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Rekha Sharma
Associate Professor, Department of Physical Education, Satyawati College, University of Delhi, New Delhi, India

Pradeep Sharma
Associate Professor, Department of Physical Education, Ram Lal Anand College, University of Delhi, New Delhi, India

Dhananjoy Shaw
Professor, Indira Gandhi Institute of Physical Education and Sports Sciences, University of Delhi, New Delhi, India

Corresponding Author:
Rekha Sharma
Associate Professor, Department of Physical Education, Satyawati College, University of Delhi, New Delhi, India

Assessing validity of the reaction board method with suspension method to determine center of gravity

Rekha Sharma, Pradeep Sharma and Dhananjoy Shaw

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Abstract
The purpose of the present study was to assess the validity of the indigenously developed reaction board method in relation to the already established suspension method to evaluate its accuracy for determining the centre of gravity in the longitudinal axis. The sample comprised of 264 wooden logs of different weights and lengths. The sample was classified in six groups; three on the basis of weight i.e. light weight (N_1=52), middle weight (N_2=159), heavy weight (N_3=53); and three on the basis of length i.e. short length (N_4=35), medium length (N_5=34), tall length (N_6=195); based on the percentiles for weight and lengths computed independently. The variables for the study included weight, length, RBMCGB (CG measured from bottom while using reaction board method), RBMCGT (CG measured from top while using reaction board method), SMCGB (CG measured from bottom while using suspension method), and SMCGT (CG measured from top while using suspension method). The data was collected while following standard protocols. Mean, standard deviation, percentile and product-moment coefficient of correlation were used to analyze the data. The study concluded that the indigenously developed reaction board method is a valid tool for determining the centre of gravity.

Keywords: Reaction board method, suspension method, centre of gravity

Introduction
The centre of gravity of an individual standing in an anatomic position marks the intersection of the three primary planes and their axes. For solid masses of uniform density, the location of this point, often called the mass centre, is at the geometric centre and remains constant no matter what position the object assumes.
The methods used for locating centre of gravity of the human body have been verified from measuring frozen cadavers (Dempster, 1955) [3] to the use of templates (Designed by Walton, 1970). Some researchers have employed immersion techniques for obtaining segmental data while others have worked with the reaction board methods (Das and Ganguli, 1982; Sen and Ray, 1983) [2, 8].
It is fairly simple matter to find an estimate of the centre of gravity of motionless body using the reaction board method. Making the use of the principle of moments, this procedure relies on the fact that the sum of the question arises whether this method is competent enough to exactly locate the centre of gravity of an object of varied mass and length as well as combination of mass and length for which it is designed/ developed. Hence, the purpose of the present study was to assess the validity of indigenously developed reaction board method and suspension method for determining the centre of gravity.

Materials and Methods
Sample
Two hundred and sixty four (264) wooden logs of different lengths and weights were selected randomly and considered as sample for the purpose of the present study. The sample was classified into six groups, three on the basis of weight i.e. Light (N_1=52), Middle (N_2=159), and Heavy (N_3=53); and three on the basis of length i.e. Short (N_4=35), Medium (N_5=34), and Tall (N_6=195); based on the percentiles for lengths and weight computed independently.

Variables
The following variables were selected for the purpose of the study:

1. Weight (kg.)
2. Length (cm.)
3. RBMCGB i.e. Measurement of Centre of Gravity (CG) from the bottom while using Reaction Board Method
4. RBMCGT i.e. Measurement of Centre of Gravity (CG) from the top while using the Reaction Board Method
5. SMCGB i.e. Measurement of Centre of Gravity (CG) from the bottom while using Suspension Method
6. SMCGT i.e. Measurement of Centre of Gravity (CG) from the top while using the Suspension Method

Procedure

1. Reaction Board Method

The length and weight of each sample was determined with the help of the anthropometer and weighting scale with an accuracy of 1 mm. and 10 gms. respectively. The formula used for calculating the CG was the same as adopted by Sen & Ray (1983) [8], which is mentioned as below:

$$X = \frac{\text{Length of the Board in cm. (R2-R1)}}{\text{Weight of the Sample (in kg.)}}$$

Where,

X = Length of the location of centre of gravity from foot rest

R1 = Reading of Weighing Scale of Reaction Board without sample

R2 = Reading of Weighing Scale of Reaction Board with sample

2. Suspension Method

The length of the sample was taken with the help of the anthropometer. The sample was tied up from the approximate centre or the mid of the shaft with the help of cable. Therefore, it was hanged up in the air and the point of balance was located by shifting the tied cable till the wooden log (sample) was balanced horizontal to the ground surface. The tied point was marked as centre of gravity or centre of mass and thereafter, the length from identified landmark to top edge as well as from identified landmark to bottom edge was measured.

Statistical Analysis

The sample description was done through Mean and Standard Deviation. Percentile was used to classify the sample, while product-moment coefficient of correlation was used to obtain the coefficient of the scores obtained using reaction board method.

Findings

The findings of the study have been presented in the tables from 1 to 4.

Table 1: Descriptive Statistics of the Selected Variables of the Specimen Sample with Weight

Variable	Light Weight (N_1=52)	Middle Weight (N_2=159)	Heavy Weight (N_3=53)
Weight (kg.)	15489.42±15260.93	39662.31±17492.23	41401.88±10768.87
Length (cm.)	190.29±20.44	197.83±17.76	197.62±17.59
RBMCGB (gms.)	78.73±11.47	80.64±9.35	80.06±9.10
RBMCGT (gms.)	111.54±16.27	117.13±16.81	117.55±17.81
SMCGB (gms.)	79.07±9.37	80.78±8.45	80.25±8.46
SMCGT (gms.)	110.38±16.42	116.97±16.88	117.52±17.73

Table-1 demonstrates the descriptive statistics of the specimen sample classified into three weight categories i.e. light weight (N_1=52), middle weight (N_2=159) and heavy weight (N_3=53) for all the selected variables, namely Weight, Height, RBMCGB, RBMCGT, SMCGB, and SMCGT.

