วารสารวิชาการสาธารณสุข
ปีที่ 29 ฉบับที่ 5 กันยายน - ตุลาคม 2563

Journal of Health Science
Vol. 29 No. 5, September - October 2020

นิพนธ์ต้นฉบับ

Original article

Factors Influencing Pediatric Weight Estimation

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Abstract The objective of this study was to determine the factors that influence pediatric weight estimation. It was conducted as a cross-sectional analytic study at the pediatric outpatient department, Ratchaburi hospital. Written informed consent was obtained from all participants. Patient characteristics were presented in descriptive analysis such as percentage, mean, and standard deviation. Age, height, head circumference, midarm circumference for prediction with weight were analyzed by multiple regression analysis. The results revealed that 290 patients were enrolled. 147 patients were male (50.7%). The mean age was 4.6 years. Weight range was 8 to 29 kg. The mean weight was 17.34 kg., and the mean height was 105.84 centimetre. Midarm circumference range was 12 to 26 cm and mean of midarm circumference was 17.4 centimetre. Correlation of weight with age, height, midarm circumference and head circumference was significant. Weight (Kg) = 0.436x (midarm circumference)+0.857x(age)+0.111x(height)-5.913. In conclusions, head circumference, midarm circumference, height and age were found to be related with body weight of pediatrics. All of them could be used to predict pediatric weight.

***Keywords*: pediatric; weight estimation; head circumference; height; age; midarm circumference**

Introduction

Global population is now nearing 7.8 billion at a population growth rate of 1.1 percent per year.[1] In 2016, the population of 0-14 year-olds was 26 percent of the total with an annual birth rate of 147 million children.[2]

In Thailand, the population in mid-2016 was 65.3 million and this number is expected to increase to 66.8 million by mid-2030. The birth rate is currently 12 per 1,000 people, with 18 percent of the population under 15 years old.[2] Children comprise nearly one in five of the Thai population.

Child mortality is a serious problem, with 5.9 million children under the age of 5 dying in 2015.[3] Major causes of death in children are pneumonia, diarrhea and preterm which can be prevented or treated.[4]

Children in developing countries die at ten times the rate for children in developed countries.[4] Many developing countries are unable to provide prevention strategies through prehospital care and emergency treatment to reduce mortality.

Pre-hospital care and emergency departments often have medication errors in paediatrics.[5,6] Some-

times, wrong drug doses are employed.[5] Correct drug dosage must be calculated from the body weight of children. This is very important for proper treatment by emergency physicians. Many pediatrics who are admitted to emergency departments do not have their weight recorded.

There are many ways to estimate pediatric weight. One is by visual inspection but this method is not accurate.[7] Others include length-based weight estimates such as the Broselow tape, Pediatric Advanced Weight Prediction in the Emergency Room (PAWPER) tape and age-based weight estimates including advanced pediatric life support (APLS)[8], The Luscombe and Owens formula (LO)[9] is also used to determine pediatric weight. Broselow tape is more accurate than age-based formulae,[10-13] but this tape is expensive and can also result in errors.[14-17] Evidence suggests that head and midarm circumferences are associated with weight in pediatrics,[18-22] but scant information exists with regard to Asian populations.

Therefore, a cross-sectional analytic study was conducted to determine the factors that influence pediatric weight estimation. If relationships between pediatric weight and influencing factors are known, then pediatric weight can be estimated more accurately to reduce incidences of erroneous drug dose. Pediatric emergency treatment will then become more effective with reduction in child mortality.

Methods

1. Study design

A cross-sectional analytical study was performed on patients presenting to the pediatric outpatient department at Ratchaburi Hospital, Ratchaburi Province, Thailand. Written informed consent was obtained from all participants. There was no agency support for this study.

2. Participant enrolment

Patients who presented to the pediatric outpatient department (OPD) at Ratchaburi Hospital were enrolled.

