最大声速值（SOSmax）与 CHN 骨龄的相关性研究

摘要：Sunlight BonAge^{TM} 超声骨龄仪在自动检测儿童青少年手腕部骨发育同时，提供了与 BonAge（Sun-BA）有关的超声速值（SOS）、距离（Distance）等技术参数。研究证实，最大声速值（SOSmax）与 Sun-BA 骨龄高度相关（r=0.88~0.90）。可在我国体育竞赛和运动员选材领域普遍推广使用 CHN 骨龄标准，倘若 SOSmax 等超声技术参数能转换为超声骨龄的平台，CHN 法骨龄也与 SOSmax 高度相关，建立超声骨龄的 Chinese BonAge 模型既有了相关性也就有了可行性。本文依据课题 1752 例检测数据，通过 CHN 法读片，探索 CHN 骨龄值与 SOSmax 之间的相关性，求得比较有效的回归方程式解。二元方程的相关性高，精确性好，回代实验效果较理想。

关键词：SOSmax 值　CHN 法　相关系数　回归方程

The Relativity Research for the value of SOSmax and CHN Skeletal Age

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Abstract: *Sunlight BonAge^{TM}Ultrasonic device may measure automatically youngsters' wrist bone maturity, at the same time, it may provide BonAge（Sun-BA） technical parameter with sos and distance concerned. The research lately makes sure that there was a highly relativity between SOSmax and BonAge.(*r=0.88~0.90*) CHN method is spread to use widely in sports competition and talent selection in our country, If there is a highly relativity between CHN method and SOSmax which will be possibility to become a switch platform not only to set up Chinese BonAge model but also to build other model on the platform. The article has probed into its relativity by measured data to obtain duality regression equation The precision of the regression equation is quiet good and the substitute of effect is much ideal.*

Key word: *Value of SOSmax CHN method correlation coefficient duality regression equation*

骨发育年龄（简称骨龄）在预防医学、临床医学、体育科学、司法等部门正广泛被应用。目前人们多采用拍摄手腕骨 X 线片的方法来评价骨发育年龄。此测试方法经历近一个多世纪的发展，已经较成熟，但是由于人眼读片时的主观误差以及 X 线拍片时对人体的辐射，对环境的污染，国内外有许多学者正尝试利用手腕骨的几何信息或者其它的一些新型技术开展骨龄的自动化判读的研究[1-3] ,这其中便有利用超声技术来进行骨成熟度的检测,此技术既可以避免 X 线的辐射损伤，又可以通过仪器的自动化系统判读来鉴定骨龄，从而避免了在 X 线读片时对视觉图像在带来的主观误差。

目前发展较成熟的超声骨龄仪器是以色列生产的 Sunlight BonAge^{TM} 超声骨龄仪。此仪器在以色列、德国、美国、韩国及中国等一些国家开始推出并投入实际应用。它采用定量超声技术，选择桡、尺骨远端作为测试部位，主要是通过最大声速（SOSmax）、距离（Distance）等超声参数的变化来判断骨成熟度状况，其评价标准仍是建立在原经典 G-P 图谱法评价标准基础上[4-8]。

然而 G-P 图谱标准的建立是依据 1930s 美国俄亥俄州克富兰地区中上社会阶层家庭的白人儿童[9]，因此许多国内的对比研究显示，G-P 图谱标准不完全适用于中国儿童骨发育评价，而 Sunlight BonAge^{TM} 超声骨龄仪又是建立在 G-P 图谱基础上，所以也可能出现类似的问题，产生判断的误差。CHN 方法是依据中国城市青少年的骨发育样本而建立的评价标准，因此它比 G-P 图谱法更加适用于中国青少年儿童骨龄的评价[10]。本研究的目的在于建立 SOSmax 和 Distance 等超声技术参数与 CHN 方法骨龄之间的超声骨龄回归模式，以适应中国骨龄的自动化评价。

2.1 对象

受试者来自上海市幼儿园、小学、中学和大学学生，年龄范围 5~18 周岁，共 1752 人构成研究样本，其中男 856 名，女 859 名。受试者身体健康，排除任何显性的内分泌疾病。拍摄 X 光片日期距生日前后 15 天之内，同一天内完成拍摄 X 光片和超声骨龄两种方法的测定。

2.2 实验仪器

30 毫安 X 光骨龄机 1 台；以色列 Sunlight 公司生产的 BonAge1.0 Sunlight BonAge^{TM} 骨龄仪 2 台。X 光拍片由 10 年以上工作经验的专业人员操作，Sunlight BonAge^{TM} 骨龄仪由经过专职培训人员操作，操作经验在 1000 人次以上。

