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Total body and hand surface area: Measurements, calculations, and comparisons in ethnically diverse children in South Africa

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ABSTRACT

Aim: The aim was to investigate hand surface as a percentage of body surface area from infancy to 13 years of age using physical measurement and digital planimetry and establish the influence of age, gender, BMI for age and ethnicity, specifically in the South African population. A secondary aim included the development of a template for burn size measurement.

Methodology: This was a cross-sectional observational study. Demographic information was obtained from each participant. Body mass index (BMI) and body surface area (BSA) were determined using several established formulas. The hand area was measured using a standard physical measurement method and a digital planimetry method. All data was presented in an Excel and SPSS spreadsheet and the calculations performed with SPSS 24.0. **Results:** Three-hundred and sixty-eight burn patients and 150 children from a nearby primary school were enrolled. The age ranged from 1 month to 13 years. The hospital patient group was significantly younger, included more boys and had a lower BMI by age. Most patients (98.7%) were African or mixed race compared to the school children who were primarily Caucasian ($p < 0.001$). The seven formulas to determine the BSA were highly comparable with Intraclass correlation coefficient (ICC) of 0.997 (95% CI 0.996-0.998). Actual hand surface area measured ranged from 22.44 cm² to 164.9 cm². The mean measured and digital percentage HSA of TBSA for all participants was 0.929% with a SD of 0.088. Male children, had a larger HSA as a proportion of TBSA by 0.036%. Generally, as the child gets older from toddler to late childhood, the hand becomes relatively smaller by a factor of approximately 0.08%. As the BMI increased, the hand got relatively smaller.

Conclusion: The potential value of the physical measurement method is that it lends itself to direct measurement during examination of the burnt child. The study showed that there are minor differences between racial groups, gender, BMI and age variations. The clinical relevance of these variations is negligible.

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1. Introduction

Burns are common amongst children of the Western Cape Region with an estimated annual prevalence rate of 6.0/10,000 child-years (c-y). They are especially prevalent in toddlers (15.8/10,000 c-y) and infants (14.6/10,000 c-y), boys (7/10,000 c-y) and girls (5.1/10,000 c-y) [1]. Forty percent of the burns are minor, 56% of moderate size and 5% severe and 50% will be referred for hospital care [2].

A review of community management of paediatric burns in this area revealed that parents and even local clinics had little understanding of the required emergency management including the assessment of the size and depth of the sustained burn. Both these factors are essential in determining the urgency of treatment, whether resuscitation is required, and if so, what volume of fluid should be given during the first 24-48h [3].

Three methods are used to calculate the percentage body surface area involved: the "Rule of Nines", the Lund and Browder chart and the formula used by Berkow. The latter was adapted to the changing bodily proportions of the developing child [4].

Children often sustain hot liquid burns which are scattered over the body, rendering these methods, which depend on confluent areas of involvement, difficult to apply with accuracy. To overcome this obstacle, methods utilising the open hand of the patient for estimating the percentage total body surface area (TBSA) were developed specifically for small scattered surface burns.

Hand surface area as a percentage of body surface area for children has been calculated and varies from 0.82% to 1.9% TBSA [5]. Most of these studies were performed on European and Asian children. Some studies note that a difference between ethnic groups in percentage hand surface area (HSA) is non-existent, while others state that differences do exist and should be considered in treatment methods [5-10]. There are no similar studies for South African children of European, African or mixed descent. The children participating in our study were from various social backgrounds, economic status and culture and therefore represented the average South African child.

The aims of the study were (1) to determine the most accurate body surface area formula for our population, (2) to compare the accuracy and differences between physical measurement and digital planimetry, (3) to calculate hand surface area (palmer and finger surface) as a percentage of TBSA from infancy to 12 years of age and (4) to establish the influence of age, gender, body mass index (BMI) for age and ethnicity specifically in the African population. Results from this study will be used to develop a simple template to calculate wound surface area in scattered burns. These findings could be used to develop a measuring tool-template equivalent to the average calculated percentage hand surface area per age that could be used in emergency room settings, especially for burns of a patchy nature.

2. Methodology

This was a cross-sectional observational study designed to evaluate the mean hand surface area as a percentage of total

body surface area in children less than thirteen years of age. Only typically developing children were recruited during the months of February to May 2015 from the outpatient's department and from a primary school in Cape Town. The study was approved by both Institutional Ethics and University of Cape Town Human Research Ethics Committees HREC. 660/2014. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

After informed consent, demographic information was obtained from each participant including the date of measurement, location, date of birth, gender and race. In terms of race, participants were asked personally as to which race they consider themselves to be, options being African, Asian, Coloured or Caucasian.

Participants were measured for body weight in kilograms and length in meters and their body mass index (BMI) and body surface area (BSA) determined. BMI was defined as the body mass divided by the square of the body height, and universally expressed in units of kg/m^2 , resulting from weight in kilograms and height in meters. The total BSA was calculated for each participant using seven published formulas for body surface area: Boyd, Costeff, Dubois, Gehan and George, Haycock, Mosteller and Yu. If the intraclass correlation coefficient between methods would be high, the mean BSA from the seven formulas for each participant will be calculated and used for all further calculations and statistical analysis.

Hand surface area was defined as the area of the palm and fingers. The hand area (either left or right) was measured using two methods. The first method used a medical tape measure and callipers. The hand length (HL) was physically measured from the midpoint of the inter-styloid line to the distal tip of the middle finger. The hand width (HW) was measured from the midpoint of the ulnar concavity at the base of the small finger to the point where the thumb diverged from the index finger. These distances were used to calculate the surface area using the formula $\text{HL} \times \text{HW} = \text{HSA}$ (Fig. 1) [10]. The second method of calculation, planimetry, involved taking a digital photograph of each hand with a Sony Cybershot[®] digital camera. Each photograph included a standard scale. Outlining the hand image in Adobe Photoshop[®] by tracing the circumference and linking measurements to the scale on the photo allowed accurate determination of the hand surface area. Similar digital methods of calculating hand surface area have been used in previous studies [9,11]. The two methods will be referred to as 'measured HSA' and 'planimetry HSA' respectively.

The percentage that HSA represented of the TBSA was calculated by dividing hand surface area (measured HSA and planimetry HSA) by the calculated BSA.

3. Data analysis

Background characteristics of the patient group and school group were compared using Fisher exact test for categorical data. Non-normally distributed continuous variables were compared with the Mann-Whitney U test. The t-test was applied to compare normally distributed variables between the two groups.

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