Journal of Sports Sciences

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/rjsp20

The effect of saddle setback and cycling intensity on saddle pressures and comfort in male and female recreational cyclists

Julia Rizo Albero, Pedro Pérez-Soriano & Alberto Encarnación-Martínez

To cite this article: Julia Rizo Albero, Pedro Pérez-Soriano & Alberto Encarnación-Martínez (20 Sep 2023): The effect of saddle setback and cycling intensity on saddle pressures and comfort in male and female recreational cyclists, Journal of Sports Sciences, DOI: 10.1080/02640414.2023.2259200

To link to this article: https://doi.org/10.1080/02640414.2023.2259200

Published online: 20 Sep 2023.

JOURNAL OF SPORTS SCIENCES
https://doi.org/10.1080/02640414.2023.2259200

Routledge
Taylor & Francis Group

SPORTS PERFORMANCE

The effect of saddle setback and cycling intensity on saddle pressures and comfort in male and female recreational cyclists

Julia Rizo Albero [a], Pedro Pérez-Soriano [a,b] and Alberto Encarnación-Martínez [a,b]

[a]Research Group in Sports Biomechanics (GIBD), Department of Physical Education and Sports, University of Valencia, Valencia, Spain; [b]Red Española de Investigación del Rendimiento Deportivo en Ciclismo y Mujer (REDICYM), University of Valencia, Valencia, Spain

ABSTRACT

Cycling is a recreational activity that helps to prevent different diseases. The practice of this popular worldwide sport requires the cyclist to maintain a particular posture in contact with the pedals, handlebars, and saddle for long periods of time. Therefore, the study of the pressure exerted on the saddle is of great importance as it is directly related to the reduction of perineal injuries and pathologies. The present research aims to study the effect on comfort and saddle pressures when performing a cycloergometer test using 3 saddle positions: own setback position (P1), forward [−10% (P2)], backward [+10% (P3)] at two exercise intensities (Ventilatory Threshold: VT1 and VT2). 34 amateur cyclists (14 women, 20 men) were analysed. The results showed that comfort was significantly reduced in P3 ($p < 0.01$) and significantly increased for some items in the VT1 condition and for men in P1 regarding overall comfort ($p < 0.01$, ES = 0.105). In addition, the average and maximum pressure in the pubic region were significantly higher at P3 ($p < 0.001$) and men show higher values for average pressure compared to women ($p = 0.006$, ES = 0.235). In conclusion, backward saddle setback positions increase pressure and discomfort to recreational cyclists in comparison with the forward and own setback position, which could increase the risk of injury.

ARTICLE HISTORY
Received 23 February 2023
Accepted 24 August 2023

KEYWORDS
Cycloergometer; ventilatory threshold; saddle; performance; amateur cycling

Introduction

Currently, cycling is one of the most popular sports worldwide (Chiu et al., 2013). It is also a recreational activity that helps to prevent and treat diseases such as hypertension, overweight, obesity, type II diabetes and can contribute to improve mental health, life quality and well-being (De Bruyne et al., 2019, Hallal et al., 2012; Organización Mundial de la Salud, 2019). As it is a cyclic sport, where the cyclist maintains a leaning posture and contact with the pedals, handlebars and saddle during the entire time of cycling, inadequate adjustment of bicycle components, a common situation among amateur cyclists, could negatively affect performance as well as lead to an increased risk of overuse injuries (Herrero-Molleda & García-López, 2021).

Among the variables commonly analysed during pedalling, saddle position influences pedalling performance and efficiency (Menard et al., 2020). Considering that the saddle is one of the major supports of the cyclist on the bike, the study of the pressure exerted by the cyclist on the saddle is frequently analysed for its relationship with the reduction of injuries and perineal pathologies (Carpes et al., 2009; Litwinowicz et al., 2021), for its role in the configuration: inclination and height (Bini, 2020; Encarnación-Martínez et al., 2021; Gatti et al., 2022; Kruschewsky et al., 2018) as well as to a lesser extent analysed, the effect of the saddle setback (Kraus et al., 2015; Manigandan et al., 2021; Ménard et al., 2020).

The assessment of the saddle pressure also allows optimisation of bike fitting, thereby enhancing sporting performance (Swart & Holliday, 2019). Multiple studies use saddle pressure systems for their reliability and validity (Braeckevelt et al., 2019; McDonald et al., 2022; Swart & Holliday, 2019), using quadrants on the saddle for their analysis: front and rear, and left and right. In addition, these systems provide information on mean pressure, pelvic orientation, mean longitudinal and transverse movement of the centre of pressure. Therefore, this technology presents a convenient and indirect method for assessing the position of the cyclist with respect to the contact points (McDonald et al., 2022).

Furthermore, it is directly related to pedalling intensity, as authors such as Holliday et al. (2019) concluded that the area loaded in the saddle pressure and the load point indices in the longitudinal and transverse planes increased significantly and progressively with increasing workload. In contrast, Ochoa-Puig et al. (2021) stated in their study that the maximum and mean pressures were significantly lower at higher intensity in the three saddle zones (pubis, left and right ischium).

As professional cycling is one of the most demanding sports combining extremes of exercise duration, intensity and frequency, the use of sports equipment is also of major importance (Jeukendrup et al., 2000; Lucía et al., 2001), because, among other things, comfort is considered key to healthy sport practice and performance (Haitang & Shan, 2021). Another of the fundamental components to ensure comfort in cyclists is the ergonomic adjustment of the bicycle to the physical characteristics of each person, as this produces improvements in efficiency, safety, muscle work balance and the reduction of muscular and skeletal injuries (Gao et al.,

CONTACT Julia Rizo Albero jurial@alumni.uv.es Research Group in Sports Biomechanics (GIBD), Department of Physical Education and Sports, University of Valencia, Valencia 46010, Spain

2019). Likewise, the perception of comfort by cyclists should be taken into account when choosing the most beneficial position on the bike for its contribution to improving performance (Priego Quesada et al., 2017). Thus, like saddle height, which has been widely studied for its association with knee pain, increased oxygen consumption and reduced pedalling economy (Bini & Priego-Quesada, 2022), saddle setback plays a significant role in sport performance (Manigandan et al., 2021). Likewise, authors such as Manigandan et al. (2021) state that saddle setback plays a crucial role in determining cyclist efficiency, demonstrating how a backward saddle position relative to a forward one, offers a greater advantage in terms of force and work effectiveness (43% vs 37.5% and 84% vs 81%). Furthermore, a backward saddle position increases peak power as plantarflexor muscles are predominantly recruited in the downward propulsion phase (Holliday & Swart, 2021) and, causes increased peak electromyographic activity in the peroneus longus, lateral and medial gastrocnemius, soleus, semitendinosus and biceps femoris (McDonald et al., 2022). In contrast, their effect on overuse injuries such as: a) bone degradation and tendinopathies (Ménard et al., 2020) and b) discomfort in the back of the knee (Herrero-Molleda & García-López, 2021) remain inconclusive. It is also a parameter to take into account when aiming to improve cyclists' comfort (Kraus et al., 2015) as more than half of them describe saddle discomfort as a limiting condition (Dettori & Norvell, 2006).

