Safe needling depths of upper back acupoints in children: a retrospective study

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Abstract

Background: Acupuncture is applied for treating numerous conditions in children, but few studies have examined the safe needling depth of acupoints in the pediatric population. In this study, we investigated the depths to which acupuncture needles can be inserted safely in the upper back acupoints of children and the variations in safe depth according to sex, age, weight, and body mass index (BMI).

Methods: We retrospectively studied computed tomography (CT) images of patients aged 4 to 18 years who underwent chest CT at China Medical University Hospital between December 2004 and May 2013. The safe depths of 23 upper back acupoints in the Governor Vessel (GV), Bladder Meridian (BL), Small Intestine Meridian (SI), Gallbladder Meridian (GB) and Spleen Meridian (SP) were measured directly from the CT images. The relationships between the safe depths of these acupoints and sex, age, body weight, and BMI were analyzed.

Results: The results indicated significant differences in safe needling depth between boys and girls in most upper back acupoints, except at BL42, BL44, BL45, BL46, GB21 and SP21. Safe depths differed significantly depending on age (p < 0.001), weight (p ≤ 0.01), and BMI (p < 0.05). Multiple regression analysis revealed that weight was the most crucial factor in determining the safe depth.

Conclusions: Sex, age, weight, and BMI are relevant factors in determining the safe needling depths of upper back acupoints in children. Physicians should pay attention to wide variations in needle depth when performing acupuncture.

Keywords: Acupuncture, Safe depth, Children, Upper back

Background

Acupuncture is a traditional Chinese medical practice that has been used to treat numerous diseases in China for thousands of years. The practice has gained popularity in Western countries and become one of the most popular forms of complementary and alternative therapy. Acupuncture has been applied to treat several conditions in children, including pain, nocturnal enuresis, postoperative nausea and vomiting, allergic rhinitis, laryngospasm, and neurological disorders [1, 2]. Thus, the safety of acupuncture is critical and should be considered carefully regarding pediatric patients.

Acupuncture may cause serious adverse events including subarachnoid hemorrhages, pneumothorax, cardiac ruptures, nerve impairment, intestinal obstruction, hemoptysis, reversible comas, and infection [3]. Pneumothorax is the most frequent organ injury caused by acupuncture [4]. Acupoints over upper back used to be applied for cough, dyspnea, backache and shoulder pain. Hence, studying the safe depths of acupoints over upper back is critical to prevent serious and common complications, such as pneumothorax from acupuncture.

The depths of acupuncture needling recorded in ancient references have variations and there was no difference between different body sizes. Besides, no references were specific for children. In clinical practice, the depths of needling were usually performed according to practitioners’ experiences and patients’ responses. However, children usually cannot response properly to the needling stimulation. There were risks for serious complications such as pneumothorax or organ damage. Therefore, we want to establish data of the safe needling depth, considering the factors of sex, age, weight and BMI in children.

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In children, the physical development process may cause changes in lean muscle mass and fat volume [5]. Particularly during puberty, the sexual dimorphism of body composition and the wide time range of pubertal onset cause wide variations in fat volume, muscle mass, and their distribution [6]. Such variations may be highly complex and may influence safe needling depth. Such difficulties are not encountered when treating adults.

Most previous studies on safe needling depth have involved small sample sizes and adult groups [7, 8]. One study measured the safe depths of back loci in adults, finding differences depending on body size but not sex [9]. Few studies have evaluated safe needling depth in children. Only two studies measuring the safe depths and therapeutic depths of abdomen acupoints have included pediatric populations [10, 11]. In this study, we included large sample sizes of children and measured the safe depths of upper back acupoints by analyzing

![Fig. 1 Total 23 acupoints over upper back. The figure was adapted from “Review on the history and practice of the needling depth of acupoints” [25]](image)

**Table 1** General characteristics of patients

| Characteristics | Subjects numbers |
|-----------------|-----------------|
| Gender          |                 |
| Male            | 205             |
| Female          | 114             |
| Age (years old) |                 |
| 4–6             | 79              |
| 7–9             | 45              |
| 10–12           | 30              |
| 13–15           | 56              |
| 16–18           | 109             |
| Weight          |                 |
| <3rd percentile | 32              |
| 3–<85th percentile | 215         |
| 85–<97th percentile | 42            |
| ≥97th percentile | 29              |
| BMI             |                 |
| Underweight     | 52              |
| Healthy weight  | 186             |
| Overweight      | 18              |
| Obesity         | 30              |