2.3 测试方法

2.3.1 X 线拍片：拍摄受试者左手腕正位片。拍摄要求与条件同手腕骨龄片。

2.3.2 Sunlight BonAge^{TM} 骨龄仪测试

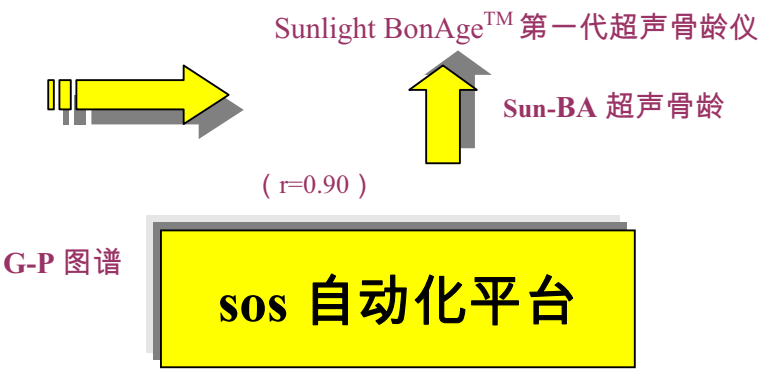
测试环境：要求室内温度相对恒定在 15℃~30℃13 之间。测试前，首先校正仪器，然后选择非优势手，定位于手腕尺骨茎突头的最高点处。测试过程中，手腕放平，手臂伸直不能进行任何移动。每次测量约进行 5~6 个周期，最长可达到 11 个周期，每个周期超声探头将自动抬升 2 毫米，测量桡、尺骨远端骺软骨的 sos 值。操作者在一个周期测量完后点击下一周期，反复 5~6 个周期，完成检测。整个测量将耗时 3 分钟左右。同时电脑显示 5 个不同断层面的最大声速值（ SOSmax ）、距离（ Distance ）、压力（ Pressure ）、厚度（ Thickness ）及波形（ Wave ）等参数，仪器仅保存超声骨龄（ Sun-BA ），预测身高，一次 SOSmax 值以及与之对应的 Distance 值等数据[11]。

3. 数据分析

通过 Sunlight BonAge^{TM} 骨龄仪对桡、尺骨远端骺的软骨生长板进行一组 5 次的测量，获取该部位的 SOSmax、Distance、Pressure、Thickness 及 Wave 等 5 个技术参数，同时，骨龄仪根据这些技术参数自行地判读出骨龄（ Sun-BA ）。X 光骨龄依据中国人骨发育标准（ CHN method ）法判读出。在本研究中将以 CHN 法骨龄为因变量，以 SOSmax、Distance 为自变量，建立 CHN 法超声骨龄的回归模式。回归方程的有效性：$p < 0.05$，其效果以复相关系数 R 和剩余标准差 S_E 来评定。

4. 结果

课题先前的小样本预实验研究结果表明，Sun-BA 骨龄值与 SOSmax 呈现高度相关，相关系数（ r ）在 0.91~0.96 范围（ $p<0.01$ ）；Sun-BA 骨龄值与距离中度相关，相关系数（ r ）在 0.55~0.78 之间（ $p<0.01$ ）。因此，在本研究中，以超声骨龄仪测试过程中产生的 SOSmax 作为超声骨龄研究的技术平台（ 图 1 ），开展 CHN 法超声骨龄自动化判读系统研究。



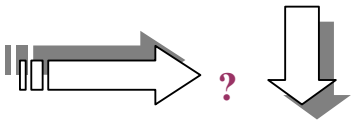


图 1.超声速值与骨龄之间的关系图

本研究的 CHN 法骨龄与 SOSmax 、Distance 相关系数见下表 2。从表中可见 CHN 法骨龄与 SOSmax 、Distance 都具有高度的相关性。

表 1 CHN 法骨龄与 SOSmax 、Distance 相关系数表

性别	人数（N）	SOSmax 相关系数（r）	Distance 相关系数（r）
男	856	0.89**	0.85**
女	895	0.88**	0.75**
男女合并	1752	0.87**	0.77**

** $p<0.0001$

以 CHN 骨龄为因变量，最大声速值（SOSmax）、距离（Distance）为自变量，建立二元回归方程评价模型（$\hat{y} = b_0 + b_1X_1 + b_2X_2$），方程中的 b_0 为常数项，b_1、b_2 分别为 Y 对 X_1、X_2 的回归系数，X_1 为 SOSmax，X_2 为距离，（见表 3）。

