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Conference Abstract

Effects of test duration on pressure distribution, pelvic stability, and subjective perception in laboratory investigations for evaluating bicycle saddles and seat pads

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Abstract: The aim of this study was to investigate the consistency of typical evaluation characteristics used to assess seating systems in cycling for both male and female cyclists, over a ride time of up to 60 minutes. Pressure distribution, pelvic stability, and subjective perception were measured in a laboratory test using a stationary bicycle. Results showed that mean pressure load increased with the duration of the test, particularly in the first 30 minutes, leading to a decrease in overall subjective comfort. The analysis of pelvic motion yielded inconclusive findings for both genders. Based on these results, it is recommended that future tests should last at least 15 minutes per condition to obtain reliable and valid data.

Keywords: sex, gender, cycling, WAHOO Kickr, pressure mapping, Inertial Measurement Unit

1. Introduction

Seat pads, or chamois pads, are a crucial element of cycling shorts, providing support and comfort to the rider's bottom at the interface with the bicycle saddle. These pads are typically made of soft, moisture-wicking materials that should conform to the rider's body shape to distribute pressure evenly across the contact points between the body and the bike seat, reducing discomfort and preventing chafing and soreness. On the other hand, different saddle designs have been reported to significantly influence the sitting posture, and subjective assessments of comfort during cycling (Bressel, & Larson, 2003).

When designing the experiments for either comparing different seat pads or saddle designs by subject studies, an important parameter is the duration of the examination. On the one hand, the duration of the study should be kept as short as possible in order not to overload the subjects physiologically and cognitively. In addition, economic standards are naturally also applied in industrial product development.

However, the study by Larsen et al. (2019) found a significant increase in discomfort after one hour of cycling among professional female cyclists. This suggests that longer rides may indeed have an impact on pressure distribution and comfort for female cyclists, but further research would be needed to confirm this.

Thus, the purpose of this study was to investigate the consistency of typical evaluation characteristics used to assess seating systems in cycling over a ride time of up to 60 minutes for both, male and female cyclists.

2. Materials and Methods

A subject study was conducted where participants cycled on a stationary bicycle while pressure distribution was measured on the saddle, subjective pressure sensations were elicited, and the extent of pelvis movement was recorded.

Subjects—Thirteen participants, thereof seven females (age: 31.5 ± 4.1 years, body weight: 61.7 ± 5.2 kg, height: 167.3 ± 3.2 cm) and six males (age: 39.5 ± 8.2 years, body weight: 80.5 ± 5.4 kg, height: 181.8 ± 4.6 cm) were recruited for this study. All participants gave informed consent and were classified as trained or well-trained based on their Peak Power Output (PPO) following the classification of Decroix et al. and Pauw et al. (Decroix, Pauw, Foster, & Meeusen, 2016; Pauw et al., 2013). No professional cyclists were included in the study.

Methodology—A stationary KICKR bike (Wahoo, Atlanta (GA), Unites States of America) was adjusted to the subject's individual anatomy and to result in a 50° trunk lean angle. Depending on the ischial tuberosity distance, a wider or narrower version of the same saddle model Cube Venec (Pending System GmbH & Co. KG., Waldershof, Germany) was mounted.

All subjects wore their favorite personal cycling pants. The pedaling resistance for the test corresponded to 70% of the individual functional threshold power (FTP) value assessed beforehand. The target cadence was set at 80 rpm. With this power (mean ♀: 136.7 ± 7.9 W, ♂: 197.1 ± 12.4 W) and cadence, the test subjects pedaled for 60 min without a break. During this time, they were not allowed to leave the saddle and had to keep their hand position as constant as possible.