**Table 2** Safe depths of 23 upper back acupoints of sexes

| Acupoints | Boys Mean ± S.D. | Girls Mean ± S.D. | P value |
|-----------|------------------|-------------------|---------|
| GV9       | 27.78 ± 8.88     | 24.87 ± 7.83      | 0.003a  |
| GV10      | 28.54 ± 8.47     | 26.02 ± 7.67      | 0.009a  |
| GV11      | 28.17 ± 8.21     | 25.88 ± 7.04      | 0.009a  |
| GV12      | 30.45 ± 9.90     | 28.03 ± 8.24      | 0.028a  |
| GV13      | 33.61 ± 10.07    | 30.59 ± 9.11      | 0.008a  |
| GV14      | 33.81 ± 10.57    | 30.70 ± 10.68     | 0.012a  |
| BL11      | 33.39 ± 10.48    | 28.95 ± 8.67      | <0.001a |
| BL12      | 35.61 ± 9.61     | 32.33 ± 8.09      | 0.001a  |
| BL13      | 28.54 ± 7.08     | 26.41 ± 5.38      | 0.003a  |
| BL14      | 24.92 ± 7.95     | 22.69 ± 6.63      | 0.008a  |
| BL15      | 25.48 ± 6.57     | 23.93 ± 5.41      | 0.024a  |
| BL16      | 24.15 ± 7.19     | 21.89 ± 6.24      | 0.004a  |
| BL17      | 25.37 ± 6.87     | 23.62 ± 6.20      | 0.021a  |
| BL41      | 30.86 ± 9.20     | 28.21 ± 7.89      | 0.010a  |
| BL42      | 28.02 ± 8.69     | 26.48 ± 7.25      | 0.110   |
| BL43      | 24.68 ± 7.54     | 22.95 ± 6.75      | 0.043a  |
| BL44      | 20.31 ± 7.79     | 19.19 ± 7.01      | 0.202   |
| BL45      | 18.45 ± 7.07     | 17.62 ± 6.50      | 0.300   |
| BL46      | 18.16 ± 6.63     | 16.96 ± 6.12      | 0.111   |
| SI14      | 36.82 ± 12.23    | 32.51 ± 10.81     | 0.002a  |
| SI15      | 38.75 ± 12.10    | 34.74 ± 10.47     | 0.003a  |
| GB21      | 28.01 ± 9.37     | 26.61 ± 8.81      | 0.192   |
| SP21      | 19.48 ± 4.39     | 18.84 ± 4.56      | 0.216   |

Unit of mean ± SD: mm

*aStatistically significant
computed tomography (CT) scans. We also evaluated the variations in safe depth according to sex, age, weight, and body mass index (BMI).

**Methods**

**Study population**

All patients aged 4 to 18 years who underwent chest CT between December 2004 and May 2013 at China Medical University Hospital (CMUH) were identified. These patients underwent CT scans for evaluating an acute chest or upper back condition such as acute accidental injuries, pneumothorax, pneumonia, and cardiac diseases. Patients with back trauma or chronic oncological diseases were excluded because of the possible effect on the thickness of subcutaneous tissues and muscles in the back. Thus, we included 4 to 18 years patients who underwent chest CT between December 2004 and May 2013 at CMUH without back trauma or chronic oncological diseases.

The age, sex, height and body weight of each patient were obtained from chart records. BMI was measured according to weight (kg)/height\(^2\) (m\(^2\)). Patients were divided into five groups according to age in years: 4–6, 7–9, 10–12, 13–15, and 16–18 on the basis of previous references [10, 11]. Patients were also divided into four weight groups according to growth charts for Taiwanese children and adolescents [12]: below the third percentile, from the third percentile up to the 85th percentile, from the 85th percentile up to the 97th percentile, and at or above the 97th percentile. Patients were divided into four BMI groups according to the same charts: underweight, defined as below the fifth percentile; healthy weight, defined as from the fifth percentile up to the 85th percentile; overweight, defined as from the 85th percentile up to the 95th percentile; and obese, defined as at or above the 95th percentile [12, 13]. The data were anonymized and this study was approved by the Research Ethics Committee of CMUH.

**Measurement of safe depths at upper back acupoints**

Acupoints were located according to a classic Chinese acupuncture technique called Tong Shen Cun (cun).

