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DERLEME/ REVIEW

VÜCUT YÜZEY ALANI VE KULLANIM ALANLARI

BODY SURFACE AREA AND USAGE AREAS

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ÖZET

Vücut yüzey alanı, ilaç doz ayarlamasından yanık tedavisine, sıvı ihtiyacının belirlenmesinden bazal metabolizma hızının hesaplanmasına kadar birçok alanda kullanılan antropometrik bir parametredir. Kemoterapi, transplantoloji, yanık tedavisi ve toksikoloji dahil olmak üzere birçok tıbbi alanda önemli bir rol oynamaktadır. On dokuzuncu yüzyıla kadar araştırmacılar vücut yüzey alanını hesaplamanın kolay yollarını aradılar ve çeşitli formüller geliştirdiler. Vücut yüzey alanını tahmin etmek için boy ve ağırlık ölçümlerinden türetilmiş farklı denklemler bulunmaktadır. Tarihsel olarak, DuBois & DuBois formülü en yaygın kullanılanıdır, ancak Mosteller'in formülü basitliği nedeniyle daha popülerdir. Günümüzde halen kullanılmakta olan vücut yüzey alanı formüllerinin doğruluğu, az sayıda örnek çalışma ile belirlendiği ve örnek seçiminde çocuk, yetişkin gibi farklı büyüklükler dikkate alınmadığı için halen tartışılmaktadır. Yeni ve pratik hesaplama yöntemleri belirlenmeye çalışılmaktadır. Bu derleme, vücut yüzey alanının ortaya çıkışını ve kullanım alanlarını incelemeyi amaçlamaktadır.

ANAHTAR KELİMELER: Vücut Yüzey Alanı, Dubois & Dubois, Mosteller

ABSTRACT

Body surface area is an anthropometric parameter used in many areas like drug dose adjustment, burn treatment, and determination of fluid requirement, as well as to calculate the basal metabolic rate. It is critical for many medical specialties, such as chemotherapy, transplantology, burn therapy, and toxicology. Until the 19th century, researchers looked for easy ways to calculate body surface area and developed various formulas. There were several different formulas derived from height and weight measurements to predict body surface area. Historically, the DuBois & DuBois formula is the most used, but Mosteller's formula is more popular due to its simplicity. The accuracy of the body surface area formulas, which are still in use today, is still being debated because they are determined by a few sample studies, and different sizes such as children and adults are not taken into consideration in sample selection. New and practical calculation methods are tried to be determined. This review aims to investigate the emergence of the body surface area and where it is used.

KEYWORDS: Body Surface Area, Dubois & Dubois, Nutrition.

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INTRODUCTION

Body surface area (BSA) is an essential anthropometric parameter with wide clinical use (1). Body surface area is important in the application of drug doses, calculating burned skin percentage and body heat transfer (2). It also determines the basal metabolic rate, blood volume, cardiac output, and renal clearance and is often used to calculate parenteral fluid requirements (3). It is believed that BSA is a better indicator of body weight and less affected by abnormal adipose tissue (4). Therefore, BSA measurement studies have attracted the attention of researchers for two centuries (2).

HISTORY OF BODY SURFACE AREA FORMULAS

With the law of Rubner, published in 1883, there were beliefs among physiologists in the late 19th century that, regardless of species, an individual's heat production was proportional to BSA. Although it was possible to measure the metabolic rate by indirect calorimetry, this method is not widely available. Measurement of BSA is considered an alternative if the metabolic rate cannot be measured in the clinical setting (5).

From the beginning of the 19th century, researchers have tried to measure or predict BSA using various methods (2, 5). Historically, creative methods such as covering the surface of the body with paper, plaster, or lead, wrapping man in silk pantyhose like a Leyden jar, and calculating the surface area by applying a metal sheet known for the area have been used (2, 6).

These methods include direct measurements and indirect measurements such as formula estimation (2). For exponential operations of these formulas, a scientific calculator or computer is needed (3, 6). Although there were several different formulas derived from height and weight measurements to predict BSA, the first published formula was in 1879 (5, 7) **(Table 1)**.

