Gender related differences in pressure distribution, pelvis movement and subjective perception during cycling

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Introduction

- Increased interest on women's cycling
  - Reintroduction of "Tour de France Femmes" in 2022 → increasing attention on woman's cycling
- Increasing number of female (recreational) cyclists ?
  - Survey about "cycling behaviour" of females vs. males (Burnside & Baker, SHIFT ACTIVE MEDIA)
  - Cycling-specific research panel (Rider Research Hub) → n = 5.000+; North America, Europe, Australia

EUROBIKE

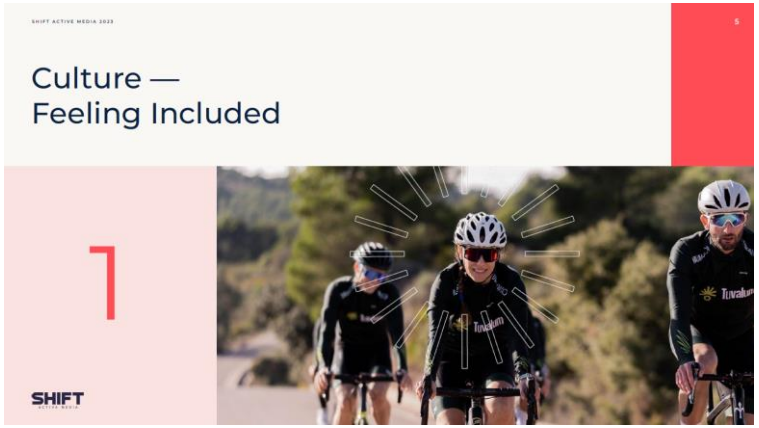
The Global Platform

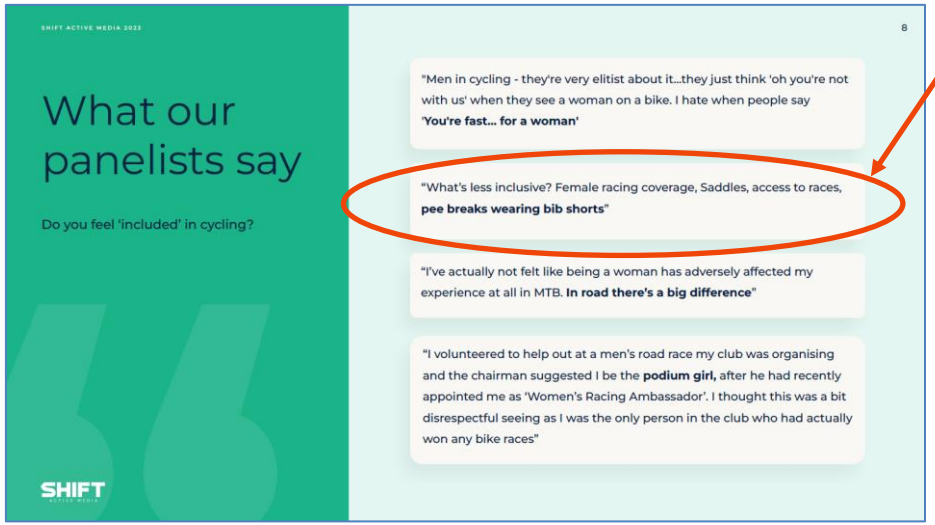
(Burnside & Baker, SHIFT ACTIVE MEDIA (2023): Decoding the differences – Unveiling 5 key traits of female vs male cyclists)

Introduction

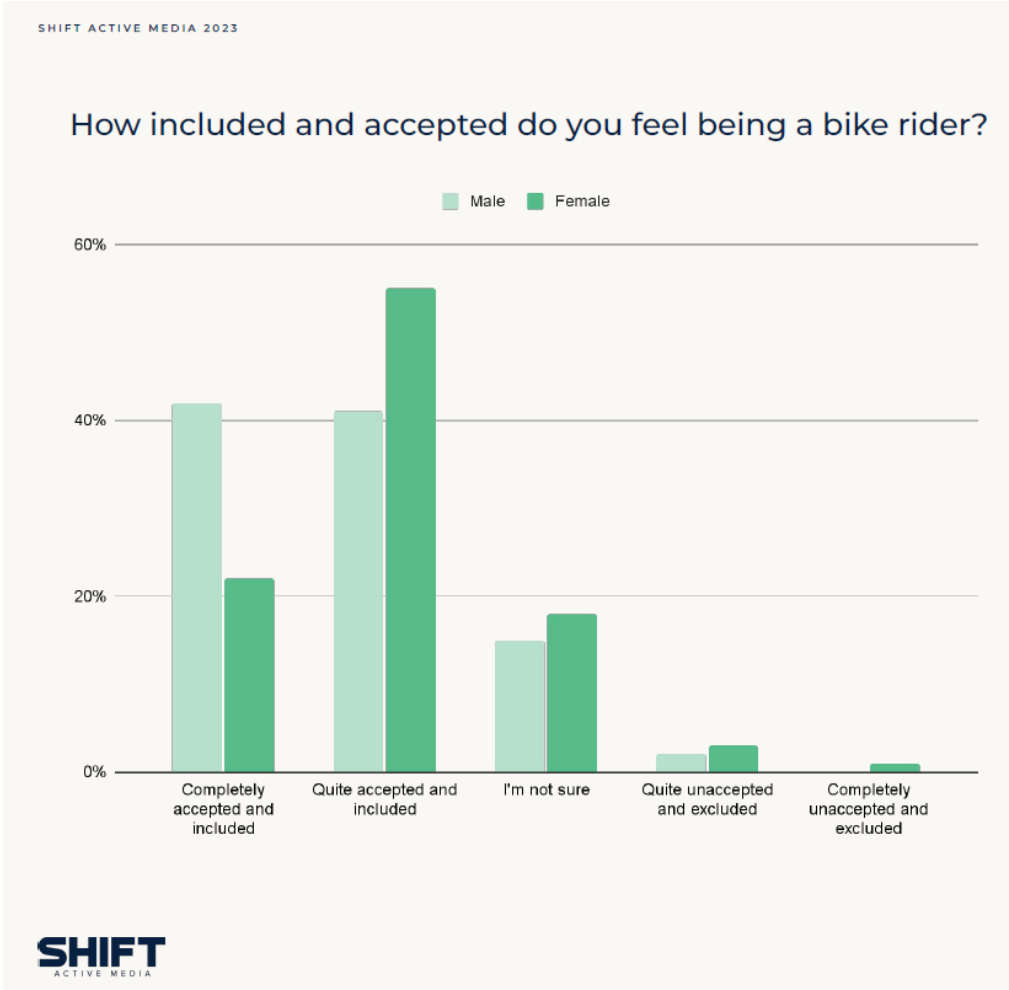
- One out of 5 key findings between male & female cyclists: Culture – Feeling included

→ **Females feel less included/accepted** within the cycling community than males





"What's less inclusive? Female racing coverage, **Saddles**, access to races, **pee breaks wearing bib shorts**"



(Burnside & Baker, SHIFT ACTIVE MEDIA (2023): Decoding the differences – Unveiling 5 key traits of female vs male cyclists)

Introduction

- Only few publications, which address females regarding cycling biomechanics
  - → Especially focused on the direct comparison between females and males
    - Potter, J. J et al. (2008). Gender differences in bicycle saddle **pressure distribution** during seated cycling. *Med Sci Sports Exerc*, *40*(6), 1126-1134.
    - Sauer, J. L. et al. (2007). Influence of gender, power, and hand position on **pelvic motion** during seated cycling. *Med Sci Sports Exerc*, *39*(12), 2204.
- Work by Potter et al. (2008) and Sauer et al. (2007) suggest that gender differences in anatomy affect pressure distribution & pelvic motion on the saddle
  - → This knowledge can play a major role in the development of saddles (+ seat pads…)

Gender Differences in Bicycle Saddle Pressure Distribution during Seated Cycling

JAMES J. POTTER[1], JULIE L. SAUER[1], CHRISTINE L. WEISSHAAR[1], DARRYL G. THELEN[1,2,3], and HEIDI-LYNN PLOEG[1,2]

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ABSTRACT

POTTER, J. J., J. L. SAUER, C. L. WEISSHAAR, D. G. THELEN, and H.-L. PLOEG. Gender Differences in Bicycle Saddle Pressure Distribution during Seated Cycling. *Med. Sci. Sports Exerc.*, Vol. 40, No. 6, pp. 1126–1134, 2008. **Introduction:** The purpose of this study was to investigate the influence of gender, power, hand position, and ischial tuberosity (IT) width on saddle pressure during seated stationary cycling. **Methods:** Twenty-two experienced cyclists (11 males and 11 females) were fitted to an adjustable stationary bicycle and pedaled at 100 and 200 W in both the tops and drops hand positions. An instrumented pressure mat was used to record saddle pressure distribution. Normalized force, maximum sensor pressure, and center of pressure were computed for anterior and posterior regions of the saddle. **Results:** When increasing power from 100 to 200 W, there were significant reductions in normalized force in all saddle regions and maximum pressure in the posterior region. When moving from the tops to drops hand position, centers of pressure in all regions moved forward, normalized force and maximum pressure on the posterior region decreased, and females (but not males) exhibited an increase in normalized force and maximum pressure in the anterior region. Male centers of pressure were farther forward in the anterior and total saddle regions than they were for females. Females exhibited a larger IT width than males. Inter-individual differences in IT width were significantly correlated with the posterior center of pressure fore–aft location on the saddle in the tops and drops hand positions and with the width between the posterior left and right centers of pressure in the tops hand position. **Conclusions:** There are significant gender-related differences in saddle loading which are important to consider when designing saddles. These differences are especially important when riders are in the hands/drops and more weight is supported on the anterior pelvic structures. **Key Words:** SADDLE DESIGN, BICYCLE FITTING, DYNAMIC LOADING, ISCHIAL TUBEROSITY WIDTH

APPLIED SCIENCES

Discomfort with sitting on a bicycle saddle for extended periods of time remains one of the most common complaints among cyclists. The loading imposed on the soft tissues has been associated with troublesome ailments such as numbness (5,18), nodules (10), chafing, erectile dysfunction (6,7,16,17,19), and traumatic urethritis (21). For these reasons, bicycle saddle designs have evolved in an effort to improve comfort and reduce the likelihood of saddle-related pathologies. Various features such as cutouts, custom widths, and variable padding exist among current saddles, with many of these features designated as gender-specific. However, there is limited data in the literature by which to quantitatively design a saddle to accommodate the unique saddle loading patterns associated with male and female riders.