表 2 SOSmax、距离与 CHN 法骨龄值的回归方程

性别	b_0	b_1（SOSmax）	b_2（Distance）	R	F value	p	Sy
男	-36.87**	0.0194**	0.2615**	0.8508**	2431.7**	0.0001	1.46

女	-42.634**	0.0254**	0.1987**	0.7978**	1759.7**	0.0001	1.61
总体	-40.961**	0.0221**	0.2364**	0.8211**	4011.5**	0.0001	1.55

** $p<0.0001$

回归公式如下：$\hat{y} = b_0 + b_1X_1 + b_2X_2$

（男 5~18 岁儿童青少年）$\hat{y}$ = -36.87+0.0194 X_1+0.2615 X_2

（女 5~18 岁儿童青少年）$\hat{y}$ = -42.634+0.0254 X_1+0.1987 X_2

（男女儿童总体）$\hat{y}$ = -40.961+0.0221 X_1+0.2364 X_2

此外，随机抽取了男女儿童各 4 人进行方程回代，其中未进入青春发育期儿童 2 人，青春期与发育后期各 1 人，回代结果较好，详见下表 3。

表 3 回归方程组的回代检验效果（单位：岁）

性别	生活年龄	CHN 骨龄	BA 骨龄	回代骨龄	性别	生活年龄	CHN 骨龄	BA 骨龄	回代骨龄
女 1	5 岁	5.9 岁	6.9 岁	7.0 岁	男 1	5 岁	6.0 岁	3.4 岁	6.4 岁
女 2	6 岁	7.7 岁	7.9 岁	8.3 岁	男 2	6 岁	6.1 岁	6.5 岁	8.3 岁
女 3	11 岁	11.3 岁	11.3 岁	10.7 岁	男 3	13 岁	13.8 岁	13.9 岁	13.2 岁
女 4	16 岁	17.3 岁	16.5 岁	15.1 岁	男 4	16 岁	17 岁	17.4 岁	17.3 岁
$\bar{x}$	9.50	10.55	10.65	10.28	$\bar{x}$	9.50	10.73	10.30	11.30
SD	5.07	5.03	4.33	3.56	SD	5.07	5.55	6.47	4.92
CV%	53.36	47.68	40.66	34.30	CV%	53.36	51.72	62.82	43.54

5.讨论

Sunlight BonAge^{TM} 属于第一代超声骨龄仪，具有无辐射、自动化、即时评价等特点。以超声骨龄仪为代表的自动判读技术（US-BA）是生物学年龄评估的发展方向，定量超声及自动化判读系统将逐渐取代传统的 X 光骨龄片判读。因此，研制与开发符合中国儿童青少年的骨龄自动判读系统势在必行，在体育竞赛、运动员选材等领域存在着巨大的市场空间。研究发现，定量超声检测骨龄值所产生的声速值、距离、压力等技术参数成为骨龄判读主要因素，其中最大声速值

（SOSmax）与骨龄值高度相关。众多文献资料显示，超声骨龄检测产生的 Sun-BA 骨龄值与 G-P 图谱法判读出的骨龄值存在着高度相关性，其相关系数 r 约在 0.81~0.93（$p<0.001$）[12]。

研究认为，既然 Sun-BA 骨龄与 G-P 骨龄的相关系数很高，而 SOSmax 在 Sun-BA 骨龄判读中又是一个主要的影响因素，且以色列研究资料亦认为 SOS 与生长发育的关系密切[13]，SOS 值的大小会随着骨发育程度的不同而发生渐增，因此，有理由把超声技术在诊断过程中生产出的 SOSmax 值看成是诸种骨龄可转换的技术平台，可以作为建立 CHN 超声骨龄模型的超声评价系统或者其它模型的超声骨龄评价系统。

上述实验结果证实，CHN 法骨龄与 SOSmax 存在很高的相关性，男 $r = 0.88$，女 $r = 0.89$，男女合并 $r=0.869$（$p<0.0001$）。此外，本研究中还对桡、尺骨远端的距离（Distance）与 CHN 法骨龄进行了相关性统计，分析结果显示，它们之间也存在着高度的相关性，男 $r = 0.85$，女 $r = 0.75$，男女合并 $r=0.77$（$p<0.0001$）。这些统计结果均表明了 SOSmax 和 Distance 在超声骨龄判读过程中是两项主要的技术参数。

根据不同年龄 SOSmax、Distance 自变量与 CHN 法骨龄，本研究建立了 5~18 岁儿童青少年的二元回归模型。同时，就方程本身的各项系数都进行了统计检验，男女方程的相关系数分别为 $r=0.8501$，0.7978（$p<0.001$），检验证明回归方程效果很显著，F 值检验非常显著（$p<0.001$），说明了方程可靠并具有实用意义。

