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ORIGINAL ARTICLE

UTILITY OF 95% CONFIDENCE INTERVALS IN ESTIMATION OF HEIGHT WITH GROWING DIMENSIONS OF HUMAN BODY SEGMENTS

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ABSTRACT: BACKGROUND: Height is the major parameter of personal identification. In any kind of mishap, forensic scientists require to estimate stature from body part(s). Confidence intervals or confidence limits provide basis for such identification. **OBJECTIVE**: To determine 95% confidence intervals for mean heights on the basis of body segment. **MATERIAL & METHODS**: The study consisted of 100 males and 100 females. Their stature and hand length, hand breadth, foot length & foot breadth on the right and left side was recorded. Logistic regression analysis was carried out to know the body segment(s) identifying gender. 95% confidence intervals of mean height for identified body segment were determined. **RESULTS**: Logistic regression analysis revealed Right Hand Width and Right Foot Length could determine correct gender. Thus 95% confidence intervals for mean heights for each observed value of Right Hand Width and Right Foot Length of male and female were generated. Validity revealed that 75% and 40% heights lie in 95% confidence interval according to Right Hand Width while 100% and 67% lie in 95% confidence interval according to Right Foot Length of males and females, respectively. **CONCLUSION**: 95% confidence intervals provide the range of height within which the individual may have his/her height instead of single value. This gives good approximation to actual value (height).

KEYWORDS: Logistic regression, 95% CI, height identification, human remains.

INTRODUCTION: Anthropometry is a series of systematized measuring techniques that express quantitatively the dimensions of human body and skeleton. Use of anthropometry in forensic science helps the law enforcement agencies in achieving personal identity in case of unknown human remains as anthropometric characteristics have direct relationship with sex and shape[1].

Height is considered as one of the parameters of personal identification. Its estimation is considered to be an important assessment in the identification of unknown human remains. For better accuracy, height estimation may be attempted only after attainment of maturity. The mass disaster, homicide, plane crashes, train and road accidents etc. require the forensic scientists to estimate stature from different body parts. There is always need for such studies which help in identifying the deceased from fragmentary and dismembered human remains. Confidence intervals or confidence limits provide a method of stating the precision or closeness of the sample statistic[2]. Thus the present study was undertaken to estimate height from 95% confidence intervals for mean heights determined on the basis of growing size of body segment.

MATERIAL AND METHODS: The present study consisted of 100 males and 100 females above 25 years of age from western Maharashtra. Only right handed subjects were included in the study. Stature and other four anthropometric measurements viz. hand length, hand breadth, foot length and foot breadth were taken on the right and left side of each individual. All measurements were taken by

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one observer in order to void inter-observer error, in a well-lighted room. The measurements were taken using standard instruments in centimeters to the nearest millimeter according to the techniques described by Vallois[3]. The subjects included in the study were healthy and free from any apparent symptomatic deformity.

Of these 100 males and 100 females 90 from each were selected randomly for determination of 95% confidence intervals. Remaining 10 were kept for validation of stature from 95% confidence intervals developed from 90. Initially data of 180 randomly selected subjects was analyzed for identification of sex by applying binary logistic regression technique to know the most appropriate body segments. 95% confidence intervals of the mean height were determined using the measurements of these body segments. These intervals were generated for each observed body segment value. Further, heights of remaining 10 males and females were compared with 95% intervals of heights, for assessment of validity.

RESULTS: The difference in measurements of all study variables between male and female study subjects was significant. Over all these measurements were significantly higher in male study subjects (Table1).

The logistic regression analysis was carried out to detect the variable i.e. body segment that classify gender of the respective individual most correctly. It was carried out by entering each variable independently. This analysis revealed that Right Hand Width and Right Foot Length could determine 83.9% and 84.4% correct gender, respectively (Table 2).

Gender wise 95% confidence intervals for mean height of these two variables were determined (Table 3, 4, 5 & 6).

In the set of 90 Right Hand Width values of male subjects; two Right Hand Width values, amongst data set of 10 males kept for validity assessment of 95% confidence intervals, were not observed. Of remaining 8 males, heights of 6 (75%) males with various Right Hand Width values found to be laying in corresponding 95% Confidence Limits. While heights of less proportion of females (40%), found lying in respective 95% Confidence Limits of height. In the set of 90 Right Foot Length values of male subjects three Right Foot Length values amongst values of 10 males were not observed. Of remaining 7 males, heights of all i.e. 100% were found to be laying in respective 95% Confidence Limits of heights. Similarly 4 observations in female subjects were not found in the set of 90 Right Foot Length values of females. For remaining 6 Right Foot Length values, heights of 4(67%) females were found to be laying in respective 95% Confidence Limits (Table 7).

