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Conference Abstract

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Pelvic Motion and Saddle Pressure of Female and Male Cyclists during a Cycling Specific Graded Exercise Test

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Abstract

The aim of the present study was to analyse the movement of the buttock on the saddle based on pelvic motion and saddle contact pressure during a cycling specific graded exercise test. Nine female and ten male recreational cyclists took part in the study. Overall, both the saddle pressure distribution and the pelvic motion show that with increasing intensity/fatigue there is more movement between the buttock and the saddle to observe. In particular, pelvic movement in the frontal plane (rocking) should be considered for bike fitting interventions as well as for the design of saddles and seat pads at high load intensities/fatigue. Substantial pelvic movement can lead to critical shear forces between the buttock and saddle. These shear forces, combined with moisture development can therefore lead to a higher risk of seating discomfort and pain.

Keywords

cycling; seating posture; pressure distribution; IMU; pelvic movement; saddle

1 Introduction

Along with the handlebars and pedals, the saddle is one of the three points of contact between the bike and the rider. Both, the saddle itself and its positioning have an influence on comfort, performance and especially the risk of injury. In this context, buttock pain is one of the most common complaints reported by cyclists (Weiss, 1985, Dettori et al., 2006). Buttock symptoms include ischial tuberosity pain, chafing and ulceration. Possible causes for the development of such buttock complaints include movement on the saddle combined with perspiration, which can lead to prolonged friction between the skin and the seat pad (Dettori et al., 2006).

The aim of the study is to analyse the movement of the buttock on the saddle based on pelvic motion and saddle contact pressure during a cycling specific graded exercise test. It is hypothesized that with increasing intensity and associated fatigue level the "buttock movement" will be also increased.

2 Material and Methods

2.1 Participants

Nine female (age: 31.1 ± 4.3 years, height: 167.7 ± 5.2 cm, weight: 63.0 ± 3.8 kg) and ten male (age: 42.1 ± 9.1 years, height: 180.9 ± 3.0 cm, weight: 80.8 ± 5.3 kg) cyclists volunteered in this study. According to the classifications done by De Pauw et al. (2013) and Decroix et al. (2026) the participants are categorized as recreationally/regularly trained (PL2).

2.2 Methodology

For each subject saddle height (Greg LeMond method; inseam length) and knee position (KOPS method; knee plumb) were determined and adjusted on a cycle ergometer (Kickr Bike, Wahoo, Atlanta, USA) based on the recommendation by Burt (2022).

All tests were carried out on a road bike saddle (Cube Venec, Pending System GmbH & Co. KG, Waldershof, Germany) and a cycling short designed for road cycling (Seat pad: R-Pad, 11 mm thickness; double-layer construction: 238/110 kg m^{-3} density, VAUDE Sport GmbH & Co. KG, Obereisenbach, Germany) was used.

All participants were positioned with a 50° trunk tilt while remaining in the brake hood position. This angle corresponds to a more relaxed torso posture on both road and mountain bike respectively (Burt, 2022).

The participants completed a cycling-specific graded exercise test that began after 10 minutes of warm-up at 90 W (♂ = 110 W) and increased by 20 W (♂ = 30 W) every three minutes until total exhaustion (McGrath et al. 2022). A cadence of 90 revolutions per minute was recommended (rpm). Cancellation criteria were defined as a cadence of less than 70 rpm or getting out of the saddle. For 10 seconds within each intensity level, pelvic movement and saddle pressure were recorded simultaneously.

An inertial measurement unit (Wave Track, menios GmbH, Ratingen, Germany) was fixed on the sacrum to record the pelvic movement. Based on the IMU data the range of motion (RoM) in the frontal (obliquity/rocking), transverse (rotation) and sagittal plane (tilt) were measured. In addition, the absolute pelvic tilt referring to the sagittal was determined.

Saddle contact pressure was measured using a gebioMized pressure measuring mat (SnM gebioMized GmbH, Münster, Germany). The saddle mat was divided horizontally into three equal parts. Mean pressure was calculated for each part and the entire area. Furthermore, the location of the center of pressure (CoP) and its trajectory were analyzed.

2.3 Statistical Analysis

Data preparation was carried out in MATLAB® (R2021a, The MathWorks Inc., Natick, United States). For the statistical analysis of the different intensity levels IL - 1, IL - 3 and IL - F (last level that the subject could finalize) repeated measures ANOVA and Bonferroni-corrected post-hoc tests were applied. The independent - samples t test was used for gender comparison (IBM SPSS Statistics Version 29, IBM Corporation, Armonk, NY). The significance level was set at $\alpha = 0.05$.