Finally, gender also seems to influence saddle comfort as shown in the study by Herrero-Molleda and García-López (2021) in which Spanish elite female cyclists confirmed a higher percentage of discomfort when using a male saddle compared to a female saddle (61% vs 40%, respectively). The problem lies in the fact that most of the studies have been conducted with male cyclists and therefore the development and design of the material is based on this (Herrero-Molleda & García-López, 2021).

Therefore, this study aims to determine the effects of pedalling at different saddle setbacks and intensity of effort on saddle pressures and comfort in male and female amateur cyclists.

Material and methods

Participants

The sample size was calculated using a linear model with two factors and repeated measures (GPower 3 software version 3.1, Düsseldorf, Germany). The analysis yielded a minimum sample of 30 cyclists to detect significant differences in the variables analysed with a minimum detectable effect size of $f = 0.253$ (moderate) ($\alpha = 0.05$, $\beta = 0.05$, power = 0.91). 34 amateur cyclists, 20 men and 14 women (Table 1) were analysed. Recruitment was based on voluntary interest. All participants met the study inclusion criteria: they were amateur cyclists aged between 18 and 50 years; they had not suffered serious lower limb injuries in the last 6 months, nor had any discomfort at the time of the study; they were not taking any medication or stimulants prior to or during the study that could affect it.

Prior to the intervention the participants' bicycles were measured by the same experienced researcher to determine the other study conditions and to adapt the dimensions of the cycloergometer to the dimensions of the participants' bicycles. Table 2 shows the geometrical measurements of the participants' bicycles. The classic saddle setback refers to the Union Cycliste Internationale (UCI) setback, described as the horizontal distance from the tip of the saddle to the centre of the bottom bracket, and the new saddle setback refers to the setback measured as the horizontal distance from the centre of the saddle to the centre of the pedal axle, including the crank length and the type of saddle. From these measurements, the other setbacks, forward (−10%) and backward (+10%), were calculated.

Table 1. Sample characteristics.

	Women (*n* = 14)		Men (*n* = 20)	
	M	SD	M	SD
Age (years)	35	10	30	8
Height (m)	1.64	0.06	1.72	0.05
Bodyweight (kg)	60.3	6.4	69.3	6.5
Km/week	120	57	197	101
Regular practice (days/week)	4.07	1.45	3.55	1.35
BMI (kg/m^2)	18.33	1.73	20.1	1.7

Note: M: mean; SD: standard deviation; BMI: body max index; m: metros; kg: kilograms; cm: centimetres.

Table 2. Bicycle characteristics.

	Women		Men	
	M	SD	M	SD
Crank length (mm)	171.1	2.5	171.8	2.3
Saddle height (cm)	85.7	4.1	90.3	4.4
Classic saddle setback (cm)	3.0	2.2	4.8	1.9
Classic saddle forward setback (cm)	−0.2	1.9	1.2	1.7
Classic saddle backward setback (cm)	6.2	2.6	8.4	2.1
New saddle setback (cm)	33.7	2.4	35.4	2.4
New saddle forward setback (cm)	30.5	2.2	31.8	2.2
New saddle backward setback (cm)	36.9	2.9	39.0	2.6

Note: M: mean; SD: standard deviation; mm: milimetres; cm: centimetres.

Informed written consent was obtained after each participant was given a verbal and a written explanation of the experimental protocol and fully understood the possible risks involved in taking part in the study. The study protocol was approved by the Ethical Review Board at the University and followed the principles as set out in the declaration of Helsinki.

Study design

The study was an experimental study with a quantitative approach and no control group. The sampling was purposive and with a repeated measures design where all participants went through all study conditions.

Each cyclist was measured and evaluated in a single session, in the first 3 weeks of February 2022, in a controlled laboratory environment under the same conditions of altitude, humidity and temperature (382 m altitude, 30% relative humidity, 16–18°C).

Participants arrived at the laboratory with their own bicycle, shoes and cycling clothes (to avoid altering their perception of comfort) after a period of 48 hours without having performed any high-intensity training sessions. Geometric measurements of the participant's bicycle were taken using an anthropometric tape, plumb bob and set square (Encarnación-Martínez et al., 2021) and anthropometric measurements of each cyclist using a wall-mounted height rod (Seca 216®, Hamburg, Germany) and a weighing scale (Tanita MC 780-P, Tokyo Japan). For the crotch measurements, cyclists were asked to maintain an upright standing position, with their heels separated by a distance equal to the width of their hips and leaning against the wall, with their arms relaxed at their sides, to obtain the distance from the pubis to the ground (Ferrer-Roca et al., 2014). The length of the foot was obtained on paper by marking the horizontal distance from the fifth metatarsophalangeal joint to the calcaneus, making contact with the heel against the wall (Encarnación-Martínez et al., 2021).

Measurements were recorded for all cyclists on the same Wattbike® cycloergometer (Wattbike Pro, Wattbike, Nottingham, England), which was adjusted to fit the own bicycle geometry of each participant. The test consisted of 10 minutes of warm-up at a free intensity chosen by the cyclist (Ferrer-Roca et al., 2017) followed by 5 minutes of pedalling at each of the saddle setbacks: their own setback position (P1), forward saddle position (P2, −10% from P1), and backward saddle position (P3, +10% from P1) (Figure 1); and estimated intensities corresponding to the first and second ventilatory thresholds (VT1 and VT2) (watts normalized to body weight): men = intensity 1 (VT1) = 2.4 $W{\cdot}kg^{-1}$ [2.3–2.5 range]; intensity 2 (VT2) = 3 $W{\cdot}kg^{-1}$ [2.9–3.1 range], women = intensity 1 (VT1) = 2.1 $W{\cdot}kg^{-1}$ [2.0–2.2 range]; intensity 2 (VT2) = 2.6 $W{\cdot}kg^{-1}$ [2.5–2.7 range] (Valenzuela et al., 2018). Moreover, a rest of 2 minutes between intensities and 5 minutes between saddle positions was defined (Ferrer-Roca et al., 2017). Next, the study variables (intensity and saddle setback) were randomized using a self-made matlab routine for randomization called free randomisation software, Randomization_v2, to control for the order effect.

