproportionate amount of pressure. A spring-based seatpost shock absorber produced a substantial reduction in the effects of oscillation in the stationary condition, indicating a role for further investigations to assess if perineal-specific shock absorption reduces perineal maladies experienced by cyclists.

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SUPPLEMENTARY DATA

Supplementary data related to this article can be found at https://doi.org/10.1016/j.esxm.2018.05.002.