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PERSPECTIVE

WHY PUBERTY RATING IS MANDATORY FOR GROWTH MONITORING OF A PERI-PUBERTAL CHILD ATHLETE?

Meritorious Professor Dr. Syed Arif Kamal
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Pubertal development affects child growth in terms of leveling of height velocity of the child and appearance of puberty-induced energy-channelization (energy-channelization III), in which a temporary drop in CDC percentile-of-height is associated with a gain in CDC percentile-of-mass. Puberty represents additional puberty-induced growth, which accelerates up to the age at peak velocity. After that it decelerates until the growth ends.

It is, therefore, well-established that learning about the normal differences in height gain of children and development of puberty is fundamental for any researcher or pediatrician dealing with pediatric endocrinology. By observing and examining youngsters referred to clinics of pediatric endocrinology, regularly, the child specialist should, immediately, appreciate the nuances of regular child growth and development (Wood *et al.*, 2019).

A child-development expert, James M. (Mourilyan) Tanner (Sunday, August 1, 1920, Camberley, United Kingdom – Wednesday, August 11, 2010, Wellington, United Kingdom) identified the visible stages of puberty, which could be recognized from the inspection of totally-stripped bodies of youngsters (Tanner, 1962). This is essential to determine if the child is achieving all the milestones of pubertal development. These days, such visible stages of puberty are identified as the Tanner stages or, in other words, sexual-maturity ratings (SMRs). They serve as a general guide to anatomical development, although each individual has a different puberty roadmap.

The author, strongly, recommends that puberty rating, based on Tanner scales, must be performed at each physical examination for peri-pubertal and pubertal girls and boys, in particular, those participating in vigorous sport activities, *e. g.*, gymnastics. Prior to physical examination a detailed history should be obtained to determine whether puberty is consonant (pattern of bodily changes consistent with normal puberty), often called 'true-precarious puberty', or disconsonant (pattern of bodily changes inconsistent with normal puberty), also termed as 'pseudopuberty'.

Because there exists energy-channelization due to the demanding routines of gymnastics, these child gymnasts are faced often with 'delayed puberty' resulting in failing to achieve their entire potential regarding height pick-up. A very well-publicized example is of star gymnast from Romania, Nadia Elena Comăneci (Kamal *et al.*, 2017).

Those child gymnasts, who show no signs of entering puberty, are considered 'pre-pubertal gymnasts' (Figure-1). Gymnasts, who are going to hit puberty, are classified as 'peri-pubertal gymnasts'. Their height

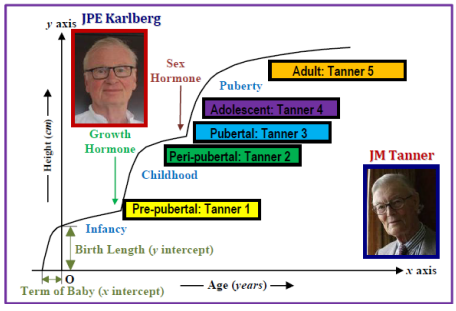

Figure-1: Karlberg's ICP model of child growth and various stages of puberty related to Tanner scores

function becomes, almost, parallel to the *x* axis (the axis representing age), which implies that the height velocity approaches zero, according to Johan P. E. (Petter Einar) Karlberg's ICP (Infancy-Childhood-Puberty) model, proposed in his PhD dissertation of 1987. Those gymnasts, who have begun to enter puberty, are termed as 'pubertal gymnasts'. 'Adolescents' are those gymnasts, who are, already, well into puberty. 'Adults' are those gymnasts, who have finished the process of attaining puberty and show the trend of achieving their final-adult height (vanishing of height velocity). This occurs, when a girl reaches the age of 19 *years*. For a boy this age is 21 *years* (Kamal *et al*., 2021).

The author has, loosely, related these puberty stages to Tanner scores — in case there are different scores in various segments, an average (arithmetic mean) is taken to assign score**:**

Tanner scale 1: pre-pubertal — describes what is happening to the youngster before the presence of any physical signs of puberty, generally, after 8th birthday of a girl and after 9th or 10th birthday of a boy.