Figure 1. Saddle setback positions.

Two records of 15 seconds of the pressures exerted on the saddle were registered in minutes 2 and 4 of each 5 minutes pedalling test, allowing to register at least 40–45 complete cycling cycle and, after each intensity, the comfort was recorded. Comfort perception was recorded using the 15 cm visual analogue comfort perception scale (VAS) (Lucas-Cuevas et al., 2015) adapted for this study. This scale includes the following items related to cyclist comfort: "general comfort", "perceived comfort on the handlebars", "comfort in pedalling", "adaptation to the pedalling rhythm", "perceived safety", "perceived stability", "boredom" and "similarity to real pedalling". Each of these items is rated from left to right from "not comfortable at all" to "best comfort imaginable".

Definition of the material and the protocol used for the recording of the pressures exerted on the saddle

A saddle pressure system (GP Bike, GebioMized, Münster, Germany) was used to record saddle pressure. This system consists of a thin, flexible saddle-shaped mat containing 64 sensors, with a sampling rate of 200 Hz, 1 mm thickness and 8 mm measurement area (De Bruyne et al., 2019). The manufacturer's instructions were followed to calibrate the pressure mat. In order to ensure the repeatability of the positioning during the tests, as well as the repeatability error of 5% (specified by the manufacturer), the pressure mat was placed on the saddle of the cycloergometer by the same researcher (De Bruyne et al., 2019). During the test, participants were not informed when data were recorded to avoid changes in the pedalling action and other possible interferences (Holliday et al., 2019). The collected data were transmitted wirelessly to the software installed on the computer (GP Bike software,v. 6.5., 2017, GebioMized, Münster, Germany). Subsequently, for the analysis of the results, the saddle was divided into three regions: 1) anterior or pubic 2) left ischium 3) right ischium (Figure 2).

Statistical analysis

For the statistical analysis, the commercial software SPSS v25 (IBM Corp., Armonk, NY.) was used. First of all, an exploratory analysis was performed where outliers were eliminated. Next, the normality of the data was checked with the ShapiroWilk test ($n < 50$), with all variables being normal. A three-way repeated measures analysis of variance (RM ANOVA) was performed to analyse the effects of saddle setback (P1, P2, P3) and intensity (Ventilatory Threshold:

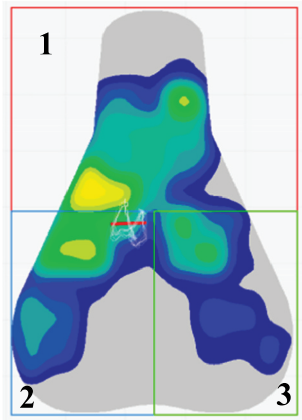

Figure 2. Pressure mat showing the areas of the anterior pubic bone (1), left ischium (2) and right ischium (3).

aerobic (VT1) and anaerobic (VT2)) as within-subject factors; and the effect of sex as a between-subject factor on each of the dependent variables (perceived comfort and saddle pressures). Additionally, differences between saddle areas were included in the repeated measures ANOVA as a within-subject factor to describe pressure distribution pattern. Pairwise comparison significance levels were adjusted for significance using the Bonferroni correction. Sphericity was also checked with the Mauchly test, and in those cases where this assumption was not met, the Huynh-Feldt adjustment was used. Finally, effect size (ES) was calculated using partial eta squared (ŋ2) (Cohen, 1988), interpreted as: small = 0.01; moderate = 0.06; large > 0.14 and the intensity of changes was shown with the difference of means and 95%ile confidence intervals, together with p and effect size. The significance level was set at $p < 0.05$.

Results

The results of the study are presented below, describing each group of variables results in the order of the examined factors: saddle setback, intensity, and participants' sex.

Results on perceived comfort

There were significant differences ($p < 0.01$) in all items of the perceived comfort variable for men (Figure 3) and women (Figure 4) related to saddle setback. Perceived comfort was significantly higher in P1 (own position) and P2 (−10%, forward) than P3 (+10%, backward), except for "boredom" where significantly higher values were only found in P1 compared to P3 (+10%) ($p < 0.01$, ES (ŋ2) = 0.162; Mean diff. = 1.050; 95%CI = 0.101/1.999). No other interaction effects were found regarding setback condition.

Regarding intensity, the results showed that the values for the items "adaptation to rhythm" and "stability" had significantly higher values for the pedalling intensity VT1 compared to the pedalling intensity VT2 ($p = 0.005$, ES (ŋ2) = 0.225; Mean diff. = 1.057; 95%CI = 0.351/1.763; $p = 0.022$, ES (ŋ2) = 0.154; Mean diff. = 0.429; 95%CI = 0.067/0.790, respectively). No other interaction effects were found regarding pedalling intensity.

There were no great differences associated to the sex of participants, but there was an interaction effect regarding sex in P1 setback. Concretely, men had higher values in the item "general comfort" than women in P1 (p < 0.01, ES (ŋ2) = 0.105; Mean diff.= −2.207; 95%CI= −3.932/- 0.483).

Results on pressure exerted on the saddle

The descriptions of the results found as a function of the pressure exerted on the saddle are shown in Tables 3–5.

Results obtained as a function of saddle setback

It was observed that P3 presented higher values in the maximum pressure in the pubic area ($p < 0.001$, ES(ŋ2) = 0.274), average pressure in the pubic area ($p < 0.001$, ES(ŋ2) = 0.277) and the pressure area in front ($p < 0.001$, ES(ŋ2) = 0.376) compared to P1 (Mean diff. = 9.236 kPa; 95%CI = 1.364/17.107 kPa, $p = 0–017$; Mean diff = 1.917 kPa; 95%ic = 0.034/3.8 kPa, $p = 0.045$; Mean diff = 3.5%; 95%CI = 1.0/6.0%, $p = 0.005$, respectively) and P2 (Mean diff = 11.61 kPa; 95%CI = 5.23/17.99 kPa, $p < 0.001$; Mean diff = 3.174 kPa; 95%CI = 1.442/4.906 kPa, $p < 0.001$; Mean diff = 6.1%, 95%CI = 3.6/8.5%, $p < 0.001$, respectively).