The emergence of pressure-sensitive mats has enabled quantitative investigations of the load distribution on the saddle during seated cycling. Earlier studies showed that the presence of a cut-out can influence pelvic tilt and perceived comfort among female cyclists (4); and that saddles with a partial cut-out or without a nose (8) reduced perineal pressure in male cyclists. In a comparison between genders, Bressel and Cronin (3) showed that a reduction in peak saddle pressure occurs when going from the tops to the drops hand position in males but not in females. It was speculated that gender-related differences in segment mass distributions (i.e., a lower center of mass in females) may have contributed to this finding (3). However, there are other factors which could play a role in gender-specific loading patterns including variations in pelvic geometry, power output, and bicycle fit. For example, if both genders were to sit in the same location on the same saddle, the greater width between ischial tuberosities among females (11) might tend to reduce the loading on the posterior bony structures and enhance the loading in the perineal region. An improved understanding of the spatial and temporal variations in saddle loading coupled with detailed anthropometric measures are important to investigate these issues further.

The primary purpose of this study was to investigate the influence of gender, power, and hand position on saddle

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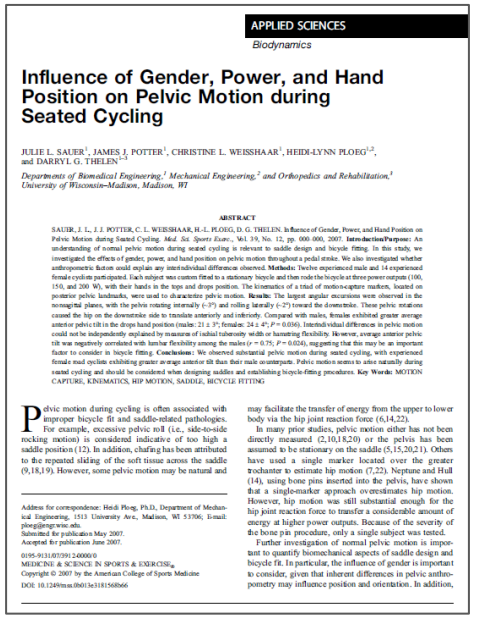

APPLIED SCIENCES
Biodynamics

Influence of Gender, Power, and Hand Position on Pelvic Motion during Seated Cycling

JULIE L. SAUER[1], JAMES J. POTTER[1], CHRISTINE L. WEISSHAAR[1], HEIDI-LYNN PLOEG[1,2], and DARRYL G. THELEN[1,3]

Departments of Biomedical Engineering,[1] Mechanical Engineering,[2] and Orthopedics and Rehabilitation,[3] University of Wisconsin–Madison, Madison, WI

ABSTRACT

SAUER, J. L., J. J. POTTER, C. L. WEISSHAAR, H.-L. PLOEG, D. G. THELEN. Influence of Gender, Power, and Hand Position on Pelvic Motion during Seated Cycling. *Med. Sci. Sports Exerc.*, Vol. 39, No. 12, pp. 000–000, 2007. **Introduction/Purpose:** An understanding of normal pelvic motion during seated cycling is relevant to saddle design and bicycle fitting. In this study, we investigated the effects of gender, power, and hand position on pelvic motion throughout a pedal stroke. We also investigated whether anthropometric data could explain any inter-individual differences observed. **Methods:** Twelve experienced male and 14 experienced female cyclists participated. Each subject was custom fitted to a stationary bicycle and then rode the bicycle at three power outputs (100, 150, and 200 W), with their hands in the tops and drops position. The kinematics of a triad of motion-capture markers, located on posterior pelvic landmarks, were used to characterize pelvis motion. **Results:** The largest angular excursion were observed in the nonsagittal planes, with the pelvis rotating internally (~3°) and rolling laterally (~2°) toward the downstroke. These pelvic rotations caused the hip on the downstroke side to translate anteriorly and inferiorly. Compared with males, females exhibited greater average anterior pelvic tilt in the drops hand position (males: 21 ± 3°; females: 24 ± 4°; $P = 0.016$). Interindividual differences in pelvic motion could not be independently explained by measures of ischial tuberosity width or hamstring flexibility. However, average anterior pelvic tilt was negatively correlated with hamstring flexibility among the males ($r = 0.75$; $P = 0.024$), suggesting that this may be an important factor to consider in bicycle fitting. **Conclusion:** We observed substantial pelvic motion during seated cycling, with experienced female road cyclists exhibiting greater average anterior tilt than their male counterparts. Pelvic motion seems to arise naturally during seated cycling and should be considered when designing saddles and establishing bicycle-fitting procedures. **Key Words:** MOTION CAPTURE, KINEMATICS, HIP MOTION, SADDLE, BICYCLE FITTING

Pelvic motion during cycling is often associated with improper bicycle fit and saddle-related pathologies. For example, excessive pelvic roll (i.e., side-to-side rocking motion) is considered indicative of too high a saddle position (12). In addition, chafing has been attributed to the repeated sliding of the soft tissue across the saddle (9,18,19). However, some pelvic motion may be natural and may facilitate the transfer of energy from the upper to lower body via the hip joint reaction force (6,14,22).

In many prior studies, pelvic motion either has not been directly measured (2,10,18,20) or the pelvis has been assumed to be stationary on the saddle (5,15,20,21). Others have used a single marker located over the greater trochanter to estimate hip motion (7,22). Neptune and Hull (14), using bone pins inserted into the pelvis, have shown that a single-marker approach overestimates hip motion. However, hip motion was still substantial enough for the hip joint reaction force to transfer a considerable amount of energy at higher power outputs. Because of the severity of the bone pin procedure, only a single subject was tested.

Further investigation of normal pelvic motion is important to quantify biomechanical aspects of saddle design and bicycle fit. In particular, the influence of gender is important to consider, given that inherent differences in pelvic anthropometry may influence position and orientation. In addition,

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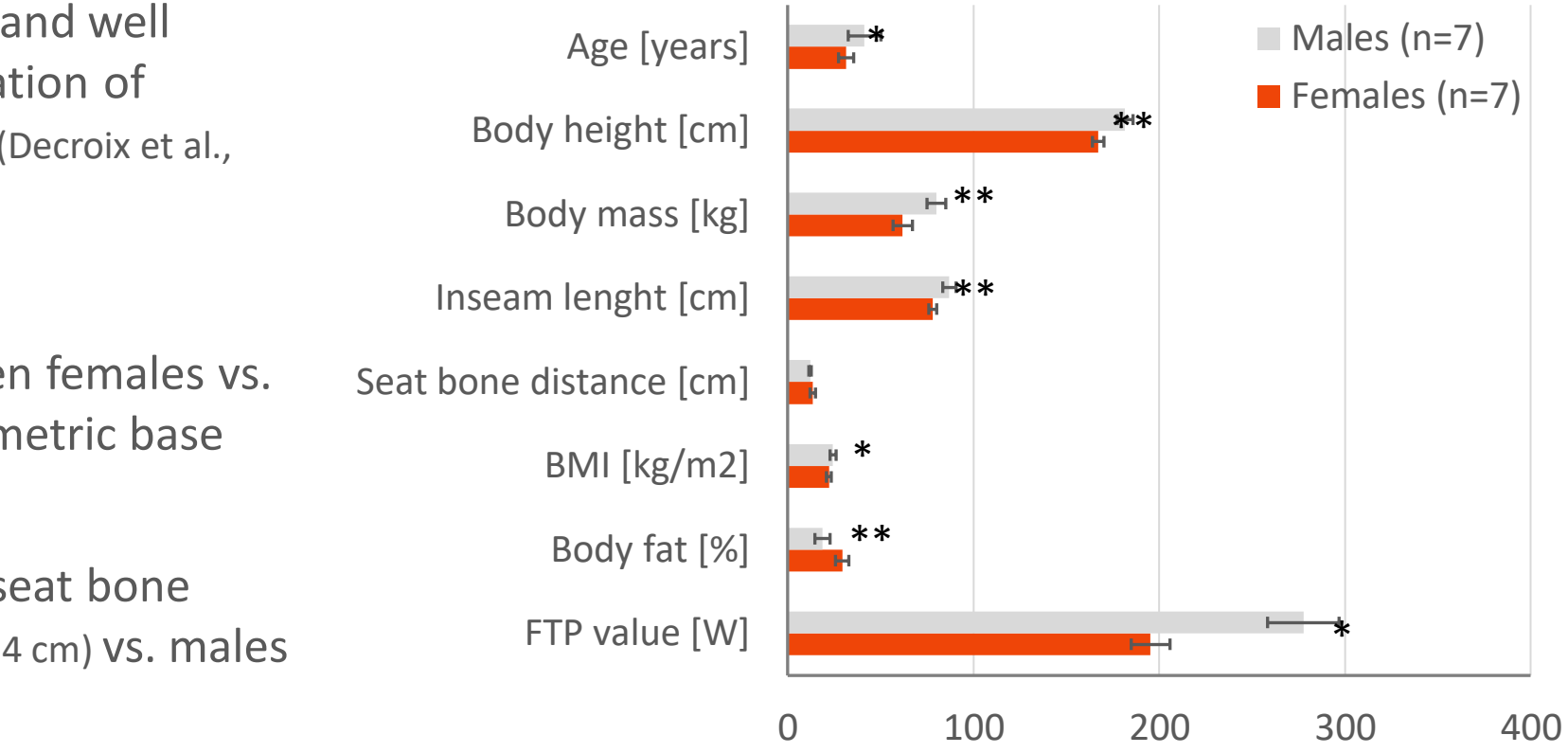
Aim of the Study

- Part of bigger project → Further development of gender specific seat pads
- Delivering insight into saddle-seat pad-interface as a baseline to derive initial gender specific design recommendations focused on cushioning and stability