另外，在对回归方程的精确性和稳定性也作了检验。首先，由于 X 与 Y 之间的关系不是简单的函数关系，所以知道了 X 值并不能精确地获取 Y 值，只能通过回归方程求得 Y 的 $\hat{y}$ 估计值。当 X 值相同时，Y 的实测值不一定恰好是 $\hat{y}$，而可能在 $\hat{y}$ 值上下范围波动，这种波动是呈正态分布的，也与骨龄判读的专业要求有关的[6]。本研究计算了回归方程的预测精度（Sy）就能获取方程的精确性。本方程的男女 Sy 值分别为 1.46 岁和 1.61 岁，略显偏大，而女方程的 Sy 要比男方程大；其次，为了验证回归方程的稳定性必须计算回归系数的标准差 Sb 值，Sb 值越小，表示 b 的波动程度越小，说明回归方程的稳定性也越好。

从上表的回代效果可见，除了男儿童 6 岁一人的回代骨龄偏大外，回代骨龄的数值、男女均值、标准差和变异系数都小于 Sun-BA 骨龄、CHN 骨龄组，其离散波动的幅度也小。由此，回代试验基本达到了回归方程的检验效果。当然，还应对二元回归方程做更多的后期实践验证。

6、结论

超声技术在检测媒质（桡、尺骨远端骺软骨）过程中所获取的最大声速值等

超声技术参数，为新型的生物学年龄自动判读系统拓展了研究方向。超声骨龄研究发现，最大声速值（SOSmax）与骨龄高度相关，BA 骨龄与 G-P 骨龄之间的相关系数为 0.94（$p<0.0001$），Sun-BA 与 CHN 骨龄的相关系数为 0.869（$p<0.0001$），建立超声骨龄的 Chinese BonAge 模型既有了相关性也就有了可行性。研究建立了 CHN 法骨龄与超声技术所产生的 SOSmax 年龄区间，成为建立 CHN 超声骨龄模型的基础。研究发现，SOSmax 与 CHN 的回归方程相关性高，精确性和稳定性也好，回代效果比较理想。

7、主要参考文献

[1]黄幼才 刘友光等 骨龄评价统计模型的建立 武汉测绘科技大学学报 [J].1995 第 20 卷 第 3 期 246~250

[2]陆晴友 吴岳嵩 人工智能专家系统及其在骨科领域中的应用 中国矫正外科杂志 [J].2005 第 13 卷 第 2 期 141~143

[3]罗家燕 林珠等 手腕骨骨龄测量的计算机系统 中华口腔医学杂志 [J].1998 第 6 期

[4]Castriota-Scanderbeg A, De Micheli V. Ultrasound of femoral head cartilage: a new method of assessing bone age. Skeletal Radiol. [J]. 1995 Apr;24(3):197~200

[5]Wagner UA, Diedrich V, Schmitt O. Determination of skeletal maturity by ultrasound: a preliminary report. Skeletal Radiol. 1995 Aug;24(6):417~20.comment to Skeletal Radiol. [J].1996 Feb;25(2):142.

[6]Castriota-Scanderbeg A, Sacco MC, Emberti-Gialloreti L, Fraracci L. Skeletal age assessment in children and young adults: comparison between a newly developed sonographic method and conventional methods. Skeletal Radiol. [J].1998 May;27(5):271~7.

[7]Bilgili Y, Hizel S, Kara SA, Sanli C, Erdal HH, Altinok D. Accuracy of skeletal age assessment in children from birth to 6 years of age with the ultrasonographic version of the Greulich-Pyle atlas. [J]. Ultrasound Med. 2003 Jul;22(7):683~90.

[8]Mentzel HJ, Vilser C, Eulenstein M, Schwartz T, Vogt S, Bottcher J, Yaniv I, Tsoref L, Kauf E, Kaiser WA. Assessment of skeletal age at the wrist in children with a new ultrasound device. Pediatr Radiol. [J]. 2005 Apr;35(4):429~433. Epub

[9]Greulich WW, Pyle SI, Radiographic Atlas of Skeletal Development of the Hand and Wrist, 2nd ed. Stanford California, Stanford University Press,1959