**Table 3** Safe depths of 23 upper back acupoints of age groups

| Points | 4-6 y/o (n = 79) | 7-9 y/o (n = 45) | 10-12 y/o (n = 30) | 13-15 y/o (n = 56) | 16-18 y/o (n = 109) | P value |
|--------|----------------|----------------|----------------|----------------|----------------|--------|
| GV9    | 19.31 ± 2.84   | 23.32 ± 6.17   | 27.20 ± 7.54   | 29.83 ± 8.04   | 31.83 ± 8.55   | <0.001* |
| GV10   | 20.70 ± 3.62   | 23.64 ± 4.93   | 28.86 ± 6.12   | 29.98 ± 7.74   | 32.84 ± 8.31   | <0.001* |
| GV11   | 22.14 ± 4.80   | 22.96 ± 4.52   | 27.70 ± 6.19   | 29.56 ± 7.56   | 31.71 ± 8.29   | <0.001* |
| GV12   | 22.26 ± 4.54   | 25.93 ± 5.59   | 30.75 ± 7.58   | 32.40 ± 8.73   | 34.63 ± 10.16  | <0.001* |
| GV13   | 23.02 ± 5.59   | 29.18 ± 7.70   | 35.75 ± 8.25   | 35.78 ± 7.99   | 38.26 ± 8.65   | <0.001* |
| GV14   | 23.26 ± 4.95   | 26.57 ± 8.05   | 32.30 ± 9.48   | 37.83 ± 8.79   | 39.29 ± 9.54   | <0.001* |
| BL11   | 24.93 ± 5.44   | 28.71 ± 8.00   | 31.29 ± 7.86   | 36.07 ± 10.53  | 36.01 ± 10.63  | <0.001* |
| BL12   | 28.54 ± 8.50   | 32.57 ± 8.48   | 34.43 ± 8.24   | 37.74 ± 8.56   | 37.78 ± 8.33   | <0.001* |
| BL13   | 24.82 ± 2.74   | 25.01 ± 3.00   | 26.53 ± 4.55   | 29.17 ± 7.57   | 30.68 ± 8.04   | <0.001* |
| BL14   | 18.90 ± 2.66   | 21.35 ± 4.32   | 24.67 ± 6.53   | 26.42 ± 8.14   | 27.71 ± 8.48   | <0.001* |
| BL15   | 20.94 ± 3.46   | 23.42 ± 4.57   | 24.45 ± 5.36   | 26.72 ± 6.45   | 27.65 ± 6.78   | <0.001* |
| BL16   | 18.23 ± 2.76   | 21.12 ± 5.04   | 23.96 ± 5.37   | 25.32 ± 7.26   | 26.79 ± 7.50   | <0.001* |
| BL17   | 19.14 ± 2.85   | 22.56 ± 4.03   | 25.60 ± 5.33   | 26.98 ± 6.76   | 28.33 ± 6.89   | <0.001* |
| BL18   | 24.77 ± 3.51   | 25.32 ± 5.99   | 27.74 ± 6.44   | 33.75 ± 8.96   | 34.17 ± 9.95   | <0.001* |
| BL19   | 21.97 ± 3.88   | 24.86 ± 5.50   | 28.20 ± 7.28   | 29.49 ± 8.15   | 31.30 ± 9.28   | <0.001* |
| BL20   | 19.41 ± 3.74   | 21.92 ± 4.32   | 24.29 ± 6.19   | 25.60 ± 7.95   | 27.46 ± 8.14   | <0.001* |
| BL21   | 15.21 ± 5.67   | 18.72 ± 5.42   | 19.68 ± 5.99   | 21.65 ± 7.61   | 22.99 ± 8.04   | <0.001* |
| BL22   | 13.14 ± 3.39   | 15.84 ± 4.47   | 19.43 ± 6.47   | 20.26 ± 6.46   | 21.32 ± 7.53   | <0.001* |
| BL23   | 12.74 ± 2.35   | 15.24 ± 3.58   | 19.34 ± 6.04   | 19.53 ± 6.45   | 21.01 ± 7.00   | <0.001* |
| SI14   | 26.30 ± 6.29   | 30.88 ± 9.25   | 34.18 ± 10.28  | 40.32 ± 11.41  | 41.31 ± 11.91  | <0.001* |
| SI15   | 26.92 ± 4.94   | 31.77 ± 7.65   | 39.52 ± 9.72   | 43.85 ± 12.10  | 43.17 ± 10.54  | <0.001* |
| GB21   | 20.84 ± 3.25   | 23.70 ± 4.99   | 30.16 ± 9.14   | 28.94 ± 8.97   | 32.45 ± 10.06  | <0.001* |
| SP21   | 16.97 ± 2.89   | 16.88 ± 2.18   | 19.89 ± 3.25   | 19.99 ± 4.44   | 21.34 ± 5.17   | <0.001* |

Unit of mean ± SD: mm

*Statistically significant
The back transverse Tong Shen Cun is one-sixth of the shortest distance between the two scapulae. The back vertical Tong Shen Cun is located using vertebral spinous processes. The safe depths of acupoints in the Governor Vessel (GV) are defined as the distance from the skin surface of the acupoint to the epidural layer. The safe depths of other acupoints in the upper back are defined as the distance from the skin surface of acupoints to the pleura.