Coefficient changes in the formulas change the results significantly, which led to the questioning of whether the formula is valid and safe for patients. In some cases, differences in calculations with formulas were large enough to affect mortality in patients, especially people with abnormal physical structure and children (7).

Meeh (1879), who developed the first BSA formula, worked on 16 people (6 adults, 10 children) and his formula emerged because of body wrapping the cylindrical areas with millimeter strips of paper. In the formula, the weight was incorrectly considered to be proportional to the volume measured in m^3, and therefore the BSA formula, which has a dimensionless constant calculated by 2/3 of the weight, gave results in m^2. The Fixed value was used as 11.9 in the BSA measurement of babies (8). Variable body density has become a problem due to neglecting body fats and other components in different proportions. Despite these inconsistencies, Meeh's formula remained standard until the DuBois & DuBois formula developed for predicting BSA was published in their articles in 1916 (6, 9).

DuBois & DuBois reported BSA measurement results with only five limited subjects and claimed that Meeh's formula was flawed. These five samples were removed from the glued silk paper and photographed, and since the weight of 1 m^2 of the photo paper was known, BSA could be calculated by cutting the exposed and unexposed photo papers (10). Although the researchers unanimously agreed that each body shape requires its own constant and it was unreasonable to expect any formula on a height and weight basis to overcome the variability of the body shape in determining BSA. The DuBois & DuBois formula also had ignored the claim that changes in body shape could be considered when calculating BSA. This formula is still used as a standard for the calculation of BSA (6, 9).

Using various methods over time, the accuracy of the DuBois & DuBois formula has been investigated (6, 9). Boyd (1935) has listed 401 direct surface area measurements obtained from the coating, triangulation, or surface integrator methods. He made direct BSA measurements on 197 subjects and proposed two formulas to calculate the surface area (11). Gehan & George (1970) proposed his formulas by re-evaluating Boyd's data. Although the studies found that this formula failed in young children and obese people, they did not make any other attempt to evaluate other models relating to height and weight to BSA (12). Haycock et al. (1978) began calculating BSA using a geometric method with the schematic reduction of body segments to cylinders and spheres (13). Compared with the DuBois & DuBois formula for adults and the Faber & Melcher (1921) formula for infants, they had obtained a very similar formula based on direct measurement of 81 people from premature babies to adults (8, 14).

Mosteller (1987), similar to the Gehan & George formula, which is akin to the DuBois & DuBois formula and easier to remember, used size analysis to derive its formula. This simple formula is widely adopted as it can be easily used in a pocket calculator (8,15).

It was explained by Slone (1993) that all BSA formulas were made on the assumption that the skin is flat and not considered in terms of contributing to the surface area of pores and follicles on the skin. These skin structures were reported to contribute extensively to the surface area, and as a result, the surface area of a person was never accurately measured. The variation in the density of pore and follicle in the unit area indicated that it could override BSA calculations, as it could vary widely between different human races, children, and adults (16).

Table 1: Body Surface Area formulas

Authors	Reference Formulas
Meeh (1879) (8)	$0.1053 \text{ X } W^{2/3}$
DuBois & DuBois (1916) (10)	$0.007184 \text{ X } W^{0.425} \text{ X } H^{0.725}$
Faber & Melcher (1921) (14)	$0.00785 \text{ X } W^{0.425} \text{ X } H^{0.725}$
Boyd (1935) (11)	$0.0003207 \text{ X } (W \cdot 1000)^{0.7285 - 0.0188 \cdot \log_{10}(W \cdot 1000)} \text{ X } H^{0.3}$
	$0.01788 \times W^{0.484} \times H^{0.5}$
Gehan & George (1970) (12)	$0.0235 \text{ X } W^{0.51456} \text{ X } H^{0.42246}$
Haycock *et al.* (1978) (13)	$0.024265 \text{ X } W^{0.5378} \text{ X } H^{0.3964}$
Mosteller (1987) (15)	$(W^{1/2} \times H^{1/2})/60$

(W:weight in kilograms and H: indicates the height in centimeters)

