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BIOMEDICAL ENGINEERING | RESEARCH ARTICLE

Models to estimate the palm surface area of students in a tertiary institution in Abeokuta, Nigeria

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Abstract: The need to use palm surface area (PSA) in ergonomics, burn therapy, thermal physiology, and medicine necessitated the studies on its determination. The purpose of this study was to determine the PSA of students in a tertiary institution in Nigeria, propose a model to obtain the PSA, and use the neural network to reflect the effects of age, height, and weight on PSA. A total of 400 students comprising of 185 male and 215 female students aged between 16- and 25-years old were used for the study. Nonlinear regression analysis on SPSS 16.0 statistical package was used to extract the best fit correlation for Nigerian students with PSA as the dependent variable; and height, weight, and age as independent variables. The neural network on SPSS 16.0 was used to design the multilayer perceptron to predict PSA using age, height, and weight of the students. The estimated values using the models were not statistically different from the obtained values from the study ($p = 0.000$). The prediction of PSA showed that the neural network can be trained with almost no significant error of the output and that there was a nonlinear relationship between the input and output variables.

Subjects: Design; Ergonomics; Occupational Health & Safety

Keywords: palm surface area; students; Nigeria; institutions; neural network; ergonomics; anthropometry



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PUBLIC INTEREST STATEMENT

The knowledge of the hand, palm, and fingers surface area would be required to estimate heat dissipated from the hands and predict heat flow more accurately and this may contribute to the thermal protection of workers exposed to extreme cold or heat environments. This study measured the palm surface area (PSA) of students in a tertiary institution in Nigeria, propose a model to obtain the PSA, and use the neural network to reflect the effects of age, height, and weight on PSA. Nonlinear regression models and artificial neural network were used to predict the PSA using age, height, and weight of the students. The prediction of PSA showed that the neural network can be trained with almost no significant error of the output and that there was a nonlinear relationship between the input and output variables.

1. Introduction

The need to use palm surface area (PSA) in ergonomics, burn therapy, thermal physiology, and medicine necessitated the studies on its determination (Amirsheybani et al., 2001; Cahill, Rode, & Millar, 2008; Choi et al., 2011; Yu, Hsu, & Chen, 2008; Yu, Lo, & Chiou, 2003). Nichter, Williams, Bryant, and Edlich (1985) noted that for determining the severity and prognosis of burn, calculating fluid resuscitation and nutritional requirements, there is a need for accurate estimation of the percentage of body surface area (BSA) burned for optimal care for burn patient. Lee, Choi, and Kim (2007) noted that knowledge of the hand, palm, and fingers surface area would be required to estimate heat dissipated from the hands and predict heat flow more accurately. They further noted that this may contribute to the thermal protection of workers exposed to extreme cold or heat environments in the form of protective work gloves. The Rule-of-Palms, which is defined as the projection area of the hand and represents 1% TBSA, has been widely used and their weaknesses well known (Sheng et al., 2014). The Rule-of-Palms technique overestimated the PSA by between 10 and 20% as some studies (Amirsheybani et al., 2001; Rossiter, Chapman, & Haywood, 1996) found that the actual PSA was 0.76–0.78%.

Measurement of PSA or BSA has been categorized into direct and indirect measurements (Choi et al., 2011). The direct methods include the use of molding method using paper, plaster bandage, or aluminum foil, and surface integration for PSA (Du Bois & Du Bois, 1989; Gehan & George, 1970; Mosteller, 1987). The indirect methods include the geometric method (Haycock, Schwartz, & Wisotsky, 1978) and the 3D scanning technology but the accuracy of the direct method is higher than that of indirect methods (Choi et al., 2011). Abeysekera and Shahnavaz (1989) confirmed that there are anthropometric differences between different populations in almost every part of the human body and among the important dimensions are those of the hand. Okunribido (2000) compiled data on 18 hand dimensions from rural farm workers in Ibadan, Nigeria. Ismaila (2009) also obtained the anthropometric data of hand, foot, and ear of university students. Literature is, however, sparse on the PSA of Nigerians. It was noted by Mellit, Benganem, and Kalogirou (2006) that Artificial Neural Network model could predict results from examples that have been trained at very high speed and can model a complex system without full understanding of the system mechanisms (Picton, 2000). Artificial Neural Network model is efficient and consume less time during modeling of complex systems compared to other known mathematical models. Neural network has been used for various applications such as modeling and prediction of in many engineering systems such as energy systems (Fadare & Dahunsi, 2009; Kalogirou, 2000), drinking water quality and treatment Baxter et al. (2001), motion analysis (Taha, Brown, & Wright, 1996), grip strength prediction (Taha & Nazaruddin, 2005), in the medical diagnosis (Nazeran & Behbehani, 2000), and heart rates of brick-laying jobs (Ismaila, Oriolowo, & Akanbi, 2013). Since, there is sparse literature on the PSA of Nigerians; this study determines the surface area of the palm of students in a tertiary institution in Nigeria. It further proposed models to obtain the PS and used the neural network to reflect the effects of age, height, and weight on PSA.