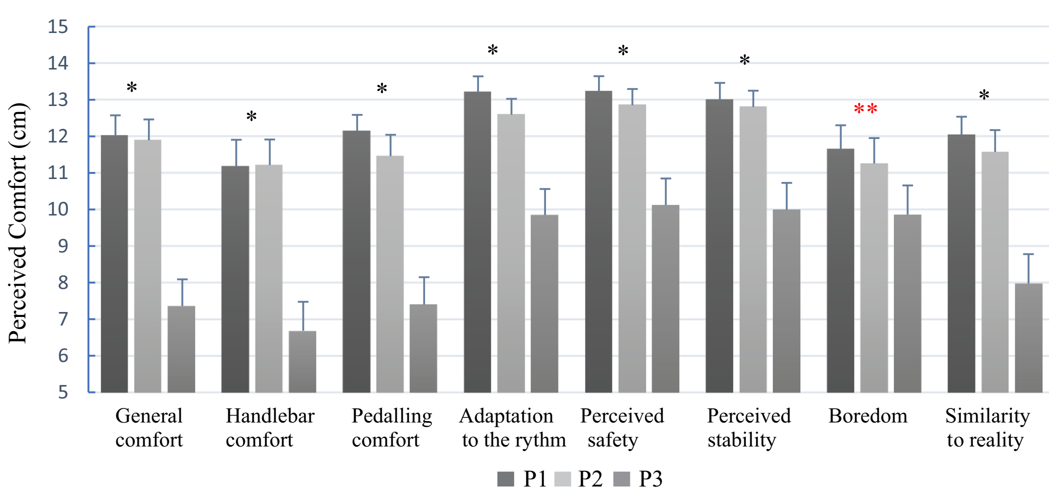

Figure 3. Perception of comfort (Mean and standard error of the mean) in male cyclists by saddle setback. *Note.* * Statistical differences between P1 and P2 with P3 (p<0.001). ** Significant differences between P1 and P3 (p<0.05).

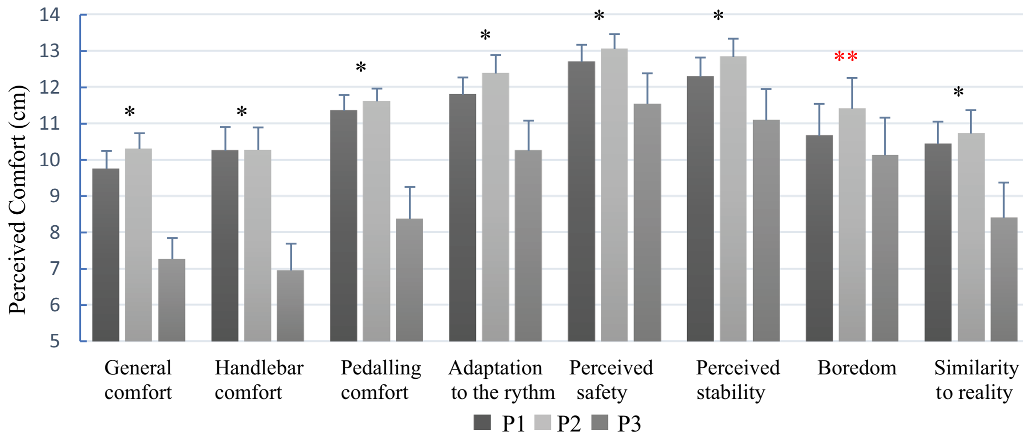

Figure 4. Perception of comfort (Mean and standard error of the mean) in female cyclists by saddle setback. Note. * Statistical differences between P1 and P2 with P3 (p<0.001). ** Significant differences between P1 and P3 (p<0.05).

Table 3. Descriptive statistics of the variable saddle pressure according to saddle area in women.

Women			Own setback position (P1)		Forward saddle position (P2, −10%)		Backward saddle position (P3, +10%)	
	Saddle areas	Intensity	M	SD	M	SD	M	SD
Maximum pressure (kpa)	Pubis	**VT1**	68.1 ‖	33.4	64.4	32.5	72.1*	37.1
		VT2	62.2 ‖	31.6	66.7	34.0	78.3*	34.5
	Left ischium	**VT1**	32.9	13.0	33.1	10.1	33.8	12.1
		VT2	32.8	13.7	32.8	10.9	31.1	13.4
	Right ischium	**VT1**	37.1	15.2	37.0	12.6	36.0	14.8
		VT2	35.4	11.9	38.6	15.5	32.9	15.0
Average pressure (kpa)	Pubis	**VT1**	19.1#	6.7	18.1	6.6	22.9* ‖	8.0
		VT2	19.9#	6.6	19.1	6.6	21.3* ‖	6.4
	Left ischium	**VT1**	13.9#	6.6	14.0**#	4.4	13.7#	6.1
		VT2	14.4#	6.9	14.4**#	5.1	12.4#	5.6
	Right ischium	**VT1**	12.5	6.0	12.4	5.1	12.6	6.3
		VT2	12.3	5.2	13.3	5.8	11.9	6.6
Loading area (m^2)	Pubis	**VT1**	0.00497	0.00145	0.00494	0.00129	0.00506	0.00118
		VT2	0.00508	0.00115	0.00494	0.00131	0.00519	0.00112
	Left ischium	**VT1**	0.00556	0.00179	0.00577**	0.00958	0.00537	0.00167
		VT2	0.00542	0.00185	0.00562**	0.00144	0.00503	0.00192
	Right ischium	**VT1**	0.00523	0.00237	0.00566†	0.00148	0.00512	0.00209
		VT2	0.00534	0.00222	0.00558†	0.00185	0.00492	0.00227

Note: M: mean; SD: standard deviation; kPa: kilopascals; m^2 : square metres; VT: ventilatory threshold.
*Significant differences with P1 and P2 (p<0.05).
†Significant differences with P3 (p<0.05).
‡Significant differences with P1 and P3 (p<0.05).
‖ Significant differences with left and right ischia (p<0.05).
#Significant differences with right ischium (p<0.05).

In relation to the above, a larger pressure area behind ($p < 0.001$; ES(ŋ2) = 0.378) was observed in P1 and P2 compared to P3 (Mean diff = 3.4%; 95%CI = 0.9/6.0%, $p = 0.005$; Mean diff = 6.1%; 95%CI = 3.6/8.5%, $p < 0.001$ respectively).