BODY SURFACE AREA USAGE IN CALCULATING BASAL METABOLIC RATE

Basal Metabolic Rate (BMR) is the amount of energy that a person spends 12 hours after eating at full rest in a comfortable lie-in position and at normal room temperature all day long (17). BMR is the energy spent on processes that continue at the moment of the body's rest. It can be indirectly determined by measuring oxygen uptake in solid laboratory conditions without consuming any food. No food should be eaten at least 12 hours before the measurement, thereby ensuring that the energy required for digestion and absorption of food in the digestive system is not increased. In addition, heavy muscle effort must not have been exerted at least 12 hours before BMR measurement. Achieving the right conditions for the accurate measure of BMR is often impossible (18). The Resting Energy Expenditure (REE) is expressed in calories per kilogram per hour. Digestion and absorption energy are included in REE. Unlike BMR, which is measured after twelve hours of fasting, REE is measured at normal fasting, but measurement should be taken 2 hours after a light meal and resting in the supine position for more than 30 minutes on the back supine. Since digestive and absorption energy is included, it is 10% more than BMR (17).

Since Galileo's time, scientists have believed that BMR and REE are related to BSA. Regarding BSA, BMR is highest in early childhood and then decreases with age. As seen in Table 2, BMR values are about 5% lower in women than in men. This is largely due to the difference in body composition. Generally, women have a higher percentage of body fat than men of the same age, and stored fat essentially does not affect metabolic rate. If BMR values are expressed per unit of lean body mass, gender differences can be neglected. Differences in body composition are explained by the 2% reduction in BMR observed in a decade in adulthood (18) **(Table 2)**.

Table 2: Relationship Of Basal Metabolic Rate With Age And Gender (kJ m^2/s)

Age	Man	Woman
5	205.1	196.5
10	183.3	178.0
15	177.9	163.2
20	165.8	152.4
25	162.0	151.5
30	157.4	151.1
35	155.7	151.1
40	156.1	151.1
45	155.3	150.3
50	154.5	146.5
55	152.4	142.7
60	149.4	139.4
65	146.5	136.9
70	144.0	135.6
75	141.5	134.8
80	139.0	133.5

(18)

Using the average BMR values for age and gender in Table 2, it is possible to find a person's daily BMR with BSA. After calculating BSA with the DuBois & DuBois formula, which is commonly used for BSA calculation, the basal metabolic rate appropriate for the person's age and gender is selected from the table. BMR can be determined by multiplying this value by 24 for the daily energy requirement. It should not be overlooked that the result found is value in kilojoule (kJ). For example, a 20-year-old man with a weight of 70 kg and a height of 177 cm has been calculated by using BSA, DuBois & DuBois formula, and the average BMR of a 20-year-old man is 165.8 kJ m^2/s (± 10) according to Table 2. Accordingly, the energy requirement is 165.8 kJ m^2/sx1.86 m^2 = 308.4 kJ. The energy requirement in the 24-hour period; 308.4 kJ m^2sx24s =7401 kJ (1762 kcal). BSA: Calculated in the form (18) in another study; To calculate a daily energy requirement, BSA, again calculated with the DuBois & DuBois formula, is found by multiplying 24 by the standard calories selected according to the gender and age group given in **Table 3** (19). For example, a male with a weight of 70 kg and a height of 177 cm, who is 20 years old, has been calculated using BSA, DuBois & DuBois formula, and the average BMR for 20 years is 39.5 kcal m^2/s (± 10). Accordingly, BSA energy requirement is 39.5 kcal m^2x1.86 m^2 = 73.47 kJ. The energy requirement in 24-hours; BMD can be found by calculating 73,47 kcal m^2/sx24 s= 1763.28 kcal (19) (Table 3).