Table 2: Descriptive Statistics of the Selected Variables of the Specimen Sample with Length

Variable	Short Length (N_4=35)	Medium Length (N_5=34)	Tall Length (N_6=195)
Weight (kg.)	35280.00±16760.09	25030.88±10918.49	42647.18±16073.41
Length (cm.)	117.00±5.18	162.17±0.86	208.08±2.14
RBMCGB (gms.)	73.57±11.98	79.10±9.01	82.30±8.19
RBMCGT (gms.)	89.81±12.75	97.21±8.06	125.57±7.76
SMCGB (gms.)	74.46±9.39	78.88±8.98	82.41±7.53
SMCGT (gms.)	88.91±10.59	97.18±7.91	125.45±8.00

Table-2 presents the descriptive statistics of the specimen sample classified into three length categories i.e. short length (N_4=35), medium length (N_5=34) and tall length (N_6=195) for all the selected variables, namely Weight, Height, RBMCGB, RBMCGT, SMCGB, and SMCGT.

Table 3: Coefficient of Correlation of the Location of Centre of Gravity Determined by Using Reaction Board Method and Suspension Method with Weight

Group	N	RBMCGB	RBMCGT	SMCGB	SMCGT
Light Weight	52	0.28*	0.22	0.30*	0.08
Middle Weight	159	0.05	0.10	0.05	0.10
Heavy Weight	53	-0.22	0.21	-0.25	.21
Short length	35	0.57*	-0.46*	0.52*	-0.37*
Medium Length	34	0.12	0.18	0.09	0.22
Tall Length	195	0.01	-0.01	0.03	0.04

*Significant at 0.05 level

It is evident from the analysis of data in table-3 pertaining to the coefficient of correlation of the location of centre of gravity determined by using reaction board method and suspension method with weight that the light weight group exhibited significant correlation with the CG obtained through Reaction Board Method as well as Suspension Method; while the correlation was insignificant in all the middle weight group; and a negative insignificant correlation was observed for the heavy weight group with all the selected variables, namely RBMCGB, RBMCGT, SMCGB and SMCGT. With regard to the length wise correlation, there was a significant positive correlation with the short length group with the location of CG from the bottom by using both the reaction board as well as suspension method; however, when the CG was calculated from the top, then there were negative significant correlation when the CG was measured from the top. All the correlations for medium and tall length were found to be statistically insignificant.

Table 4: Coefficient of correlation of the location of centre of gravity determined by using reaction board method and suspension method with length

Group	N	RBMCGB	RBMCGT	SMCGB	SMCGT
Light Weight	52	0.61*	0.04	0.60*	0.86*
Middle Weight	159	0.17*	0.87*	0.22*	0.87*
Heavy Weight	53	0.08	0.85*	0.10	0.85*
Short length	35	0.40*	-0.21	0.35*	-0.12
Medium Length	34	0.37*	0.17	0.35*	0.17
Tall Length	195	0.07	0.22*	0.11	0.22*

*Significant at 0.05 level

The analysis of data in table-4 related to the coefficient of correlation of the location of centre of gravity determined by using reaction board method and suspension method with length (Height) that the light weight group exhibited significant correlation with the CG obtained from bottom and top through Reaction Board Method as well as Suspension Method except when it was measured using suspension method from the top, where it was insignificantly correlated. In the middle weight group; significant positive correlations was observed for all the methods; while heavy weight group observed significant correlation while obtaining CG from the top in both the methods and insignificant correlation obtaining CG from the bottom. With regard to the length wise correlation, there was a significant positive correlation with the short length group with the location of CG from the bottom by using both the reaction board as well as suspension method; however, when the CG was calculated from the top, then there were negative insignificant correlation when the CG was measured from the top. In medium length, there were positively significant correlations using both RBM and SM from the bottom; but insignificant correlation when the CG was obtained from the top in both methods. The reverse was true in case of Tall length samples, where the significant correlations were observed while obtaining CG from the top and insignificant when the CG was obtained from the bottom using both the reaction board as well as suspension methods.

Table 5: Validity coefficient of reaction board method and suspension method in determining the centre of gravity

Group	N	CG from Bottom (r)	CG from Top (r)
Light Weight	52	0.88	0.93
Middle Weight	159	0.94	1.00
Heavy Weight	53	0.98	1.00
Short length	35	0.87	0.89
Medium Length	34	1.00	0.99
Tall Length	195	0.93	0.96

The analysis of data in table-4 with regard to the cross validity co-efficient between reaction board method and suspension method for determining centre of gravity from bottom and top were found to be statistically significant at.05 level, with respect to all the classified group specimen samples, namely light weight group (r=0.88 for determining CG from the bottom; and r=0.93 while obtaining CG from the top; middle weight group (r=0.94 for determining CG from the bottom; and r=1.00 while obtaining CG from the top); heavy weight group (r=0.98 for determining CG from the bottom; and r=1.00 while obtaining CG from the top); short length group (r=0.87 for determining CG from the bottom; and r=0.89 while obtaining CG from the top); short length group (r=1.00 for determining CG from the bottom; and r=0.99 while obtaining CG from the top); and tall length group (r=0.93 for determining CG from the bottom; and r=0.96 while obtaining CG from the top).

Conclusion

Within the limitations of the present study, it is concluded that the indigenously developed reaction board method is a valid method for determination of centre of gravity as compared to the already established suspension method.

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