Twenty-three back acupoints located in the GV, Bladder Meridian (BL), Small Intestine Meridian (SI), Gallbladder Meridian (GB) and Spleen Meridian (SP) were measured. Patients diagnosed with pneumothorax were measured on the healthy side of their backs. GV14, GV13, GV12, GV11, GV10, and GV9 were located at the central points between the spinous processes of C7 and T1, T1 and T2, T3 and T4, T5 and T6, T6 and T7, and T7 and T8, respectively. The BL was 1.5 and 3 cun lateral to the GV. For example, BL13 and BL42 were 1.5 and 3 cun lateral to the GV12. SI15 was 2 cun lateral to GV14 and SI14 was 3 cun lateral to GV13. GB21 was located at the midpoint of the line between the C7 and the lateral end of acromion. Sp21 was located at intersection of the sixth intercostal space and the midaxillary line (Fig. 1).

The CT machines used at CMUH were the Optima Speed CT Scanner (GE Healthcare, General Electric, USA), Optima CT660 (GE Healthcare) and Light Speed 16 CT Scanner (GE Healthcare). All CT images were captured in the transverse plane and body positions of all the participants were supine. The section thickness between each image was 5 mm. Safe depths were measured by examining the CT images on a Picture Archiving and Communication System (PACS) monitor (Realsync, Taiwan).

### Statistical analysis

The safe depths of acupoints among different age, weight, and BMI groups were analyzed using a one-way analysis of variance. Student's t tests were used to compare the safe depths of acupoints between boys and girls. Multiple regression models were used to analyze

| Table 4 Safe depths of 23 upper back acupoints in different weight groups |
|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
| Points  | <3rd (n = 32) | 3rd–85th (n = 215) | 85th–97th (n = 42) | ≥97th (n = 29) | P value |
| Mean ± S.D. | Mean ± S.D. | Mean ± S.D. | Mean ± S.D. | Mean ± S.D. |<0.001 a |
| GV9  | 23.95 ± 5.74 | 26.00 ± 7.55 | 29.07 ± 9.61 | 32.00 ± 13.69 |<0.001 a |
| GV10 | 25.88 ± 5.85 | 26.45 ± 7.16 | 30.51 ± 8.18 | 34.18 ± 13.32 |<0.001 a |
| GV11 | 24.98 ± 5.10 | 26.41 ± 6.55 | 29.28 ± 8.97 | 34.25 ± 12.74 |<0.001 a |
| GV12 | 27.58 ± 6.53 | 28.12 ± 6.65 | 32.47 ± 9.81 | 38.48 ± 19.01 |<0.001 a |
| GV13 | 30.21 ± 8.23 | 31.25 ± 8.44 | 35.47 ± 9.16 | 40.42 ± 16.13 |<0.001 a |
| GV14 | 31.31 ± 9.68 | 31.66 ± 9.36 | 34.88 ± 12.04 | 38.63 ± 16.11 |0.004 a |
| BL11 | 29.99 ± 9.18 | 30.87 ± 8.57 | 33.96 ± 10.81 | 37.51 ± 16.68 |0.003 a |
| BL12 | 33.08 ± 9.92 | 33.58 ± 8.33 | 36.21 ± 8.89 | 39.23 ± 12.94 |0.007 a |
| BL13 | 26.25 ± 4.70 | 26.96 ± 4.99 | 29.26 ± 6.82 | 33.51 ± 12.84 |<0.001 a |
| BL14 | 21.86 ± 5.44 | 23.45 ± 6.48 | 25.99 ± 8.42 | 28.99 ± 12.37 |<0.001 a |
| BL15 | 22.86 ± 4.42 | 24.13 ± 5.20 | 27.28 ± 6.72 | 29.73 ± 10.12 |<0.001 a |
| BL16 | 21.36 ± 5.25 | 22.50 ± 5.90 | 25.42 ± 7.59 | 28.89 ± 10.86 |<0.001 a |
| BL17 | 22.23 ± 4.57 | 24.13 ± 6.07 | 26.70 ± 6.78 | 29.35 ± 9.86 |<0.001 a |
| BL18 | 26.45 ± 5.32 | 29.14 ± 7.03 | 31.83 ± 10.67 | 36.77 ± 15.45 |<0.001 a |
| BL19 | 24.59 ± 5.71 | 26.38 ± 6.55 | 29.53 ± 6.86 | 35.74 ± 15.50 |<0.001 a |
| BL20 | 22.17 ± 4.95 | 23.00 ± 5.34 | 26.11 ± 8.25 | 30.98 ± 13.86 |<0.001 a |
| BL21 | 17.10 ± 4.24 | 19.06 ± 6.13 | 22.28 ± 8.10 | 25.90 ± 13.45 |<0.001 a |
| BL22 | 15.01 ± 4.16 | 17.28 ± 5.57 | 20.52 ± 7.03 | 24.72 ± 11.74 |<0.001 a |
| BL23 | 15.41 ± 4.58 | 16.80 ± 4.87 | 20.12 ± 6.69 | 23.66 ± 12.14 |<0.001 a |
| SI14 | 31.64 ± 9.57 | 33.98 ± 9.68 | 37.57 ± 12.13 | 45.32 ± 20.78 |<0.001 a |
| SI15 | 35.12 ± 10.03 | 36.39 ± 10.09 | 38.22 ± 12.86 | 45.15 ± 18.52 |0.001 a |
| GB21 | 25.40 ± 9.45 | 26.32 ± 7.88 | 31.09 ± 9.68 | 33.27 ± 13.27 |<0.001 a |
| SP21 | 17.97 ± 4.26 | 18.83 ± 4.12 | 20.26 ± 4.15 | 22.46 ± 5.89 |<0.001 a |