2. Methodology

2.1. Subjects

Students of the Federal University of Agriculture Abeokuta, Ogun State, within the age range of 16–25-years old were used for the study. A total of 400 students comprising of 215 females and 185 males were selected as subjects.

A scientific graph paper was used as the “standard stencil” for calculating the surface area. The graph paper consisted of two sizes ($2 \times 2 \text{ cm}^2$ and $0.2 \times 0.2 \text{ cm}^2$) of square boxes.

The PSA was defined as the total surface area of the palm of human hand including the fingers.

The dominant hands were traced on the paper using the method described by Agarwal and Sahu (2010). When this was done, the palm was removed; the number of boxes covered by the palm were

counted (both small boxes and big boxes), the number of the small boxes covered by the palm was multiplied by the area of small boxes and the number of big boxes covered by the palm was also multiplied by the area of the bigger boxes. The total area of the bigger boxes was added to the total area of the smaller boxes. The addition of the two areas gave the total surface area of the palm (PSA). The heights and weights of the students were also measured and their ages known. This was done for both males and females; the data were used to formulate a model for estimating the surface area.

All data were expressed as mean and standard deviation. The data collected from the subjects were recorded and tabulated based on gender (males and females), height, and weight.

Nonlinear regression analysis on SPSS 16.0 statistical package was used to extract the best fit correlation for Nigerian students with PSA as the dependent variable and height, weight, and age as independent variables.

All the statistical outcomes based on the two-sided *t*-test were completed using SPSS software (version 16). A *p*-value < 0.05 was regarded as statistically significant.

Also, the neural network on SPSS 16.0 was used to design the multilayer perceptron to predict PSA using age, height, and weight. The data were partitioned into 70% for training and 30% for testing.

For the architecture, automatic custom architecture with a minimum number of units in hidden layer of one and a maximum number of units in hidden layer of 50 was selected with the program asked to automatically compute number of units. To train the data, batch was selected and scaled conjugate gradient was selected as optimization algorithm. Cases with user-missing values on factors and categorical-dependent variables were excluded. Choose automatically was specified as data to use to compute prediction error, while maximum epochs were computed automatically. The predicted values using the multilayer perceptron and the measured PSA were statistically compared.

3. Results and discussion

The PSA is needed in the development of manual equipment, hand protective gloves, heat exchange in thermal physiology, assessment of exposure in occupational toxicology (Lee et al., 2007), and estimation of total surface area to determine the area of burn (Rhodes, Clay, & Phillips, 2013). This study developed some models for the determination of PSA.

Compared to the every other method, the sectional method is easier and cheaper for the determination of the area of the human PSA. In this study, the mean PSA of males was 169.3 cm², while that of females was 142.9 cm². The mean PSA for combined males and females was 155.0 cm². The PSA in this case included the fingers as opposed to the suggestion of Jose, Roy, Vidyadharan, and Erdmann (2004) that the palm of the hand does not include the fingers.

Table 1 shows the summary of demographic details of 400 students, while Table 2 shows the statistics of 185 male students with age ranging from 17 to 25 years with height of 172 ± 6.9 cm; weight of 60.1 ± 7.6 kg; age of 20.4 ± 2.1 years; and PSA of 169.2 ± 14.6 cm². From Table 2, there were 215 female students with age ranging from 17 to 25 years with the height of 161 ± 5.8 cm, weight of 54.1 ± 8.8 kg, age of 19.8 ± 1.9 years; and PSA of 142.9 ± 12.2 cm² age.

Table 3 shows the statistics of all the students (male and female) with age ranging from 17 to 25 years with the height of 166.1 ± 8.4 cm; weight of 56.9 ± 8.7 kg; age of 20.1 ± 2.1 years; and PSA of 155.0 ± 18.7 cm².

