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A Correlation of Peak Height Velocity and Olecranon Apophysis Ossification Assessed by Ultrasound

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A B S T R A C T

Peak height velocity (PHV) is defined as the period of the fastest growth during puberty. An ability to predict annual growth and the timing of PHV may provide an opportunity to modify treatment of many diseases and conditions of the skeletal system such as scoliosis and kyphosis, slipped capital femoral epiphysis, leg length inequality and adolescent Blount's disease. There is a good correlation of peak height velocity and skeletal age determined from the radiographic assessment of olecranon. To avoid radiation, we tested value of olecranon ultrasound in prediction of annual growth and peak height velocity. In present study, using ultrasound, we made a classification of olecranon apophysis in 7 levels (0–6) according to the amount of cartilage left unossified. In 134 healthy children, aged from 10 to 15, evaluation of olecranon sonographs and staging was done by two observers in two spaced time intervals. Calculation of intra-examiner and inter-examiner agreement presented satisfactory reliability (intraclass correlation coefficient for Rater 1=0.967 and Rater 2=0.836) and very good reproduciblity (Cohen's Kappa 0.85). We measured increase in height, during six month period, for 54 children, who were classified by ultrasound in levels from 0 to 6. The greatest growth was noted in children classified as level 4. Olecranon apophysis maturity level 4, assessed by ultrasound could correspodent to peak height velocity.

Key words: *peak height velocity, skeletal maturity, ultrasound assessment*

Introduction

Puberty is the period of human life in which rapid growth and sexual development occurs. Girls experience puberty at an average age of 11 years and boys about two years later. Onset of puberty is characterized by a sudden increase of growth in height. Before puberty, the annual growth of the children average 5.5 cm, and during puberty it accelerate to about 1 cm per month[1]. Peak height velocity (PHV) is defined as the period of fastest growth during puberty[2]. It takes place in the second year of puberty, and then followed by period of deceleration of the growth. Peak height velocity is important to determine in many diseases and conditions of a skeletal system such as scoliosis and kyphosis, slipped capital femoral epiphysis, leg length inequality and adolescent Blount's disease[3–5]. In the treatment of fractures in children, timing PHV determine the method of therapy in terms of surgical or conservative treatment[6].

Determining PHV requires several consecutive measurements of height at intervals of 6 months during puberty[2]. Thus, the data of PHV gets retrograde, in the phase of slower growth of the child, when certain interventions on the musculoskeletal system delayed.

The ability to correlate the timing of PHV to skeletal maturity (bone age) may provide an opportunity to modify treatment based on amount of growth remaining[2,4,7–9].

There are several methods to determine bone age using X-rays of different regions of the body: hand and wrist, elbow and pelvis.

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Greulich-Pyle's and Tanner-Whitehouse III methods can be used to predict PHV but requires scoring individual bones of hand and wrist, making it impractical clinically[10,11].

The focus of Risser method is iliac apophysis ossification that occurs unfortunately, a few months after the apex of pubertal growth[12].

The Sauvegrain method uses anteroposterior and lateral radiographs of the left elbow to determine skeletal age based on 27-point scoring system of four anatomical landmarks: the lateral condyle/epicondyle, the trochlea, the olecranon apophysis and the proximal radial epiphysis[13]. Charles and Dimeglio simplified Sauvegrain method by analyzing exclusively olecranon apophysis[14]. The authors have divided the olecranon ossification in 5 substages (two ossification nuclei, half-moon image, rectangular aspect, the beginning of fusion and a complete fusion. Bone age determined by the Charles method correlate very well with bone age determined by the Sauvegrian method.

A reduction of the radiation dose may be achieved by using ultrasound devices to estimate of the skeletal age.

Due to its simplicity, accessibility and non-ionizing nature the elbow ultrasound could be an excellent alternative to X-rays to determine bone age[15].

The aim of this research was to test weather assessment of olecranon apophysis ossification by ultrasound have value in prediction of annal gowth and peak heght velocity.

Calculaton of intra-examiner and inter-examiner agreement for this new method will be performed.

Subjects and methods

275 healthy school children, age from 10 to 15, were enrolled in this prospective clinical study. During first visit body height and sitting height was measured by a stadiometer. We determined a chronological age of the subjects, calculated it from the date of the birth and expressed it as a decimal number with one decimal place (eg. for a child at the age of 12 years and 6 months chronological age is 12,5). In all subjects we made ultrasound examination of iliac crest as described by Torlak at al., in order to determine Risser grade[16].

