PREFERRED SADDLE HEIGHT IN RELATION TO COMFORT AMONG FEMALE AND MALE OCCASIONAL CYCLISTS

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Studies on optimal saddle height have primarily used experienced cyclists and focussed on performance. This study examined the preferred saddle height (SH) in relation to comfort and potential for injury among college-aged female (n = 14) and male (n= 14) occasional cyclists (cycle approximately 1-2 x per month). This population was chosen to ensure they have not been influenced by a previous bicycle configuration. Participants cycled at a moderate pace for 5 minutes with 3 minutes rest randomly at three different SH: a) 27.5° knee flexion when crank was at bottom dead centre, b) 109% of inseam length, and c) preferred SH. Comfort levels were significantly greater at the preferred SH than at the other two heights. Regression with zero intercept was significant ($p < 0.001$, $R^2 > 0.999$) for both females (107% x inseam length) and males (112% x inseam length). However, in both cases, there was greater knee flexion angles (females = 40.2 ± 12.1°; males = 44.0 ± 6.6°) when the crank was at bottom dead centre than the range (25-30°) suggested in the literature to reduce injuries. Occasional cyclists (approximately <1x per month) may not be at a frequency to cause chronic injuries. However, for those planning on increasing the frequency of cycling for commuting, recreational or sports purposes should gradually increase saddle height such that the knee angles are within acceptable ranges.

KEYWORDS: bike, seat height, bicycle, cycling.

INTRODUCTION: Bicycling can be considered a sport, a form of transportation, a means for exercise or simply a means for recreation. A proper fitting bicycle can improve performance and reduce the chances of injury. Optimal saddle height has been extensively examined among advanced cyclists (Bini & Priego-Quesada, 2021). However, for individuals just starting out cycling and perhaps even among recreational cyclists, comfort would likely be more important than performance. Unfortunately, many of the methods developed to determine optimal saddle height focus on performance among advanced cyclists and therefore may not be appropriate for occasional cyclists.
A common anthropometric method for setting saddle height is based on inseam length (Hamley & Thomas, 1967). Although this method may be simple to use, it has been suggested that knee kinematic methods are better at establishing saddle heights that reduce knee injuries (Holmes et al., 1994). Static or dynamic (while bicycling) knee angle methods can be used to determine saddle height though the knee angle ranges are different for each method (Millour et al., 2019). In addition, equations for saddle height calculations for male cyclists (Ferrer-Roca et al., 2012) are different than those for female cyclists (Encarnación-Martínez et al., 2021). Optimal saddle heights have yet to be established for both female and male occasional cyclists without the influence of previous bicycle configurations. Therefore, the purpose of this study was to compare previous methods for determining saddle heights to preferred saddle height in relation to comfort for both sexes separately. With this information, the preferred saddle heights of occasional cyclists can be established and help determine if these heights may result in future injuries especially for those who plan on taking up cycling at a greater frequency and/or intensity in the future.

METHODS: Fifteen females (21.9 ± 1.4 years old) and fifteen males (23.0 ± 4.0 years old) participated in this study. Prior to testing, each participant was explained the testing protocol and signed a consent form approved by the Institutional Review Board where the study took place. Participants had to be free of any injuries for at least six months and did not regularly ride (i.e. less than 1-2 times per month) a specific bicycle, to avoid any influence of previous

configurations on preferred saddle height. Overall, participants indicated that they cycled on occasion but at the most, a few times per month and primarily in the summer months.
An initial warm-up consisting of a 5-minute moderate walk on a treadmill was performed on a treadmill (slope = 0%, speed = 1.34 ms^{-1}). The warm-up was performed on the treadmill rather than on the bicycle to avoid any influence an initial saddle height may have. Markers were placed on the right side of the participants at the tip of greater trochanter, the distal portion of lateral epicondyle, the lateral malleolus, calcaneus and dorsal aspect of the 5th metatarsal. Three measures of the distance between the greater trochanter and the floor, as well as three measures of inseam length were recorded. The average of each of the three measures was used for analysis.
Participants then rode a Velotron bicycle (SRAM; Chicago, IL, USA) for three bouts of 5 minutes with a 3-minute rest between each bout. The saddle was randomly set at 109% inseam length (Hamley & Thomas, 1967), at 27.5° knee flexion when the crank was at bottom dead centre and a preferred height. The 27.5° was chosen for its midpoint between the 25 to 30° range indicated by Holmes et al. (1994) to minimize knee injury. Knee angle was measure using a goniometer (Jamar; Warrenville, IL). Participants were asked to cycle at a rate of perceived exertion (RPE) of 12 on the Borg scale. RPE was chosen over heart rate or power to allow the occasional cyclists to pedal at an effort that was comfortable to them. Cadence was maintained between 70 to 80 revolutions per minute and the tension was adjusted until the appropriate RPE was reached. At 4 minutes into each bout, a digital camera (Cannon PowerShot G7X; Melville, NY, USA) recorded the right sagittal image of the participant at 60 Hz for 30 seconds. At this point, participants were asked to rate their discomfort level using the CR10 (Borg, 1998) scale, where 0 = nothing at all and 10 = extremely strong discomfort. In addition, a 30-second heart rate and power output average were recorded. Three knee angles when the crank was at bottom dead centre were digitized and a correction factor of 2.2° was added (Fonda et al., 2014) because the digitization was performed in two-dimensions.
All statistical analyses were performed for females and males, separately. Any significant differences in comfort level between the three saddle heights was calculated using the Friedman test with a Wilcoxon signed rank test for post-hoc analysis. An analysis of variance was used to determine whether there was a significant difference in the three saddle heights. Finally, a regression analysis was performed using inseam length as the predictor for preferred saddle height. For all tests, alpha was set to 0.05.

