

## Onset of Puberty: Mother Knows Best

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### ABSTRACT

**Study Objective:** Several strategies have been proposed to determine onset of puberty without examination by a trained professional. This study sought to evaluate a novel approach to determine onset of puberty in girls.

**Design, Setting, and Participants:** This study used the Cincinnati cohort of the Breast Cancer and the Environment Research Program. Girls were recruited at 6-7 years of age and followed every 6 months in the initial 6 years, and annually thereafter. Breast maturation and foot length were performed at each visit by health professionals certified in those methods. Mothers were asked to provide the age at which they believed that their daughter's shoe size had increased more rapidly.

**Results:** These analyses include 252 participants. Age at increase in shoe size was correlated to age at onset of puberty ( $r = 0.21$ ) and increase in foot length ( $r = 0.24$ ). The difference of reported age of increased shoe size was 0.46 years before breast development.

**Conclusion:** Reported increase in shoe size occurred somewhat earlier and was significantly correlated to age of breast development. These preliminary results suggest that mother's report of increase in shoe size appear to be as accurate as reports of other indirect methods of determining onset of puberty, such as self- or maternal estimates of breast development.

**Key Words:** Puberty onset, Breast development

### Introduction

Determination of pubertal status, both absolute (current pubertal stage) and relative (early, on time, or late relative to peers), is important for comparison with physiologic measures, as well as vulnerability to risk-taking behaviors. For example, laboratory parameters such as alkaline phosphatase and hemoglobin are affected by pubertal status, and girls who mature earlier than their peers have a greater likelihood of mental health issues as well as engaging in risk-taking behaviors, such as tobacco use and sexual activity, which may carry into their adult years.<sup>1-3</sup> In addition, earlier pubertal timing is associated with greater risk of several adult morbidities, such as breast cancer (particularly premenopausal breast cancer)<sup>4</sup> and insulin resistance and type 2 diabetes.<sup>5</sup>

Multiple methods have been used to determine pubertal status in both the clinical and research areas. Dorn et al<sup>6</sup> reviewed different approaches to evaluation of pubertal maturation and noted that researchers reported direct assessment by study staff as the single most frequently cited approach, although many studies reported "according to Tanner" without further specifying the technique used. The

objective of this study was to compare a novel approach to determine the onset of puberty, using recalled changes in shoe size.

### Materials and Methods

#### Participants and Procedures

This study used a subset of the Cincinnati puberty study cohort of the Breast Cancer and the Environment Research Program. Participants were recruited at 6-7 years of age and followed every 6 months in the initial 6 years and annually thereafter. The study protocol has been described in detail<sup>7</sup> and was approved by the Cincinnati Children's Hospital Institutional Review Board.

Breast maturation was performed at every visit by a female advanced practice nurse or physician (clinician), trained and certified for this study, using the methods published by Marshall and Tanner,<sup>8</sup> with the addition of breast palpation. Foot length was assessed at each visit by the clinician using the Brannock foot device (Liverpool, NY) by staff trained and certified in that technique.

We surveyed parents of school-aged children not in the study to determine how to ask families about changes in shoe size, and incorporated their suggestions into the study survey. When study participants were 10-11 years of age (range, 9-13 years), we asked mothers of participants, "How old was your daughter when she began needing larger shoe sizes at a faster rate?"

Onset of puberty was defined by age at breast stage 2 (B2), as published previously.<sup>9</sup> Foot size velocity was

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calculated by taking the difference in value between consecutive visits divided by length of time between those visits and then annualized. The age at increase in foot length was determined by the initial age when the annualized foot length increase exceeded 1.5 cm per year. Pearson correlation coefficients were calculated for comparisons of age at increase in foot length, age that shoe size increased, and age at breast stage 2. The kappa ( $\kappa$ ) statistic was used to assess interrater agreement of the 2 reports when a mother reported age in change of shoe size at 2 different visits; the  $\kappa$  statistic evaluates observed agreement compared to that expected by chance alone.<sup>10</sup>

## Results

This study included 252 participants with a mother's report regarding age that the shoe size increased. There were 2100 clinical observations with simultaneous foot length and breast maturation assessments performed in these participants. The majority of reports (228/252, 90.5%) regarding the age that shoe size increased were in the 24-month window around the age of breast development. There were 2 reports from 17 mothers; difference in age of shoe size change was 0.24 years, and agreement was moderate ( $k = 0.53$ ).<sup>10</sup> Two mothers misunderstood the question and reported that the age of shoe size increase was less than 1 year of age, and were excluded from the analyses.