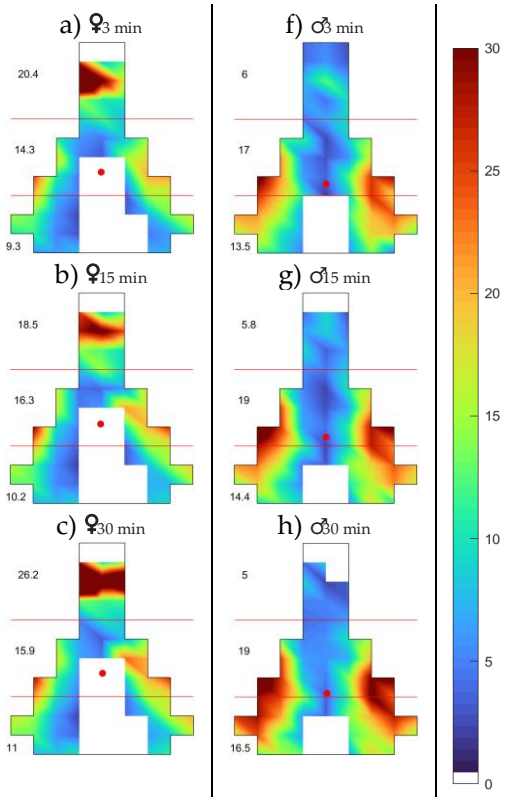
After 3, 15, 30, 45, and 60 minutes of test duration, objective data were recorded for intervals of 10 s using a saddle pressure measuring system (gebioMized, Münster, Germany) and an inertial measurement unit (WaveTrack, menios GmbH, Ratingen, Germany) placed on the sacrum. In addition, participants were asked to subjectively rate the perceived pressure intensity, discomfort caused by pressure, and stability on the saddle-seat pad interface. Data was processed using Matlab (R2022b, The MathWorks Inc., Natick, United States).

Statistical Analysis— Due to the small sample size, non-parametric data analysis was performed. The independent variables were evaluated utilizing both Spearman's rank correlation coefficient and Friedman's post-hoc test analysis.

3. Results

3.1. Pressure distribution

In Figure 1, the pressure distribution patterns of females and males are displayed. Qualitatively, it can be noted that both sexes differed in the location of high-pressure areas. The female participants exhibited the greatest pressures around the saddle nose at all measurement times. The male participants, in turn, generated the highest pressures in the middle area, especially around the saddle cheeks.



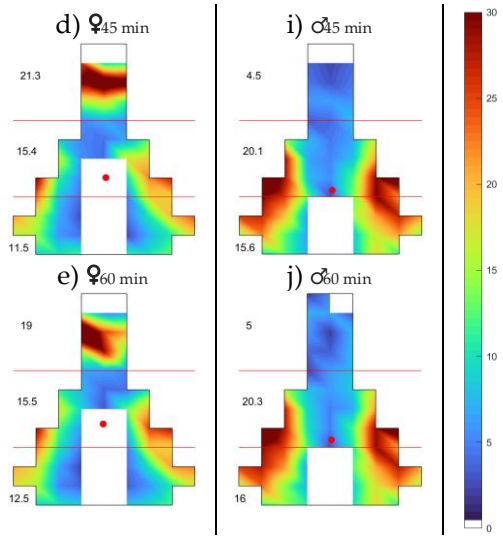


Figure 1. Pressure distribution of female (a-e) and male (f-j) participants in the hourly test with indication of the mean pressure (in kPa) in three zones delimited from each other.

For both sexes, the mean pressure load tended to increase with the duration of the test, especially in the first 30 minutes (cf. Table 1). The Bonferroni post hoc test indicates that there were significant differences in the results of the female participants at 45 min ($p = 0.0235$) and 60 min ($p = 0.0072$) compared to the initial measurement taken at 3 min.

Table 1. Mean pressure (kPa) over 10 s intervals recorded at discrete time points.

Measurement time	Females	Males
3 min	12.3 ± 3.9	14.5 ± 2.2
15 min	13.2 ± 2.6	15.5 ± 2.8
30 min	14.4 ± 5.2	16.9 ± 2.1
45 min	14.8 ± 3.0	16.4 ± 3.0
60 min	14.7 ± 3.3	16.8 ± 2.8

In parallel, there was an increase in the total force normalized to the body weight, again mainly in the first half of the test duration. (see Table 2). Again, the Bonferroni post hoc test revealed significant differences in the results of the female participants after 45 min ($p = 0.0132$) and 60 min ($p = 0.0005$) compared to the first measurement time point after 3 min as well as between 60 min and 15 min ($p = 0.0235$). Male participants total forces were significantly higher after 60 min ($p = 0.0191$).

Table 2. Normalized total force (BW) over 10 s intervals recorded at discrete time points.

Measurement time	Females[1]	Males
3 min	0.42 ± 0.08	0.47 ± 0.06
15 min	0.45 ± 0.10	0.51 ± 0.03
30 min	0.48 ± 0.09	0.56 ± 0.05
45 min	0.51 ± 0.10	0.56 ± 0.06
60 min	0.51 ± 0.08	0.57 ± 0.06

[1] Spearman's rank correlation $\varrho = 1$, $p = 0.01667$.