DISCUSSION: In practice, it is not logical to predict single value of height; which has less chances of matching with actual height. 95% confidence intervals provide the range of values (heights) within which the 95% values (of heights) will lie. This gives good approximation to actual value (height) and avoids barriers in the search/study. The concept of 95% confidence interval is widely used in health studies viz. in developing reference ranges[2] as well as cutoff values[4] to identify healthy and diseased individuals.

It was preferred to carry binary logistic regression analysis with only one independent variable. This was with assumption that in any kind of mishap the single body segment may obtain. In present study only two measurements that were highly classifying subjects' gender were considered. But as measurements of hands and feet provide good approximation about the height of the person[5],

on all measurements 95% confidence intervals can be determined as nobody knows which body segment may found. These confidence intervals contain the population value with probability 0.95. It provides a formal expression of the uncertainty which must be attached to the point estimate on account of sampling errors alone[6]. Also in present study 95% confidence intervals are generated on the basis of only 90 observations. If the number of observations is increased it will facilitate to give enough large number of observations viz. heights, for each single value of the predictor variable like Rt. Hand Width & Rt. Foot Length, and generate very highly diagnostic 95% confidence intervals according to growing value of the predictor variable.

CONCLUSION: The 95% confidence intervals provide the range of height within which the individual may have his/her height instead of single value. This gives good approximation to actual value (height).

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Gender	Statistic	Height	Right Hand Length	Left Hand Length	Right Hand Width	Left Hand Width	Right Foot Length	Left Foot Length	Right Foot Width	Left Foot Width
Male	N	90	90	90	90	90	90	90	90	90
	Minimum	136.00	15.30	15.10	7.30	7.00	22.20	22.10	8.50	8.20
	Maximum	178.00	21.00	21.00	9.10	9.10	28.40	28.30	10.70	10.70
	Mean	165.32	18.29	18.17	8.18	7.97	24.85	24.78	9.73	9.62
	Median	165	18.20	18.20	8.20	8.00	24.75	24.65	9.80	9.70
	SD	7.18	0.95	0.96	0.45	0.49	1.25	1.26	0.51	0.53
Female	N	90	90	90	90	90	90	90	90	90
	Minimum	140.00	14.70	14.70	6.70	6.50	20.00	19.50	7.30	7.20
	Maximum	165.00	18.30	18.20	8.30	8.30	24.50	24.40	10.00	10.00
	Mean	151.44	16.64	16.55	7.43	7.28	22.57	22.42	8.79	8.64
	Median	152.00	16.70	16.5	7.40	7.30	22.55	22.50	8.80	8.65
	SD	5.67	0.85	0.81	0.33	0.32	0.996	1.06	0.57	0.56
Unpaired 't' test value		14.396	12.270	12.245	12.612	11.160	13.568	13.575	11.620	12.165
P value		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Table 1: Descriptive statistics of study variables

DOI: 10.14260/jemds/2014/2028

Independent Variable	β coefficient	Constant	Prediction		
			Male (90)	Female (90)	% correct
Rt. Hand Length	-2.188	38.179	71	70	78.3
Lt. Hand Length	-2.260	39.169	74	72	81.1
Rt. Hand Width	**-4.868**	**37.793**	**75**	**76**	**83.9**
Lt. Hand Width	-4.069	30.859	70	75	80.6
Rt. Foot Length	**-2.157**	**50.980**	**76**	**76**	**84.4**
Lt. Foot Length	-2.086	49.099	74	78	84.4
Rt. Foot Width	-3.009	27.909	74	67	78.3
Lt. Foot Width	-3.177	29.052	75	72	81.7