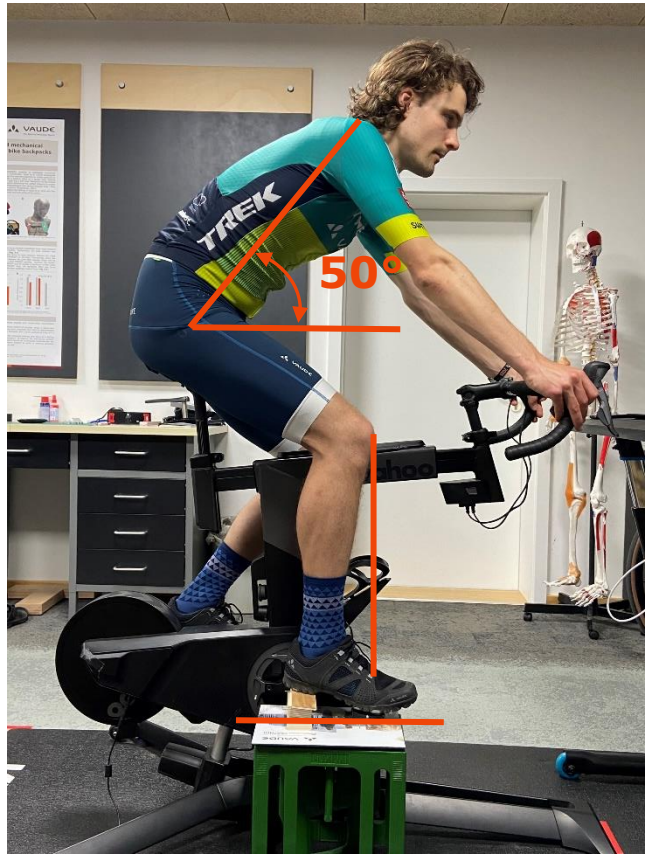
Material & Method – Subject Group

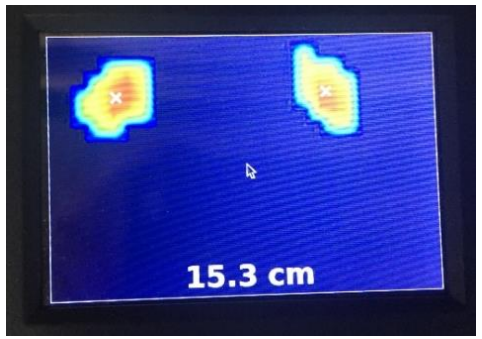
- 7 females & 7 males
- Subjects classified as trained and well trained following the classification of Decroix et al. and Pauw et al. (Decroix et al., 2016; Pauw et al., 2013)
- No professional cyclists
- Significant differences between females vs. males related to all anthropometric base measurements
- No statistically differences in seat bone distance between females (13,4 cm) vs. males (12,0 cm)
- Males (277,6W) reached significantly higher FTP value than females (195,3 W)



Material & Method – Test Set-Up & Bike Fit

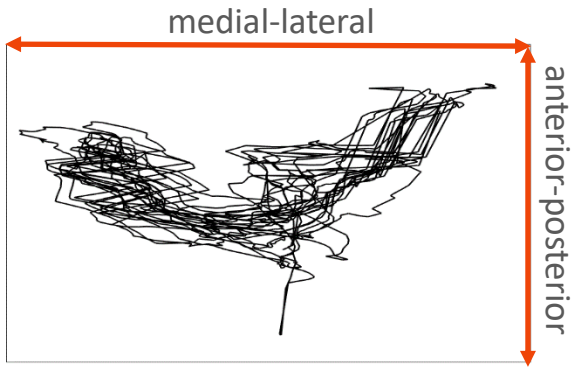
- Indoor trainer: KICKR bike (Wahoo Fitness LLC, Atlanta, Unites States)
- Seating position based on Burke (Burke, 2003)
  - Saddle height: “Greg LeMond-Method” (inseam length)
  - Fore and Aft saddle position: “KOPS-Method” (pedal aligned horizontally)
  - Trunk inclination set to 50°
- Saddle: Cube Venec (Pending System GmbH & Co. KG, Waldershof, Germany)
  - Two different saddle width: Selected by seat bone distance: < 13cm >
  - Seat bone measurement cube (CUBE, Pending System GmbH & Co. KG, Waldershof, Germany)
- Cycling tight/seat pad: Vaude prototype (14 mm; 100 kg/m^3) (VAUDE Sport GmbH & Co. KG, Obereisenbach, Germany)

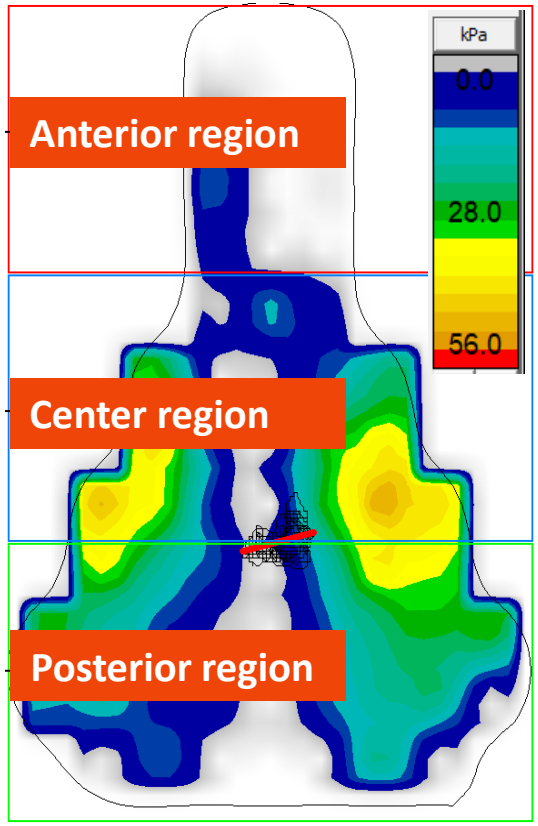




Material & Method – Pressure Distribution

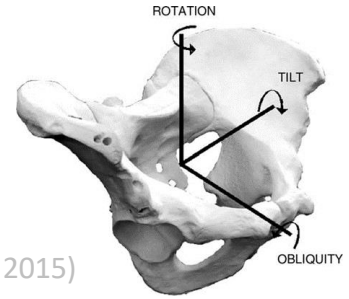
- gebioMized pressure measuring mat (SnM gebioMized GmbH, Münster, Germany)
  - 64 resistive sensors with a sensor size of 8*8 mm
- Saddle divided horizontally into three equal regions
- Calculation of mean pressure for each region and the entire area
- Calculation of CoP trajectories
  - Anterior-posterior position
  - Medial lateral position
  - Anterior-posterior amplitude
  - Medial-lateral amplitude
  - CoP movement area (length x width dimensions)



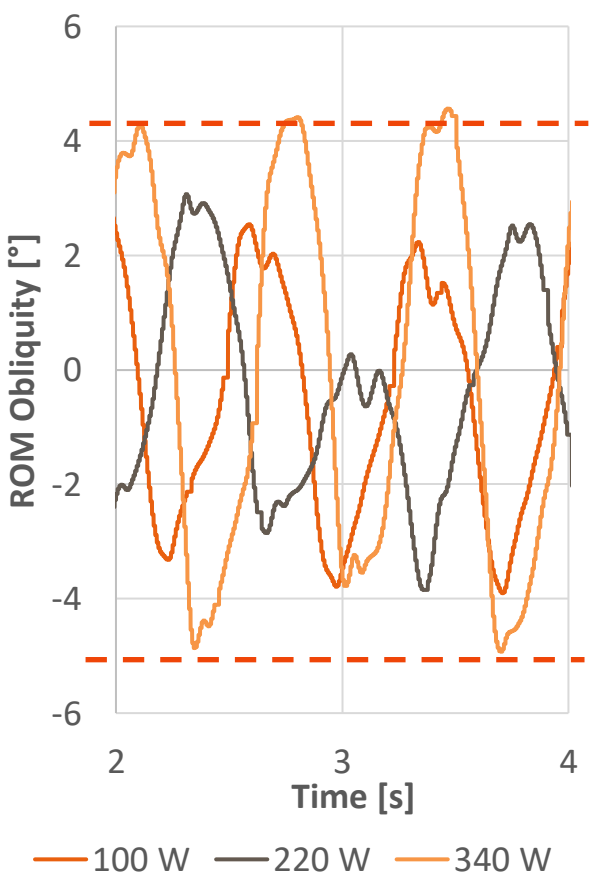


Material & Method – Pelvic Motion

- Movement detection by means of an inertial measurement unit (Wave Track, menios GmbH, Ratingen, Germany)
- IMU placed on the sacrum
- “Indicator” for stability
- Data collection (10 seconds)
  - ROM - pelvic rotation
  - ROM – pelvic obliquity
  - ROM – pelvic tilt
  - Absolute pelvic inclination with respect to vertical axis
  - Movement velocity of the sacrum



(Marcolin et al, 2015)



Material & Method – Further Information

Cycling Workload

- Exercise intensity: 70 % of the individual FTP value (mean of power: ♀: 136.7 ± 7.3 W, ♂: 194.3 ± 13.5 W).
- Pedal frequency: 80 ± 5 rpm
- Data were recorded after 3 minutes of cycling for a 10-second period

Subjective Feedback

- Interview based on standardized questionnaire on bike

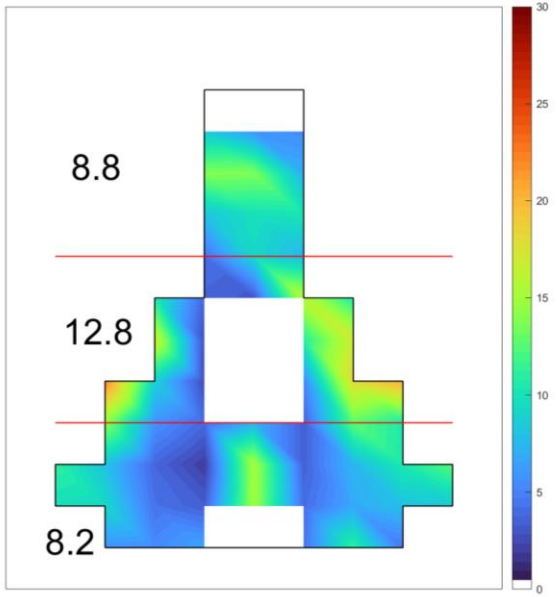
Statistics

- Data preparation done in Matlab (R2022b, The MathWorks Inc., Natick, United States)
- Non-parametric data analysis
  - Mann-Whitney-U test
  - Significance level: $\alpha = 0.05$.

