Available online at www.sciencedirect.com

ScienceDirect

Journal of the Chinese Medical Association 81 (2018) 649−656

www.jcma-online.com

Original Article

Reference equations for predicting standing height of children by using arm span or forearm length as an index

Wei-Yu Chen [a,b,c], Yu-Ting Lin [a], Yin Chen [a], Ken-Chun Chen [b], Benjamin Ing-Tiau Kuo [e], Pei-Chen Tsao [b,d], Yu-Sheng Lee [b,d], Wen-Jue Soong [b,d], Mei-Jy Jeng [a,b,d,*]

[a] *Institute of Emergency and Critical Care Medicine, School of Medicine, National Yang-Ming University, Taipei, Taiwan, ROC*
[b] *Department of Pediatrics, Taipei Veterans General Hospital, Taipei, Taiwan, ROC*
[c] *Department of Pediatrics, National Yang-Ming University Hospital, Ilan, Taiwan, ROC*
[d] *Department of Pediatrics, School of Medicine, National Yang-Ming University, Taipei, Taiwan, ROC*
[e] *Laboratory of Epidemiology and Biostatics, Department of Medical Research, Taipei Veterans General Hospital, Taipei, Taiwan, ROC*

Received May 16, 2017; accepted May 31, 2017

Abstract

Background: Standing height (SH) is the most reliable parameter used to predict spirometric values in children, but measurement of this parameter may be difficult in children with thoracic or spinal abnormalities. This study was designed to establish reference equations to estimate SHs of children using their arm span length (ASL) or forearm ulnar length (UL) as an index.
Methods: Children aged 1−17 years were enrolled to measure their SH, body weight, ASL, and UL. Sex and age were also recorded. The relationship between SH and children's weight, age, ASL, and UL were analyzed. Regression equations using different indexes for SH of enrolled cases were used, and adults aged 18−64 years were also enrolled for comparison.
Results: A total of 512 children and 144 adults were enrolled. There was a strong linear relationship between SH and both ASL and UL in children and adults. Pearson's correlation coefficients of SH for ASL and UL were 0.989 and 0.968 ($p < 0.001$) in children and 0.933 and 0.845 ($p < 0.001$) in adults. The linear regression equations for estimating SH in children were calculated as SH = 9.363 + 0.943 ASL ($r^2 = 0.978$, $p < 0.001$) and SH = 14.542 + 5.570 UL ($r^2 = 0.936$, $p < 0.001$). In adults, age and sex were also added as indexes: SH = 59.849 + 0.642 ASL−0.047 Age +3.431 Sex (male = 1; female = 0) ($r^2 = 0.887$, $p < 0.001$) and SH = 102.824 + 2.317 UL −0.049 age + 6.739 sex ($r^2 = 0.773$, $p < 0.001$).
Conclusion: Both ASL and UL have a significant linear relationship with SHs of children and adults. True SH can be estimated using regression equations with ASL or UL as a single index for situations where direct measurement of SH is difficult.

Keywords: Arm span length; Children; Regression equation; Standing height; Ulnar length

1. Introduction

The pulmonary function test is a crucial test used to evaluate lung function in patients with potential pulmonary dysfunction. The measured lung function may help clinical physicians to assess pulmonary dysfunction, operative risk, and management protocols. To evaluate pulmonary function, normative reference data are required.[1−3] However, normative reference of pulmonary function test may be influenced by multiple factors, including ethnicity, body height, body weight, age, and sex.[3−8] Standing height (SH) is the most common parameter to estimate predictive spirometric values and is used in evaluating the pulmonary function of children. Among these factors, SH measurements may not be reliable in

Conflicts of interest: The authors declare that they have no conflicts of interest related to the subject matter or materials discussed in this article.

* Corresponding author. Dr. Mei-Jy Jeng, Department of Pediatrics, Taipei Veterans General Hospital, 201, Section 2, Shi-Pai Road, Taipei 112, Taiwan, ROC.
E-mail address: mjjeng@vghtpe.gov.tw (M.-J. Jeng).

https://doi.org/10.1016/j.jcma.2017.08.023

patients with thoracic skeletal deformities. These individuals typically have lower SHs than expected, which may result in an over-estimation of their pulmonary function, which can underestimate their risk of surgery and difficulty of extubation.

As reported in several previous studies, arm span length (ASL) was the most common measure used to estimate patients' true SH.[7−12] However, some patients may not be able to extend their arms. Forearm ulnar length (UL) has been reported to be another choice to estimate patients' true SH for predictive spirometric values.[13] ASL and UL are typically not affected by spinal or thoracic deformities, which suggest that they might serve as an alternative index for estimating SHs.[12] There have been previous investigations worldwide describing the relationship between ASL and height. However, a lack of studies on ASL and UL with SH in children living in Taiwan during last decades may prevent its use in a clinical setting.[4,6,10,13−16] Linear regression equations for estimating true SH from ASL or UL in Chinese children, especially for those <6 years old, are also needed to successfully employ this technique. Therefore, it seems worthy to investigate the relationship between SH and children's ASL and UL and determine the regression equations for the children living in Taiwan.