In 134 subjects graded as Risser 0, further we performed ultrasound examination of olecranon apophysis. Transverse and longitudinal sonograms were recorded and printed. Evaluation of sonographs was done by two observers (one orthopaedic surgeon who made ultrasond examination and one general surgeon) and olecanon apophysis was staged in seven levels (0–6) according to the amount of cartilage left unossified (Figures 1a–g).

Reevaluaton of sonographs and staging olecranon apophysis was done 7 days later in order to determine both intrareter and inerrater reliablity.

After 6 months, there were children 54 for the growth analysis. We repeated height measurements and calculate increase in height and sitting height. The main characteristics of the sample are shown in Table 1.

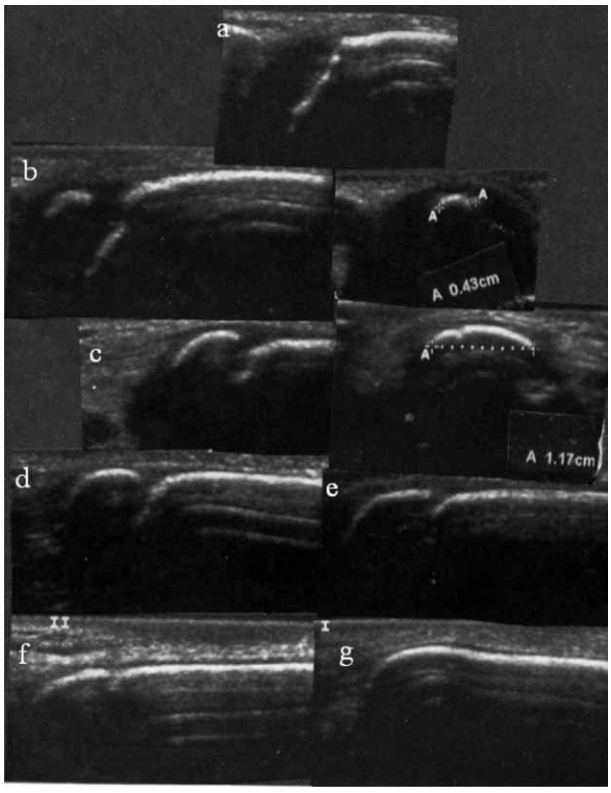

Fig. 1. a) level 0: no olecranon apophysis ossificaton, b) level 1 (L1): appeareance of olecranon apophysis ossification on longitudinal scans, on transverse scans ossificaton center less than 5 mm, c) level 2 (L2): on transverse scans ossificaton center more than 5 mm, on longitudinal scans there is more than 1 mm of a cartilage between periosteum and ossification center, d) level 3 (L3): on longitudinal scans, ossification center reaching periosteum, oval shaped apophysis, e) level 4 (L4): on longitudinal scans, ossification center reaching periosteum, rectanglar shaped apophysis, f) level 5 (L5): on longitudinal scans olecaranon apophysis fusion almost complete, g) level 6 (L6): on longitudinal scans olecaranon apophysis fusion complete.

Results

ICC, intraclass correlation coefficients were calculated in order to estimate the concordance between the two measurements of the same rater, meaning the reliability for a single judge's rating. In Table 2a and 2b we can see that individual concordance was high for both raters, even though it was much higher for the rater 1 then for Rater 2 (ICC for Rater 1=0.967 vs. Rater 2= 0.836). In conclusion we could say that single measure reliability is satisfactory.

For the concordance between two raters on same individuals Cohen's Kappa was used. The differences in scoring were weighted according to the differences between the two raters (Table 3). The value of calculated Cohen's Kappa was 0.85 which can be interpreted as satisfactory,

TABLE 1
THE MAIN CHARACTERISTICS OF THE POPULATION ENROLLED IN THE STUDY

	$\overline{X}$	Minimum	Maximum	SD
Age	12.48	10.7	16.2	0.9702
Height	158.20	144.5	174.5	7.6274
Weight	49.97	33	99	12.658
BMI	19.03	12.03	35.08	3.8336

SD – standard devation, BMI – body mass index

TABLE 2a.
ANALYSIS OF VARIANCE RATER 1 (N=134)

	df	SSq	MSq	F
Between raters	1	0.239	0.239	4.697
Between cases	133	409.687	3.080	60.594
Within cases	134	7	0.052	
Residual	133	6.761	0.051	
Total	267	416.687		
Intraclass Correlation				
Individual	0.967			
Meaned	0.983			