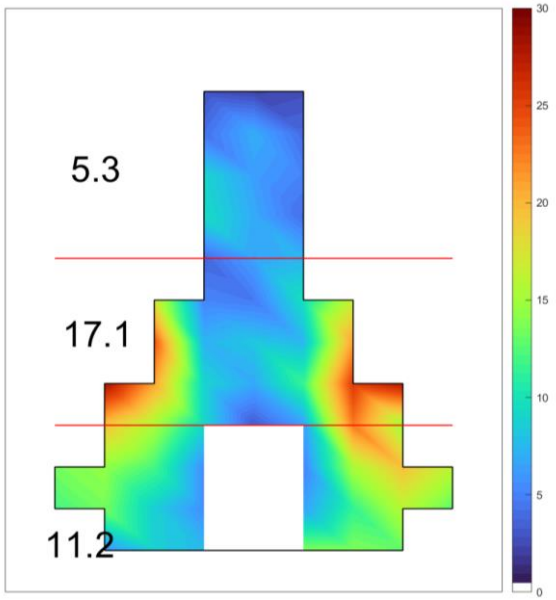
Results – Pressure Distribution: Mean Pressure

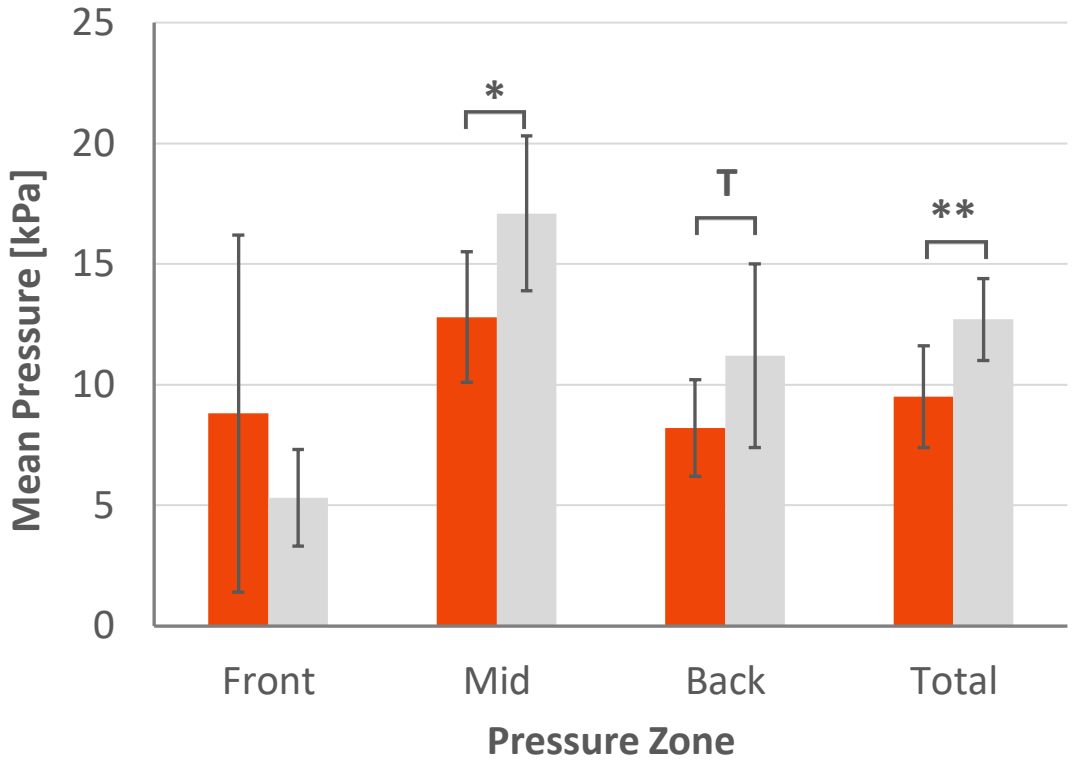
- Significant higher total mean pressure and P_{mean} center zone in males (statistical trend for back zone)
- Statistically not significant → Females exhibit higher mean pressure in the frontal zone
- Significant higher forces in males (367 ± 39N) vs. females (241± 47N)
- Significant larger contact area in males (70,3 ± 5%) vs. females (62,1 ± 5%)

Females (n=7)



Males (n=7)





Mean pressure distribution of males and females (T: 0.1 ≥ p > 0.05; *: 0.05 ≥ p > 0.01; **: 0.01 ≥ p)

Results – Pressure Distribution: CoP

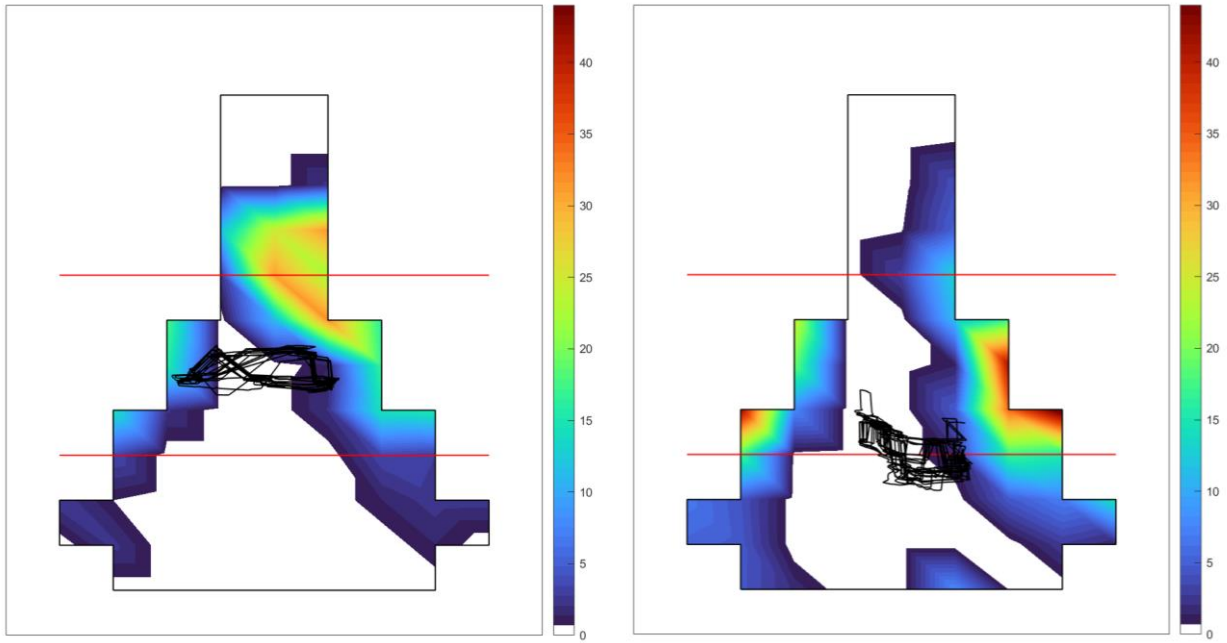
- No significant differences for all measured CoP parameters → High standard deviations
- CoP of females tends to located more anteriorly compared to males

Parameter of CoP	Females	Males
anterior-posterior amplitude [mm]	28.0 ± 14.0	20.0 ± 9.0
medial-lateral amplitude [mm]	35.7 ± 12,4	32.6 ± 8.7
area [mm²]	985.0 ± 518.5	663 ± 393.8
anterior-posterior position [mm]	92.0 ± 25.6	79.3 ± 20.1
medial-lateral position [mm]	0.3 ± 3.4	3.2 ± 4.8

Parameters of Center of Pressure

Female Subject

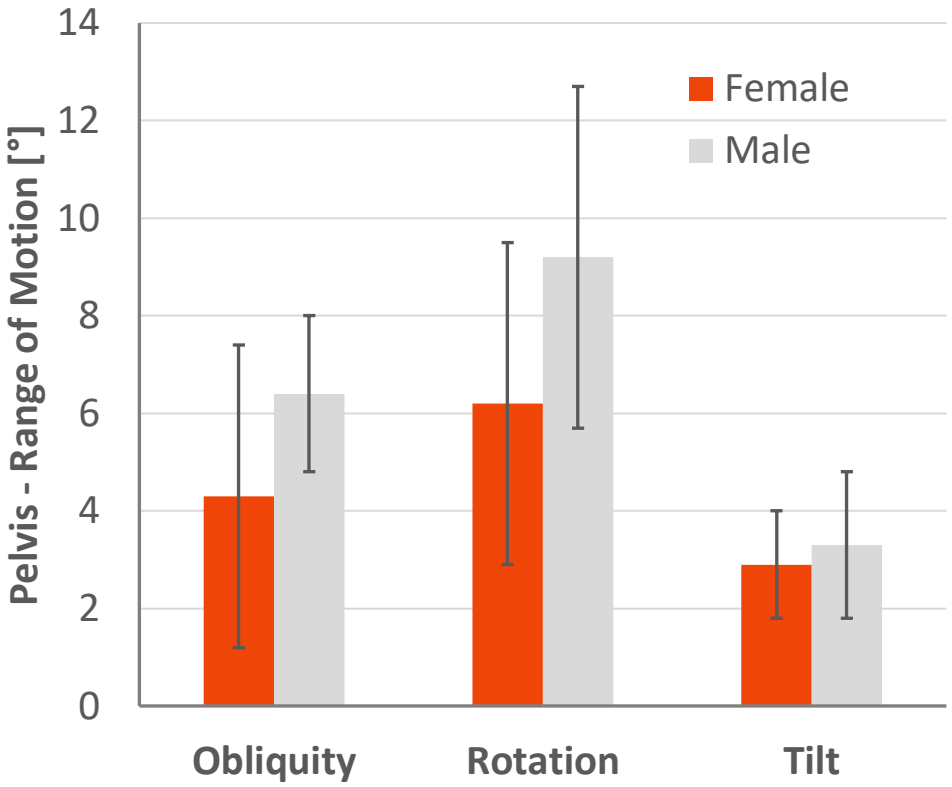
Male Subject

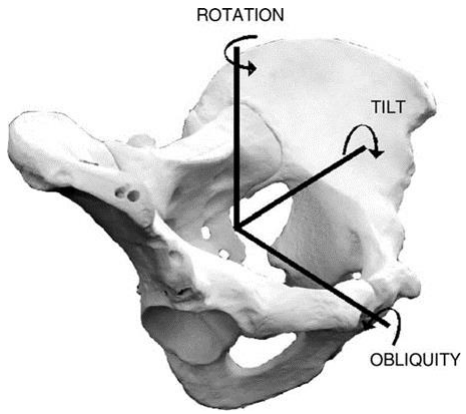


Exemplary CoP trajectories of a male and a female participant

Results – Pelvic Motion

- No significant differences regarding ROM between males vs. females
- No significant differences for pelvic velocity
- Significant difference (**) for absolute pelvis tilt → Pelvis more inclined forward in females