The mean PSA of 155.0 cm² for the combined male and female students obtained in this study was higher than 139.46 cm² obtained by Agarwal and Sahu (2010) for Indian adults with age ranging

Table 1. Summary of demographic details of 400 students

| Age | Male | | | Female | | |
|-----|---------------|-------------|-----------------------|--------------|-------------|-----------------------|
| | Height (m) | Weight (kg) | PSA (m ²) | Height (m) | Weight (kg) | PSA (m ²) |
| 17 | 171.6 ± 6.4 | 60.3 ± 8.3 | 170.4 ± 15.6 | 160.9 ± 6.2 | 54.7 ± 11.1 | 140.6 ± 12.8 |
| 18 | 172 ± 8.2 | 62.2 ± 8.3 | 172.9 ± 15.7 | 162.5 ± 6.9 | 56.6 ± 8.2 | 148.3 ± 12.9 |
| 19 | 172.2 ± 5.48 | 60.9 ± 6.34 | 169.9 ± 10.6 | 161.7 ± 6.0 | 52.8 ± 6.8 | 141.6 ± 11.5 |
| 20 | 172.56 ± 7.24 | 60.6 ± 8.28 | 170 ± 15.0 | 160 ± 5.23 | 53.8 ± 7.6 | 140 ± 10.6 |
| 21 | 170 ± 7.6 | 60.5 ± 9.5 | 169 ± 14.7 | 160.6 ± 5.37 | 52.5 ± 8.6 | 143.8 ± 10.7 |
| 22 | 174.2 ± 7.42 | 58.6 ± 6.3 | 172 ± 15.0 | 162.8 ± 4.2 | 56.6 ± 7.2 | 149.2 ± 13 |
| 23 | 171.4 ± 7 | 58 ± 5.2 | 165.6 ± 14.7 | 160.2 ± 7.6 | 56.9 ± 13.5 | 147.1 ± 16.0 |
| 24 | 172 ± 6.9 | 59 ± 6.1 | 164 ± 17.0 | 160.9 ± 3.3 | 54.7 ± 7.6 | 139.7 ± 9.3 |
| 25 | 169.7 ± 2.9 | 54.3 ± 3.0 | 161.3 ± 15.4 | 156.5 ± 9.2 | 42 ± 4.2 | 130 ± 8.5 |

Table 2. Statistics for the male and female students

| | Male | | | | Female | | | |
|--------------------|--------|--------|------|-------|--------|--------|------|-------|
| | Height | Weight | Age | PSA | Height | Weight | Age | PSA |
| N | 185 | 185 | 185 | 185 | 215 | 215 | 215 | 215 |
| Mean | 172.0 | 60.1 | 20.4 | 169.2 | 161.0 | 54.1 | 19.8 | 142.9 |
| Std. error of mean | 0.5 | 0.6 | 0.2 | 1.1 | 0.4 | 0.6 | 0.1 | 0.8 |
| Median | 173.0 | 60.0 | 20.0 | 168.0 | 161.0 | 53.0 | 20.0 | 143.0 |
| Mode | 173.0 | 60.0 | 20.0 | 157.0 | 159.0 | 50.0 | 20.0 | 150.0 |
| Std. deviation | 6.9 | 7.6 | 2.1 | 14.6 | 5.8 | 8.8 | 1.9 | 12.1 |
| Minimum | 35.0 | 46.0 | 8.0 | 74.0 | 145.0 | 36.0 | 17.0 | 106.0 |
| Maximum | 155.0 | 44.0 | 17.0 | 126.0 | 181.0 | 90.0 | 25.0 | 176.0 |
| Percentiles | 5 | 161.0 | 49.0 | 17.0 | 148.0 | 42.0 | 17.0 | 122.6 |
| | 50 | 173.0 | 60.0 | 20.0 | 168.0 | 53.0 | 20.0 | 143.0 |
| | 95 | 183.0 | 73.7 | 24.0 | 192.0 | 170.0 | 24.0 | 162.0 |

from 18 to 60 years. The paired samples *t*-test showed that there was significant difference between the heights ($p = 0.000$); weights ($p = 0.000$); PSA ($p = 0.000$); and age ($p = 0.022$) of the male and female students.

The mean PSA of 169.2 cm² obtained in the study for male students was lower than 269.39 cm² obtained for Korean males between the ages of 7- and 18-years old by Choi et al. (2011). Lee et al. (2007) obtained from 65 Koreans with age ranging from 20 to 63 years, the PSA (including the bottoms of fingers) of 217 (183–259) cm² for males, and 189 (141–235) cm² for females.

The obtained models were Equations (1)–(3) for the PSA of male, females, and the combined students, respectively:

$$PSA = 1.4[Height^{0.79} \times (Weight)^{0.24} \times (Age)^{-0.073}] \tag{1}$$

$$PSA = 2.6[(Height)^{0.59} \times (Weight)^{0.24} \times (Age)^{0.04}] \tag{2}$$

$$PSA = 0.06[(Height)^{1.35} \times (Weight)^{0.23} \times (Age)^{0.23}] \tag{3}$$

The estimated values using the models were not statistically different from the obtained values from the study ($p = 0.000$).