3.2. Pelvic stability

IMU measurement data quantifying the extent of pelvic motion resulted in essentially inconclusive findings for males and females. Common to both sexes was a decrease in pelvic tilt angle, with reference to the frontal plane. With increasing test duration, the participants sat more upright. Post hoc Bonferroni testing indicated statistical significantly different results for females after 60 min of riding compared to the first measurement time after 3 min ($p = 0.0072$)

The male participants generally had a smaller tilt angle than the female participants (cf. Table 3).

Table 3. Pelvic tilt angle (in °) as arithmetic mean over 10 s intervals recorded at discrete time points.

Measurement time	Females	Males[1]
3 min	30.0 ± 5.5	23.7 ± 7.0
15 min	26.5 ± 4.8	22.9 ± 5.4
30 min	25.9 ± 3.1	22.6 ± 5.0
45 min	26.0 ± 3.6	21.3 ± 6.1
60 min	23.5 ± 5.3	20.0 ± 5.7

[1] Spearman's rank correlation $\varrho = -1$, $p = 0.0167$.

Compared to the measurement time point after 3 min of testing, hip rotation decreased in the female participants. In contrast, men experienced an increased range of motion between 15 and 30 min (cf. Table 4).

Table 4. Range of motion in hip rotation (in °) recorded at discrete time points.

Measurement time	Females	Males
3 min	3.4 ± 1.8	3.9 ± 1.5
15 min	2.8 ± 1.4	3.8 ± 1.2
30 min	2.7 ± 1.5	4.3 ± 1.7
45 min	2.8 ± 1.3	4.4 ± 1.7
60 min	2.9 ± 1.2	4.4 ± 1.7

3.3. Subjective perception

The subjective feedback changed with increasing test duration. The male participants rated the perceived stability of the seating position significantly better with advanced riding time. For the females, there was a trend in the opposite direction (cf. Table 5).

Table 5. Perceived stability of the seating position recorded at discrete time points, ten-point scale from “stable" (1) to "wobbly" (10).

Measurement time	Females	Males[1]
3 min	1.9 ± 0.9	3.3 ± 2.5
15 min	2.1 ± 1.3	3.0 ± 2.0
30 min	2.0 ± 1.2	2.7 ± 1.5
45 min	2.1 ± 1.1	2.7 ± 1.5
60 min	2.3 ± 2.3	2.7 ± 1.5

[1] Spearman's rank correlation ϱ = -0.894, p = 0.0405.

The overall impression regarding seating system worsened significantly for females the longer the test lasted (cf. Table 6). The Bonferroni post hoc test revealed significant differences in the results of the female participants after 45 min (p = 0.0159) and 60 min (p = 0.002) compared to the first measurement time point after 3 min as well as between 60 min and 15 min (p = 0.0116).

Table 6. Overall impression recorded at discrete time points using a ten-point scale from "very good" (1) to "very poor" (10).

Measurement time	Females[1]	Males
3 min	3.1 ± 1.1	3.0 ± 2.1
15 min	3.6 ± 1.5	3.0 ± 1.7
30 min	4.6 ± 1.8	3.3 ± 1.9
45 min	5.6 ± 2.2	3.7 ± 2.3
60 min	6.3 ± 2.8	3.3 ± 1.9

[1] Spearman's rank correlation ϱ = 1, p = 0.0172

4. Discussion

A comparative examination of the results in the two test subject collectives leads to interesting findings. First, it can be stated that various changes in the biomechanics of pedaling are associated with increasing test duration. A shift in the body's center of gravity toward the saddle due to fatigue with simultaneous reduction of the pelvic tilt angle results in increased mechanical pressure on the biological tissue around contact with the saddle. This increase in pressure is perceived negatively by female subjects. This finding is consistent with the results of Larsen et al. (2019).

The ranges of values of the mean pressure load are in accordance with the results of Marcolin et al. (2015), but this group of researchers had limited the duration of their study to 20 min.

5. Practical Applications.

Based on the available data, numerous recommendations can be made as to how future investigations should be designed. It is obvious that the collected characteristic values stabilize between approx. 15 min and 30 min of test duration. Therefore, investigations that serve to evaluate seating systems in cycling based on pressure distribution measurements, kinematics of the pelvis, or subjective assessment should also last at least 15 min per condition.

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Conflicts of Interest: The authors declare no conflict of interest.

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