Regarding the left ischium, it was observed that the average pressure and loading area was significantly higher in P2 ($p < 0.001$, ES(ŋ2) = 0.277, $p < 0.001$, ES(ŋ2) = 0. 231, respectively) compared to P3 (Mean diff = 1.279 kPa; 95% CI = 0.215/2.344 kPa, $p = 0.014$; Mean diff = 0.00034 mm^2; 95%CI = 2.13 e-5/0.00066 mm^2, $p = 0.034$, respectively). The area of the right ischium was significantly higher in P2 compared to P1 and P3 (Mean diff = 0.00028 mm^2; 95%CI = 8,9e-6/0.00056 mm^2, $p = 0.041$; Mean diff = 0.00045 mm^2; 95%CI = 0.00015/0.000745 mm^2, $p = 0.002$, respectively). No other interaction effects were found regarding setback condition.

Results obtained as a function of pedalling intensity

No statistically significant differences were found ($p > 0.05$) in the variable pressure exerted on the saddle as a function of pedalling intensity. No other interaction effects were found regarding pedalling intensity.

Results obtained as a function of sex

Men showed significantly higher average pressure values ($p = 0.006$, ES(ŋ2) = 0.235) compared to women (Mean diff. = 2.647 kPa; 95%CI = 0.836/4.459 kPa). No other interaction effects were found regarding sex.

Results obtained as a function of saddle zone

The pubic area showed significantly higher maximum pressure values ($p = 0.002$, ES(ŋ2) = 0.277) compared to the left and right ischial areas in P1 (Mean diff. = 25.742 kPa; 95%CI = 7.282/44.202 kPa, $p = 0.004$; Mean diff. = 22.279 kPa; 95%CI = 4.137/40.422 kPa,

Table 4. Descriptive statistics of the variable saddle pressure according to saddle area in men.

			Own setback position (P1)		Forward saddle position (P2, −10%)		Backward saddle position (P3, +10%)	
Men	Saddle areas	Intensity	M	SD	M	SD	M	SD
Maximum pressure (kpa)	Pubis	**VT1**	58.6‖	29.5	50.9	24.0	67.4*	34.5
		VT2	54.5‖	26.2	50.9	24.3	63.5*	30.4
	Left ischium	**VT1**	43.8	12.7	45.6	12.3	42.9	16.8
		VT2	44.5	14.1	44.0	13.8	43.3	15.7
	Right ischium	**VT1**	46.7	12.9	49.7	13.1	46.0	15.7
		VT2	46.6	10.5	48.4	16.0	46.5	12.8
Average pressure (kpa)	Pubis	**VT1**	20.6#	8.2	18.5	7.6	21.8*‖	8.2
		VT2	19.7#	7.4	18.3	7.7	21.1*‖	6.7
	Left ischium	**VT1**	17.7#	5.7	19.0**#	6.1	17.2#	6.8
		VT2	18.3#	6.0	18.8**#	6.8	17.6#	6.9
	Right ischium	**VT1**	16.2	4.5	16.1	4.8	15.4	5.9
		VT2	15.4	4.5	15.9	5.4	15.1	5.2
Loading area (m^2)	Pubis	**VT1**	0.00580	0.00086	0.00558	0.00094	0.00594	0.00070
		VT2	0.00584	0.00089	0.00568	0.00096	0.00607	0.00057
	Left ischium	**VT1**	0.00564	0.00123	0.00577**	0.00109	0.00547	0.00157
		VT2	0.00575	0.00116	0.00577**	0.00112	0.00561	0.00142
	Right ischium	**VT1**	0.00565	0.00140	0.00589†	0.00126	0.00542	0.00174
		VT2	0.00570	0.00140	0.00585†	0.00136	0.00563	0.00163

Note: M: mean; SD: standard deviation; kPa: kilopascals; m^2 : square metres; VT: ventilatory threshold.
*Significant differences with P1 and P2 (p<0.05).
**Significant differences with P3 (p<0.05).
†Significant differences with P1 and P3 (p<0.05).
‖Significant differences with left and right ischia (p<0.05).
#Significant differences with right ischium (p<0.05).

Table 5. Descriptive statistics of the variable saddle pressure in women and men.

		Own setback position (P1)				Forward saddle position (P2, −10%)				Backward saddle position (P3, +10%)			
		VT1		VT2		VT1		VT2		VT1		VT2	
Pressure area	Sex	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Front (%)	Women	58.8	19.4	59.6	17.1	56.9	14.3	57.5	16.8	63.4*	16.3	64.2*	17.1
	Men	54.0	16.0	52.8	15.9	50.3	16.2	50.5	17.0	56.6*	17.0	56.2*	15.4
Behind (%)	Women	41.2**	19.4	40.4**	17.1	43.1**	14.3	42.5**	16.8	36.6	16.3	35.8	17.1
	Men	46.0**	16.0	46.9**	15.7	49.7**	16.2	49.6**	17.0	43.5	17.0	43.8	15.4
Left (%)	Women	53.0	4.2	52.6	5.3	54.3	6.9	53.3	5.3	53.9	6.0	53.9	7.6
	Men	53.2	5.2	53.8	4.6	53.8	4.8	53.8	4.6	52.9	5.2	53.1	4.9
Right (%)	Women	47.0	4.2	47.4	5.3	45.8	6.9	46.8	5.3	46.1	6.0	46.1	7.6
	Men	46.8	5.2	46.2	4.6	46.2	4.8	46.2	4.6	47.2	5.2	46.9	4.9

Note: M: mean; SD: standard deviation; VT: ventilatory threshold.
*Significant differences with P1 and P2 (p<0.01).
**Significant differences with P3 (p<0.01).

$p = 0.012$, respectively). Similarly, it was found that the average pressure was higher in the pubic area ($p = 0.018$, ES(ŋ2) = 0.168) compared to the right and left ischial areas in P3 (Mean diff. = 6.644; 95%CI = 0.756/12.532 kPa, $p = 0.023$; Mean diff. = 8.028 kPa; 95%CI = 2.362/13.693 kPa, $p = 0.004$, respectively).