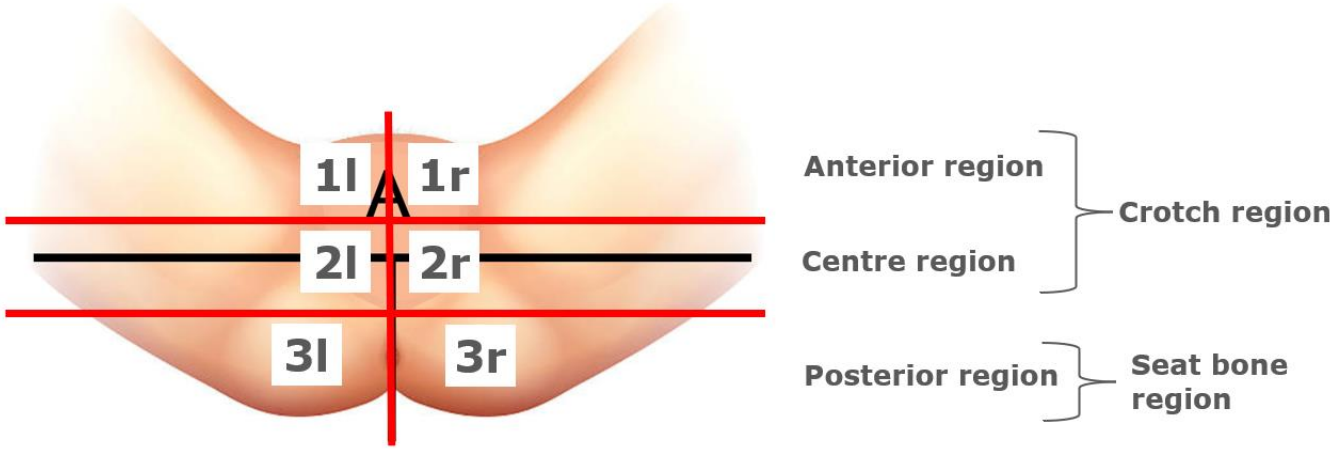


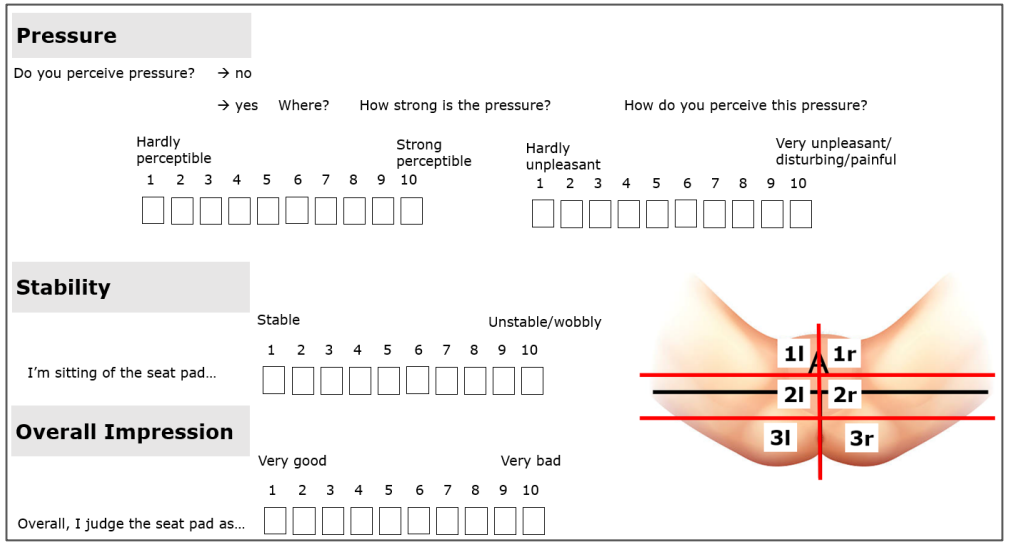


(Marcolin et al, 2015)

Results – Subjective Feedback

- Females experienced significantly greater "*discomfort*" caused by pressure in the anterior region than males
- Males experienced significantly more *"discomfort"* in the posterior region
- Females tended to rate *pressure intensity* in the anterior region higher than males
- No significant differences related to *perceived stability* on the saddle and *overall impression* between males and females





Discussion

In General

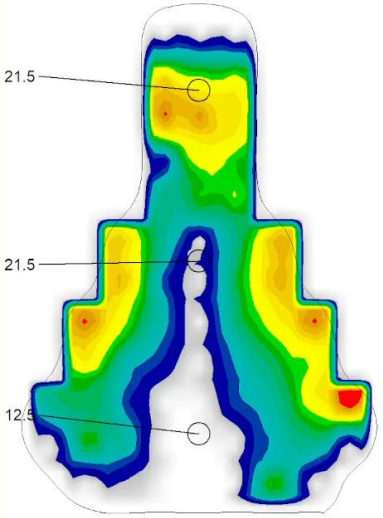
- Direct comparison of data difficult
  - → Different test protocol & different measurement systems
  - → Conclusions & deductions still possible

Seat bone distance (width between ischial tuberosities)

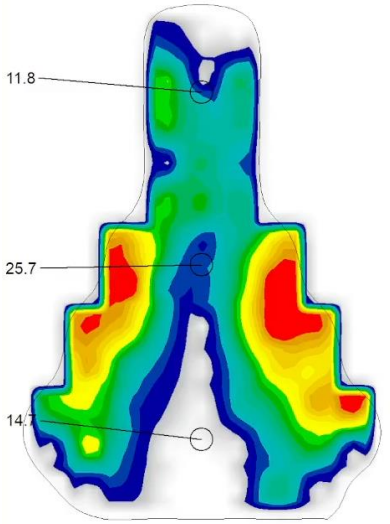
- Greater seat bone distance in females (♀ 13,4 vs. ♂ 12,0 cm)
  - – Finding is consistent with study down by Potter et al. (2008; ♀ 13,5 vs. ♂ 11,4 cm) and Feodoroff et al. (2014; ♀ 13,0 vs. ♂ 11,6 cm)

Pressure Distribution

- Higher total mean pressure in males compared to females
  - – Finding is consistent with study down by Potter et al. (2008)
- Females showed higher pressure in the anterior region
  - – Finding aligns with both Potter et al. (2008)



Female Subject



Male Subject

Discussion

CoP

- No significant differences between females vs. males → High standard deviations
  - Magnitude of CoP-length comparable with Marcolin et al. (2015)
  - No data for gender-specific comparison

Pelvic Motion

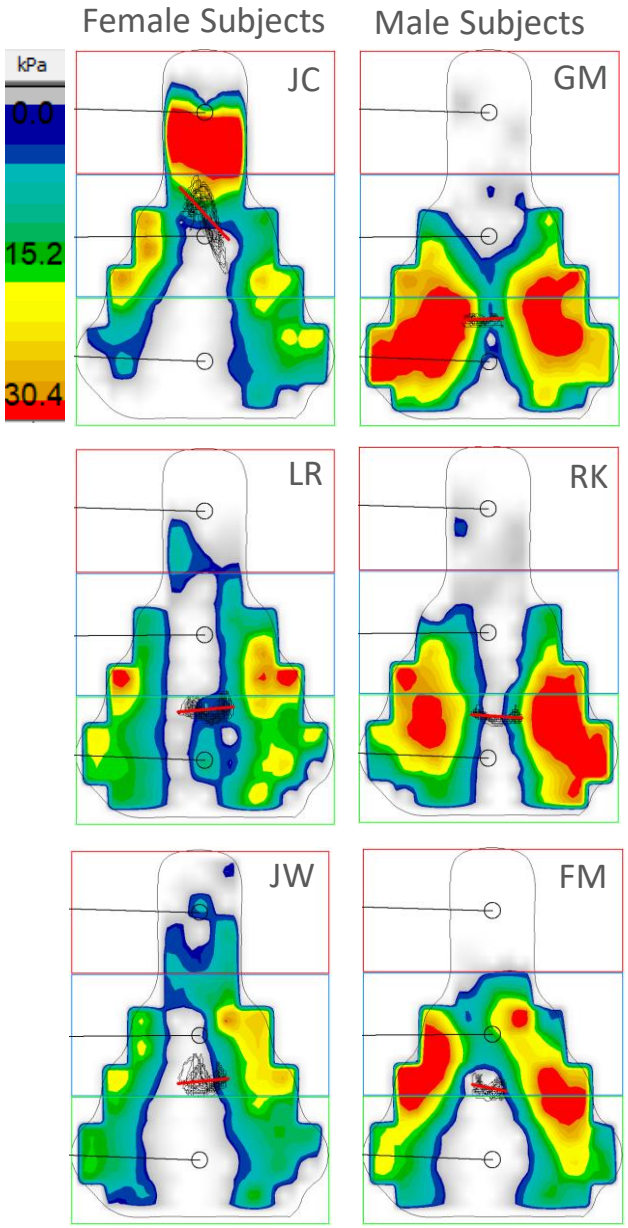
- Pelvis more inclined forward in females vs. males
  - Finding aligns with Sauer et al. (2007)
- Higher pelvic ROM in non-sagittal planes
  - Finding is consistent with Sauer et al. (2007) and Marcolin et al. (2015)