TABLE 2b.
ANALYSIS OF VARIANCE RATER 2 (N=134)

	df	SSq	MSq	F
Between raters	1	0.0598	0.059	0.144
Between cases	133	613.641	4.613	11.169
Within cases	134	55.000	0.410	
Residual	133	54.940	0.413	
Total	267	668.641		
Intraclass Correlation				
Individual	0.836			
Meaned	0.911			

TABLE 3
COHEN'S KAPPA CALCULATION FOR ANALYSIS OF THE CONCORDANCE BETWEEN TWO RATERS ON SAME INDIVIDUALS

	L1	L2	L3	L4	L5	L6	Total
L1	6	1	0	0	0	0	7
L2	3	13	1	1	0	0	18
L3	1	12	9	14	0	0	36
L4	0	0	1	9	28	0	38
L5	0	0	0	0	20	7	27
L6	0	0	0	0	0	8	8
Total	10	26	11	24	48	15	134

actually very good agreement, depending on the set of guidelines used (Cohen Kappa 0.81–1 almost perfect agreement or Cohen Kappa >0.75=excellent agreement)[17,18].

We also wanted to test the hypothesis if olecranon ossification levels could be related to growth. In order to search for differences in growth between the levels the ANOVA analysis was performed. It was not significant

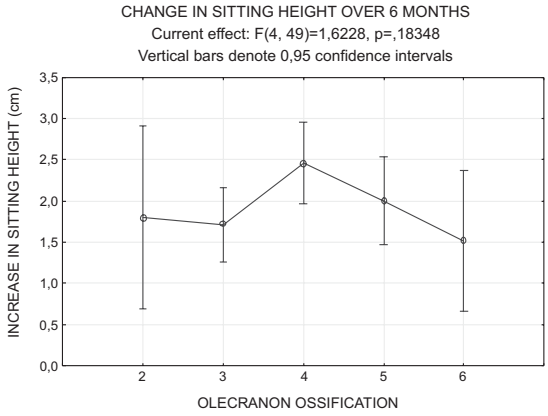

Fig. 2. Change in sitting height over 6 months for olecranon ossificaton levels 2–6.

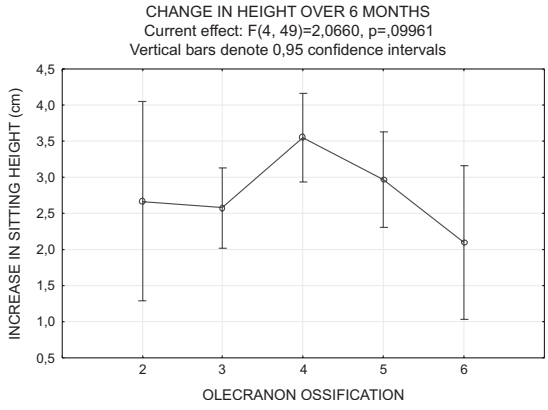

Fig. 3. Change in overall height over 6 months for olecranon ossificaton levels 2–6.

for the change in total body height (p=0.093) and not significant for changes in sitting height (p=0.183). after the 6 months. Though, in Figures 2 and 3 it is visible that the changes in both variables were the highest in olecranon ossification Grade 4.

Analysing data with Student t-test for independent samples between the olecranon ossification levels 3 and 4, the change in overall height is significantly larger for level 4 (Table 4).

Discussion and Conclusion

The chronologic age is assumed not to be as accurate as bone age in determining maturity and residual growth of the patient. In clinical practice, several parameters have been proved to be more usefull in maturity determination, such as the rib apophysis, timing of menarche, peak height velocity, assessment of the olecranon and the Risser sign[4,7,12,14,19].

Timing of menache is not appropriate for boys, peak heigh velocitiy is not simple to determine and main disadvantage of all others are exposure to radiation.

Only few studies have mentioned sonography as an image-guided alternative to examine bone age. Mentzel performed a study to compare the Greulich and Pyle method with the sonographic evaluation of the same hand. Concordance of these methods was not good, moreover, Mentzel's technique requires a special ultrasound device[20].

Castriota-Scanderbeg et al. investigated sonographic bone age by measuring the thickness of the articular cartilage of the femoral head and compared it with the Greulich and Pyle and the Tanner–Whitehouse method[21]. This method also proved to be inaccurate and Castriota-Scanderbegs suggested not using femoral head ultrasound evaluation in routine diagnostics. Thaler et al invastigated Risser grade by ultrasound[22]. They concluded that ultrasound evaluation of the Risser Grade is an accurate technique compared to radiographic techniques and that routine use of this ultrasound method may significantly reduce radiation exposure for patients followed for scoliosis. The limitation of Risser method is a fact that iliac apophysis ossification begins few months after the PHV[12]. During apex of pubertal growth olecranon ossification should be observe[14].