Additionally, it was also observed that the average pressure of the pubic and left ischial area was significantly higher compared to the right ischial area in P1 (Mean diff. = 5.858; 95%CI = 0.508/11.207 kPa, $p = 0.028$; Mean diff. = 1.787 kPa; 95%CI = 0.2/3.374 kPa, $p = 0.023$, respectively). Finally, it was found that the average pressure of the left ischial area was significantly higher compared to the right ischial area in P2 and P3 (Mean diff. = 2.015; 95%CI = 0.644/3.385 kPa, $p = 0.002$; Mean diff. = 1.384 kPa; 95%CI = 0.016/2.751 kPa, $p = 0.047$ respectively). No other interaction effects were found regarding saddle zone.

Discussion

The main objective of this study was to analyse the effect of saddle setback and pedalling intensity on saddle pressures and comfort in male and female amateur cyclists.

Perceived comfort

All items of the comfort scale, except boredom, presented higher values in P1 and P2 (forward) in relation to P3 (backward). These results are consistent with previous studies (Verma et al., 2016) where discomfort was also increased ($p <$ 0.05) when cyclists pedal in a raised saddle position and a setback position compared to the neutral position. This may be due to changes in saddle position as comfort is known to be influenced by different factors related to bicycle components (Ayachi et al., 2015). Findings on the effects of changing saddle position on comfort and biomechanics during cycling from the study by Verma et al. (2016) showed that discomfort also increased over time and lead to changes in cycling biomechanics. Despite this, there is limited scientific evidence on the effects of different saddle setbacks on the perceived comfort of cyclists.

On the other hand, in relation to the influence of pedalling intensity on comfort, the results indicated a better adaptation to the rhythm and greater stability the lower the intensity. These differences could be explained by the characteristics of the sample as they are amateur cyclists used to train infrequently per week (2–5 times) and at an intensity more similar to that of VT1 (Jeukendrup et al., 2000).

Finally, regarding the effects produced by the sex variable on comfort, it was concluded that men had a greater overall comfort in P1 compared to women. These results may be due to the fact that the geometry of the cycle ergometer (Wattbike Pro, Wattbike, Nottingham, England) allowed for a very tight fit on the smaller cyclists, which may have resulted in less comfort.

Saddle pressures

Referring the effect of setback on pressure distribution, the maximum and average pressure in the pubic area and the pressure area in front, was observed to be higher in P3 compared to P1 and P2. This is consistent with the results of the study of Guiotto et al. (2022) in which an increase in pressure on the pubic bone area was recorded while cycling with the hands on the lever in comparison to the hands-on drop handlebar and an increase on the contact surface on the pubic bone area where the hands were on the drop handlebar compared to the hands on the lever. Moreover, a significant anterior shift in the COP (centre of pressure) and peak position was detected during the hands on the drop handlebar position compared to the hands-on top handlebar position.

Furthermore, there was an increase in the pressure area behind in P1 and P2 compared to P3. These variations in pressures may be explained by the participants' reaction to changes in the saddle positions, adjusting their position in the saddle, as Kraus et al. (2015) confirmed that there is a moderate relationship between adjusting the centre of pressure towards the rear of the saddle and a reduction in peak pressure in the pubic area, as well as an increase in the loaded area under the ischial tuberosity.

It was also observed that the average pressure and loading area of the left ischium were higher in P2 compared to P3. That could have been caused by the changes in the kinematics between the two limbs. The assumption that the movement is cyclical and similar in both lower limbs led to the analysis of the right lower limb only, and therefore no differences or conclusions can be drawn (Galindo-Martínez et al., 2021).

On the other hand, no differences were found in the variable pressure exerted on the saddle as a function of pedalling intensity, coinciding with previous studies (Holliday et al., 2019) where no differences were found in the mean pressure and load distribution between pedalling intensities. However, other studies (Holliday et al., 2019; Potter et al., 2008) reported increases in the loaded area in the longitudinal and transverse planes, in the contact area between the cyclist and the saddle, the movement of the centre of pressure and the peak pressure in the posterior region with increasing pedalling intensity. Similarly, in the work of Carpes et al. (2009) an increase in saddle pressures with increasing pedalling intensity was recorded. These results may be due to the choice of pedalling intensity, since there was a difference between VT1 and VT2 of 60.1 watts for women and 76.5 watts for men in our study, whereas in the study by Carpes et al. (2009) the difference was much higher, 150 watts. In addition, these participants maintained the trunk angle at 60° and in our study the posture was allowed to be free.

In addition to the above, the only result found in reference to sex was that men showed higher values in the average pressure compared to women. Thus, Carpes et al. (2009) indicated that there was a decrease in saddle pressure in the forward trunk position (60°) when using the saddle model with a hole and that this may be influenced by saddle design, trunk position and male anatomy. In contrast, for women, saddle pressure was not influenced by trunk position or saddle design. On the other hand, Potter et al. (2008) showed that the maximum pressure in the anterior region increased for women when their hands rest on the lower part of the handlebars. In addition, male pressure centres were more forward in the anterior and total regions of the saddle than in females because of the greater width of the ischial tuberosities in females. Sex-related differences in pressure profiles may arise from fundamental differences in pedalling technique, pelvic geometry and/or anthropometric characteristics (Potter et al., 2008).

Finally, the results comparing saddle pressure distribution between areas showed higher maximum pressure values in the pubic area compared to the left and right ischial areas in P1. Similarly, it was observed that the average pressure of the pubic area was higher compared to the left and right ischial areas in P3. These results are consistent with recent studies postulating a higher mean anterior pressure for a wide saddle in recreational cyclists (Larsen et al., 2018) and an increased peak pressure over the pubic region in male cyclists (Sanford et al., 2018). These maximum pressure zones have implications for both men and women in genitourinary diseases and should therefore be taken into consideration in the choice and configuration of saddle design (Sanford et al., 2018).

Conclusions

The further the saddle is set back (P3), the greater the maximum and average pressure in the pubic region compared to the other saddle positions used in this study. On the other hand, the forward saddle position (P2) and the freely chosen position (P1) showed an increase in pressure in the posterior area, thus producing a decrease in pressure in the pubic region. However, pedalling intensity does not produce changes in the pressure levels on the saddle. Finally, the sex factor is only expressed by increasing mean pressure values in the left ischium in the case of men.

Acknowledgments

We would like to thank all the participants to voluntary participate in this study. We also want to thank Aitex for their collaboration in borrowing the GebioMized® mat for recording saddle pressures. And finally, we would like to thank the Spanish Network for Research on Sports Performance in Cycling and Women (REDICYM), for allowing us to continue within its strategic line of research.

Disclosure statement

The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request.