Inclusion criteria

- Age 1-14 years old

Exclusion criteria

- Previous diagnosis of congenital anomalies
- Unable to measure height, weight, head or mid-arm circumference
- Refused to participate in the study

3. Intervention

Simple random sampling techniques were used to collect data when patients entered the pediatric outpatient department. Parents gave informed consent before data collection. Age was recorded in years. Patients were advised to remove shoes and heavy clothing before measure and stood with both feet in the center of the digital scale. If patients could not stand, weight was recorded when patients lay down on digital infant scale. Weight was recorded in kilograms. Height was assessed by standiometer. Patients stood with head, shoulders, buttocks, and heels touching the flat surface of standiometer. Flat headpiece was moved down until it firmly touches the crown of the head. Hight was recorded when eyes were at the same level as the headpiece. If the patient could not stand, then horizontal length was measured by measuring board. The length was recorded when head against the headpiece and heel against the foot piece. Midarm circumference was measured in the left arm at the midpoint between tip of olecranon and acromion by measure tape. Head circumference was recorded by

measure tape. Head was wrapped by the tape around forehead, above eyebrow, above the ears and occipital protuberance. Midarm circumference and head circumference were collected. All data were filled on a data collection sheet. After the measurement procedure, all patients were asked about their illness and told to wait for their doctor.

4. Methods of measurement, data collection and processing

All data collectors were informed about the methods of measurement. They examined the equipment used to record height, head and midarm circumference.

Digital scales were calibrated using standard weight objects to achieve triplicate measurements of the same value. Digital scales provided a measurement result with a decimal fraction. Tapes used to measure head and midarm circumference passed the standard test of measurement. Tapes provided a result in centimeters. Standiometer passed calibration before using in this study and it provided a result in centimeters.

Two experts from the pediatric department and one expert from the emergency department assumed the roles of reviewers. Revisions to the measurement procedures were made as advised by the experts.

5. Outcome

Data of patient characteristics were collected in record form. Age of patients was collected in years. Data for actual weight were collected from digital weighing scales. All weighing scales were calibrated before use. All data collectors were instructed in the methods of measurement. Head circumference, midarm circumference and height were recorded in centimetres. Both internal and inter-reliability were tested.

6. Statistical analysis

Sample size was calculated using Green's formula to test relationship outcomes with individual predictors as:[23]

$n > 104 + m$

n = sample size

m = number of predictors

There were four predictors, so sample size was more than 108.

Patient characteristics were presented as descriptive analysis including percent, mean, and standard deviation. Age, height, head circumference, and midarm circumference for prediction of weight were assessed by multiple regression analysis using SPSS version 21.

Results

A total of 290 patients were enrolled in the pediatric outpatient department and 147 were male (50.7%). Mean age was 4.6 years. Weight range was 8 to 29 kg., the mean weight was 17.34 kg., height was 105.84 cm., midarm circumference range was 12 to 26 cm and mean of midarm circumference was 17.40 cm. (Table 1).

Correlation of weight with age, height, midarm circumference and head circumference was significant at 0.01. (Table 2)

Linear regression analysis was used to determine the correlation of weight to each factor as shown:

Weight = 1.6 x (age) + 10

(adjusted $R^2 = 0.66$)

Weight = 0.25(height/length) - 9.14

(adjusted $R^2 = 0.69$)

Weight = 0.86 x (head circumference) - 24.7

(adjusted $R^2 = 0.25$)

Weight = 1.1 x (midarm circumference) -1.4
(adjusted R^2 = 0.24)

Significant variables from univariate regression were analyzed by multiple regression analysis. Height, age, and midarm circumference were co-predictors of weight (adjusted R^2 = 0.76). Formulae to predict pediatric patient weight by the factors are shown in Table 3.