Table 2: Logistic Regression analysis predicting gender

Rt. Hand Width (cm)	n	Height (cm)						
		Minimum	Maximum	Median	Mean	S.D.	95% Confidence Limit	
							Lower Limit	Upper Limit
7.30	1	163	163	163	163	-	-	-
7.40	6	151	165	157.5	157.5	5.36	151.88	163.22
7.50	1	161	161	161	161	-	-	-
7.60	5	157	164	161	160.8	2.59	157.59	164.01
7.70	2	153	159	156	156	4.24	117.88	194.12
7.80	7	156	172	167	163.9	6.91	157.46	170.25
7.90	7	157	177	165	165.1	6.36	159.26	171.03
8.00	13	136	174	163	161.2	9.5	155.41	166.90
8.10	2	160	162	161	161	1.41	148.29	173.71
8.20	6	160	178	170.5	170.2	6.91	162.91	177.42
8.30	4	165	171	167.5	167.8	2.5	163.77	171.73
8.40	12	160	176	167.5	167.9	4.48	165.07	170.76
8.50	3	169	173	170	170.7	2.08	165.50	175.84
8.60	6	169	178	170.5	172.5	4.32	167.96	177.04
8.70	4	158	168	163	163	4.4	156.00	169.99
8.80	3	163	170	164	165.7	3.79	156.26	175.07
8.90	3	165	174	172	170.3	1.73	158.59	182.07
9.00	4	162	177	171.5	170.5	6.35	160.39	180.61
9.10	1	178	178	178	178	-	-	-

Table 3: Right hand width wise 95% confidence intervals for mean height of males

DOI: 10.14260/jemds/2014/2028

Rt. Hand Width (cm)	n	Height (cm)						
		Minimum	Maximum	Median	Mean	S.D.	95% Confidence Limit	
							Lower Limit	Upper Limit
6.70	1	140	140	140	140	-	-	-
6.80	2	146	157	151.5	151.5	7.78	81.62	221.38
7.00	10	142	160	149	148.9	6.47	144.27	153.53
7.10	6	140	153	148.5	147.8	4.87	142.72	152.95
7.20	12	142	153	150	148.9	3.96	146.40	151.44
7.30	5	140	162	152	152	8.92	140.93	163.07
7.40	10	150	165	154.5	155.3	4.97	151.75	158.85
7.50	10	145	165	152	152.4	6.53	147.72	157.08
7.60	12	145	162	152.5	151.6	4.76	148.56	154.61
7.70	8	146	155	152	151.3	2.82	148.90	153.60
7.80	4	145	153	149	149	4.62	141.65	156.35
7.90	5	153	158	154	154.8	2.17	152.11	157.49
8.00	2	159	161	160	160	1.41	147.29	172.71
8.10	1	154	154	154	154	-	-	-
8.20	1	155	155	155	155	-	-	-
8.30	1	159	159	159	159	-	-	-

Table 4: Right hand width wise 95% confidence intervals for mean height of females

Rt. Foot length (cm)	n	Height (cm)						
		Minimum	Maximum	Median	Mean	S.D.	95% Confidence Limit	
							Lower Limit	Upper Limit
22.20	1	153	153	153	153	-	-	-
22.40	1	164	164	164	164	-	-	-
22.80	1	153	153	153	153	-	-	-
23.00	2	158	166	162	162	5.66	111.18	212.82
23.10	1	151	151	151	151	-	-	-
23.30	3	155	160	160	158.3	2.89	151.16	165.50
23.40	2	159	160	159	159.5	0.71	153.15	165.85
23.50	2	160	161	160	160.5	0.71	154.15	166.85
23.60	1	157	157	157	157	-	-	-
23.70	6	155	169	161	161.3	5.32	155.75	166.91
23.90	2	161	169	165	165	5.66	114.17	215.62
24.00	4	157	168	160	161.5	4.65	154.09	168.91
24.10	1	171	171	171	171	-	-	-
24.20	3	136	167	160	154.3	16.26	113.94	194.72

DOI: 10.14260/jemds/2014/2028

24.30	4	156	167	164	162.8	4.79	155.13	170.37
24.40	4	160	168	162	163.3	3.95	156.97	169.53
24.50	3	165	167	165	165.7	1.15	162.80	168.53
24.60	1	163	163	163	163	-	-	-
24.70	3	162	170	165	165.7	4.04	155.63	175.71
24.80	5	163	169	164	165	2.34	162.09	167.91
24.90	4	164	171	167	167.5	3.51	161.91	173.09
25.00	1	156	156	156	156	-	-	-
25.10	2	162	170	166	166	5.66	115.18	216.82
25.30	2	171	177	174	174	4.24	135.88	212.12
25.40	4	158	177	171	169.3	8.06	156.43	182.07
25.50	3	156	170	169	165	7.81	145.60	184.40
25.60	1	167	167	167	167	-	-	-
25.70	2	175	178	176	176.5	2.12	157.44	195.56
25.80	2	165	168	166	166.5	2.12	147.44	185.56
25.90	2	169	171	170	170	1.41	157.29	182.71
26.00	1	165	165	165	165	-	-	-
26.20	1	169	169	169	169	-	-	-
26.30	2	168	176	172	172	5.66	121.18	222.82
26.40	2	168	170	169	169	1.41	156.29	181.71
26.50	3	168	173	173	171.3	2.89	164.16	178.50
26.70	2	166	178	172	172	8.49	95.76	248.23
27.00	2	174	174	174	174	0.00	-	-
27.20	1	177	177	177	177	-	-	-
27.50	2	172	178	175	175	4.24	136.88	213.12
28.40	1	178	178	178	178	-	-	-

Table 5: Right foot length wise 95% confidence intervals for mean height of males.