[10]张绍岩主编《中国人骨成熟度评价标准及应用》人民体育出版社[M].p11~13 1995

[11]以色列阳光医疗有限公司“Sunlight BonAge™ 设备操作手册”2003

[12]Hans-J. Mentzel, Claudia Vilser, Marcus Eulenstein, Tseela Schwartz Susanna Vogt, Joachim Böttcher, Irit Yaniv.,et al, Assessment of skeletal age in children with a new ultrasound device at the wrist. Pediatric Radiology [J]2005.(4):429-433

[13]Sunlight Omni sense 7000p---8000p Bone Meter User Guide Software Version2.4 DUM0050 Rev 01 以色列阳光医疗有限公司“为 Sunlight BonAge™ 设备建立参考数据库”临床研究协议，2003

The Relative Research of the value of SOSmax and CHN Method

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Abstract: *Sunlight BonAge^{TM}Ultrasonic device may measure automatically youngsters' radio-ulna bone maturity, at the same time, it may provide BonAge(Sun-BA) technical parameter with sos and distance concerned. The research lately makes sure that there was a highly relativity between SOSmax and Sun-BA.(*r=0.88~0.90*) CHN method is spread to use widely in sports competition and talent selection in our country, If there is a highly relativity between CHN method and SOSmax that will be possibility to become a switch platform not only to set up Chinese BonAge model but also to build other model on the platform. The article has probed into its relativity by measured data to obtain duality regression equation The precision of the regression equation is quiet good and the substitute of effect is much ideal.*

Key word: *Value of SOSmax, CHN method, correlation coefficient, duality regression equation*

The Skeletal Age (BA for short) is now widely used in the preventive medicine, clinic medicine, sports science, judicial departments and other fields. This way of testing has been developed for more than 100 years and it comes to its maturity. However, due to the subjective mistakes made by interpreting the X-ray radiographs barely by eyes and the radiation brought by taking the X-ray, the pollution to the environment, many scholars at home and abroad are now trying to using the geometry information of the wrist bones or other new technologies to launch the researches on the automatic assessment of the skeletal age[1-3]. Among these new technologies there is the way of testing the bone maturity through the ultrasonic technology. This kind of technology can avoid the eradicative injuries brought by the X-ray, it can also identify the skeletal age by the automatic assessment system so that it can get rid of the subjective mistakes made by interpreting the visual images on the radiographs.

Nowadays the much mature ultrasonic skeletal age device is the Sunlight BonAge^{TM} (Sunlight Medical Ltd. Co. Israel). This device has been introduced and put into practice in Israel, Germany, United States, Korea, China and some other countries. It adopts the quantitative ultrasonic technology and chooses the far end of the radio-ulna bone as the testing part. It judges the maturity of the bone mainly according to the ultrasonic parameters such as SOSmax, Distance and so on. Its criterion is still on the basic of the classic G-P Atlas criterion[4-8].

However the G-P Atlas criterion is based on the white children of the middle and high social classes in Cofu-land, Ohio, the United States of 1930s, so many domestic contrastive researches show that the G-P Atlas criterion is completely unsuitable for the bone development evaluation of Chinese children. Yet Sunlight BonAge^{TM} ultrasonic skeletal age device is based on the G-P Atlas, so it is possible that it may

confront such problems that may lead to wrong judgments. The CHN method is the criterion set up on the basis of the teenagers' bone development samples in the Chinese cities, so it is more suitable than the G-P Atlas for the evaluation of the skeletal age of Chinese teenagers[10]. The aim of this research is to establish a regressive mode between the CHN method skeletal age and the ultrasonic technical parameters such as SOSmax and distance so that the mode can adapt to the automatic evaluation of Chinese skeletal age.

Methods

Subjects and procedure

The subjects were from kindergartens、elementary schools、middle schools and universities in Shanghai, all of whom were between the ages of 5 years and 18 years. The total samples were 1752 people who were consisted by 856 boys (48.9%) and 859 girls (51.1%). Subjects were healthy who excluded any distinct endocrine diseases. The dates of radiographs were fixed within 15 days before or after their birthdays, and they finished the radiographs and the tests of ultrasonic bone age in one day.

One 30 mA X-ray skeletal age device; two BonAge1.0 Sunlight BonAge^{TM} devices made by Sunlight Ltd Co, Israel. The radiographing is operating by professionals who have the work experience for more than 10 years. BonAge1.0 Sunlight BonAge^{TM} device operated by technicians who were trained and have the operating experience of more than 1,000 times.

The X-ray radiographing: radiograph the testee's left wrist from the front. The requirements and conditions are the same as those of the radiographs of the wrist skeletal age.