Unit of mean ± SD: mm

*Statistically significant
whether sex, age, weight, or BMI are relevant factors in determining the safe depths of acupoints. Statistical analyses were performed using the SPSS software package, Version 18.0 (SPSS Inc., Chicago, IL), and \( p < 0.05 \) was considered significant.

**Results**

A total of 319 patients (205 boys and 114 girls) aged 4 to 18 years were included in this study. The general characteristics of the patients are shown in Table 1.

The mean and standard deviation of the safe depths of boys and girls at 23 back acupoints are listed in Table 2. The shallowest and greatest depths of both sexes were at BL46 and SI15, respectively. Among the upper back acupoints, the deepest safe depth was 2.13 times in boys and 2.05 times in girls than the shallowest one. The safe depths of most back acupoints differed significantly between boys and girls, except BL42, BL44, BL45, BL46, GB21 and SP21. All 23 acupoints in boys were deeper than in girls.

Safe depths significantly differed among age groups (\( p < 0.001; \) Table 3). Almost all safe depths significantly correlated with an increase in age. The safe depth was greater in those who are older.

Safe depths significantly differed between weight groups (\( p < 0.01; \) Table 4) and significantly increased with weight at all 23 acupoints. Safe depths among those weighing above the 97th percentile were between 1.19 (BL12) and 1.65 (BL45) times deeper than among those weighing below the third percentile.

Safe depths also significantly varied between BMI groups (\( p < 0.05; \) Table 5). An increase in BMI was significantly correlated with increased safe depth. Safe depths in the obese group were between 1.18 (BL12) and 1.47 (BL44) times deeper than in the underweight group.