Table 3: Standard Calorie Values According To Body Surface Area Per Hour (According To Height-Weight Formula)

Age	Man	Woman
14-16	46.0	43.0
16-18	43.0	40.0
18-20	41.0	38.0
20-30	39.5	37.0
30-40	39.5	36.5
40-50	38.5	36.0
50-60	37.5	35.0
60-70	36.5	34.0
70-80	35.5	33.0

(19)

BURN AND BODY SURFACE AREA RELATIONSHIP

The skin, which has functions such as regulation of body temperature, sense of touch, protection of the body from the external environment, and maintaining the functions of the immune system, is the largest organ of the body, and it is one of the most important (20). The energy requirement of burn increases significantly due to basal REE, but this increase varies over time and is proportional to the burned body surface area (BBSA). In burn patients with more than 40% of BBSA, REE increased by 180% in the acute period, 150% after healing of burns, 120% after 9 months of injury, and 110% 1 year after injury (21). It plays an important role in increasing metabolic rate after the loss of heat and insufficient burns in thermoregulation. The correct assessment of the energy requirement is necessary for effective nutritional support. Because both excessive feeding and malnutrition prolong hospital stay and increase the risk of morbidity and mortality (22). Although an indirect calorimeter is superior to all hand-held devices and equations in estimating energy requirements, it is an impractical and expensive method since it requires experienced personnel and devices for routine use in burn patients (23). The 46 estimation equations used to calculate the REE of burn patients were compared with the indirect calorimeter results, and it was found that the energy expenditures were not fully estimated, but the equations developed by Zawacki (1970), Xie (1993), and Milner (1994) were the most sensitive formulas (24 - 26) **(Table 4)**. Milner concluded that estimation equations could be used within the first month after injury, but 30 days later, estimation equations were not suitable, indirect calorimeter measurements were required, and to improve the equation the number of days after burn adapted the Carlson equation by adding factors (26) (Table 4).

Table 4: Formulas Used In Calculating Energy Expenditure In Burn Patients And Some Energy Intake Suggestions

Zawacki(1970) (24)	REE= 1440 x BSA
Xie (1993) (25)	REE= (1000 x BSA) + (25 x TBSA)
Milner (1994) (26)	REE= (BMR** x (0.274 + 0.0079 x BBSA - 0.004 x PBD) + BMR**) x 24 x BSA x activity factor
Curreri (1974) (28)	REE= (25 x Weight) + (40 x BBSA)
Carlson (1992) (29)	REE= BMR** x (0.89142 + (0.01335 x BBSA)) x BSA x 24 x activity factor

BBSA, (%) x 100 (Body surface area affected by burn - real start burn size, use cut-off for big burns)
BSA, (m^2) $[(\text{height} \times \text{weight}) / 3600]^{0.5}$
PBD, Days after burn
BMR** Man: 54.337821 - (1.19961 x age) + (0.02548 x age^2) - (0.00018 x age^3)
Woman: 54.74942 - (1.54884 x age) + (0.03580 x age^2) - (0.00026 x age^3)

Xie et al. found that, although the energy consumption estimation formulas they developed in 1993 were simple and practical, about twenty years after the formula was used, patients with a wide burn percentage calculated high energy consumption. BBSA was evaluated for 66 burn patients ranging from 4% to 96% at different times after injury and developed two new linear and nonlinear formulas for energy expenditure estimation (25) **(Table 5)**. It compared indirect calorimeter measurement and commonly used formulas such as Curreri (1974), Carlson (1992), Xie (1993), and Milner (1994) to evaluate the validity and reliability of new formulas (25, 26, 28, 29).

Comparative analysis has revealed that the new formulas provide energy consumption estimates with significantly higher accuracy and reliability compared to the widely used Milner formula, which is commonly believed to be accurate (23, 30) (Table 5).

Table 5: Results Of Multiple Linear Regression For Energy Consumption Estimation

Nonlinear formula: REE=(1094.2477 + 7.3670 x BBSA + 22.3935 x PBD-0.0766 x $BBSA^2$-1.3496 x PBD^2 + 0.4568 x BBSA x PBD) x BSA
Linear formula: REE= (1122,4345 + 6,8634 x BBSA + 9, 1156 x PBD) x BSA, if BBSA ≤70 and PBD ≤14 REE= (1346,1578 – 0,4040 x BBSA + 32,1819 x PBD) x BSA, if BBSA > 70 and PBD ≤14 REE= (1326,4286 + 9,8823 x BBSA – 13,8294 x PBD) x BSA, if BBSA ≤70 and PBD > 14 REE= (1460,5689 + 1,3440 x BBSA + 11,9390 x PBD) x BSA, if BBSA >70 and PBD >14