Age at onset of puberty was significantly different by race: 8.4 years in black and 9.2 years in white participants. The mean age of pubertal onset (regardless of race) was 8.77 years; the mean age of increase in foot length velocity was 8.95 years, and the estimated age that shoe size increased was 8.57 years. The correlation of increase in foot growth velocity with increase in shoe size was 0.26 ( $P < .0001$ ) (Table 1).

There was no significant difference in mean age of measured increase in foot length and age of pubertal onset in a given individual (Fig. 1). The reported increase in shoe size was 0.46 years before the age of B2 (Fig. 2); the Pearson correlation between shoe size and age of pubertal onset was 0.21, and shoe size increase with actual increase in foot length was 0.24 (Table 1). In addition, 76% of the parent reports of age at increase in shoe size were within 12 months of the calculated increase in foot length (Figure 2).<sup>11–23</sup>

## Discussion

Tanner noted that the first evidence of pubertal development in girls is onset of the growth spurt, with the limbs growing before the trunk and the distal limbs before the

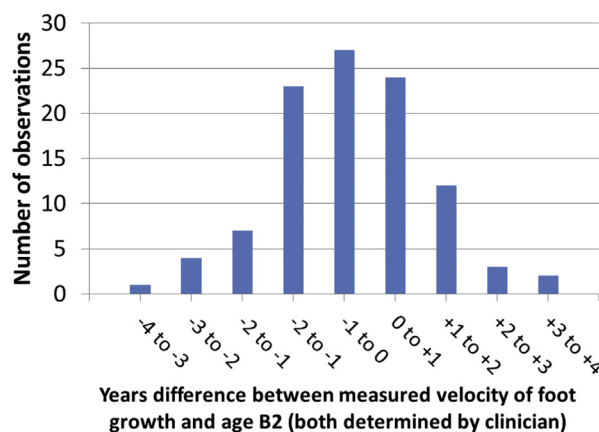


Fig. 1. Difference (years) between measured increase in velocity of foot growth and age at breast development (B2).

proximal limbs.<sup>24</sup> We previously reported that the increase in foot length velocity and the pubertal growth spurt occurred at the same age and before breast stage 2.<sup>25</sup> This observation led to the concept of this project, which was to ask the mothers of our participants to estimate the age at which their daughters had a noticeable increase in their shoe size. Two mothers misunderstood the question and provided the age at which their daughters first wore shoes. Overall, the mothers' report of the noticeable shoe size increase occurred 0.46 years before the appearance of breast stage 2 development, consistent with Tanner's observation, and correlated significantly with the actual increase in foot length. The increase in foot length and shoe size occurred concurrently with the previous report of increase in serum concentrations of estradiol in this cohort 6–12 months before B2.<sup>26</sup> We found no previous reports in the literature of studies using foot size to assess pubertal maturation.

In addition to clinician assessment, there have been multiple approaches to estimate age at onset of puberty, including self and parent assessment through line figures or photographs, scales examining several different pubertal milestones, and levels of sex hormones. Our results are somewhat lower but compare favorably to previous studies using participant or parent assessment, which are

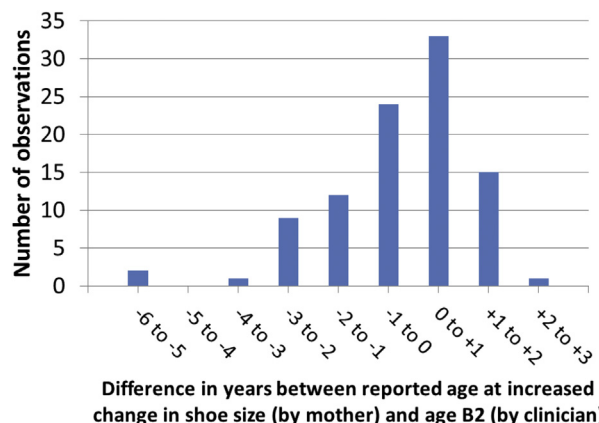


Fig. 2. Difference (years) between reported age at increased change in shoe size and age at breast development (B2).

