Bone Age Estimation for Whom by Whom? By Which Method?

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Abstract

Bone (skeletal) age determination is the simplest and most used index for the assessment of developmental and physiological age in healthy children and those with growth disorders. At present the test is done by manual or automated reading of the hand and wrist X-rays, necessitating two visits by the child: to the pediatrician and radiology departments. A newly developed simple quantitative ultrasound technique (QUST) using several hand and wrist bones, which can be performed in the pediatrician's office could combine the child's growth and biological age evaluation in one visit.

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Key words: *Growth, Bone (skeletal) age, Bone age/ Chronological age ration, Methods of bone age determination, Developmental age, Physiological age*

Introduction

If a child is healthy, his growth, development and physiological function fit its chronological age however, if the child suffers from a physio-pathological disorder, discrepancies between the chronological age and biological age develop. This difference may start "*in utero*" and last until the onset of adult age or beyond.

Crampton (1) was the first to introduce the idea of "developmental age or physiological maturity". Among the measures of physiological milestones are the age at menarche in girls (2) and age at spermarche (first ejaculation) in boys (3). Another index reported was the age at maximum height velocity (4). However, these milestones are only of certain stages of the child development and not a consecutive evaluation of the physiological age.

Skeletal (bone) as a measure of developmental stage has been introduced by several authors starting in the 1930's (5-7) and resulted in the printing of Atlasses of Skeletal.

Maturation of the Hand (8,9). Tanner (10) developed this concept further and showed that using consecutive hand and wrist X-rays during growth, each bone begins as a primary center of ossification, continues with a stage of enlargement, shaping the ossified area, and finally reaches epiphyseal fusion as a sign of adult age. Of importance is the observation that the sequence of events in each bone is the same in all individuals, irrespective of whether the bone development is retarded or advanced in relation to the individual's chronological age. Thus was born the term bone age (BA) (short for skeletal age) vs. chronological age (CA). Since then BA has become the most convenient, simplest and most frequently used measure of biological, i.e. developmental age. Study of the BA from infancy to adult age in healthy girls and boys showed the difference in physical maturation between the genders and lead to improved reference atlasses

for different populations (11-14); The American Atlas by Greulich and Pyle (11) and the British one by Tanner and Whitehouse (14) from birth to maturity have been so far the most used references. Comparing these atlasses, it appears that the American children investigated were somewhat more mature for a given chronological age than the Dutch (12) or English children (15). The standards are published in the form of radiographs. Comparison of a given radiograph with the set of standards involves a good deal of subjective judgment and systemic errors between one rating to another (10). The consistency of a single observer was found to fall within ±6 months (16).

Attempts were also made to assign a skeletal age for each bone of the hand (17). This led to the new Tanner-Whitehouse-Healy Atlas (18). The negative aspects of these methods are their limitation to the prepubertal or early pubertal stages and that a given bone age may be between one stage and another. It is also a time consuming method.

In recent years attempts have been made to exchange the use of the simple manual method of BA estimation of the hand and wrist X-ray with automated methods (19,20). Reviewing the available data on the automated X-ray reading DeSantis *et al.* (21) concluded that there is not enough established data yet for the healthy population and that the debate is ongoing.

At present skeletal maturity assessment is part of any growth and development evaluation. Following is a discussion on the importance and usefulness of the consecutive use of bone age not only by specialists in investigations and follow-up of children with abnormal growth, endocrine and metabolic disorders (22,23) but also by the primary care pediatrician (**Figure 1**).

In addition, bone age determination is also used by anthropologists to compare the physiological development between different ethnic and racial groups (24) comparing the rate of development of various parts of the body such as dental age (25) or peak mandibular growth (26). With the continuously increasing use of growth hormone treatment of short children with or without GH deficiency, BA estimation became an indispensible tool to evaluate the bone age growth velocity relationship (27,28) and as a predictor of growth response (29) in states with normal GH secretion, and possible GH resistance such as Turner syndrome (30) Shox haploinsuffciency (31), in under or over nutrition (32,33) (**Figure 2**) and in forensic age estimations (35). BA estimation is also used during the diagnosis and follow up of children under investigation for hypo- or hyperthyroidism, hypercorticism or children receiving