Funding

This study was funded by Consejo Superior de Deportes, Ministerio de Cultura y Deporte, Gobierno de España (2083210_2021 - Ayudas para Investigación 37/UPB/21)

ORCID

Julia Rizo Albero http://orcid.org/0000-0003-0224-620X
Pedro Pérez-Soriano http://orcid.org/0000-0002-9825-3801
Alberto Encarnación-Martínez http://orcid.org/0000-0003-2149-134X

References

Ayachi, F. S., Dorey, J., & Guastavino, C. (2015). Identifying factors of bicycle comfort: An online survey with enthusiast cyclists. *Applied Ergonomics*, *46*(A), 124–136. https://doi.org/10.1016/j.apergo.2014.07.010

Bini, R. R. (2020). Acute effects from changes in saddle height in perceived comfort during cycling. *International Journal of Sports Science and Coaching*, *15*(3), 390–397. https://doi.org/10.1177/1747954120918965

Bini, R., & Priego-Quesada, J. (2022). Methods to determine saddle height in cycling and implications of changes in saddle height in performance and injury risk: A systematic review. *Journal of Sports Sciences*, *40*(4), 386–400. https://doi.org/10.1080/02640414.2021.1994727

Braeckevelt, J., De Bock, J., Schuermans, J., Verstockt, S., Witvrouw, E., Dierckx, J. (2019). The need for data-driven bike fitting: Data study of subjective expert fitting. In *7th International Conference on Sport Sciences Research and Technology Support (icSPORTS)*, Vienna, Austria (pp. 181–189). Scitepress.

Carpes, F. P., Dagnese, F., Kleinpaul, J. F., de Assis Martins, E., & Bolli Mota, C. (2009). Bicycle saddle pressure: Effects of trunk position and saddle design on healthy subjects. *Urologia Internationalis*, *82*(1), 8–11. https://doi.org/10.1159/000176017

Chiu, M.-C., Wu, H.-C., & Tsai, N.-T. (2013). LNCS 8016 - the relationship between handlebar and saddle heights on cycling comfort. In S. Yamamoto (Ed.), *Human interface and the management of information. Information and interaction design* (Vol. 8016, pp. 12–19). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-39209-2_2

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. (2nd Ed.) Hillsdale, NJ: Lawrence Erlbaum Associates. https://doi.org/10.4324/9780203771587

De Bruyne, G., Aerts, J. M., & Berckmans, D. (2019). Efficiency of cycling pads in reducing seat pressure during cycling. In F. Rebelo & M. Soares (Eds.) *Advances in ergonomics in design. AHFE 2018*. advances in intelligent systems and computing (Vol. 777, pp. 38–47). Springer International Publishing. https://doi.org/10.1007/978-3-319-94706-8_5

Dettori, N. J., & Norvell, D. C. (2006). Non-traumatic bicycle injuries. *Sports Medicine*, *36*(1), 7–18. https://doi.org/10.2165/00007256-200636010-00002

Encarnación-Martínez, A., Ferrer-Roca, V., & García-López, J. (2021). Influence of sex on current methods of adjusting saddle height in indoor cycling. *The Journal of Strength & Conditioning Research*, *35*(2), 519–526. https://doi.org/10.1519/JSC.0000000000002689

Ferrer-Roca, V., Bescós, R., Roig, A., Galilea, P., Valero, O., & García-López, J. (2014). Acute effects of small changes in bicycle saddle height on gross efficiency and lower limb kinematics. *The Journal of Strength & Conditioning Research*, *28*(3), 784–791. https://doi.org/10.1519/JSC.0b013e3182a1f1a9

Ferrer-Roca, V., Rivero-Palomo, V., Ogueta-Alday, A., Rodríguez-Marroyo, J. A., & García-López, J. (2017). Acute effects of small changes in crank length on gross efficiency and pedalling technique during submaximal cycling. *Journal of Sports Sciences*, *35*(14), 1328–1335. https://doi.org/10.1080/02640414.2016.1215490

Galindo-Martínez, A., López-Valenciano, A., Albaladejo-García, C., Vallés-González, J. M., & Elvira, J. L. L. (2021). Changes in the trunk and lower extremity kinematics due to fatigue can predispose to chronic injuries in cycling. *International Journal of Environmental Research and Public Health*, *18*(7), 3719. https://doi.org/10.3390/ijerph18073719

Gao, J., Sha, A., Huang, Y., Liu, Z., Hu, L., Jiang, W., Yun, D., Tong, Z., & Wang, Z. (2019). Cycling comfort on asphalt pavement: Influence of the pavement-tyre interface on vibration. *Journal of Cleaner Production*, *223*, 323–341. https://doi.org/10.1016/j.jclepro.2019.03.153

Gatti, A. A., Keir, P. J., Noseworthy, M. D., Beauchamp, M. K., & Maly, M. R. (2022). Equations to prescribe bicycle saddle height based on desired joint kinematics and bicycle geometry. *European Journal of Sport Science*, *22*(3), 344–353. https://doi.org/10.1080/17461391.2021.1902570

Guiotto, A., Spolaor, F., Albani, G., & Sawacha, Z. (2022). Could proprioceptive stimuli change saddle pressure on male cyclists during different hand positions? An exploratory study of the effect of the Equistasi® device. *Sports*, *10*(6), 88. https://doi.org/10.3390/sports10060088

Haitang, Z., & Shan, C. (2021). Ergonomic performance research and evaluation method of cycling clothes. *Journal of Physics*, *1790*(1). https://doi.org/10.1088/1742-6596/1790/1/012022

Hallal, P. C., Andersen, L. Bo., Bull, F. C., Guthold, R., Haskell, W., & Ekelund, U. (2012). Global physical activity levels: surveillance progress, pitfalls, and prospects. *The Lancet*, *380*(9838), 247–257. https://doi.org/10.1016/S0140-6736(12)60646-1

Herrero-Molleda, A. H., & García-López, J. G. (2021). El reto de ajustar la bicicleta a la mujer: situación actual y perspectivas futuras. *Logía, educación física y deporte: Revista Digital de Investigación en Ciencias de la Actividad Física y del Deporte*, *2*(1), 1–14.

