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Anthropometric measurements of the female perineum for design of the opening shape of urination device

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ABSTRACT

This study measured the anthropometric characteristics of the perineum among Chinese young women. The three-dimensional surface of the perineum was reconstructed to design an opening shape for a female urination device. Twenty-four young healthy females participated in this study. The width of the perineal furrow, the diameter of the ischial tuberosity, the distance from the exterior urethral opening to the anus, the distance from the exterior urethral opening to the tuberosities, and the distance from the tuberosities to the anus were measured using the Martin measurement approach. The perineum was then scanned using a three-dimensional scanner with raster display technology. The scanned data were used for three-dimensional shape reconstruction. From the measurements, three types of relative positions among the exterior urethral opening, ischial tuberosity, and anus were discovered. The results from this study not only advance our understanding of the anthropometric measurements of the perineum but also provide anthropometric information for the design of the opening shape of a female urination device.

Relevance to industry: The anthropometric data collected in this work provide urination device designers with data for the length, width, and curvature of the perineum for the surface design of the opening part of female urination devices. The relationship between female urination devices design and perineum size proposed in this paper can provide design guidelines.

1. Introduction

Removal of urine from incapacitated humans has been undertaken using a variety of devices and methods with mixed results (Otto, 2005). While diapers collect most of the urine produced by patients, they can be subject to leakage, which can lead to rashes (Williams et al., 2008). Bedpans have been successfully used to collect urine, but they produce undesirable odors and are at times unsightly. Catheters are efficient at removing urine from men; however, catheters carry a significant risk of infection (Touré et al., 2013; Hanna et al., 2013). Thus, there is a need for a portable urine collector that is easy to use with incapacitated females.

A female urination device (FUD) or female urination aid is a device that helps a female to urinate while standing upright or confined to a bed (Female urination device, 2014). There are mainly three application fields for female urination devices. Medical FUDs are used by women who fall ill and are confined to bed, have weak bladders or bladder conditions, wear a spica brace or have suffered spinal fracture, need assistance to sit on the toilet, have undergone a vulvectomy, are wheelchair users/chair-bound, or must provide a urine sample (this is especially useful for pregnant women). Travel FUDs are used by women who frequently travel or participate in

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outdoor activities and events, where they must remain standing and clothed. Aviation FUDs are used for urine collection by female aviators and astronauts.

The main factors that need to be considered for the ergonomics design and industrial processing of FCUs include the fit of the device for the user and the urine capacity of the device. The fit is determined by the structural anthropometric measurements and size of the female physiological triangle region. Consequently, further research employing a reliable measurement system is needed to generate anthropometric data for the design of FUDs, specifically for industrial applications.

Various anthropometric studies existed for different purposes (Jeong and Park, 1990; Kayis and Ozok, 1991; Dursun Kaya et al., 2003; Paquet and Feathers, 2004; Dewangan et al., 2005; Prado-Lu and Leilanie, 2007; Parkinson and Reed, 2010). However, there are few studies on the anthropometric dimensions for the design of FCUs. Only NASA has performed anthropometric measurement of the body for the design of waste management facilities (Liskowsky, 2010), including four anatomical dimensions, lateral separation of ischial tuberosity, width of perineal furrow, anterior and posterior separation between tuberosities and exterior urethral opening, anterior and posterior separation between anus and external urethral opening. In reduced-gravity conditions, seat contours and restraints can help the crewmember locate the ischial tuberosities and thereby properly position the anus and urethra in relation to the collection devices. If airflow is used for collection and entrainment of feces and urine, it may be necessary to minimize the size of the air duct or collector opening for sealing. They proposed that the anatomical structures should be considered in the design of FUD.