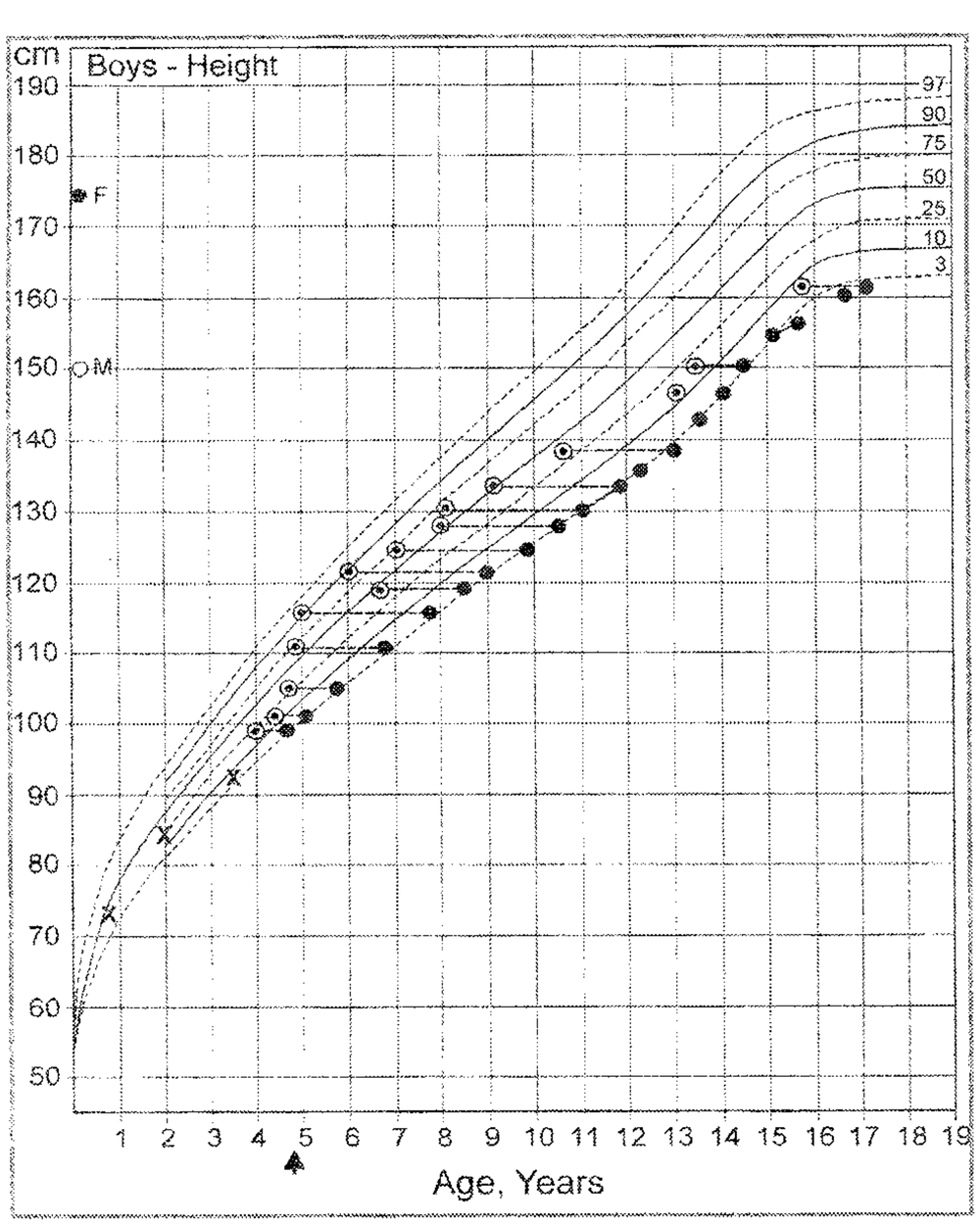

Figure 1. Height (•) and bone age (o) of a boy growing along the lower centiles. *Note: bone age determinations in routine follow up.*
F=father's height
M=mother's height
X=previous measurements
↑=age at referral

