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Predicting external ischial tuberosity width for both sexes to determine their bicycle-seat sizes

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A B S T R A C T

Previous studies have investigated the measurement of the external ischial tuberosity width (EITW) for bicycle seat design. In this study, the EITW values, as well as the anthropometric data, were obtained from 30 men and 30 women to develop the EITW prediction models separately for the men and the women by multiple stepwise regression analysis. The models were then validated by the data from another 8 men and 8 women. The results show that sex difference in EITW measurements was observed (male:12.0 cm; female:13.6 cm). Hip circumference is an effective predictor for EITW values with percentages of explained variances of 64.1% for male and 61.2% for female. The validation result also shows that there was no significant difference between the measured and the predicted EITWs for both sexes.
Relevance to industry: Previous method of measuring the EITW has generally employed the impression method, however, the method was limited by equipment restrictions or complex procedures. The predictive model established in this study is a simple and valid method for acquiring EITW values to assist riders to determine their seats for bicycling.

1. Introduction

Cycling exercise reduces the risk factors for chronic diseases and overweight/obesity, and improves cardiorespiratory fitness (Oja et al., 2011). Because of the rapid growth of bicycling communities in recent years, the bicycle design has been investigated. One of the designing factors for bicycle or car seats is buttock–seat contact (Udo et al., 1997; Du et al., 2013; Mohanty and Mahapatra, 2014).

When riding, the buttock–seat contact causing distinct discomfort and pain perceived by riders are mainly influenced by the degree of seated pressure on seat-protruding node and seat-pad between the seat and the rider's buttocks (Potter et al., 2008). Chen and Liu (2014) had suggested that a 6-cm seat-protruding node length is the optimal reference for bicycle seat design. Another crucial factor is the width of the seat pad. Seats with different widths may produce distinct seated pressure distributions, which are mainly influenced by the degree of seated pressure between the ischial tuberosities (ITs) of the human pelvis and the seat surface (Potter et al., 2008). Sequenzia et al. (2016) preliminarily proposed a seat-width adjuster to improve weight distribution especially since every cyclist has a different anatomical shape. In other words, knowing the geometric distance between the ITs of the pelvis may appropriately fit and support rider's buttocks on the seat.

Intrusive X-ray scanning is the most effective and accurate method for measuring the distance between human ITs (Gemery et al., 2007). However, during riding, the ITs do not have direct contact with the seat surface because they are separated by the muscle and adipose tissue that cover the pelvis. The buttocks comprise the gluteus maximus muscles and gluteus medius muscles, on which a layer of adipose tissue is superimposed and enable primates to sit comfortably without imposing weight on the legs; this also increases the stress on the buttocks. Goossens et al. (2005) have studied the pressure sensitivity of the ischial tuberosity areas and found that the buttocks' sensitivity is dependent on the size of the contact area which the pressure is exerted. This implied that the ischial tuberosities should be well supported when a seating comfort is required. Consequently, understanding external ischial tuberosity width (EITW), which represents the width of the ITs covered in fat pads, is practical for determining a bicycle seat of an individual. In practice, a narrowest seat can minimize the

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interference between the thighs and the seat during cycling. However, this seat can not completely support cyclist's buttocks (Sequenzia et al., 2016).

In addition to the practical applications of EITW measurements, different male and female pelvic structures may lead to possible variations in EITW. The differences in male and female pelvic structures include IT width, pubic arch angle, and the position of the pubic symphysis (Potter et al., 2008). Typically, women have greater IT widths than men do; in addition, the angles of female pubic arches are typically greater than 90°, whereas the angles of male pubic arches are typically less than 90°. Sauer et al. (2007) determined that the average EITW difference between men and women is approximately 18.4 mm and that the EITW measurements for men and women are 116.5 mm and 134.9 mm, respectively. Recently, the sex difference in EITW measurements between sexes was 14.0 mm in Taiwanese subjects (Chen and Yang, 2016).

By way of improving the fit between cyclist and bicycle (and assisting bicycle shopkeepers to select the right bicycle for their customers), a commercial bicycle fitting system had been proposed and developed by Christiaans and Bremner (1998). Unfortunately, the information regarding seat size was lacking in the system. Previous method of measuring the EITW has generally employed the impression method (Potter et al., 2008; Chen and Yang, 2016). However, the method was limited by equipment restrictions or complex procedures. Accordingly, developing a simple and useful prediction tool for EITW measurements is required and valuable for a rider to determine his/her bicycle seat, especially in seat width.