Table 1  
Association of Ages of Breast Development, Change in Measured Foot Length, and Reported Age of Shoe Size Increase

	Age–Shoe Size	Age–Pubertal Onset
Age–foot length	0.243 (0.0014)	0.259 (<0.0001)
Age–shoe size		0.205 (0.0074)

Data are Pearson correlation coefficient (probability value).

**Table 2**  
Studies Examining Alternatives to Direct Pubertal Assessment

Authors (Year)	Participants, n	Age, yr	Results
Duke, Litt (1980)	43	9–17	K = 0.81 BR (self, examiner) K = 0.91 PH (self, examiner)
Morris, Udry (1980)	47	12–16	R = 0.63 BR (self, examiner) R = 0.81 PH (self, examiner)
Brooks-Gunn (1987)	151	11–13	R = 0.52–0.68 BR (self, examiner) R = 0.58–0.74 PH (self, examiner) R = 0.69–0.82 BR (mother, examiner) R = 0.57–0.83 PH (mother, examiner)
Brooks-Gunn (1987)	78–142	11–13	R = 0.74–0.75 (self, PDS) R = 0.54–0.58 (examiner, PDS)
Hergenroeder (1999)	107	8–17	K = 0.35–0.42 BR (self, examiner) K = 0.26–0.44 PH (self, examiner)
Wu (2001)	621	9–10	K = 0.32–0.51 BR (self, examiner)
Shirtcliff (2009)	78	9–14	K = 0.36 BR (self, examiner) K = 0.36 BR (examiner, PDS) K = 0.29 BR (self, PDS)
Desmangles (2006)	130	11.3 ± 3	K = 0.49 BR (self, examiner) K = 0.68 PH (self, examiner)
Lamb (2011)	115	8–18	K = 0.81 BR (self, examiner) K = 0.78 PH (self, examiner)
Pereira (2014)	481	6–9	K = 0.10 BR (self, examiner) K = 0.70 (mother, examiner)
Jaruratanasirikul (2015)	927	7–15	K = 0.50 BR (self, examiner) K = 0.68 PH (self, examiner)
Rasmussen (2015)	418	7.4–14.9	K = 0.28 BR (self, examiner) K = 0.55 PH (self, examiner) K = 0.28 BR (mother, examiner) K = 0.41 PH (mother, examiner)
Terry (2016)	282	6–15	K = 0.66 BR (self, mother) K = 0.38 BR (self, examiner) K = 0.46 BR (mother, examiner)
Chavarro (2017)	131	10.3 ± 1.7	R = 0.71 BR (self, examiner) R = 0.89 BR (self, “true” status) R = 0.80 BR (examiner, “true” status)

BR = breast stage; K = kappa statistic; PDS = Peterson Developmental Scale; PH = pubic hair stage; R = correlation coefficient.

summarized in Table 2. The majority of these studies use line drawings, figures, and photographs; alternatively, scales have been designed around a series of questions about pubertal milestones, such as Pubertal Development Scale (PDS).<sup>27</sup> The PDS is the most frequently used self-report method without figures or drawings; figures and drawings of breast and pubic hair have been regarded by some schools and parents as offensive.<sup>28</sup> Our method has an advantage over the PDS in that there is minimal time and little apparent affiliation with puberty and sexual characteristics that might trouble parents of adolescents, but the disadvantage is that the only data obtained are associations with onset of breast development, and by inference, the onset of the pubertal growth spurt.<sup>25</sup> Either of these associations would be useful to categorize a given individual as having an early/on-time/late maturation. Additionally, 76% of our participants entered puberty within 12 months of the reported increased velocity of shoe size change. Of note, the pubertal growth spurt in boys is a later pubertal event, but increase in shoe size should apply as well. Moreover, boys may have even greater reticence than girls for direct maturation assessment.

To avoid confusion that we noted with responses from 2 mothers, we would recommend revising the question to read, “Since entering kindergarten, how old was your daughter when she began needing larger shoe sizes at a faster rate?” Of note, we used assessment by the health professional as the standard, although the recent study by

Chavarro et al using a method of triads, which incorporated self and physician assessment of maturation status with average hormone ranks, noted self-assessment may be superior to physician assessment.<sup>23</sup>

This study provides a new methodologic approach to determine pubertal onset in girls (B2) that is brief and straightforward and that provides a degree of accuracy similar to that of many of the published studies. We are not proposing to replace direct clinician assessment, which is still considered the gold standard, but offer this straightforward question as a noninvasive tool to assess pubertal onset in research studies.

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