Holliday, W., Fisher, J., & Swart, J. (2019). The effects of relative cycling intensity on saddle pressure indexes. *Journal of Science and Medicine in Sport*, *22*(10), 1097–1101. https://doi.org/10.1016/j.jsams.2019.05.011

Holliday, W., & Swart, J. (2021). Performance variables associated with bicycle configuration and flexibility. *Journal of Science and Medicine in Sport*, *24*(3), 312–317. https://doi.org/10.1016/j.jsams.2020.09.015

Holliday, W., Theo, R., Fisher, J., & Swart, J. (2019). Cycling: Joint kinematics and muscle activity during differing intensities. *Sports Biomechanics*, *22*(5), 1–15. https://doi.org/10.1080/14763141.2019.1640279

Jeukendrup, A. E., Craig, N. P., & Hawley, J. A. (2000). The bioenergetics of world class cycling. *Journal of Science and Medicine in Sport*, *3*(4), 414–433. https://doi.org/10.1016/S1440-2440(00)80008-0

Kraus, L., Schade, D., & Natrup, J. (2015). Evaluating the central pressure point to determine the optimal saddle setback. *Journal of Science and Cycling*, *4*(2), 43–44. https://jsc-journal.com/index.php/JSC/article/view/213

Kruschewsky, A. B., Dellagrana, R. A., Rossato, M., Ribeiro, L. F. P., Lazzari, C. D., & Diefenthaeler, F. (2018). Saddle height and cadence effects on the physiological, perceptual, and affective responses of recreational cyclists. *Perceptual and Motor Skills*, *125*(5), 923–938. https://doi.org/10.1177/0031512518786803

Larsen, A. S., Larsen, F. G., Sørensen, F. F., Hedegaard, M., Støttrup, N., Hansen, E. A., & Madeleine, P. (2018). The effect of saddle nose width and cutout on saddle pressure distribution and perceived discomfort in women during ergometer cycling. *Applied Ergonomics*, *70*, 175–181. https://doi.org/10.1016/j.apergo.2018.03.002

Litwinowicz, K., Choroszy, M., & Wróbel, A. (2021). Strategies for reducing the impact of cycling on the perineum in healthy males: Systematic review and meta-analysis. *Sports Medicine*, *51*(2), 275–287. https://doi.org/10.1007/s40279-020-01363-z

Lucas-Cuevas, A. G., Priego-Quesada, J. I., Aparicio, I., Giménez, J. V., Llana-Belloch, S., & Pérez-Soriano, P. (2015). Effect of 3 weeks use of compression garments on stride and impact shock during a fatiguing run. *International Journal of Sports Medicine*, *36*(10), 826–831. https://doi.org/10.1055/s-0035-1548813

Lucía, A., Hoyos, J., & Chicharro, J. L. (2001). Physiology of professional road cycling. *Sports Medicine*, *31*(5), 325–337. https://doi.org/10.2165/00007256-200131050-00004

Manigandan, S., Gunasekar, P., Praveen Kumar, T. R., Alahmadi, T. A., Subramanian, N., Pugazhendhi, A., & Brindhadevi, K. (2021). Influence of dynamic position, fluid intake, hydration, and energy expenditure on sustainable mobility transport. *Applied Acoustics*, *175*, 107809. https://doi.org/10.1016/j.apacoust.2020.107809

McDonald, R., Holliday, W., & Swart, J. (2022). Muscle recruitment patterns and saddle pressure indexes with alterations in effective seat tube angle. *Sports Medicine and Health Science*, *4*(1), 29–37. https://doi.org/10.1016/j.smhs.2021.10.007

Menard, M., Domalain, M., Decatoire, A., & Lacouture, P. (2020). Influence of saddle setback on knee joint forces in cycling. *Sports Biomechanics*, *19*(2), 245–257. https://doi.org/10.1080/14763141.2018.1466906

Ménard, M., Lacouture, P., & Domalain, M. (2020). Iliotibial band syndrome in cycling: A combined experimental-simulation approach for assessing the effect of saddle setback. *International Journal of Sports Physical Therapy*, *15*(6), 958–966. https://doi.org/10.26603/ijspt20200958

Ochoa-Puig, B., Pérez-Soriano, P., Aparicio-Aparicio, I., & Encarnación-Martínez, A. (2021, November 27 - 29). Influencia del sexo y la altura del sillín sobre las presiones ejercidas en el sillín en ciclistas amateurs. [Oral communication]. In *XI international congress of the Spanish association of sports science* (pp. 122–123). UCAM - Universidad Católica San Antonio.

Organización Mundial de la Salud. (2019). Plan de acción mundial sobre actividad física 2018- 2030. Personas más activas para un mundo más sano [PDF file]. https://apps.who.int/iris/bitstream/handle/10665/327897/WHO-NMH-PND-18.5-spa.pdf?sequence=1yisAllowed=y

Potter, J. J., Sauer, J. L., Weisshaar, C. L., Thelen, D. G., & Ploeg, H. L. (2008). Gender differences in bicycle saddle pressure distribution during seated cycling. *Medicine and Science in Sports and Exercise*, *40*(6), 1126–1134. https://doi.org/10.1249/MSS.0b013e3181666eea

Priego Quesada, J. I., Pérez-Soriano, P., Lucas-Cuevas, A. G., Salvador Palmer, R., & Cibrián Ortiz de Anda, R. M. (2017). Effect of bike-fit in the perception of comfort, fatigue and pain. *Journal of Sports Sciences*, *35*(14), 1459–1465. https://doi.org/10.1080/02640414.2016.1215496

Sanford, T., Gadzinski, A. J., Gaither, T., Osterberg, E. C., Murphy, G. P., Carroll, P. R., & Breyer, B. N. (2018). Effect of oscillation on perineal pressure in cyclists: Implications for Micro-Trauma. *Sexual Medicine*, *6*(3), 239–247. https://doi.org/10.1016/j.esxm.2018.05.002

Swart, J., & Holliday, W. (2019). Cycling biomechanics optimization—the (r) evolution of bicycle fitting. *Current Sports Medicine Reports*, *18*(12), 490–496. https://doi.org/10.1249/JSR.0000000000000665

Valenzuela, P. L., Morales, J. S., Foster, C., Lucia, A., & de La Villa, P. (2018). Is the functional threshold power a valid surrogate of the lactate threshold? *International Journal of Sports Physiology and Performance*, *13*(10), 1293–1298. https://doi.org/10.1123/ijspp.2018-0008

Verma, R., Hansen, E. A., de Zee, M., & Madeleine, P. (2016). Effect of seat positions on discomfort, muscle activation, pressure distribution and pedal force during cycling. *Journal of Electromyography and Kinesiology*, *27*, 78–86. https://doi.org/10.1016/j.jelekin.2016.02.003