The Testing Environment: the indoor temperature should be constantly between the range of 15℃ to 30℃. Before the test, adjust the device first, and then choose the non-advantageous hand to be fixed at the highest point of the prominent part of the radio-ulna bone. During the measurement, the wrist should be in horizontal level and the forearm should be straight and not move any more. Each test will last 5 or 6 periods, the longest one can last 11 periods. The ultrasonic probe will rise by 2 mm every period to test the sos datas for the epiphysis cartilage of the far end of the radio-ulna bones. The operator will click the next period after finishing the previous period. The test will be completed after repeating 5 or 6 periods. The whole test will take about 3 minutes. At the same time the computer will show some parameters such as SOSmax, distance, pressure, thickness, wave and others of 5 different fault planes. The device only keep the datas such as Sun-BA, the forecasting stature, one SOSmax and the corresponding distance and so on[11].

Datas Analysis

Through the a group of 5 times testing to the epiphysis cartilage growing plunk of the far end of the radio-ulna bone by the Sunlight BonAge^{TM} skeletal age device, we have

5 technical parameters of the part such as SOSmax, distance, pressure, thickness and wave. At the same time the BonAge device will automatically judge the Sun-BA according to these technical parameters. The X-ray skeletal age is judged by the CHN method. In this research the CHN skeletal age will be taken as the dependent variable while SOSmax and distance as the independent variables in order to establish a regressive mode of CHN ultrasonic skeletal age. The validity of the regression equation($p < 0.05$), its result is evaluated by the duality correlation coefficient R and the surplus std. deviation $S_{E.}$

Results

The results of pre-experiment and the end research all showed that Sun-BA and SOSmax were highly related, correlative coefficient (r) was 0.91-0.96 (P<0.01); the relation between BA and distance was of middle level (r=0.55-0.78, P<0.01). So in this research we take the SOSmax, produced by ultrasonic technique, as the platform of ultrasonic Sun-BA research (see fig.1) and launch the research of automatic assessment system for the CHN ultrasonic device.

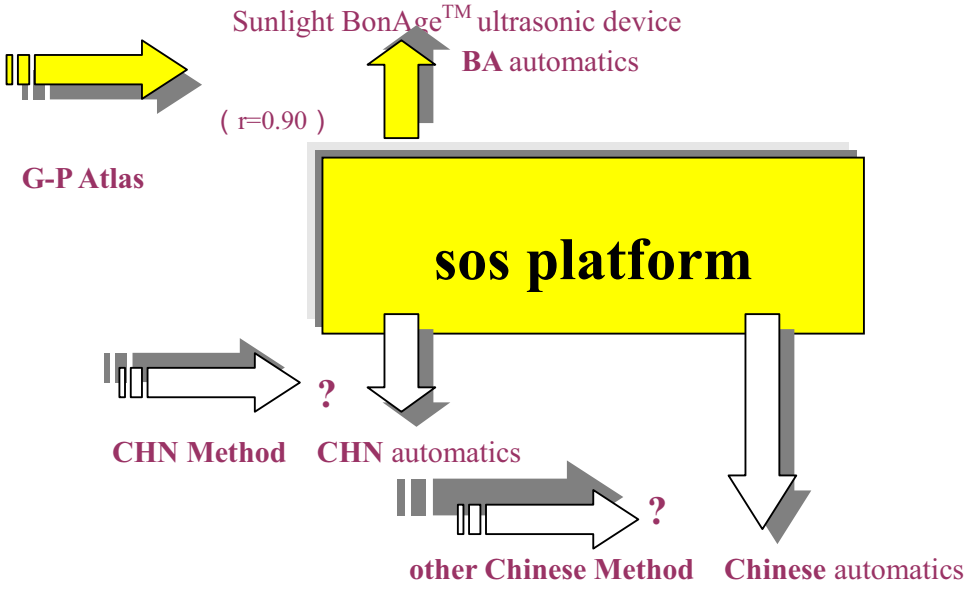

Fig. 1 The relational map between SOSmax platform and skeletal age

The test found that the correlative coefficient of CHN method and SOSmax is high (see table 2).

Table 2 Correlative coefficient of SOSmax and CHN skeletal age

Gender	Amounts (n)	Correlative coefficient (r)	p
Male	856	0.890	0.0001
Female	895	0.878	0.0001
Total	1752	0.869	0.0001

** p<0.0001

We establish the duality regression equation model ($\hat{y}=b_0+b_1X_1+b_2X_2$)on the basis that the SOSmax and distance should be the independent variables while the CHN method be the dependent variable, and b_0 is constant in equation, b_1、b_2 is regression coefficient of X_1、X_2 respectively, X_1 represents the SOSmax and X_2 represents the distance (see table 3).