### Table 5 Safe depth of 23 upper back acupoints of BMI groups

| Points | Underweight\(^a\) (n = 52) Mean ± S.D. | Healthy weight\(^b\) (n = 186) Mean ± S.D. | Overweight\(^c\) (n = 18) Mean ± S.D. | Obesity\(^d\) (n = 30) Mean ± S.D. | P value |
|--------|--------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|---------|
| GV9    | 24.40 ± 5.94                         | 26.21 ± 7.73                        | 29.42 ± 10.63                       | 30.92 ± 12.99                       | 0.003\(^e\) |
| GV10   | 25.27 ± 5.47                         | 26.75 ± 7.21                        | 30.51 ± 8.62                       | 33.58 ± 12.14                       | <0.001\(^e\) |
| GV11   | 25.23 ± 5.02                         | 26.38 ± 6.94                        | 30.47 ± 8.26                       | 33.40 ± 11.82                       | <0.001\(^e\) |
| GV12   | 26.91 ± 5.80                         | 28.54 ± 6.89                        | 32.23 ± 9.25                       | 36.78 ± 17.38                       | <0.001\(^e\) |
| GV13   | 30.62 ± 7.26                         | 31.61 ± 8.36                        | 34.86 ± 9.39                       | 38.70 ± 14.71                       | <0.001\(^e\) |
| GV14   | 30.26 ± 9.19                         | 31.84 ± 9.39                        | 33.86 ± 13.01                      | 38.80 ± 14.75                       | 0.002\(^e\) |
| BL11   | 30.25 ± 8.39                         | 30.90 ± 8.96                        | 33.94 ± 11.20                      | 37.66 ± 15.18                       | 0.003\(^e\) |
| BL12   | 32.78 ± 9.13                         | 33.86 ± 8.52                        | 33.92 ± 8.54                       | 38.57 ± 11.70                       | 0.037\(^e\) |
| BL13   | 26.09 ± 4.78                         | 27.06 ± 4.89                        | 28.94 ± 7.44                       | 33.22 ± 12.10                       | <0.001\(^e\) |
| BL14   | 22.72 ± 5.91                         | 23.33 ± 6.60                        | 26.68 ± 8.13                       | 29.00 ± 11.85                       | <0.001\(^e\) |
| BL15   | 22.62 ± 3.81                         | 24.57 ± 5.35                        | 26.70 ± 6.67                       | 29.78 ± 9.61                       | <0.001\(^e\) |
| BL16   | 21.98 ± 5.31                         | 22.37 ± 6.17                        | 26.30 ± 6.86                       | 28.62 ± 10.07                       | <0.001\(^e\) |
| BL17   | 23.21 ± 4.98                         | 24.20 ± 6.00                        | 26.35 ± 6.94                       | 29.03 ± 9.72                       | <0.001\(^e\) |
| BL41   | 27.33 ± 5.67                         | 29.16 ± 7.41                        | 32.41 ± 10.18                      | 35.88 ± 14.86                       | <0.001\(^e\) |
| BL42   | 25.42 ± 6.23                         | 26.60 ± 6.51                        | 30.06 ± 6.90                       | 32.92 ± 13.70                       | <0.001\(^e\) |
| BL43   | 21.98 ± 4.87                         | 22.00 ± 5.56                        | 27.11 ± 6.64                       | 30.25 ± 13.17                       | <0.001\(^e\) |
| BL44   | 17.59 ± 4.86                         | 18.99 ± 6.29                        | 23.29 ± 7.90                       | 25.85 ± 12.07                       | <0.001\(^e\) |
| BL45   | 15.98 ± 4.77                         | 17.42 ± 5.63                        | 21.73 ± 6.97                       | 22.89 ± 11.49                       | <0.001\(^e\) |
| BL46   | 16.15 ± 4.54                         | 16.94 ± 5.00                        | 19.67 ± 6.69                       | 22.71 ± 11.53                       | <0.001\(^e\) |
| SI14   | 32.40 ± 9.29                         | 33.88 ± 9.94                        | 39.87 ± 12.20                      | 42.61 ± 18.58                       | <0.001\(^e\) |
| SI15   | 35.25 ± 9.01                         | 36.41 ± 10.49                      | 39.54 ± 11.60                      | 45.26 ± 18.02                       | <0.001\(^e\) |
| GB21   | 26.43 ± 8.52                         | 26.67 ± 8.11                        | 31.23 ± 11.01                      | 31.41 ± 12.84                       | 0.012\(^e\) |
| SP21   | 19.36 ± 4.86                         | 18.76 ± 4.03                        | 20.40 ± 4.55                       | 20.68 ± 5.50                       | 0.086\(^e\) |

Unit of mean ± SD: mm

\(^a\)Underweight: patients with BMI below the fifth percentile
\(^b\)Healthy weight: patients with BMI from the 5th percentile up to the 85th percentile
\(^c\)Overweight: patients with BMI from the 85th percentile up to the 95th percentile
\(^d\)Obese: patients with BMI at or above the 95th percentile
\(^e\)Statistically significant
We performed multiple regression models to analyze whether age, sex, weight, and BMI are relevant factors in determining the safe depths of acupoints. The results revealed that weight was significantly correlated with safe depth at all 23 acupoints. (Table 6) Thus, weight was the most crucial factor in determining the safe depths of upper back acupoints.

**Discussion**
Performing acupuncture on back acupoints has been demonstrated to be an effective alternative therapy for local myofascial pain [14, 15], asthma, allergic rhinitis [16], and tuberculosis consumptive diseases [17]. As the popularity of acupuncture increases, the importance of determining the safe depths of acupoints also increases, particularly the safe depths in the upper back. Acupuncture on the upper back may cause pleural and lung injuries [18, 19]. In pediatric groups, safe needling depths vary largely because of rapid changes in body size and shape. This study is the first to estimate the variations in the safe depths of upper back acupoints according to sex, age, weight, and BMI in children aged 4 to 18 years. We observed boys had deeper safe depth than girls. The safe depths were greater among older groups, heavier weight groups, and higher BMI groups.