Therefore, precise measurements of the perineum are very critical. The measured dimensions usually include the width of the perineal furrow, the diameter of the ischial tuberosity, the distance from the exterior urethral opening to the anus, and the three-dimensional (3D) shape of perineum. Many studies have measured a subset of the aforementioned perineum dimensions for different research purposes. Different results were obtained for the same index (e.g., for the diameter of the ischial tuberosity or the distance from the exterior urethral opening to the anus). The average value of the ischial tuberosity diameter is 9 cm as listed in the obstetric medical book (Yue and Gu, 2000; Liu and Tang, 1985; Zhang et al., 2001). Huang and Liu (2004), however, measured the ischial tuberosity diameter at 8.6 cm in a cohort of 793 pregnant women to examine the possible factors influencing the maternity delivery process. To investigate the impact of gender, power, hand position, and ischial tuberosity width on saddle pressure during seated stationary cycling, the ischial tuberosity width of twenty-two experienced cyclists was measured with a pressure mat. In this study, the measured value for the female ischial tuberosity was 13.53 cm (Potter et al., 2008). The lateral separation of ischial tuberosity for the design of body waste management facilities was measured by David, who obtained a range of 11–16 cm (Liskowsky, 2010).

The measurement values of the ischial tuberosity diameter used in the obstetric medical books, average value 9.0 cm, are in a similar range to the diameters presented by Huang (2004), 8.6 cm. The value from Potter et al. (2008) with 13.53 cm is within the range determined by Liskowsky (2010), 11–16 cm. Although the results from these studies were obtained with the same dimension, there are still large differences among the measured values.

Even with the great capabilities of Martin (traditional) anthropometric instruments for conducting the anthropometric measurement, it is difficult to reflect the 3D structure of the perineum surface (Xi and Chen, 2010). With the development of digital photography and image analysis techniques, 3D optical scanning has recently made it possible to reconstruct the body shape (Han et al., 2010; Ma et al., 2011; Sims et al., 2012) and local three-dimensional shape of physiological structures (Burnsides et al., 1996),such as body (Ma et al., 2011), hand (Harih and Dolsak, 2013; Choi et al., 2014), foot (Witana et al., 2006; Tu, 2014) and breast (Zheng et al., 2007). And the 3D anthropometric is more consistent and accurate than the traditional manual measurement (Han et al., 2010). However, no approach has reconstructed the 3D surface of the perineum.

So far, there is no precise or systematical anthropometric measurements of female perineum, not to mention the 3D surface model reconstruction. Thus, the present study aims to: 1) systematically and precisely conduct anthropometric measurements of the perineum; 2) examine whether these measured dimensions are related to each other; 3) develop an accurate approach to reconstruct the 3D surface of the perineum and apply it to female participants; 4) discover the relative positions among the exterior urethral opening, ischial tuberosity, and anus; and 5) analyze the relationship between the perineum dimensions and the opening shape design of a urine collection device. The results from this study will provide basic guidelines for FUD design.

2. Materials and methods

2.1. Participants

Twenty-four healthy young Chinese females participated in this study (Table 1). Participants were randomly recruited from the research staff of the Astronaut Research and Training Center of China, the teachers and the students of Beihang University. Measurement procedure received approval from the Beihang University and Astronaut Research and Training Center of China. The participants provided written consent prior to participation. The measurements were taken place at Beihang University and Haidian Maternal & Child Health Hospital of Beijing. All participants were free of any gynecological disease and were paid for their participation.

2.2. Experimental set-up

A customized measurement chair similar to the obstetrics and gynecology examination chair (Fig. 1-a) for the measurement in Beihang University, vernier caliper, pelvimeterone-off glove, medical alcohol, and iodine were used for the Martin measurements (traditional measurements). The five main dimensions reflecting the female perineum were precisely measured in this study (Fig. 1-b), including the width of the perineal furrow (A in Fig. 1-b), the ischial tuberosity diameter (B), the distance from the exterior urethral opening to the tuberosities (C), the distance from the exterior urethral opening to the anus (D), and the distance from the tuberosities to the anus (E). Disposable underwear and a 3D measurement scanner for phasic raster display (3D CaMega, China) were used to develop the reconstruction approach and reconstruct the 3D surface of the perineum. The resolution of the scanner was less than 0.05 mm.

2.3. Experimental procedures

First, the participants were taken one-by-one into a closed room with a female gynecologist who performed the measurements. In

Table 1
The summary statistics for the demographic information of participants.

	Age (years)	Mass (kg)	Height (cm)
Range	21–38	48–66	155–174
Mean	31.08	57.16	163.81
SD	4.37	5.14	4.93