Rt. Foot length (cm)	n	Height (cm)						
		Minimum	Maximum	Median	Mean	S.D.	95% Confidence Limit	
							Lower Limit	Upper Limit
20.00	1	144	144	144	144	-	-	-
20.40	1	142	142	142	142	-	-	-
20.50	1	142	142	142	142	-	-	-
20.80	2	140	149	144.5	144.5	6.36	87.32	201.68
21.00	2	142	148	145	145	4.24	106.88	183.12
21.20	2	142	145	143.5	143.5	2.12	124.44	162.56
21.30	2	140	157	148.5	148.5	12.02	40.50	256.50
21.40	1	152	152	152	152	-	-	-
21.50	1	142	142	142	142	-	-	-
21.60	2	145	147	146	146	1.41	133.29	158.71

DOI: 10.14260/jemds/2014/2028

21.70	3	145	152	150	149	3.61	140.04	157.96
21.80	7	140	155	152	149.9	5.24	145.01	154.71
21.90	2	150	152	151	151	1.41	138.29	163.71
22.00	2	146	150	148	148	2.83	122.59	173.41
22.10	1	147	147	147	147	-	-	-
22.20	1	150	150	150	150	-	-	-
22.30	3	148	154	149	150.3	3.22	142.35	158.32
22.40	5	147	158	152	152.2	4.15	147.05	157.35
22.50	6	145	154	150	150	3.63	146.19	153.81
22.60	5	145	155	145	148	4.47	142.44	153.55
22.70	1	156	156	156	156	-	-	-
22.80	4	148	157	152.5	152	3.70	146.62	158.38
22.90	2	145	153	149	149	5.66	98.18	199.82
23.00	2	152	158	155	155	4.24	116.88	193.12
23.10	1	165	165	165	165	-	-	-
23.20	5	152	162	154	156.4	4.72	150.54	162.26
23.30	3	152	159	158	156.3	3.79	146.93	165.74
23.50	7	149	162	153	155.1	4.71	150.79	159.49
23.60	1	157	157	157	157	-	-	-
23.70	2	153	160	156.5	156.5	4.95	112.03	200.97
23.80	3	152	159	154	155	3.61	146.04	163.96
23.90	3	153	155	153	153.7	1.15	150.80	156.54
24.00	2	150	165	157.5	157.5	10.61	62.20	252.80
24.20	1	155	155	155	155	-	-	-
24.40	2	156	159	157.5	157.5	2.12	138.44	176.56
24.50	1	153	153	153	153	-	-	-

Table 6: Right foot length wise 95% confidence intervals for mean height of females

MALES					FEMALES				
Height	Rt. Hand Width	Esti mation	Rt. Foot Length	Esti mation	Height	Rt. Hand Width	Esti mation	Rt. Foot Length	Esti mation
154	7.5	--	23.6	--	155	7.2	×	21.4	--
154	7.9	×	22.3	--	157	7.1	×	23.8	√
163	8.2	√	24.5	√	165	7.7	×	23.5	×
184	9.4	--	27.4	--	163	7.8	×	23.8	√
175	8.6	√	25.5	√	140	7.4	×	20.5	--
172	8.4	×	25.3	√	155	7.3	√	22.6	×
165	8.0	√	24.2	√	148	7.3	√	22.2	--
169	8.3	√	24.9	√	149	7.5	√	22.5	√
165	8.3	√	23.7	√	155	7.4	√	22.3	√
175	8.8	√	25.7	√	147	7.4	×	21.5	--

Table 7: Estimation of height from 95% confidence intervals

DOI: 10.14260/jemds/2014/2028

--: No respective variable value (Rt Hand Width / Rt Foot Length) in processed (90 subjects) data set.
×: Height doesn't lie in 95% Confidence Interval
√: Height lies in 95% Confidence Interval

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