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Evaluation of Centre of Gravity (Cog) of Adult Bengali Population in Relation to Gender and Age

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Abstract

This study aims to assess age and sex related variation of center of gravity (CoG) of human body and its association with some anthropometric characteristics. A total of 150 subjects (75 male and 75 female) from the age group of 25 to 55 years were selected at random and they were divided into three age groups: 25-35 years, 36-45 years, and 46-55 years. The whole-body CoG was determined by segmental method. A software was used for computing the location of CoG in the body. The vertical location of CoG was expressed in terms percentage body height taking ground as the reference line and the horizontal location was expressed as the percentage of length of base taking left border of the base as reference line. Results revealed that there was a significant difference in the location of vertical CoG between male and female subjects. No significant difference was noted in horizontal CoG between two sexes. From the results of ANOVA, it was observed that there was no significant difference in the locations of vertical CoG and horizontal CoG among the subjects of different age groups both in cases of males and females. There was no significant correlation between vertical or horizontal CoG and the anthropometric parameters, viz., height, weight, weight, and BMI among the age groups in male and female subjects. It was concluded that the variation of the location of vertical CoG between male and female subjects might not be related to the anthropometric characteristics of the subjects.

Keywords: Center of Gravity, Age, Gender variation

Introduction

The center of gravity is a geometric property of any object. The center of gravity is the average location of the weight of an object. The CoG is the point at which the total body mass can be assumed to be concentrated without altering the body's

translational inertia properties. Forces applied through the CoG of an unrestrained body generate zero moment and result in translation but no rotation of the body. The position of the CoG characterizes whole body position and is subject to body posture control. Quantifying the motion of the CoG allows comparative assessment of motion performance (Benda *et al*., 1994).

Good posture of human may be defined as the ability to maintain the body center of mass in such a relation to the support base that falls are avoided and correct execution of movements is allowed (Westcott *et al*., 1997). The centre of gravity may be varied during body movement. Tesio *et al*., (1998) showed the changes in the centre of gravity of the body in the forward, lateral, and vertical directions during normal level walking at low and intermediate speeds to evaluate biomechanical alterations.

Investigation was done find the influence of initial projection of the centre of gravity (CoG) on the spatial and temporal organization of the dynamic phenomena accompanying a voluntary movement in humans. From a horizontal quadrupedal stance, ten normal subjects were instructed to raise the right forelimb towards a support target in self-paced velocity conditions (Gelat *et al*., 1996). As a case study of Centre of gravity, the young female Olympic Gymnastics athletes that composed the analyzed group had a better alignment of the lower limb (decreased knee valgus, medial rotation of the femur and pelvic asymmetry). However, there was an increased prevalence of anterior pelvic tilt, as well as a trend for increased lumbar hyperlordosis in the test group. These factors may have relevant clinical implications in the future of these athletes (Guimarães *et al*., 2007). Postural stability becomes compromised with advancing age, but the neural mechanisms contributing to instability have not been fully explicated. Accordingly, this quantitative physiological and MRI study of sex differences across the adult age range examined the association between components of postural control and the integrity of brain structure and function under different conditions of sensory input and stance stabilization manipulation. The groups comprised 28 healthy men (age 30-73 years) and 38 healthy women (age 34-74 years), who completed balance platform testing, cognitive assessment, and structural MRI. The results supported the hypothesis that excessive postural sway would be greater in older than younger healthy individuals when standing without sensory or stance aids, and that introduction of such aids

would reduce sway in both principal directions (anterior-posterior and medial-lateral) and in both the open-loop and closed-loop components of postural control even in older individuals. Sway reduction with stance stabilization, that is, standing with feet apart, was greater in men than women, probably because older men were less stable than women when standing with their feet together. Greater sway was related to evidence for greater brain structural evolutional changes, indexed as ventricular and sulcal enlargement and white matter hyper intensity burden. In women, poorer cognitive test performance related to less sway reduction with the use of sensory aids. Thus, aging men and women were shown to have diminished postural control, associated with cognitive and brain structural involution, in unstable stance conditions and with diminished sensory input (Sullivan *et al*., 2009).

The current investigation was based on the hypothesis that the centre of gravity of the human body may be varied with the age, gender and BMI among the adult Bengali populations.