REE: Resting energy expenditure BBSA: Burned body surface area PBD: Days after burn BSA: Body Surface Area (30)

RELATIONSHIP BETWEEN GLOMERULAR FILTRATION RATE AND BODY SURFACE AREA

Evaluation of the individual's kidney function is an essential part of routine medical practices. Various kidney function tests are used to assess individuals' overall health, determine the appropriate dose for drugs administered through the kidney, to prepare for invasive diagnosis or treatment procedures, and to diagnose and monitor acute and chronic renal failure (31, 32). The amount of glomerular filtrate formed in one minute (unit time) in all nephrons of both kidneys is called Glomerular Filtration Rate (GFR) (33). The glomerular filtration rate is one of the frequently used tests that is accepted as the best indicator among kidney function tests (34, 35).

McIntosh et al. (1928) proposed kidney function indexed to BSA in their studies describing the concept of kidney clearance, and the average BSA of Americans at the age of 25 was calculated, and the index value was proposed as 1.73 m^2 (36). In many countries, GFR's indexing by BSA overrides, as BSA, calculated from the height-weight formulas of adults, changes over time, and the index value is arbitrarily selected. However, it is crucial to fix the index value to facilitate historical comparison studies (8, 37).

Although the BSA index value was taken as 1.73 m^2 in the studies, they stated that this value does not represent the patients currently receiving treatment in the UK due to not considering the gender-specific differences or the recent increase in obesity. In a study conducted on 2838 patients who received chemotherapy between 1996 and 2000 in Australia, their mean BSA was reported as 1.80 m^2 (female 1.70 m^2, male 1.89 m^2), while Baker et al. (2002) reported that BSA was 1.86 m^2 in an international retrospective study that included 1650 patients between 1991 and 2001. This study represents a group of patients with higher BSA than the general population (38, 39).

GFR is commonly multiplied by 25-year-old adults with a value of 1.73 m^2 representing the average BSA, and correction can be applied by dividing the BSA of the person (40). However, this application may cause GFR to appear more than small in individuals with small structures. It is recommended to use the actual GFR instead of corrected when adjusting the chemotherapy dose (41). Although there are nearly 500 formulas used in the calculation of GFR today, the most frequently used and accepted ones are; MDRD (Modification of Diet in Renal Disease-2000) and Cockcroft-Gault (1976) formulas (42, 43). The Cockcroft-Gault formula provides 24-hour creatinine clearance; Serum creatinine is calculated in ml/min using age, sex, and weight variables. The results of the Cockcroft-Gault formula are uncorrected according to BSA (43). The MDRD formula is expressed as GFR ml/min/1.73 m^2, as opposed to the Cockcroft-Gault formula, since its validation was made against the GFR corrected according to BSA (44). The average GFR value was developed by measuring patients in the hospital due to CRF of 40 ml/min/1.73 m^2 (33).

Drug dosing is based on kidney function measurements or estimates not adjusted for BSA, and GFR estimates adjusted for BSA are generally sufficient except for patients whose body size differs significantly from the mean (31). Therefore, the National Kidney Foundation recommended using absolute GFR instead of BSA for drug dose adjustments in clinical practice. Thus, large population samples with different body sizes should be studied to determine what the best method can be in GFR indexing (45). Despite this, BSA continues to be used to index GFR (37).