The safe depths of all upper back acupoints in boys were deeper than in girls, and all such differences were significant, except at BL42, BL44, BL45, BL46, GB21 and SP21. Girls tend to accumulate more total body and subcutaneous fat, which is deposited mainly in the gynoid region and thigh during and after puberty. However, among boys, more fat is deposited in the upper segment of the body, both subcutaneously and intraabdominally, and more total lean and muscle mass is developed in this period [5, 20]. The greater amount of muscle mass and trunk fat among boys could explain this difference between the sexes, which has not been observed in studies on pediatric abdomen acupoints [10] or adult back acupoints [9].

**Table 6** Multiple regression analysis for safe depths of 23 upper back acupoints

| Points | Variables in multiple regression model | β (95% CI) | P value | β (95% CI) | P value | β (95% CI) | P value |
|--------|----------------------------------------|------------|---------|------------|---------|------------|---------|
| GV9    | Age (0.38–0.26) 0.716                   | 0.33 (0.22–0.43) <0.001* | 0.08 (0.16–0.32) 0.527 | -0.60 (–0.25–0.95) 0.446 |
| GV10   | Weight (0.31–0.28) 0.927                | 0.28 (0.18–0.38) <0.001* | 0.23 (0.01–0.45) 0.038* | -0.85 (–0.27–0.57) 0.241 |
| GV11   | 0.25 (0.55–0.05) 0.100                   | 0.31 (0.22–0.41) <0.001* | 0.19 (0.04–0.41) 0.098 | -1.05 (–0.29–0.39) 0.152 |
| GV12   | -0.14 (–0.48–0.20) 0.412               | 0.34 (0.23–0.45) <0.001* | 0.21 (–0.04–0.47) 0.101 | -1.41 (–0.36–0.24) 0.093 |
| GV13   | 0.27 (–0.07–0.60) 0.114              | 0.27 (0.16–0.38) <0.001* | 0.27 (0.02–0.52) 0.035* | -0.82 (–0.25–0.81) 0.324 |
| GV14   | 0.46 (0.05–0.86) 0.027*              | 0.26 (0.13–0.39) <0.001* | 0.17 (–0.13–0.48) 0.261 | -0.61 (–0.25–0.16) 0.544 |
| BL11   | -0.07 (–0.50–0.37) 0.757            | 0.29 (0.15–0.44) <0.001* | 0.10 (–0.22–0.43) 0.531 | 1.34 (–0.78–3.46) 0.213 |
| BL12   | 0.18 (–0.24–0.60) 0.395             | 0.19 (0.06–0.33) 0.005* | 0.02 (–0.30–0.33) 0.927 | 1.06 (–0.97–3.09) 0.304 |
| BL13   | -0.51 (–0.78–0.24) <0.001*            | 0.31 (0.22–0.40) <0.001* | 0.04 (–0.16–0.24) 0.700 | -0.52 (–1.83–0.80) 0.442 |
| BL14   | -0.32 (–0.62–0.01) 0.044*             | 0.32 (0.22–0.42) <0.001* | 0.03 (–0.19–0.27) 0.755 | -0.82 (–2.31–0.68) 0.284 |
| BL15   | -0.33 (–0.58–0.09) 0.008*             | 0.25 (0.17–0.33) <0.001* | 0.20 (0.01–0.38) 0.035* | -0.77 (–1.96–0.42) 0.201 |
| BL16   | -0.16 (–0.44–0.12) 0.253            | 0.24 (0.15–0.33) <0.001* | 0.20 (–0.01–0.40) 0.065 | -0.14 (–1.48–1.20) 0.835 |
| BL17   | -0.22 (–0.47–0.03) 0.078           | 0.29 (0.21–0.37) <0.001* | 0.05 (–0.14–0.23) 0.609 | -1.16 (–2.36–0.04) 0.057 |
| BL41   | -0.51 (–0.86–0.16) 0.005*             | 0.43 (0.31–0.54) <0.001* | 0.08 (–0.35–0.19) 0.553 | -1.14 (–2.86–0.57) 0.191 |
| BL42   | -0.32 (–0.64–0.01) 0.046*             | 0.33 (0.23–0.44) <0.001* | 0.06 (–0.17–0.30) 0.598 | -1.69 (–3.23–0.14) 0.032* |
| BL43   | -0.32 (–0.62–0.02) 0.036*             | 0.28 (0.19–0.38) <0.001* | 0.13 (–0.09–0.36) 0.242 | -0.07 (–0.24–0.47) 0.186 |
| BL44   | -0.36 (–0.68–0.04) 0.026*             | 0.29 (0.18–0.39) <0.001* | 0.13 (–0.10–0.38) 0.256 | -1.62 (–3.17–0.07) 0.040* |
| BL45   | -0.40 (–0.67–0.14) 0.003*             | 0.34 (0.25–0.42) <0.001* | 0.00 (–0.20–0.20) 1.000 | -0.25 (–3.53–0.98) 0.001* |
| BL46   | -0.31 (–0.55–0.07) 0.012*             | 0.31 (0.23–0.38) <0.001* | -0.01 (–0.19–0.18) 0.938 | -1.66 (–0.24–0.47) 0.066* |
| SI14   | -0.10 (–0.56–0.36) 0.674          | 0.41 (0.26–0.56) <0.001* | 0.13 (–0.22–0.47) 0.473 | 0.03 (–0.22–0.27) 0.978 |
| SI15   | 0.20 (–0.26–0.66) 0.383           | 0.34 (0.20–0.49) <0.001* | 0.18 (–0.16–0.53) 0.300 | -0.22 (–0.25–0.20) 0.846 |
| GB21   | -0.26 (–0.64–0.13) 0.189         | 0.39 (0.26–0.51) <0.001* | -0.17 (–0.46–0.12) 0.249 | -2.12 (–3.99–0.25) 0.026* |
| SP21   | -0.04 (–0.24–0.16) 0.695       | 0.14 (0.08–0.21) <0.001* | -0.07 (–0.22–0.09) 0.389 | -0.57 (–1.55–0.41) 0.254 |