Table 1 Patient characteristics

Characteristic	Mean	SD	Range
Male sex (%)	147	50.7	NA
Age (yr)	4.6	2.76	1-13
Height (cm)	105.84	17.75	45-151
Head circumference (cm)	48.81	3.08	26-54
Midarm circumference (cm)	17.40	2.41	12-26
Weight (kg)	17.34	5.34	8-29

Table 2 Correlation between age height head circumference mid arm circumference and weight

	Age	Height	Head circumference	Mid arm circumference	Weight
Age	1.000				
Height	0.855**	1.000			
Head circumference	0.442**	0.523**	1.000		
Midarm circumference	0.302**	0.427**	0.503**	1.000	
Weight	0.818**	0.832**	0.498**	0.488**	1.000

** $p<0.01$

Table 3 Multiple regression analysis from factor to predict pediatric weight

	R	R^2	AdjR^2	R^2Change	b	Beta	t
Height	0.832	0.692	0.691	-	0.111	0.369	6.269
Age	0.857	0.735	0.733	0.042	0.857	0.444	7.957
Mid arm circumference	0.875	0.766	0.763	0.300	0.436	0.197	6.15
Constant = -5.913 S.E.= 1.521 overall F							

Weight (Kg) = 0.436x (midarm circumference)+ 0.857x(age)+0.111x(height) -5.913

Discussion

This study aimed to assess the relationship between head circumference, midarm circumference, height, and age with body weight of pediatrics. Data were randomly collected and analyzed from 290 subjects at the pediatrics outpatient department, Ratchaburi Hospital.

Head circumference, midarm circumference, height, and age were related to body weight of pediatrics. A new formula weight (kg) = 0.436 x (midarm circumference) + 0.857 x (age) + 0.111 x (height) - 5.913 was presented. Age had more influence than other factors. As a single factor, length or height gave the most accurated weight but the combined factors showed increased accuracy.

Age

Age significantly correlated with weight. From data, growth of pediatrics correlated with age.[24] Linear regression analysis showed that weight 1.6 = x (age) + 10 (adjusted R^2 = 0.66). This differed from other formulae. Weight as age-based in this study was lower than APLS and LO formulae. APLS and LO formulae have been extensively studied in Europe and Australia where circumstances, food and ethnicity are different. Results of Eric Cheung for BMI from Asian pediatrics were lower than White.[25] Age-based formulae may not be suitable for Asian pediatrics.

Height

Height or length correlated with weight. A height or length-based formula showed most accuracy to predict weight. Other studies also found that Brocelow tape, as a length based-formula, was more accurate than an age-based formula.[11,12,26] In USA, Using Powper tape was more accurate than Brocelow tape. Both of them known to be inaccurate in obese pediatrics.[27] In sudan, brocelow tape was used in malnutrition paediatrics. It was markedly inaccurate in malnutrition patients.[28] Because of ethnic, BMI values of patients in this study were lower than caucacian. Length based formula predicted weight inaccurately in abnormal BMI and differed from another studies.

Midarm circumference (MAC)

The relationship between weight and midarm circumference is shown as the new formula, weight = 1.1 x (midarm circumference) - 1.4. Few studies have addressed the relationship between midarm circumference and weight. Giles N Cattermole proposed a formula[29] as weight in kg = 3.75 x (MAC in cm) - 43.45. Cattermole' formula is based on Europe populations. This study is based on Asian populations, so new formula is more suitable for Thai. In Philippines, midarm circumference formula was the most accurate in estimating weight.[30] Midarm circumference correlated with BMI.[31] From limited amount of MAC data, MAC-based formulae should be further investigated.

Head circumference

Head circumference was related with weight as weight = 0.86 x (head circumference) - 24.7. No reference to this relationship was found in the literature review. To the best of our knowledge, this is the first prediction of weight from head circumference. Further study may improve the accuracy of this formula for application in Emergency Departments.