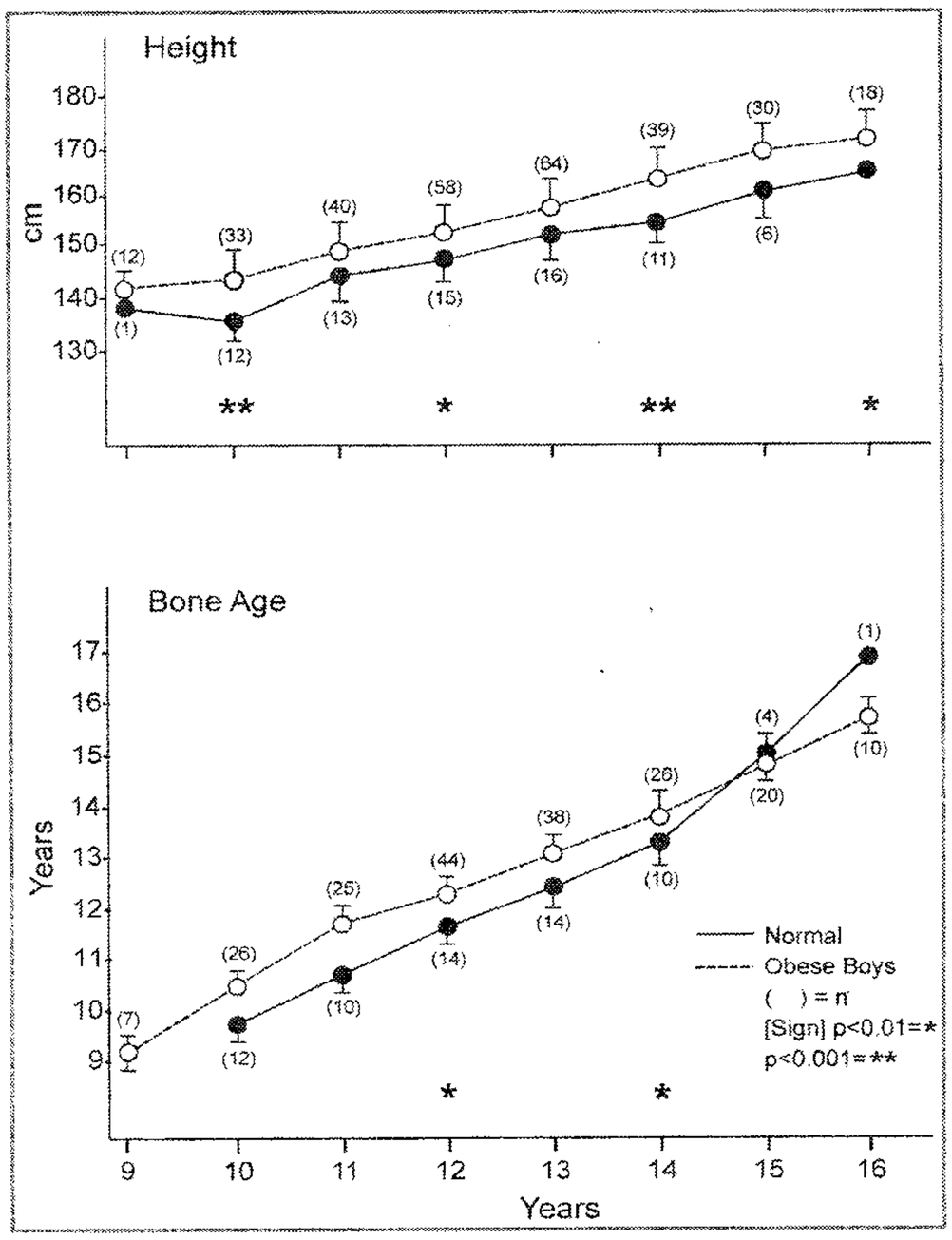

Figure 2. Height and bone age of obese and non-obese boys
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hydrocortisone for allergic or immunologic diseases, and delayed or precocious puberty (**Figure 3**), and in children of parents (especially mother) with a history of delayed or early puberty.