3 Results

The RoM of the pelvis in the transverse plane (rotation) is significantly increasing from intensity level 3 (IL- 3) to the final intensity level (IL- F) for females and males as well (Table 1 & 2).

Table 1. Females (n=9): Pelvic Motion (RoM) and absolute pelvis tilt during cycling in different intensity levels (IL), mean values ± standard deviation.

Pelvic motion [°]	IL-1 90 W	IL-3 130 W	IL-F 206±25 W
Obliquity (RoM)	6.3 ± 1.6	6.9 ± 1.5	10.2 ± 1.7
Rotation (RoM)	3.9 ± 1.2	4.9 ± 1.3	8.1 ± 1.3
Tilt (RoM)	2.3 ± 0.5	2.4 ± 0.8	3.1 ± 0.7
Absolute pelvic tilt	55.8 ± 10.3	56.7 ± 9.8	57.2 ± 9.7

Table 2. Males (n=10): Pelvic Motion (RoM) and absolute pelvis tilt during cycling in different intensity levels (IL), mean values ± standard deviation

Pelvic motion [°]	IL-1 110 W	IL-3 170 W	IL-F 300±37 W
Obliquity (RoM)	6.5 ± 1.6	7.4 ± 2.3	10.1 ± 3.5
Rotation (RoM)	3.6 ± 1.4	4.7 ± 1.9	7.8 ± 3.2
Tilt (RoM)	2.1 ± 0.7	2.3 ± 0.7	3.3 ± 1.4
Absolute pelvic tilt	73.3 ± 8.0	73.3 ± 7.6	69.3 ± 7.1

Both females and males show significantly more movement in the frontal plane (obliquity) during cycling at IL- F compared to IL-1 and IL- 3. Moreover, females exhibit a significantly increased range of motion in the sagittal plane (tilt) when riding in the IL-F compared to IL-1 and IL-3. Contrary, male subjects reveal a significant lower absolute pelvic tilt in IL- F compared to IL-1 and IL-3.

Both the male and the female subject group show significantly less total mean pressure during riding in IL-F compared to IL-1 and IL-3, largely due to the pressure pattern in the center region of the saddle (Figure 1).

With an increasing intensity level, the course of the CoP in medio-lateral and anterior-posterior direction is increasing significantly as well. This is valid for females and males.