Limitations

- Small number of subjects
- Non-professional cyclists
- 3 minutes of cycling before data acquisition

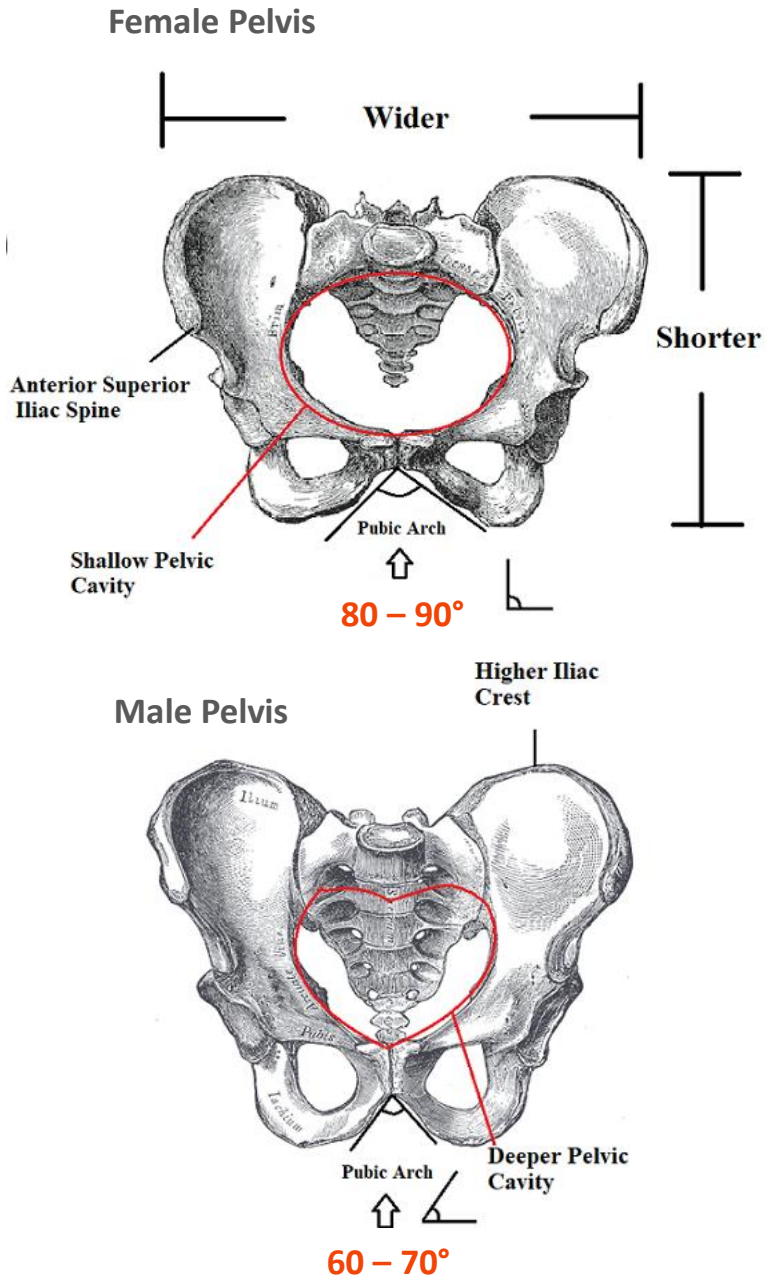
High standard deviations

  - Non-professional cyclists require some time to settle into the saddle (Marcolin et al., 2015)



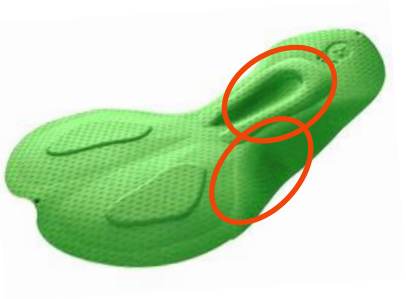
Conclusion & Practical Applications

- Gender-specific differences in anatomy have a significant impact on both objective and subjective pressure distribution, in terms of location and magnitude.
- Higher pressure in the frontal zone, a more anteriorly located CoP, and a more forward inclined pelvis in females seems to be related to anatomical differences of the pelvis (Potter et al., 2008, Sauer et al., 2007)
  - Females have a greater angle between the pubic arches
  - Pubic arches of females can not rest on too narrow and/or curved saddle shapes
  - Leading to more load on the pubic symphysis or saddle nose, respectively
- Seat bone distance (ischial tuberosity width) not sufficient to describe gender-specific difference of pelvic anatomy
- Other factors such as the pubic rami, pubic arch angle, and soft tissues may also need to be considered in determining the structures providing support (Sauer et al., 2007)



Conclusion & Practical Applications

- Due to differences in body weight **stiffness characteristics of padding material** of entire seating system should be considered
- Considering contact area (geometry & contour) and padding characteristics of **anterior region** (due to large anterior tilt & pressure pattern)
- Importance of **center region** (transition zone) because of the forward and downward motion of the hip during downstroke, which could contribute to shear loading at this interface
  - I**ncreased emphasis on designing the saddle contour** to support the ischiopubic rami while not excessively stressing tissue in the perineum and pubic arch
  - Females: bony support (pubic rami/pubic arch) → slightly wider transition region (+ posterior region → seat bones)
- Gender-specific curvature of **posterior** saddle **region** to stabilize pelvic tilt



SHIFT Survey - Takeouts

→ "**Female** respondents were more likely to engage with **research specific purchases**"

(Burnside & Baker, SHIFT ACTIVE MEDIA (2023): Decoding the differences – Unveiling 5 key traits of female vs male cyclists)

Thanks for your attention

Gender related differences in pressure distribution, pelvis movement and subjective perception during cycling

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A4SEE Alliance for Sports Engineering Education
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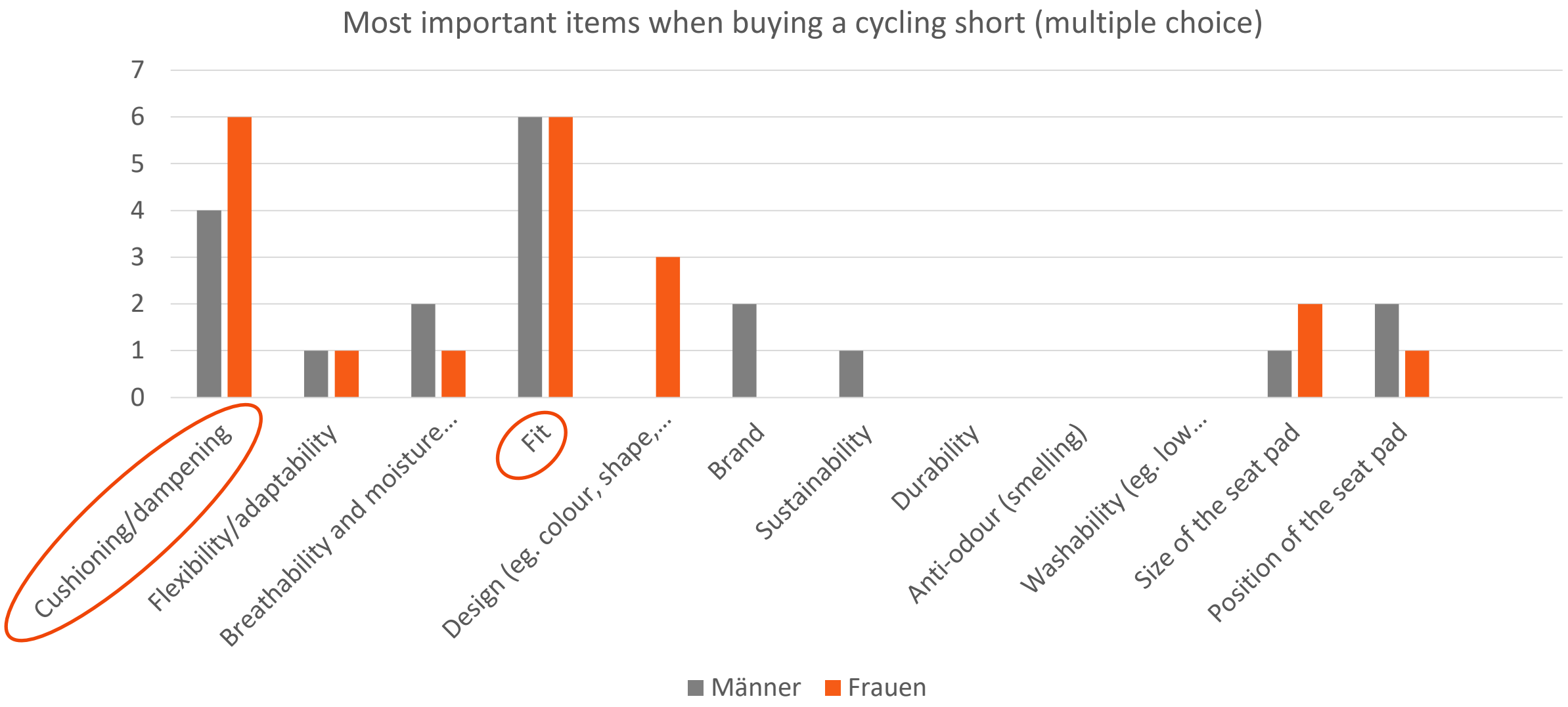
APPENDIX