Thus BA determination is an extremely useful and very frequently used index in pediatric medicine.

The presently used methods require two visits: one to the pediatrician and another to a radiological department which delay the decisions of the physicians.

The quest for improving this state is not new; quantitative ultrasound techniques (QUST) to assess skeletal maturation have been reported, such as quantifying the cartilage of the femural head (36) or at a single site of the head of the ulna (37). Both these methods showed little agreement with the Grenlich and Pyle method (38). Recently a novel method of QUST (BAUS by Sonic Bone Medical, Rishon Le Zion, Israel) using several bones (phalanx III, distal metacarpal bones, distal radius ulna) has been found compatible with the manual and automated Greulich and Pyle and with the TW3 methods (39,40). This simple technique can be used in the pediatrician's office and could help to reach a faster diagnosis of growth problems and earlier treatment decision. Further experience with this technique will prove whether this method meets its expectations.

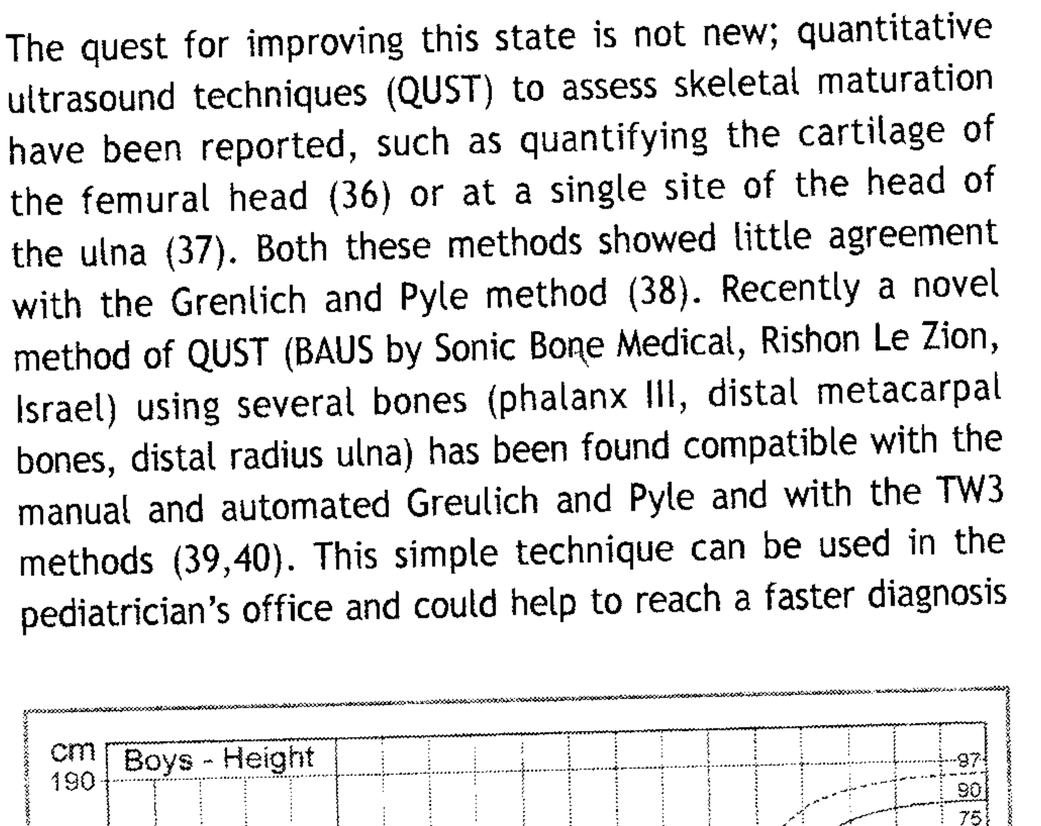

Figure 3. Height and bone age of a boy with fast puberty treated by a gonadotropin releasing hormone analog (GnRH)

F=father's height

M=mother's height

X=previous measurements

↑=age at referral

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Disclosure

Zvi Laron has nothing to declare

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