Tanner scale 2: peri-pubertal — marks the start of physical development, hormones activate and initiate sending signals to the body.

Tanner scale 3: pubertal — physical changes are becoming more recognizable for both girls as well as boys, accompanied by a rapid gain in height, the youngster's hormones are working very hard, extending development from the previous stage.

Tanner scale 4: adolescent — puberty is almost complete during stage 4; both girls and boys are experiencing many changes.

Tanner scale 5: adult — begins the peak of development of an individual, who reaches complete physical maturation, including attaining of final-adult height.

Puberty could be considered as an interval described by the appearance of secondary-sexual characteristics, increased height velocity, rise in sex-hormone secretion, gonadal maturity (testes in boys; ovaries in girls), and the capability for reproduction. The process is, generally, finished within 2-5 *years*. Before secondary- sexual characteristics appear, activity increases and interaction enhances among the hypothalamus, the pituitary and the gonads. It is well-understood that the appearance as well as the further progression of puberty is governed by the hypothalamo-putitary-gonadal axis. Hypothalamus is responsible for the production of gonadotrophin-releasing hormone (GnRH), the key regulator of the reproductive axis. The hormones of the pituitary gland are proteins that consist of polypeptide chains, *i. e.*, Leutinizing hormone (LH) and follicle-stimulating hormone (FHS). The testes in boys and the ovaries in girls start and progressively increase the production of testosterone (in males) and oestrogen (in females). These hormones are, then, responsible for secondary-sexual characteristics that establish puberty.

An example of puberty rating, explained through Growth-and-Obesity Vector-Roadmap 4.5 (Kamal, 2022) of Hr. S., is available as Additional File on author's homepage**:** https://www.ngds-ku.org/Papers/J73/Additional_File.pdf

This document, also, provides mathematical relationships describing 'excessively-early puberty' (very-early bloomer) — the age-of-onset of puberty (the age when Tanner stage of 3 is achieved, which is the arithmetic mean of 'thelarche', signs of pubertal development superior to naval, and 'adrenarche', signs of pubertal development inferior to naval, in girls and equivalent average in boys) falls below two standard deviations subtracted from the gender-specific mean age, an additional condition exists, which states that the sum of modified-scaled percentile-of-height and modified-scaled percentile-of-mass is equal to or more than 100; 'early puberty' (early bloomer) — the age-of-onset falls between two and one standard deviation, each subtracted from the gender-specific mean age; 'normal puberty' — the age-of-onset of puberty lies within one standard deviation of the gender-specific mean age; 'delayed puberty' (late bloomer) — the age-of-onset falls between one and two standard deviations each added to the gender-specific mean age; 'excessively-delayed puberty' (very-late bloomer) — the age-of-onset exceeds two standard deviations added to the gender-specific mean age; 'precarious puberty' — the age-of-onset falls below two standard deviations subtracted from the gender-specific mean age, an additional condition exists, which states that the sum of modified-scaled percentile-of-height and modified-scaled percentile-of-mass is less than 100. Clinicians start to suspect precarious puberty when secondary-sexual characteristics show up before 8th birthday of a girl or 9th birthday of a boy. Precarious puberty is, at times, responsible for enhanced skeletal development and a reduction in final-adult height. Two forms of precarious puberty may be termed as 'gonadotrophin-dependent-precarious puberty', also, known as 'central-precarious

puberty (CPP)', due to premature activation of the hypothalamo-pituitary-gonadal axis, and 'gonadotrophin-independent-precarious puberty (GIPP)', due to autonomous secretion of sex steroids.

It is to be appreciated that pubertal development is linked to 'physical maturity' (related to chronological, phenotypic and skeletal ages), whereas 'mental maturity', 'social maturity' as well as 'spiritual maturity' each is related to the developmental age. 'Chronological age' is determined by taking the difference of the date, when the age needs to be computed, and the date of birth. 'Developmental age' is the age at which a child's brain functions. 'Phenotypic age' is the age at which a youngster's body functions (also termed as 'biological age'). 'Skeletal age' is the age at which a boy's or a girl's skeleton is formed (also called 'osseous age'). There are variations in age-of-onset of puberty and these seem to be strongly correlated with osseous maturation as compared to the chronological age.

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