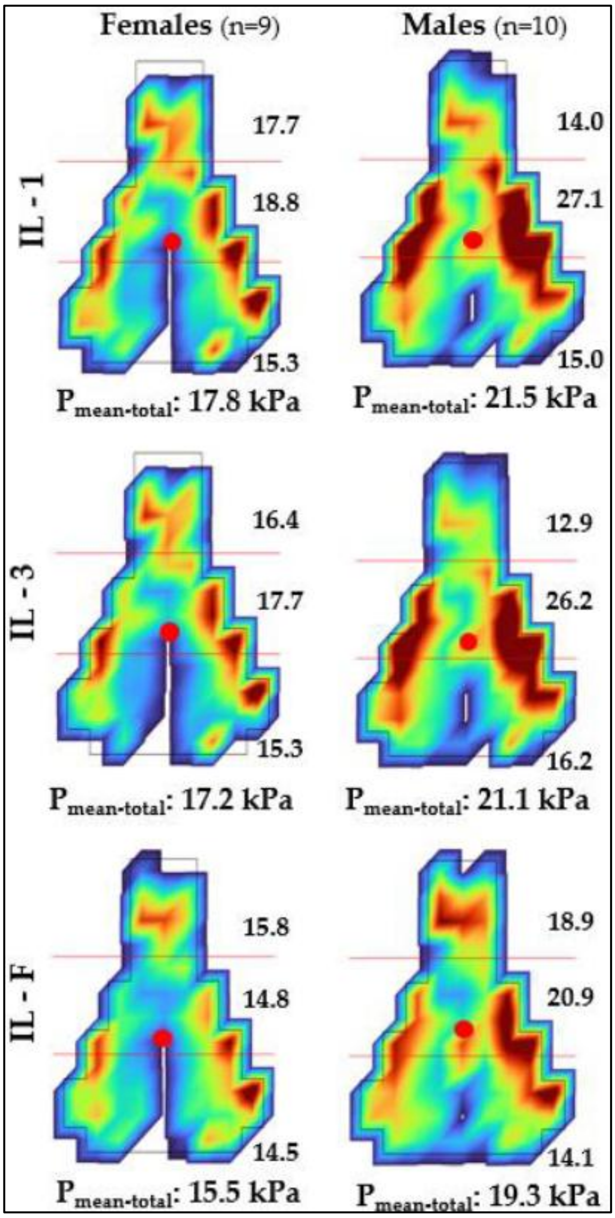

Figure 1. Mean pressure [kPa] distribution of male and female cyclists during cycling in different intensity levels for each saddle region and entire saddle region ($p_{mean-total}$); red dots indicate CoP, red horizontal lines subdivide anterior, center and posterior saddle region.

There are no gender specific differences regarding pelvic RoM for all three planes and intensity levels (Table 1 & 2). However, females display a significant higher absolute pelvic tilt (sagittal plane) for all three intensity levels compared to males.

The mean total saddle pressure and the mean pressure of the center zone are significant lower for females compared to males (Figure 1). This is valid for all three analyzed intensity levels.

Only during cycling in the final intensity level females exhibit a significantly higher CoP displacement in medio-lateral as well as in anterior-posterior direction compared to the male subjects.

4 Discussion

4.1 Comparison of Intensity Levels

Overall, both the saddle pressure distribution and the IMU (pelvic motion) data show that with increasing intensity/fatigue there is more movement between the buttock and saddle.

Regarding the pelvic movement the findings of the present study are supported by Sauer et al. (2007) and Galindo-Martinez et al. (2021). It seems that the pelvic movement in the frontal plane (rocking) is most affected by increased intensity and/or fatigue. This finding can be also explained by a kinematic movement analysis, where it was found that with increasing load intensity, the knee joint becomes more extended (Michel et al., 2024). In addition, a lower plantar flexion in the ankle joint as well as a lower sole angle towards a heel-down position was observed (Michel et al., 2024).

Also, Holliday et al. (2019) could demonstrate in male cyclists that the CoP excursion increases significantly in both the anterior-posterior and medio-lateral directions with increasing intensity level.

Previous studies support the present results, that the total mean saddle pressure (Bressel et al., 2005) and the normalized maximum pressure in the posterior saddle region (Potter et al., 2008) decreases with increasing intensity and this for male and female cyclists respectively.

4.2 Gender Dimorphism

In a previous study done by Richter et al. (2023) the participants had to ride at an exercise intensity of 70 % of their individual FTP value. As in the present study, Richter et al. (2023) also found no significant differences between the female and male subject groups regarding the RoM of the pelvis during stationary cycling with 50° trunk inclination. However, as in the current study, Richter et al. (2023) also observed that the pelvis was tilted significantly more forwards in females than in males.

The significantly lower total mean pressure of the female compared to the male test group can be explained mainly by the higher body weight of the men (ca. 18 kg). Previous studies confirm this finding (Bressel & Cronin, 2005, Potter et al., 2005, Richter et al., 2023).

5 Practical Applications and Conclusions

The results of the present study clearly show that the movement between the buttock and the saddle increases with increasing exercise intensity/fatigue, and this applies to both men and women. In particular, pelvic movement in the frontal plane (rocking) should be considered for bike fitting interventions as well as the design of saddles and seat pads at high load intensities/fatigue.

For bike fit analyses of performance-oriented cyclists, it is recommended that these are carried out at least at the load intensity at which they train most of the time (Sauer et al., 2007, Michel et al., 2024). It can also be useful to carry out analyses in a state of fatigue to identify possible risk factors (Galindo-Martinez et al., 2021).

The pelvic movement when cycling can basically be regarded as natural (Sauer et al., 2007). However, a significantly increased pelvic movement - as especially observed at an increased intensity level or fatigue status - can lead to increased shear forces between the buttock and seat pad as well as between the seat pad and saddle. These shear forces in combination with the corresponding moisture development can therefore lead to a higher risk of sustaining buttock symptoms described by Dettori et al. (2006). Hence, special attention should be paid on the design and materialisation of seat pads and saddles to minimise shear forces (Scholler et al., 2023) and to improve climate comfort in terms of moisture control (Bressel & Cronin, 2005).

The present results concerning the gender differences in total mean pressure mainly due to the higher body weights of men confirm the demand for gender-specific seat pads and, above all, gender-specific saddles (Potter et al., 2008, Richter et al., 2023).

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