Table 3. Statistics for the combined male and female students

| | | Height | Weight | Age | PSA |
|--------------------|----|--------|--------|------|-------|
| N | | 400 | 400 | 400 | 400 |
| Mean | | 166.1 | 56.9 | 20.1 | 155.0 |
| Std. error of mean | | 0.4 | 0.4 | 0.1 | 0.9 |
| Median | | 165.0 | 56.0 | 20.0 | 153.0 |
| Mode | | 159.0 | 56.0 | 20.0 | 150.0 |
| Std. deviation | | 8.4 | 8.7 | 2.1 | 18.7 |
| Minimum | | 145.0 | 36.0 | 17.0 | 106.0 |
| Maximum | | 190.0 | 90.0 | 25.0 | 200.0 |
| Percentiles | 5 | 153.1 | 45.0 | 17.0 | 127.0 |
| | 50 | 165.0 | 56.0 | 20.0 | 153.0 |
| | 95 | 180.0 | 72.0 | 24.0 | 189.0 |

The prediction of PSA showed that the neural network can be trained with almost no significant error of the output and that there was a nonlinear relationship between the input and output variables. The actual values and the predicted values of PSA were also nonlinear.

For the female students, the predicted values of PSA were not different from the determined PSA ($p = 0.878$) and those of the male students were also not different ($p = 0.051$) suggesting that Neural Networks may be used to predict PSA using age, height, and weight of the students. Similarly, for the combined male and female students, Neural Networks may be used to predicting the PSA of the students as $p = 0.562$.

Figure 1 shows the graph of predicted PSA and actual value of PSA, while Figure 2 shows the importance of the variables in predicting PSA. The importance chart shows that the results are dominated by the height, followed by weight and age in that order.

Figure 2 shows the importance of the variables in predicting PSA. The importance chart shows that the results are dominated by the height, followed by weight and age in that order.

Figure 1. Graph of predicted PSA and actual value of PSA.

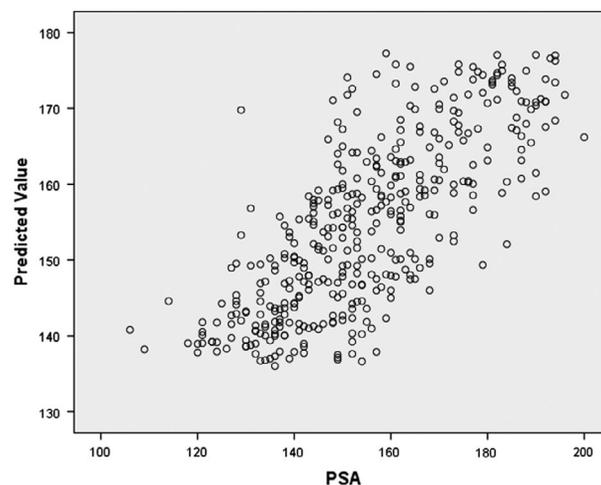
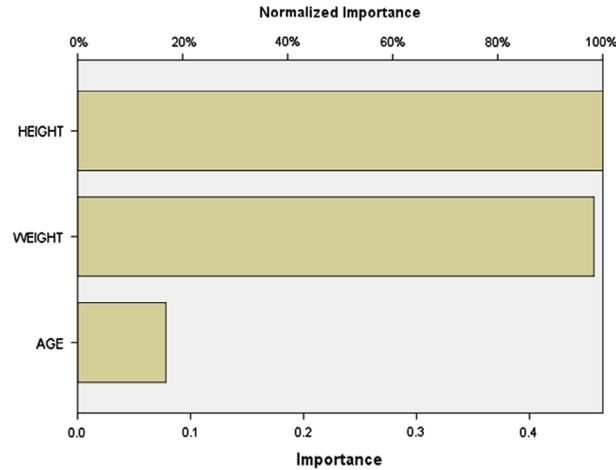


Figure 2. Independent variables importance.



4. Conclusion

It was found in this study that the mean PSA of Nigerian youth males was 169.2 cm², while that of females was 142.9 cm². The mean PSA for combined males and females was 155.0 cm², which indicated a statistically significant difference. The formula for estimating our PSA was determined using height, age, and weight. The empirical PSA equation and data are a very useful tool that could be utilized in anthropometry and ergonomics studies.

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