Methods

Prior authorization and ethical approval (Ethical Approval No. IEC/5-16/C-6/15) were acquired from the 'Institutional Ethics Committee' before the commencement of the study. The study was conducted on 150 subjects, of which 75 were male and 75 were female belonging to the age range of 25-55 years. The subjects were selected from different districts of West Bengal. They were divided into three age groups: 25-35 years, 36-45 years, and 46-55 years. Each age group was consisted of 25 male subjects and 25 female subjects. Anthropometric measures, e.g., height and weight were taken from the subjects with following standard technique and appropriate landmark by using anthropometer and weighing machine (Libra) respectively. From measures of height and weight of the subjects, the body mass index (BMI) was computed using the following standard equation (Park, 2009):

$$BMI = Weight\ (kg) / Height^2\ (meter)$$

The whole-body center of gravity (CoG) of male and female subjects was determined by segmental method (Page, 1978). The location of the Center of Gravity (CoG) of individual during normal condition requires a highly useful procedure called segmental method. In this method CoG of 14 segments of the human body was determined by considering the proportion body weight of each segment. In this

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present study above method was followed by using "Wise Annalist Software". This technique used the photograph of the subject, which was compressed to the defined size of the software by using 'Adobe Photoshop'. The location of the whole-body center of gravity was shown within the diagram of the subject in computer screen. The hard copy of the diagram was taken. The location of horizontal CoG and vertical CoG were determined, in terms of percentage of total length of the subject in the photograph, by using the formula:

Vertical CoG (%) = (Height of whole-body CoG / Full length of subject) *100

Horizontal CoG (%) = (Distance of CoG from the left border of the baseline / Distance of the baseline from the left and right border) *100

To test the significance of difference of CoG and physical parameters between male and female subjects, the student's t-test was performed. ANOVA was employed to find the significance of difference of those parameters among the subjects of three different age groups. The correlation coefficient was made by using Origin Pro software.

Results

The study was carried out on healthy male and female subjects. The height and weight of the subjects were within the normal limit. The mean BMI of the male subjects was normal but in female subjects it was slightly higher than the normal cutoff value (WHO, 2000). Table 1 shows the physical parameters of the subjects according to sex. The results revealed that there was no significant difference in weight, and BMI between male and female subjects. However, the males were significantly taller ($p<0.001$) than that of the female subjects. Research on Bengali agricultural workers by Mahata *et al*., (2019), apparently reveals the same finding.

Parameter	Male (n=75)	Female (n=75)
Height (cm.)	162.75±5.76	153.39±11.91***
Weight (kg.)	61.67±7.33	59.65±8.71
BMI (Kg/m^2)	23.32±2.88	26.94±17.66

w.r.t. male. *** $p<0.001$

Table 1: Mean ± SD of physical parameters and CoG of the subjects (N = 150).

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The locations of vertical and horizontal CoG of male and female subjects have been presented in Table 2. There was a significant difference ($p<0.001$) in vertical CoG between male and female subjects. No significant difference in horizontal CoG was observed between male and female subjects.

Types of CoG location	Male (n=75)	Female (n=75)
Vertical CoG (%)	53.57±1.82	56.14±6.29***
Horizontal CoG (%)	55.0±15.76	55.09±15.43

w.r.t. male. *** $p<0.001$

Table 2: Comparison of Horizontal and vertical CoG between male and female

The subjects were divided into three different age groups (25-35 years, 36-45 years and 46-55 years. The height, weight and BMI were compared between male and female subjects as well as among the age groups as shown in Table 3. In the age group of 25-35 years the height and BMI were significantly different ($p<0.001$) between male and female subjects. However, no significant difference in weight was observed between two sexes in this age group. The height was significantly higher ($p<0.001$) in males than that of females in other two age groups, viz., 36-45 yrs and 46-55 yrs. Though there was no difference in BMI in the age group of 36-45 years, the BMI was significantly different between males and females in upper (36-45 years) and lower (25-35 years) age groups. In case of male subjects there were significant variations ($p<0.001$) in weight and BMI among the age groups. In case of female subjects no significant variation was observed in all the anthropometric variables among the age groups studied.

Parameters	Age 25-35 yrs		Age 36-45 yrs		Age 46-55 yrs		F ratio	
	Male (n=25)	Female (n=25)	Male (n=25)	female (n=25)	Male (n=25)	Female (n=25)	Male	Female
Height	163.80 ±5.34	152.68 ±4.85 ***	163.04 ±6.25	156.24 ±5.09 ***	161.42 ±5.64	151.24 ±19.35 *	1.12	1.17
Weight	58.76	56.92	63.48	59.84	62.76	62.20	3.18#	2.39

	±4.49	±7.08	±7.17	±9.04	±8.89	±9.35		
BMI	21.95 ±2.13	24.42 ±2.80 ***	23.91 ±2.69	24.60 ±4.26	24.10 ±3.29	31.78 ±2.99 ***	4.71#	1.43

w.r.t. male *** $p<0.001$; # $p<0.05$

Table 3: Mean ±SD of physical parameters of different age groups

The variation vertical and horizontal CoG in different age groups has been presented in Table 4. The results of the ANOVA revealed that both the horizontal and vertical CoGs had no significant variation among the age groups. However, gender difference was noted in vertical CoG in some of the age groups. In two upper age groups, that is, 35-46 years and 46-55 years there was a significant difference in vertical CoG ($p<0.001$) between male and female subjects. No gender difference was found in case of horizontal CoG in any of the age group studied.