STUDIES TO EVALUATE THE RELATIONSHIP BETWEEN BSA FORMULAS

Chhapola et al. (2013) conducted a study to determine the best equation among the current BSA equations and to design a new equation for calculating BSA in non-edematous acutely undernourished (NE-SAM) children in the hospital. He decided that the current BSA equations were derived from healthy children and that children with acute non-edematous acute malnutrition could not truly predict BSA. The study was conducted on 471 NE-SAM children, and BSA calculations were made with seven existing equations. These equations are preferred in the study because they contain pediatric calculations and are derived in independent studies using direct BSA measurement methods. A new equation created to calculate BSA was designed using linear regression with the formula of Mosteller modified 164.551 x [H x W] 0.5 (cm^2), constant (a0) 164.551 ($p < 0.0001$), considering that it is easy to calculate. On 66 children with NE-SAM, Mosteller, Boyd, and the new equation were compared and calculated. As a result of the study, it was concluded that the equation of the Mosteller was more accurate among the seven equations used. As a result, in the study, the newly derived SAM Mosteller equation has given minor error and has been updated to serve as an accurate measure in these children until an equation was invented based on direct BSA measurement (1).

There are several cross-sectional studies conducted to compare BSA formulas. In a study conducted on 2745 healthy children (1229 boys, 1246 girls) aged 1-11 years in Ibadan North Local Government Area (IBNLGA), Oyo State, Nigeria. Estimated average BSA values were found for each child's age with different formulas (DuBois & DuBois, Boyd, Gehan & George, Haycock et al., and Mosteller). It was concluded that the formulas of Mosteller and Boyd are more accurate than other formulas for BSA estimation. It was concluded that the formula of DuBois & DuBois showed a clinically unacceptably low estimate of BSA in children under 6 years of age. As a result of this study, it is concluded that Mosteller's formula will show the most useful, reliable, and accurate BSA for Nigeria when standardization of physiological parameters is needed (46).

Villa et al. (2017), in their study, adult male cadavers used computed tomography (CT) to calculate BSA and aimed to evaluate whether the new formula was needed by comparing the results with the nine formulas in the literature. The sample was scanned within three days from the date of death of 55 male cadavers with a different body mass index, aged between 20 and 87, and the average BSA of the cadavers was determined to be between 1.84 - 1.87 m2. BSA values calculated from CT scans were found very close to the 9 formulas in the literature. When calculating BSA, CT scans have advantages over surface scanners. The CT scanner, on the other hand, cannot scan every surface of the body. Some crucial parts of 3D models have gaps that need to be filled. As a result, the study strongly supported the need for modified formulas for small and large BMI values (47).

BSA formulas of DuBois & DuBois and Mosteller are considered largely equivalent in clinical practice. The mathematical relationship between the formulas is high, and there are subtle differences between them (5).

Rapid and accurate determination of BSA and BBSA is very important during the treatment of burns, and BSA is used to determine the drug dose and to evaluate the surface of the skin required for transplantation, as well as to estimate the chance of survival of patients. BSA, which is used to evaluate the degree of kidney function, can be questioned because of its poor correlation with GFR, especially in children, obese and anorexic individuals, since GFR is widely multiplied by 1.73 m2, which represents the average body surface area of 25-year-old adults. However, BSA remains a major variable in the treatment of the nephrotic syndrome (7).

Recent studies mostly used three dimensions (3D) laser-scanning techniques to determine BSA (7). The 3D body scanner can measure many objects with great precision. It is considered that the accuracy of BSA measurement by scanning is within 1% and better than past direct measurement methods. It can be used with BSA surface integration software to calculate with great accuracy after 3D measurement of the body. However, despite the excellent abilities of the 3D scanners, unresolved details in the hands, feet, and face areas and numerous holes in the shadow areas such as the armpits, groin areas, and toes are observed. These unresolved details and gaps should not be overlooked in assessing the potential problems that using 3D body scanners may introduce in BSA measurement (2).

REFERENCES

1. Chhapola V, Sandeep KK, Shafı OM, Kumar P. Accurate estimation of body surface area in under-5 children with non-edematous severe acute malnutrition summary. J Trop Pediatr Vol. 2013;59(6):515-17.

2. Yu CY, Lin CH, Yang YH. Human body surface area database and estimation formula. Burns. 2010;36(5):616-629.

3. Furqan M, Haque A. Surface area in children: a simple formula. Indian Pediatr. 2009; 46(12):1085-87.

4. Fancher KM, Sacco AJ, Gwin RC, Gormley LK, Mitchell, CB. Comparison of two different formulas for body surface area in adults at extremes of height and weight. J Oncol Pharm Pract. 2016;22(5):690-95.