The puprse of our invastigaton was to establish whether ultrasound of the olecranon apophysis could be usefull in determining skeletal maturity and peak height velocity.

TABLE 5
APPROXIMATION OF ULTRASOUND AND X-RAY STAGES OF OLECRANON APOPHYSIS MATURATION

Olecranon ultrasound	Olecranon X-ray
Level 2	Two ossification nuclei
Level 3	Half-moon image
Level 4	Rectangular aspect
Level 5	Beginning of fusion
Level 6	Complete fusion

TABLE 4
ANALYSIS OF INCREASE IN SITTING AND OVERALL HEIGHT FOR OLECRANON APOPHYSIS OSSIFICATION LEVEL 3 AND 4 BY STUDENT T-TEST FOR INDEPENDENT SAMPLES

	$\overline{X}$ level 3	$\overline{X}$ level 4	t-value	SD level 3	SD level 4	F-ratio	p
Increase in sitting height	2.067	2.660	–1.390	1.203	1.242	1.066	0.1743
Increase in overall height	2.572	3.547	–2.157	1.212	1.384	1.303	0.0389

SD – standard deviation

We made classfication by measuring amount of cartilage in olecranon apophysis that have been osiffied. In lower levels there is more cartilage than bone and in higher levels there is less cartilage than bone (Figures 1a–g). We assumed that level 2 could be Charles two nuclei stage, level 3 half-moon image, level 4 rectangular shape, level 5 begining of fusion and level 6 complete fusion (Table 5).

In our study, the most rapid growth occured in group that have been classified as level 4 and level 5 olecranon apophysis maturation. Even though the ANOVA showed no significance we could not assume that the differences do not exist but only that they were not confirmed in this study. The limitation for that might be the sample size, and there still remains to test the hypothesis on larger sample. Analysing data with Student t-test for independent samples between the olecranon ossification grades 3 and 4, the change in overall height is significantly larger for grade 4.

In Charles paper, apex of pubertal growth occured in »rectangular aspect« and „beginning of fusion« which correspodents to ultrasound olecranon level 4 and 5. This contribute that our approximation of stages determined by ultrasound and X-ray is valid. To test it properly, the study of sonographic and radiographic assessment of olecranon within the same individuals should be performed. Although there is good to excellent intra-examiner and inter-examiner agreement for ultrasound staging of olecranon maturity we do not recommande to use it in clinical practice until study on larger group come out.

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POVEZANOST VRŠKA PUBERTETSKOG ZAMAHA RASTA S OSIFIKACIJOM APOFIZE OLEKRANONA ANALIZIRANE ULTRAZVUKOM

SAŽETAK

Vršak zamaha rasta (PHV) je period najbržeg rasta tijekom puberteta. Predviđanje godišnjeg rasta i vrška zamaha rasta omogućuje modifikaciju liječenja mnogih bolesti i stanja koštanog-zglobnog sustava kao što su skolioza i kifoza, poskliz glave bedrene kosti, nejednakost duljine nogu i adolescentne Blountove bolesti. Postoji povezanost između vrška zamaha rasta i koštane dobi određene rentgenogramima olekranona lakta. Da bi se izbjeglo ionizirajuće zračenje testirali smo vrijednost ultrazvuka lakta u predviđanju vrška zamaha rasta. U ovoj studiji, koristeći ultrazvuk, klasificirali smo apofizu olekranona u sedam stupnjeva (0–6), ovisno o količini hrskavice koja još nije okoštala. Za 134 zdrava djeteta, u dobi od 10 do 15 godina, dva su ispitivača evaluirali i stupnjevali ultrazvučne snimke u dvije vremenski odvojene evaluacije. Izračun usaglašenosti između ispitanika pokazao je vrlo dobru pouzdanost metode (koeficijent korelacije među stupnjevima za ispitanika 1=0.967, a za ispitanika 2=0.836) i vrlo dobru ponovljivost metode (Cohenova Kappa 0.85). Za 54 djeteta, klasificirana u stupnjeve od 0 do 6 mjerili smo rast u 6 mjeseci. Najveći rast je izmjeren u skupini 4. Dakle, stupanj 4 razvoja apofize olekranona mogao bi se podudarati s vrškom pubertetskog rasta.