In this regard, the purpose of this study was to analyze the relationship between SH and ASL or UL in children living in Taiwan and to establish reference regression equations for estimating true SHs of children based on their ASL or UL and to compare these values with those obtained from adults.

2. Methods

2.1. Subject enrollment

This study was approved by the local Institutional Review Board of Taipei Veterans General Hospital (IRB approval number: 2012-06-017A). The study period was from November 2012 to February 2014. Informed consent was obtained from the parents or guardians of all children aged 1−17 years. Exclusion criteria were as follows: presence of spinal or thoracic deformities, non-Taiwanese nationality, refusal to provide age and other data, and difficulty in extending arms. Adults aged 18−64 years also signed informed consent and were included in the analysis for comparison.

2.2. Assessment

SH, ASL, UL, and body weight of enrolled participants were measured with participants bare feet and standing against a wall. ASL was measured from the tip-to-tip of the two middle fingers while the participant was standing or sitting against a wall and stretching both arms as much as possible (Fig. 1A). UL was measured as the length of the right ulnar bone from the ulnar styloid process to the olecranon process (Fig. 1B). Numeric data were measured to the nearest 0.1 cm per length and 0.1 kg per weight. The basic characteristics of the data obtained from the children were categorized into 1−5, 6−10, and 11−17-year-old (y) subgroups for comparison with adults.

2.3. Statistical analysis

Descriptive analysis was performed, and numeric data were presented as mean ± standard deviation. One way analysis of variance tests were used to compare data among groups and were followed by *post-hoc* LSD test for pairwise comparison. Pearson's correlation coefficients were calculated for SH with ASL, UL, body weight, and age. Linear regression models were performed for SH with variables ASL, UL, body weight, age, and sex. SPSS (Version 22.0, SPSS Inc., Chicago, IL, USA) was used for data analysis, and SigmaPlot (Version 12.0, Systat Software Inc. San Jose, CA, USA) was used for drawing graphs. A *P*-value of <0.05 was considered statistically significant for all results.

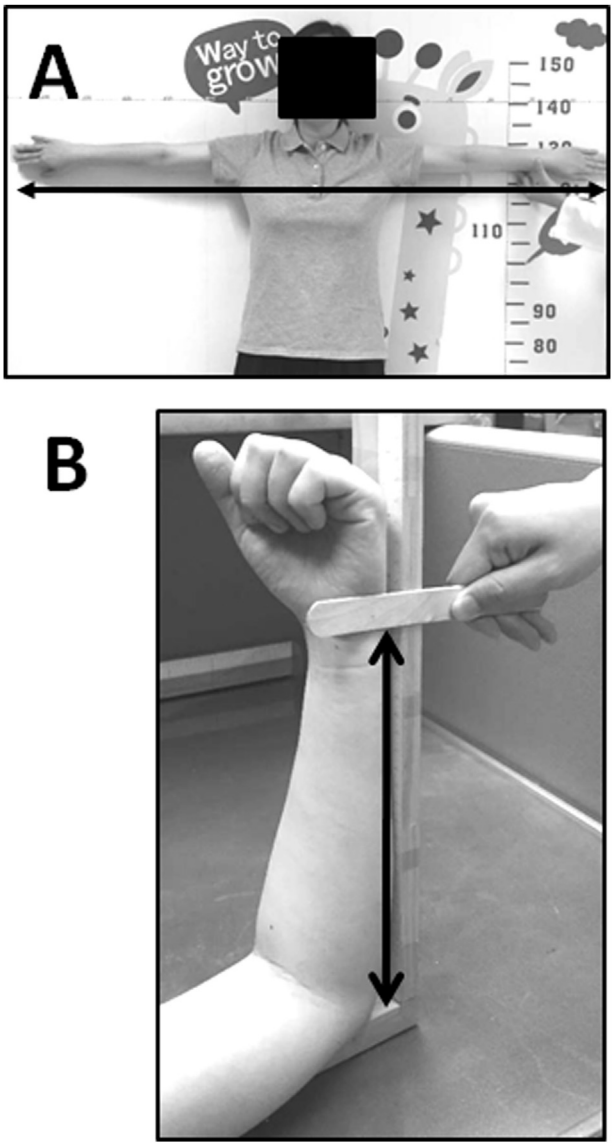

Fig. 1. Illustrations of measurements of the arm span length (A) and ulnar length of the forearm (B).