Types of CoG	**Age 25-35 yrs**		**Age 36-45 yrs**		**Age 46-55 yrs**		**F ratio**	
	Male (n=25)	Female (n=25)	Male (n=25)	female (n=25)	Male (n=25)	Female (n=25)	Male	Female
Vertical CoG	53.72 ±2.17	54.02 ±10.24	52.91 ±1.21	57.65*** ±2.61	54.09 ±1.80	56.75*** ±1.68	2.92	2.34
Horizontal CoG	58.91 ±14.61	58.57 ±15.55	53.81 ±15.59	51.38 ±15.20	52.28 ±16.85	55.30 ±15.29	1.02	1.37

w.r.t. male *** $p<0.001$

Table 4: Mean ± SD and F ratio of CoG in different age groups

The correlation coefficient was computed to find association between CoG and anthropometric variables in male and female subjects (Table 5). It was observed that the correlation coefficients between CoG and anthropometric variables, viz., height, weight and BMI were very poor in both the sexes.

Parameters	Male (n=75)		Female (n=75)	
	Vertical CoG	Horizontal CoG	Vertical CoG	Horizontal CoG
Height	0.202	0.045	-0.008	0.023
Weight	-0.051	-0.045	-0.032	-0.103
BMI	-0.158	-0.079	0.031	-0.057

Table 5: Correlation Coefficient between CoG and other parameters (Height, weight, BMI)

Discussion

The location of the center of gravity (CoG) in the human body is extremely important in determining the state of equilibrium at any moment. Like everything, any consideration of human movement, the position of the CoG of the body plays an important role.

The main objective of this study was the variation of vertical and horizontal CoG according to age and sex. In the present method the location of vertical CoG was pointed out in terms of the percentage of body height. It was observed that the location of vertical CoG in male was 53.57% of the body height whereas in female it was 56.14%. The horizontal CoG was determined as the percentage of the length of base contact with the ground surface. The results showed that the horizontal CoG of male was 55% and female horizontal CoG was 55.09%. The difference in CoG between the sexes may be due to the difference in body mass and body shape between males and females. Another determining fact is that the structure of the male pelvis is significantly heavier and thicker than that of the female (Leong 2006). Other investigators also observed similar results for the location of CoG in the human body. The location of CoG in female was observed to be 54-57% of their standing height in a normal standing position (Hellebrandt, 1942) and CoG in male to be 53-56% percent of their height in a normal standing position (Croskey *et al*., 1922). Hamandi (2012) showed a higher value of vertical CoG in their study. They showed that the percentage of height of the center of gravity to the total body height

is 60% in mean, which represents the point located in the lower torso, slightly below the waist and in the pelvic region.

The centre of gravity is described as balance or spin point of human body. If the CoG is shifted to higher position, then it becomes more difficult to maintain one's equilibrium. Lowering of CoG increases the stability of the body. According to Page (1978), the shifting of CoG towards upper side of body makes the body unstable which imposes postural load. The biomechanical stress may be reduced if the CoG remains on the central axis of the body and it was symmetric in nature (Ray and Atreya, 1997). Caron *et al*., (1997) conducted a study to estimate the horizontal positions of the body's centre of gravity in a standing posture, on the basis of the horizontal positions of the centre of pressure (CoP). It was observed that there is no significant difference in vertical CoG of male and female among the age groups. However, in case females the CoG was located at slightly higher position of the body in the subjects of higher age groups than that of the lower age group. In horizontal CoG there was there was no significant difference among the age groups in both sexes.

From the correlation study it was observed that the position the whole-body CoG of the subjects was poorly correlated with the physical characteristics of the body, viz., height, weight and BMI. In some of cases negative correlation was found, although non-significantly. The same trend of results was noted in both vertical and horizontal CoG. Duggar (2016) studied the location of the centers of gravity of the human body and body segments. It was shown that the selection of source and the manner of applying center of gravity data will depend on anthropometric characteristics of the population under study and body positions anticipated.

Conclusion

From the results it was concluded that there was a significant gender difference in the location of vertical CoG but no such difference was observed in case of horizontal CoG. There was no variation in the location of CoG with age among the adult male and female in the age groups of 25-55 years. There was no significant association between vertical or horizontal CoG and the anthropometric characteristics of the male and female subjects.

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