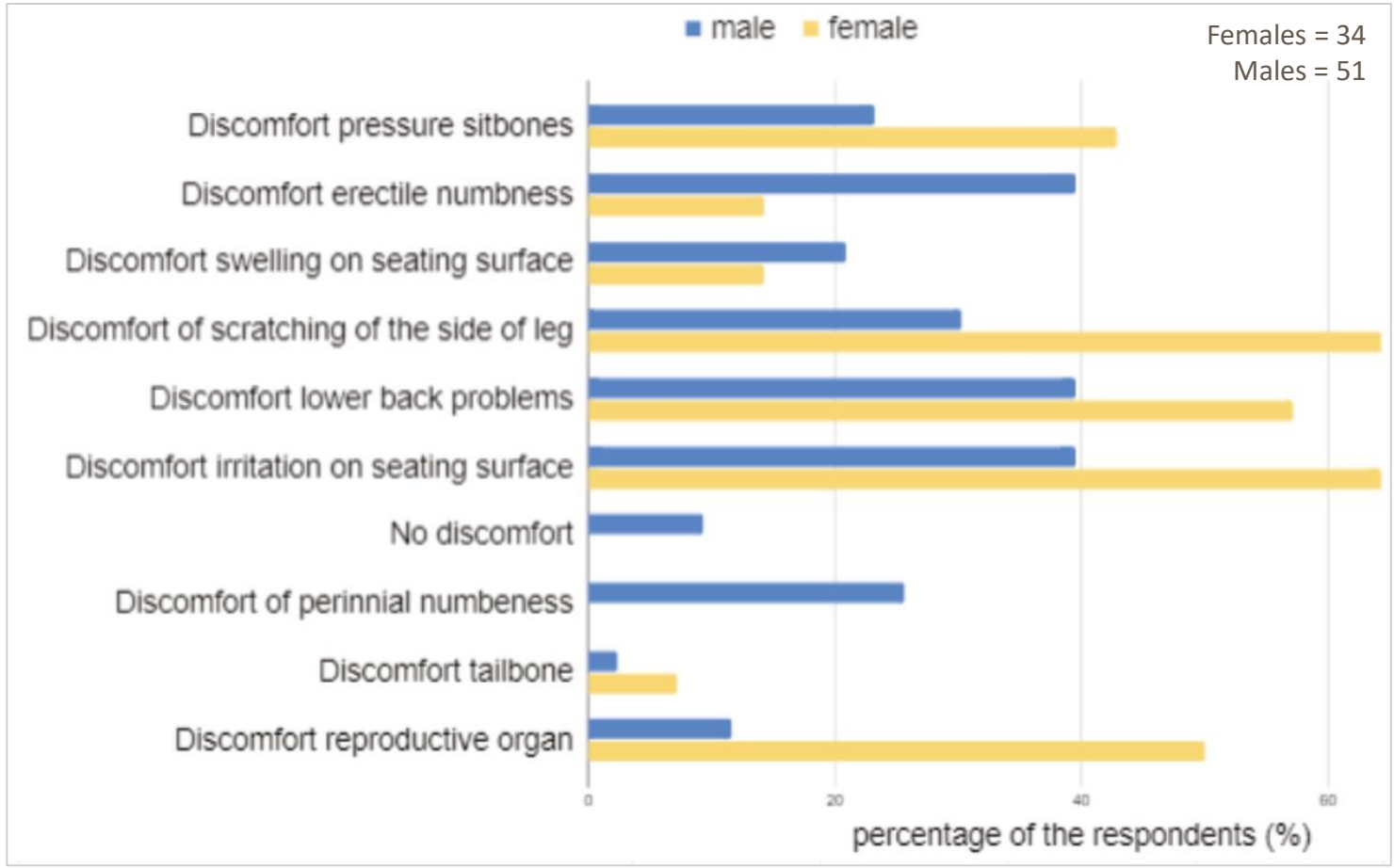
Why should we think about seat pads?

Athlete survey



“Perineal Issue”

Sensitivity analysis

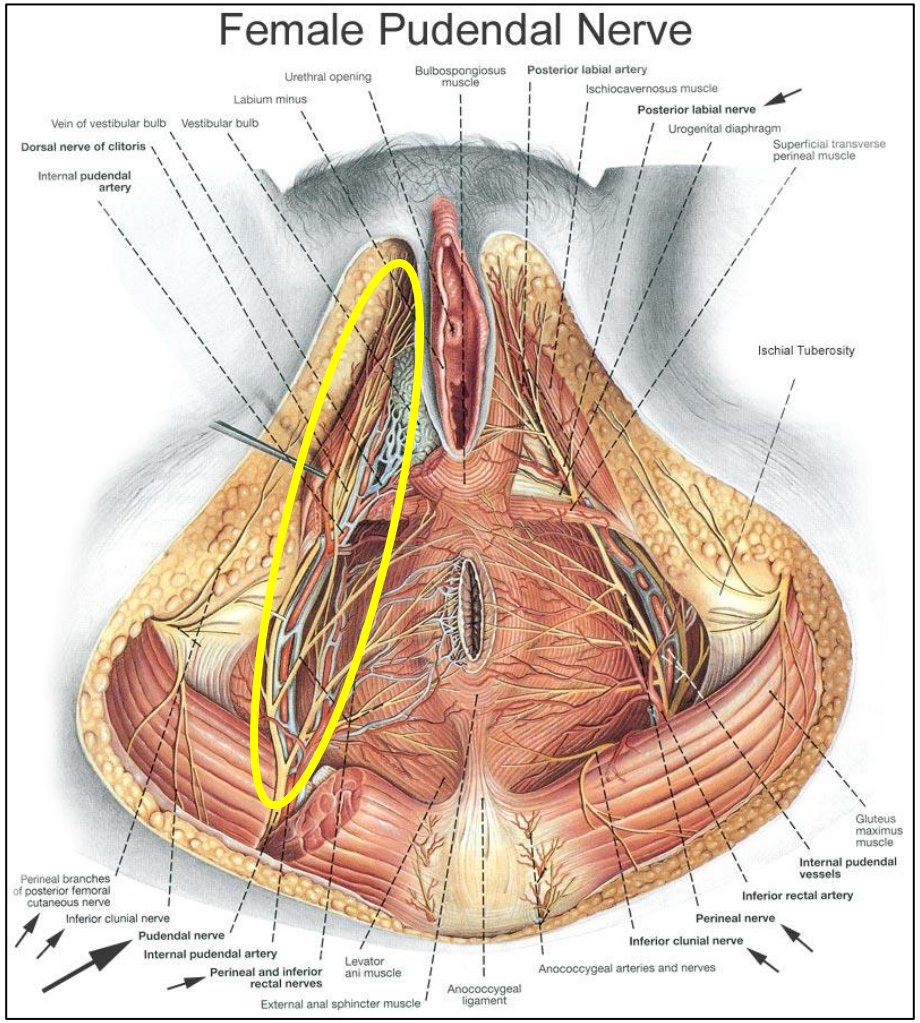


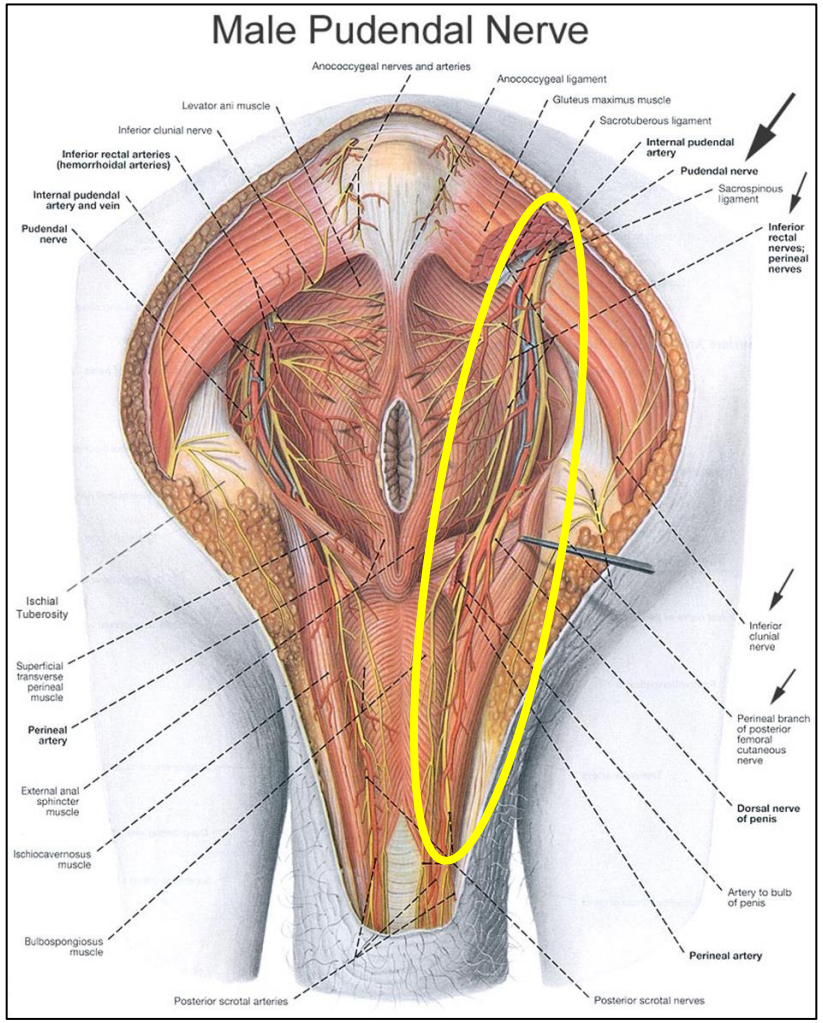
Result:

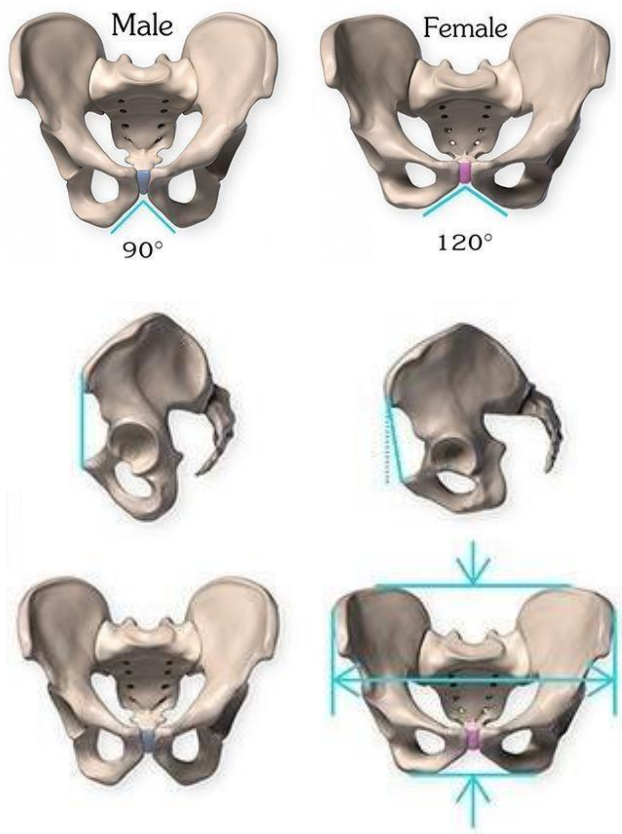
- 50% of the **females** feel discomfort at the **reproductive organ**
- 39% of the **males** have **genital numbness** when riding a bike