Multiple regression analysis showed that age, height, and midarm circumference were all co predictors of weight as follows:

Weight (kg) = 0.436 x (midarm circumference)

+ 0.857 x (age) + 0.111 x (height) -5.913

Head circumference was significant in univariate regression but this factor decreased power of regression models in multivariate analysis. Incremental patterns of head circumference were different from other predictors so the results indicated that head circumference cannot be used as a co predictor with other variables.

Strengths of the study

Measurements in this study were accurate and methods of measurement were standardized before data collection.

Limitations of the study

1. The population was only single site as Asian pediatrics; therefore, formulation may not be applicable for use in Europe or America. But it was suitable for Asian population.

2. The population in this study consisted of pediatrics who were ill. Results might inaccurate in well-being pediatrics.

3. This study was not excluded diarrheal patients. Estimated weight from this formula might less than exact weight.

Suggestions

Our formula can be applied to pediatric patients to predict weight. Doctors can use these formulas to calculate the correct doses of drugs to resuscitate pediatric patients in the emergency department. Further studies are required to collect data from multiple ethnic populations which can then be applied globally.

Conclusion

Head circumference, midarm circumference, height, and age are related to body weight of pediatrics. All these measurements can be used to predict pediatric weight.

Acknowledgments

The author thanks Dr. Patcharin Somboon for useful suggestions during this research.

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บทคัดย่อ: ปัจจัยที่มีอิทธิพลต่อการประมาณน้ำหนักเด็ก

สิโรตม์ ศรีมหาดไทย พ.บ, วว. (เวชศาสตร์ฉุกเฉิน)
กลุ่มงานเวชศาสตร์ฉุกเฉิน โรงพยาบาลราชบุรี
Journal of Health Science 2020;29(5):923-30.

การศึกษานี้เป็นการศึกษาแบบตัดขวาง โดยทำการศึกษาที่กลุ่มงานกุมารเวชกรรม แผนกผู้ป่วยนอก โรงพยาบาลราชบุรี ผู้เข้าร่วมการศึกษาและผู้ปกครองทุกคนจะผ่านกระบวนการขอความยินยอมในการเข้าร่วมการศึกษา ข้อมูลลักษณะทั่วไปของผู้ป่วยจะถูกนำเสนอในรูปแบบพรรณนา ส่วนข้อมูล อายุ ความสูง เส้นรอบศีรษะ เส้นรอบกึ่งกลางแขน จะถูกนำมาหาความสัมพันธ์โดยการวิเคราะห์แบบถดถอยพหุคูณ ผลการศึกษาพบว่า มีผู้เข้าร่วมการศึกษาทั้งสิ้น 290 คน เป็นผู้ชาย 147 คน อายุเฉลี่ย 4.7 ปี น้ำหนักเฉลี่ย 17.34 กิโลกรัม ความสูงเฉลี่ย 157.84 เซนติเมตร เส้นรอบกึ่งกลางแขนเฉลี่ย 17.4 เซนติเมตร โดยน้ำหนัก ส่วนสูง อายุ เส้นรอบกึ่งกลางแขน มีค่าสหสัมพันธ์แสดงออกถึงความสัมพันธ์กันกับน้ำหนักอย่างมีนัยสำคัญ โดยจากการวิเคราะห์แบบถดถอยพหุคูณ พบว่าน้ำหนัก (กิโลกรัม) = 0.436 x (เส้นรอบกึ่งกลางแขน) + 0.857 x (อายุ) + 0.111 x (ความสูง) - 5.913. โดยสรุปจากการศึกษานี้ อายุ ความสูง เส้นรอบศีรษะ เส้นรอบกึ่งกลางแขน มีความสัมพันธ์กับน้ำหนักของผู้ป่วยเด็ก และแต่ละตัวแปรสามารถนำมาคำนวณหาน้ำหนักได้

คำสำคัญ: **อายุ; ความสูง; เส้นรอบศีรษะ; เส้นรอบกึ่งกลางแขน; การประมาณน้ำหนัก**