RESULTS: One male and one female data were corrupt, resulting in n = 14 for each sex. Power and heart rate were nearly identical between trials for both the female and male groups (Table 1). However, there were large variations within the two groups in terms of the power output and the heart rate as indicated by the large standard deviations.

Table 1: Power and Heart Rate average ± SD at the three saddle heights.

	Preferred	109% Inseam	27.5° Knee Angle
Female Power (Watts)	77.5 ± 16.1	83.9 ± 21.1	78.0 ± 18.3
Female Heart Rate (bpm)	143.4 ± 33.5	139.6 ± 39.4	142.2 ± 36.9
Male Power (Watts)	95.5 ± 27.8	94.6 ± 26.4	94.7 ± 29.1
Male Heart Rate (bpm)	122.0 ± 20.7	119.7 ± 18.7	117.0 ± 26.6

Median and interquartile ranges for preferred saddle height across the three saddle heights are shown in Table 2. Overall, females found their preferred saddle height more comfortable than that of the other two heights χ^2 (2) = 10.59, p = 0.005, whereas the males found their preferred height more comfortable than the 27.5° knee angle height χ^2 (2) = 8.67, p = 0.013. Average saddle heights for the females were significantly different ($F(1.6,21.6) = 4.54$, $p = 0.028$). Their preferred height was significantly lower by approximately 3 cm than at 27.5° and lower than at 109% by approximately 1 cm, but not significant. Average saddle height for the males were also significantly different ($F(1.6,20.2) = 15.2$, $p < 0.001$). The preferred height was significantly lower than at the 27.5° height by approximately 4 cm, but slightly higher (but not significant) than the 109% by approximately 1.5 cm. At the preferred saddle height, knee angles were 40.2 ± 12.1° for the females and 44.0 ± 6.6° for the males.

Table 2: Median (Interquartile Range) for comfort at different saddle heights and average ± SD saddle heights (cm). A lower value = greater comfort. * + = significant difference (p < 0.05) between the two saddle heights.

	Preferred	109% Inseam	27.5° Knee Angle
Female Comfort Rating	2.00 (1.75-3.00)*+	3.00 (2.00-6.00)*	4.50 (2.75-5.25)+
Male Comfort Rating	1.50 (0.00-3.00)*	2.00 (0.75-3.00)	3.00 (1.75-4.00)*
Female Saddle Height	81.71 ± 3.43*	82.75 ± 4.48	84.69 ± 4.16*
Male Saddle Height	87.74 ± 4.44+	85.19 ± 4.40*	92.31 ± 5.82*+

Regression analysis with zero intercept (Grainger et al., 2017) resulted in significant regression equation for both females and males ($p < 0.001$, $R^2 > 0.999$). The female preferred saddle height (cm) was equal to 1.07 x inseam (cm) whereas the male preferred saddle height was 1.12 x inseam. Saddle height was measured from the top of the saddle to the top of the pedal when the pedal was in line with the seat tube.

DISCUSSION: The goal of this study was to determine the preferred saddle height in both female and male occasional cyclists and to compare this height to traditional methods of setting saddle height. The overall results of this study suggest that both sexes are more comfortable at a saddle height similar to the 109% method established to improve performance. There were no significant differences in the saddle heights for both sexes between the preferred height and the 109% height (Hamley & Thomas, 1967). In this study females preferred a slightly lower (107% of inseam length) height and males a slightly higher height (112% of inseam length). The slightly lower saddle height for females was significantly different in terms of comfort compared to the 109% height. In the males, the higher preferred height (versus the 109% method) did improve comfort, but not significantly. Grainger et al. (2017) also found a high coefficient of determination for saddle height in relation to comfort (0.875 x inseam length, $R^2 = 0.999$), where saddle height was measured from the top of the saddle to the axis of the crank arm. Direct comparison of saddle heights cannot be made because the crank length was adjusted to 20% of leg length in that study.
There was a slight difference between the females and males in relation to the degree of knee flexion when the crank was at bottom dead centre, when pedalling at the preferred saddle height. It would be expected that the females would have a larger knee bend angle because of the lower saddle height, though they had a smaller knee bend by approximately 4 degrees. This difference could be accounted for by hip rocking or changes in ankle angles. In both sexes, the knee angle is greater than what is suggested to reduce knee injuries (Holmes et al., 1994). However, the frequency and intensity levels for occasional cyclists may not be at a level that could cause chronic knee injuries. Still, if occasional cyclists intend to start cycling for frequently, whether it be for recreation, sport or commuting, a slow increase in saddle height to knee angles that minimize injury may be warranted.
There were two primary limitations of this study. First, cross validation study is still needed to assess how well the inseam length measures perform on a different sample of recreational cyclists who do not regularly use a specific bicycle configuration. Second, a comparison between more simplistic methods for establishing saddle heights were used. These were chosen so that the general population could use these methods. However, more advanced methods (e.g. dynamic knee angles) may yield alternate results.

CONCLUSION: Saddle height is one of the key factors determining comfort in cyclists. This study established a baseline saddle height calculation for females and males in relation to comfort for occasional cyclists who have not been influenced by a previous bicycle configuration. Using inseam height as the criterion allows for the general population to be able to set their saddle heights without special equipment. Although these heights result in knee angles that could potentially result in chronic injuries, the frequency and intensity may not be at a level to cause concern.

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