5. Gibson S, Numa A. The importance of metabolic rate and folly of body surface area calculations. Anaesthesia. 2003;58:50-83.

6. Lack JA, Stuart-Taylor ME. Calculation of drug dosage and body surface area of children. Br J Anaesth. 1997;78(5):601-605.

7. Redlarski G, Palkowski A, Krawczuk M. Body surface area formulae: an alarming ambiguity. Sci Rep. 2016;6:1-8.

8. Meeh K. Oberflachenmessungen des menschlichen Korpers. Z Biol. 1879;15:425–85.

9. Sahay M. (Edited by). Basic nephrology and acute kidney injury. In: Hoste L, Pottel H. Is body surface area the appropriate index for glomerular is body surface area the appropriate index for glomerular filtration rate?. InTech, 2012:4-20.

10. DuBois D, DuBois EF. Clinical calorimetry: tenth paper a formula to estimate the approximate surface area if height and weight be known. Arch Intern Med. 1916;17:863–71.

11. Boyd E. Growth of surface area in human body. In: Issue 10 of Monograph Series, University of Minnesota Institute of Child Development and Welfare. University of Minnesota Press, Minneapolis, MN. 1935.

12. Gehan EA, George SL. Estimation of human body surface area from height and weight. Cancer Chemother Rep. 1970;54:225–35.

13. Haycock G, Schwartz G, Wisotsky D. Geometric method for measuring body surface area: a height-weight formula validated in infants, children, and adults. J Pediatr. 1978;93(1):62-66.

14. Faber HK, Melcher MS. A modification of the DuBois height-weight formula for surface areas of newborn infants. Proc Soc Exp Biol Med. 1921;19(1):53.

15. Mosteller RD. Simplified calculation of body-surface area. N Engl J Med. 1987;317:1098.

16. Slone TH. Body surface area misconceptions. Risk Analsis. 1993;13(4):375-77.

17. Aksoy M. (Editör) Ansiklopedik beslenme, diyet ve gıda sözlüğü. 1nci Baskı, Ankara: Hatipoğlu Yayınevi, 1978;733.

18. Eston R, Reilly T. (Edited by) Kinantropometry and exercise physiology laboratory manual: Volume 2. In: Cooke C. Metabolic rate and energy balance. 2nd Edition, London: Routledge, 2008:147-74.

19. Curtis BY. Basal Metabolism Nomogram. J Biol Chem. 1929;135(2):607-609.

20. Tabel Y. Association of voiding dysfunction and urinary tract infection in children; a nephrological perspective. Turkish Assoc Pediatr Surg. 2016;30(2): 106-109.

21. Hart DW, Wolf SE, Mlcak R, Chinkes DL, Ramzy PI, Obeng MK, et al. Persistence of muscle catabolism after severe burn. Surgery. 2000;128(2):312-19.

22. Sabuncular G, Acar-Tek N. Energy metabolism in burn injury and current approaches to determine the energy requirements. Turkiye Klin J Heal Sci. 2017;2(3): 184-91.

23. Aydoğan C, Ekici Y. Yanık Hastalarında Beslenme. Türk Yoğun Bakım Derneği Derg. 2012;10(2):74-83.

24. Zawacki BE, Spitzer KW, Mason AD Jr, et al. Does increased evaporative water loss cause hypermetabolism in burned patients? Ann Surg. 1970;171:236–40.

25. Xie WG, Li A, Wang SL. Estimation of the calorie requirements of burned Chinese adults. Burns. 1993;19:146–49.

26. Milner EA, Cioffi WG, Mason AD, et al. A longitudinal study of resting energy expenditure in thermally injured patients. J Trauma. 1994;37:167–70.

27. Dickerson RN, Gervasio JM, Riley ML, Murrell JE, Hickerson WL, Kudsk KA, et al. Accuracy of predictive methods to estimate resting energy expenditure of thermally-injured patients. J Parenter Enteral Nutr. 2002;26(1):17-29.