Table 3 Regression equation of SOSmax、distance and CHN method

Gender	b_0	b_1 (SOSmax)	b_2 (Distance)	R	F value	p	Sy
Male	-36.87**	0.0194**	0.2615**	0.8508**	2431.7**	0.0001	1.46
Female	-42.643**	0.0254**	0.1987**	0.7978**	1759.7**	0.0001	1.61
Total	-40.961**	0.0221**	0.2364**	0.8211**	4011.5**	0.0001	1.55

**P<0.0001

Regression equation as follows: $\hat{y}=b_0+b_1X_1+b_2X_2$

(male, children and adolescents between the ages of 5 years and 18 years)

$\hat{y}=-36.87+0.0194X_1+0.2615X_2$

(female, children and adolescents between the ages of 5 years and 18 years)

$\hat{y}=-42.643+0.0254X_1+0.1987X_2$

(total, children and adolescents between the ages of 5 years and 18 years)

$\hat{y}=-40.961+0.0221X_1+0.2364X_2$

Besides, we randomly select 4 men and women respectively for comparative test to do substitutable equation. There were 2 children, adolescents and adults was 1 respectively. The results of substitution were as follows (see table 4).

Table 4 Effect of substitutable test of regression equations (years)

Gender	CA (yr)	CHN (yr)	BA (yr)	substitute (yr)	Gender	CA (yr)	CHN (yr)	BA (yr)	substitute (yr)
Woman1	5	5.9	6.9	7.0	Man1	5	6.0	3.4	6.4
Woman2	6	7.7	7.9	8.3	Man2	6	6.1	6.5	8.3
Woman3	11	11.3	11.3	10.7	Man3	13	13.8	13.9	13.2
Woman4	16	17.3	16.5	15.1	Man4	16	17	17.4	17.3
χ	9.50	10.55	10.65	10.28	χ	9.50	10.73	10.30	11.30
SD	5.07	5.03	4.33	3.56	SD	5.07	5.55	6.47	4.92
CV%	53.36	47.68	40.66	34.30	CV%	53.36	51.72	62.82	43.54

Discussion

Sunlight BonAge^{TM} is the first ultrasonic device for bone age test, which has so

many advantages as lack of ionizing、automation、immediate estimation and so on. Because US-BA, which represented by ultrasonic device for bone age test is the heading of assessment of biological ages, the automatic assessment system would substitute the conventional radiographs system. Hence, it is necessary to research and develop an automatic assessment system for skeletal age test adapting to children and adolescents in our country. And it would have a large market space in sports competition and talent selection and so on. The important factors for skeletal age test are technologic parameters by quantitative ultrasound test, such as SOS、distance and pressure and so on. And the relation between SOSmax and skeletal age is the highest among them. Many documents showed that the relation between Sun-BA value by ultrasonic device and G-P atlas is high. And its correlation coefficient is in the range of 0.81 to 0.93 ($p<0.001$) [12].

The research shows that since the correlation coefficient between the value of Sun-BA and the G-P, and SOSmax is an important factor in the Sun-BA skeletal age assessment, and the research papers of Israel also showed that SOS is closely related to the growth[13] for the data of the SOS gradually increasing with the degree of the bone growth, so it is reasonable to take the SOSmax which produced from the diagnosis of ultrasonic technique as the switch platform of various skeletal ages, and it can be the ultrasonic assessment system of setting up the CHN ultrasonic skeletal age model or other models.

The research verified that the relation of CHN value and SOSmax was high. The male, $r = 0.88$, the female, $r = 0.88$, and in total, $r=0.869$, ($p<0.0001$). Besides, we did the correlation statistics between the distance of the radio-ulna and the CHN method. The results showed that they were also highly related, the male $r=0.85$, the female, $r=0.75$, and in total, $r=0.77$, ($p<0.0001$). All these statistics showed that SOSmax and distance were two important technical parameters in the process of ultrasonic skeletal age assessment.

According to the independent variables as SOSmax, distance of different ages and the CHN skeletal age, we set up a duality regressive model of the youngsters from 5 to 18 in this research. Meanwhile, we count and examine all kinds of coefficients of the equation itself. Each coefficient of equation was tested ($p<0.001$). Male and female's correlative coefficient of equation was 0.8501, 0.7978 (r) respectively. It showed that the effects of regression equation and F value test was obvious, and suggested that the equation was reliable and had practical significance.