Influencing factors - Anatomy

Gender specific nerve tracts and blood vessels

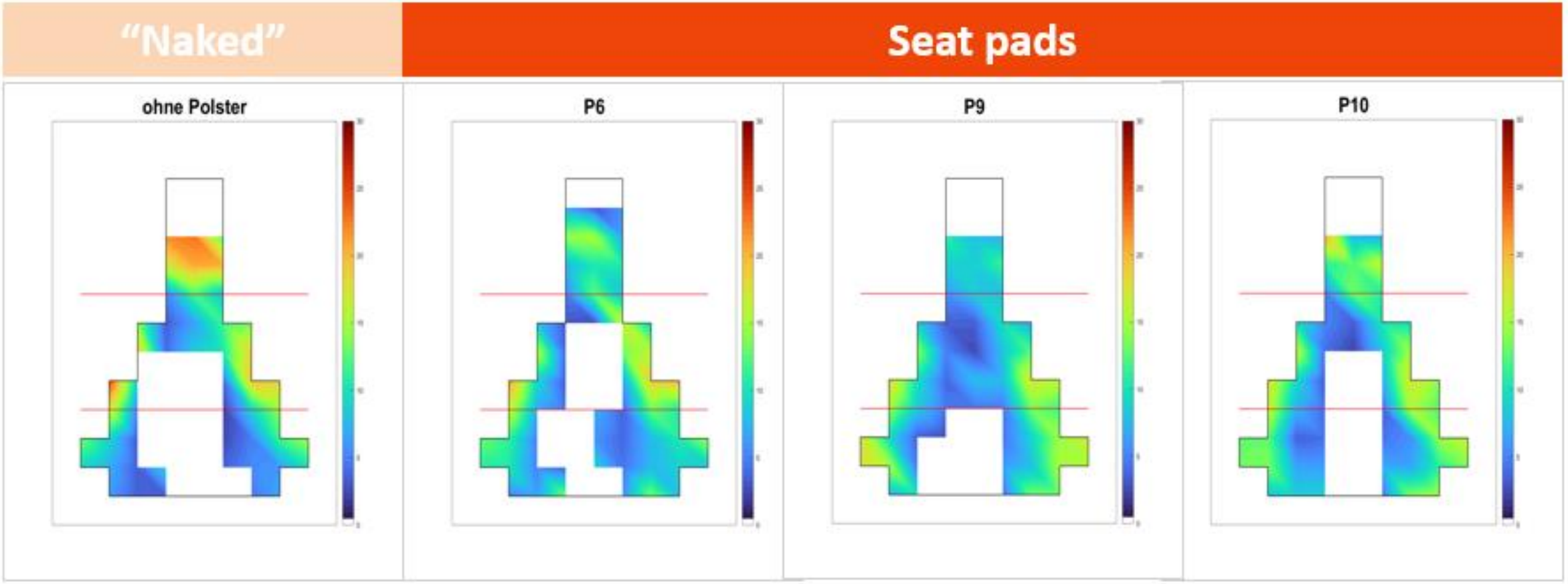






MONKHOUSE, W.S. (1997) Anatomy. A Regional Atlas of the Human Body. Baltimore and London: Williams & Wilkins.

Pressure distribution: “Naked” vs. Seat pad



Pressure Patterns - Females

Results

Results:

- Material thickness & stiffness effects stability (wobbling/sliding on the saddle, objectively. & subjectively)
- Cushioning & stability needs to be balanced (interaction)

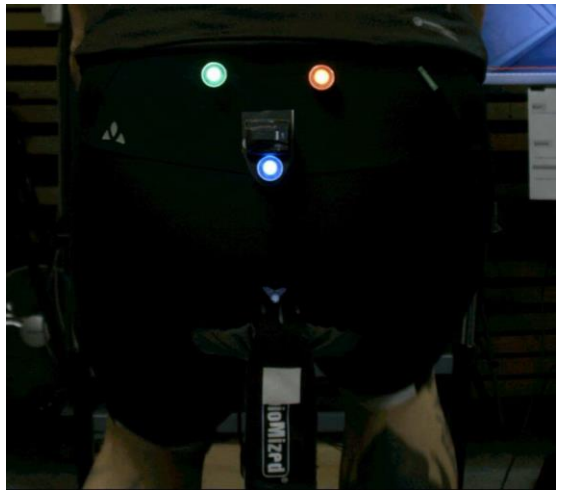
Decision:

- Thickness not higher than needed or benchmark (15mm)

Cushioning
- Thickness
- Stiffness

Antagonism

Stability
- Wobbling
- Sliding



"Our results would support the contention that the choice of saddle design should not be dictated by interface pressure alone since optimal anterior seat pressure and perceived seat stability appear to be inversely related."

Bressel, E., Bliss, S., & Cronin, J. (2009). **A field-based approach for examining bicycle seat design effects on seat pressure and perceived stability**. *Applied Ergonomics, 40*(3), 472-476.

Kick off – Literature Research

Most common sites of injury
(Bini/Di Alencar, 2014):
- Knee: 21-65%
- Upper back: 9-66%
- Hands/wrist: 10-70%
- Buttocks: 42-64%
- Low back: 30-75%

Injuries in CYCLING

Acute Injury

Overuse Injury

Contact Injury

Hands Handlebar Interface

Saddle Interface

Shoe Pedal Interface

Buttock

- Saddle soreness (phrase is used for a number of different riders to refer to a of different problems involving the skin of the upper thigh and the rear end [Baker, 2000])
- Sit bone pain
- Ischial tuberosity pain
- Skin Chafing
- Ulceration
- Haemorrhoids
- Crotch dermatitis (♀) → (use bike shorts with breathable, moisture wicking crotch, American-made Terry saddles have padding and are less stiff)

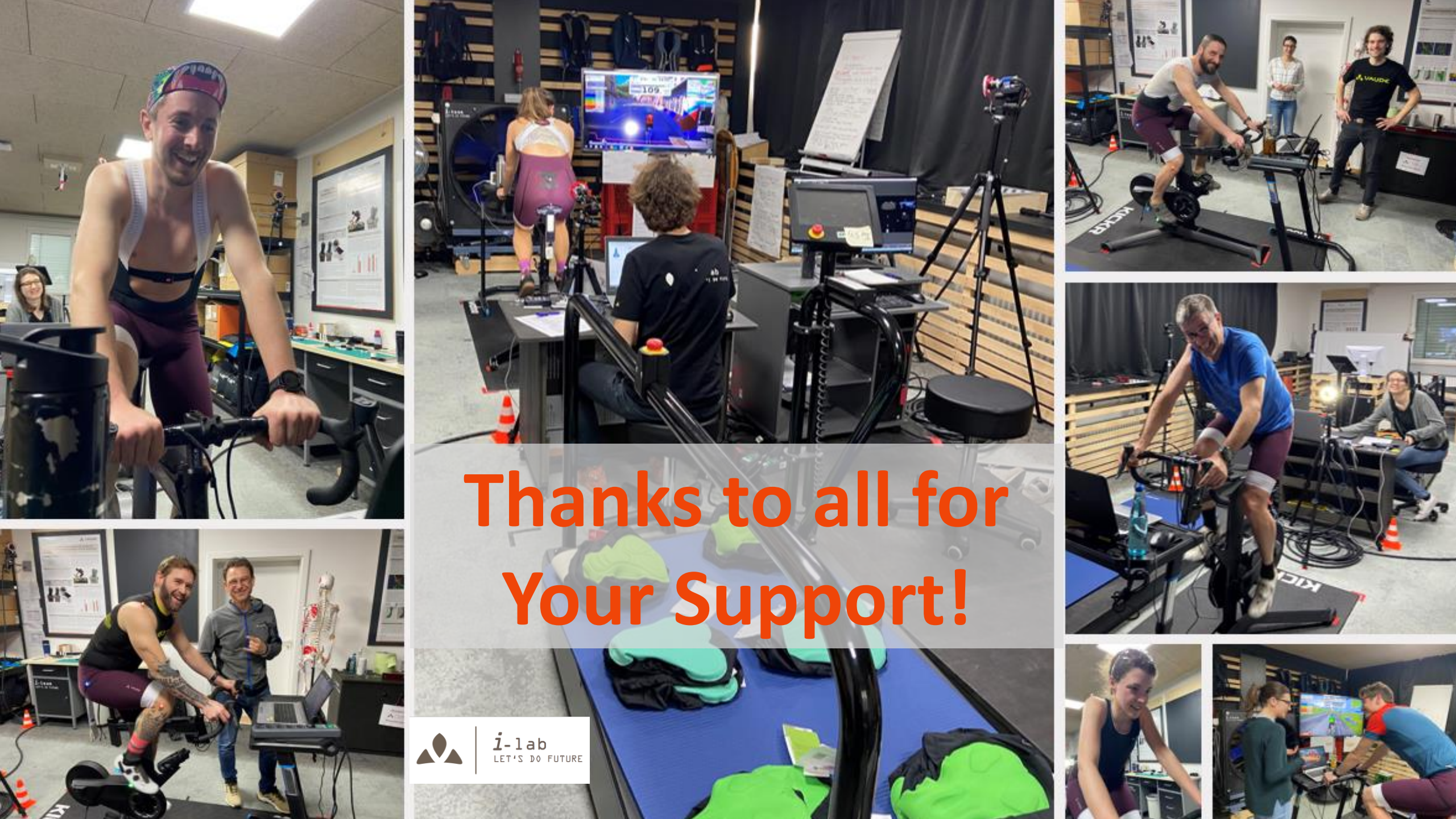
Seat position / Posture

Saddle
(e.g., adjustment, design/geometry/shape, padding)

Cycling pant / Seat pad

Perineum

- Numbness [penile numbness → pressure on the pudendal nerve]
- Erectile dysfunction [penile erection/priapism] (♂)
- Impotence (♂)
- Vulva trauma (♀)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