28. Curreri PW, Richmond D, Marvin J, et al. Dietary requirements of patients with major burns. J Am Diet Assoc. 1974;65:415–17.

29. Carlson DE, Cioffi WG Jr, Mason AD Jr, et al. Resting energy expenditure in patients with thermal injuries. Surg Gynecol Obstet. 1992;174:270-76.

30. Xi P, Kaifa W, Yong Z, Hong Y, Chao W, Lijuan S, et al. Establishment and assessment of new formulas for energy consumption estimation in adult burn patients, PLoS One. 2014;9(10):1-11.

31. Stevens LA, Levey AS. (Edited by). Frequently asked questions about GFR estimates. 1st Edition, National Kidney Foundation, Inc. 2011;1-20.

32. Levey AS, Stevens LA, Schmid CH, Zhang Y, Castro AF, Feldman HI, et al. A New Equation to Estimate Glomerular Filtration Rate, Ann Intern Med. 2009;150(9): 604-12.

33. Ustaalioğlu YE, Bal AS, Oral AY. Glomerüler Filtrasyon Belirteçleri ve Hesaplama Formülleri, Uludağ Üniversitesi Tıp Fakültesi Dergisi. 2015;41(2);95-102.

34. Abefe SA Abiola AF, Olubunmi AA, Adewale A. Utility of predicted creatinine clearance using MDRD formula compared with other predictive formulas in Nigerian patients. Saudi J Kidney Dis Transpl. 2009;20(1):86-90.

35. Açıkgöz EH, Tüysüz Ö, Sarandöl E, Dirican M. Glomerüler filtrasyon hızı tahmininde MDRD formülünün kreatinin klirensi ile karşılaştırılması. Türk Klin Biyokim Derg. 2013;11(1):21-29.

36. McIntosh JF, Möller R, Van Slycke DD. Studies on urea excretions: III. The influence of body size on urea output. J Clin Invest. 1928;6:467–83.

37. Geddes CC, Woo YM, Brady S. Glomerular filtration rate - What is the rationale and justification of normalizing GFR for body surface area? Nephrol Dial Transplant. 2008;23(1):4-6.

38. Baker SD, Verweij J, Rowinsky EK, Donehower RC, Schellens JHM, Grochow LB, et al. Role of body surface area in dosing of investigational anticancer agents in adults, 1991-2001. J Natl Cancer Inst. 2002;94(24):1883-88.

39. Sacco JJ, Botten J, Macbeth F, Bagust A, Clark P. The average body surface area of adult cancer patients in the UK: a multicentre retrospective study. PLoS One. 2010;5(1):1-6.

40. Lamb E. Assessment of kidney function in adults. Medicine (United Kingdom). 2015;43(7): 368-73.

41. Jin R, Grunkemeier GL, Brown JR, Furnary,AP. Estimated Glomerular Filtration Rate and Renal Function. Ann Thorac Surg., 2008;86(1): 1-3.

42. Bostom AG, Kronenberg F, Ritz E. Predictive performance of renal function equations for patients with chronic kidney disease and normal serum creatinine levels. J Am Soc Nephrol., 2002;13(8):2140-44.

43. Cockcoft DW, Gault MH. Prediction of creatinine clearance from serum creatinine. Nephron. 1976;16(1):31-41.

44. Woolloongabba DJ. Evaluation of renal function - Use of serum creatinine concentration to assess level of kidney function, Nephrology. 2005;10:133-76.

45. Botev R, Mallie JP, Wetzels JFM, Couchoud C, Schück O. The clinician and estimation of glomerular filtration rate by creatinine-based formulas: Current limitations and Quo vadis. Clin J Am Soc Nephrol. 2011;6(4):937-50.

46. Orimadegun A, Omisanjo A. Evaluation of five formulae for estimating body surface area of nigerian children. Ann Med Health Sci Res. 2014;4(6):889-98.

47. Villa C, Primeau C, Hesse U, Hougen HP, Lynnerup N, Hesse B. Body surface area determined by whole-body CT scanning: need for new formulae?, John Wiley & Sons. 2017:37(2):183-93.