2. Methods

This study recruited 76 healthy male and female participants (38 of each) who were paid hourly. Data of 30 men and 30 women were used for model development, and data of the other 8 men and 8 women were used for model validation. None of the participants had musculoskeletal disorders in their medical histories, and each of them was thoroughly informed of the experimental procedure and relevant details. Informed consent was obtained from all participants, and the Ethics Committee of Chang Gung Memorial Hospital approved the experimental procedures. The mean age, height, and body mass among the participants for model development (validation) was respectively 21.2 (22.3) years, 173.9 (174.1) cm, and 66.7 (65.8) kg for the men, and 21.7 (21.9) years, 160.1 (160.8) cm, and 52.6 (51.9) kg for the women. Detailed anthropometric data for the four participant groups are listed in Table 1.

The participants were required to dress in swimwear. For implementing the impress method, this study referred to and revised the method used by Chen and Yang (2016) and Potter et al. (2008). Because the cycling posture was simulated, the angle between trunk and thigh (θ) of the participant was set at 135° (Fig. 1), which presented an average θ during cycling (Sanderson and Black, 2003). The angle was set referring to the method of a previous study (Chen et al., 2015). The measuring procedure proceeded as follows:

1) A large, round plastic basin was placed on the wooden block.
2) The top of the block was placed with clay, and the surface of the clay was evened and smoothed.
3) The clay was covered with a layer of plastic wrap to keep it moist and malleable.
4) The participants slowly sat on the clay in a squatting posture, assisted by an experimenter, thus the shape of the ITs was fully imprinted in the clay.
5) The participants carefully stood with an experimenter's assistance and examined the two concavities in the clay, placing a small steel ball at the bottom of each concavity to provide a measuring mark, and the distance between the two balls was measured using a vernier caliper and recorded.
6) Each participant was repeated the measuring procedure twice for reliability examination, and the average of the two measures was used in the analysis.

In this study, a Pearson product-moment correlation (r) was used to explore the repeat reliability of EITW measurement and an independent t-test was used to examine the difference in EITW values between the sexes. To determine whether anthropometric values were predictive of EITW, we conducted a multiple stepwise regression analysis of the EITW values (30 men and 30 wimen), using the anthropometric data (Pheasant (1988), as the items shown in Table 1) as predictors. For model validation, differences between the measured and the predicted EITW values (8 man and 8 women) were examined using a paired t-test. This study used SPSS 17.0 statistical software for the statistical analyses, with the level of significance set at $\alpha = 0.05$.

3. Results and discussion

In the analysis, the reliabilities of the repeated measurements of the participants, regardless of gender, were higher than 0.9 (male: r = 0.917; female: r = 0.930), indicating satisfactory consistency. Result also shows that the difference in EITWs between the sexes was statistically significant ($t = 5.751$, $p < .001$). The mean (SD) EITW values measured in this study were 12.0 (1.2) cm and 13.6 (0.9) cm for the male and female, respectively, which were accorded with the results of the previous studies (Sauer et al., 2007; Chen and Yang, 2016). However, the female EITW measured in this study was inconsistent with the data measured by Wang et al. (2015), the value in 8.36 cm. This may be the differences in measuring posture and testing protocol among these studies. Sauer et al. (2007) concluded that pelvic motion seems to arise naturally during seated cycling and should be considered when designing

Table 1
Anthropometric data and the EITW values[a] of the male and the female participants.

Items	Model development		Model validation	
	Male (N = 30)	Female (N = 30)	Male (N = 8)	Female (N = 8)
Age (yr)	21.2 (2.3)	21.7 (2.6)	22.3 (2.7)	21.9 (2.3)
Height (cm)	173.9 (3.8)	160.1 (4.0)	174.1 (2.0)	160.8 (3.1)
Body mass (kg)	66.7 (7.9)	52.6 (6.3)	65.8 (8.3)	51.9 (7.1)
Abdomen depth (cm)	17.5 (1.5)	15.4 (1.4)	17.3 (1.7)	15.1 (1.2)
Waist circumference (cm)	79.4 (8.9)	70.0 (7.4)	81.2 (9.5)	69.6 (7.5)
Hip width (cm)	43.3 (3.0)	43.1 (3.2)	43.8 (3.1)	43.4 (3.5)
Hip circumference (cm)	92.9 (4.9)	92.3 (5.0)	93.1 (6.0)	92.1 (5.5)
EITW (cm)	12.0 (1.2)	13.6 (0.9)	12.0 (1.3)	13.5 (0.8)

[a] Data in mean (SD, standard deviation).