Besides, we verified the accuracy and the stability of the regression equation. First of all, because the relation of X and Y was not simple function one, it could not request Y value accurately by got X value, we could only request $\hat{y}$ value that is reckoned value of Y through the equation. When the X value was same, the fact was that the Y value might be just not the $\hat{y}$ value, and it was possible to fluctuate with $\hat{y}$. And that's normal distribution is related with professional demands [6]. It could get the

accuracy of equation after computed its forecasted accuracy. This equation's Sy was 1.46 years and 1.61 years respectively that appeared little high, and Sy of the female's equation was larger than that of the male. Secondly, it was necessary to compute the std. Deviation (Sb) for checking the stability of regression equation. It showed that the less the Sb was, the less the extent of fluctuation of b was, which explained that the stability of regression equation is higher.

It could be seen from table 5 that the average、SD and CV% of the substitutable group were all smaller than that of Sun-BA or CHN method, as well as the extent of fluctuation except a boy who was 6 years old. As a result, it could conclude that the substitutable equations got the demands basically. Certainly, it should do more research to verify in later practices.

Conclusion

The ultrasonic technique provided the parameters, such as SOS of medium epiphysis. Research of ultrasound BonAge^{TM} found that the relation of SOSmax and skeletal age was high, the correlative coefficient of Sun-BA and G-P value was 0.94 ($p<0.0001$), and the correlative coefficient of Sun-BA and CHN value was 0.869 ($p<0.0001$). Thus, the platform of SOSmax is the fundament for building BonAge system, meanwhile, there is a reason for establishing platform with automatic assessment system for skeletal age test adapting to children and adolescents in china (the ultrasonic automatic assessment system bases on CHN method). The relation、accuracy and stability of regression equation of SOSmax and CHN method, established by this research, were high. So its effect of substitution was very well.

References

[1]Huang Youcai, Liu Youguang etc,. The Establishment of the Skeletal Age Counting Model, the Transaction of Wu Han Mapping Science and Technology University, P246~250, Volume 20, the Third Issue,[J].1995

[2]Lu Qingyou, Wu Yueshong, The Artificial Intelligence Expert System and its practical use in the field of the orthopaedics, the Chinese Corrective Surgery Magazine, P141~143, Volume 13, the Second Issue, [J].2005

[3]Luo Jiayan, Lin Zhu and other writers, the Computer System of Testing the Skeletal Age of the Wrist Bone, the Chinese Oral Medicine Magazine, the Six Issue, [J].1998

[4]Castriota-Scanderbeg A, De Micheli V. Ultrasound of femoral head cartilage: a new method of assessing bone age. Skeletal Radiol. [J]. 1995 Apr;24(3):197~200

[5]Wagner UA, Diedrich V, Schmitt O. Determination of skeletal maturity by ultrasound: a preliminary report. Skeletal Radiol. 1995 Aug;24(6):417~20.comment to

Skeletal Radiol. [J].1996 Feb;25(2):142.

[6]Castriota-Scanderbeg A, Sacco MC, Emberti-Gialloreti L, Fraracci L. Skeletal age assessment in children and young adults: comparison between a newly developed sonographic method and conventional methods. Skeletal Radiol. [J].1998 May;27(5):271~7.

[7]Bilgili Y, Hizel S, Kara SA, Sanli C, Erdal HH, Altinok D. Accuracy of skeletal age assessment in children from birth to 6 years of age with the ultrasonographic version of the Greulich-Pyle atlas. [J]. Ultrasound Med. 2003 Jul;22(7):683~90.

[8]Mentzel HJ, Vilser C, Eulenstein M, Schwartz T, Vogt S, Bottcher J, Yaniv I, Tsoref L, Kauf E, Kaiser WA. Assessment of skeletal age at the wrist in children with a new ultrasound device. Pediatr Radiol. [J]. 2005 Apr;35(4):429~433. Epub

[9]Greulich WW, Pyle SI, Radiographic Atlas of Skeletal Development of the Hand and Wrist, 2nd ed. Stanford California, Stanford University Press,1959

[10] Zhang Shaoyan as editor in chief, The Evaluation Criterion and Practical Usage for the Chinese bone maturity, the People Sports Press, [M].p11~13 1995

[11]The Operating Pamphlet of Sunlight BonAge™ device, 2003, Sunlight Medical Ltd., Israel

[12]Hans-J. Mentzel, Claudia Vilser, Marcus Eulenstein, Tseela Schwartz Susanna Vogt, Joachim Böttcher, Irit Yaniv.,et al, Assessment of skeletal age in children with a new ultrasound device at the wrist. Pediatric Radiology [J]2005.(4):429-433

[13]Sunlight Omni sense 7000p---8000p Bone Meter User Guide Software Version2.4 DUM0050 Rev 01, 2003