*Statistically significant β regression coefficient, CI confidence interval*
Safe depth significantly differed among age groups and was significantly correlated with an increase in age for nearly all acupoints. Age influences safe depths because muscle mass and subcutaneous adipose tissue increase with age [5] among children. However, age need not be considered when determining the safe depths in adults.

Safe depths significantly differed between weight groups and significantly increased with weight at all 23 acupoints. Thicker fat or muscle tissue layers in heavier children may explain this observation, which is compatible with the results of an adult study in which the safe depths of back acupoints were related to body size [9]. At BL42, BL44, BL45, and BL46, the safe depths of patients weighing above the 97th percentile were approximately 1.5–1.6 times the safe depths of those weighing below the third percentile. Clinicians should be aware of these weight-related differences and the risk of pneumothorax when performing acupuncture in this area of the body.

The BMI characterizes the relative proportion of child’s weight and height percentile for age and sex. The BMI is the optimal clinical standard for diagnosing obesity in children and adolescents [21, 22]. We found that increasing BMI was significantly correlated with increased safe depths. At BL43, BL44, BL45, and BL46, the safe depths in the obesity group were approximately 1.4–1.5 times deeper than those in the underweight group. This result was similar to that in the weight group.

Multiple regression analysis revealed that weight was the most critical factor in determining the safe depths of upper back acupoints. Previous studies have observed that BMI percentile changes may not accurately reflect changes in adiposity in children, particularly among male adolescents and children with lower BMIs [23]. The BMI is limited in its usefulness in predicting adiposity by its inability to distinguish fat mass from lean body mass in pediatric populations. We used growth charts for Taiwanese children and adolescents [12, 13] for decreasing ethnic differences, but BMI was also influenced by age, sex and pubertal status [24]. This might explain why BMI was less crucial than weight in influencing safe depths in this study.

This study has three noteworthy strengths. First, the study included larger pediatric sample sizes. Second, we studied factors such as sex, age, weight, and BMI that influence safe depth. Finally, the study determined safe depths by examining in vivo CT images, a more accurate method than recording measurements from cadavers. Depths from cadavers are unreliable because the tissues dries and contracts after freezing, anticroosive positioning, and dyeing processes.

This study has limitations. First, the study used a retrospective design. Second, the examined children were patients, not healthy children. However, to increase validity, patients with diseases that might have affected the thickness of the subcutaneous tissues or muscles in their backs were excluded. Third, the sample size of the overweight group was small. Finally, this study was conducted in a single medical center, limiting its population generalizability.

Conclusions
This study determined that the safe depths of most upper back acupoints significantly differ between the sexes. Safe depths significantly differed among age groups and significantly increased with weight and BMI. Acupuncturists should consider wide variations in safe needling depth in the upper backs of children to balance treatment effects and complications.

Abbreviations
BMI: body mass index; CT: computed tomography; CMUH: China Medical University Hospital; GV: Governor Vessel; BL: bladder meridian; SI: small intestine meridian; GB: gallbladder meridian; SP: spleen meridian.

Competing interests
The authors declare that they have no competing interests.

Authors’ contributions
YCM designed the study and drafted the initial manuscript. JGL helped the study’s conception, and reviewed and revised the manuscript. CTP helped to conduct the literature review and supervised the field activities, quality assurance and control. YCH designed the study’s analytic strategy and conducted the data analysis. HYL helped to measure the depth of acupoints. All authors read and approved the final manuscript.

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