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Ergonomics Evaluation of Different Car Seat Design

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Abstract—* Automobile seat design is always a big challenge for the designers. There are numbers of seats available in the market and each seat has different comfort level which is generally defined by the driver. This study is concentrated over three different car seat design (sedan) with the help of anthropometric parameters for the ergonomic evaluation. The aim of this research is to provide the choice to end users to access the car seat design suitable for them. The study has been carried out on three more used sedan cars in India with their different year models. It incorporates both short and tall person with their anthropometric data associated with driver cabin. In evaluation the seat back angle are 95, 105 and 125 for short and tall person. The response parameters used in evaluation are steering wheel clearance (q), boot space (r), head clearance(s), sitting height (t), knee angle (α), elbow angle (φ) and foot angle (γ). The one way analysis of variance (ANOVA) has been used to see the significant difference in several parameters separately. There is no significant difference was found for five responses i.e steering wheel clearance (q), boot space (r), knee angle (α), foot angle (γ) and elbow angle (φ). However significant difference was observed for sitting height (t) and head clearance (s) for some modal of cars. Honda city which has high head clearance (s) gives more comfort for tall individuals, however, Toyota corolla gives comfort sitting height (t) for tall individuals.
Keywords—* car seat, sedan, ergonomics, anthropometry, ANOVA

I. INTRODUCTION

In today's world, rising customer expectations forcing the automotive industry to focus design efforts on occupant comfort. In other words, comfortable seating is no longer considered a luxury, it is a requirement. No one can judge the seat comfortable by appearance of seat. There are several other factors which are responsible for seating comfort. It is necessary to understand and design for variability represented in the population, spanning such attributes as age, height etc. [9] Ergonomics plays a vital role in the development of car due to its various impact like safety, health and productivity of users. Safety and seating comfort are two factors that the seat is distinguished from the other competitor. [4] The relationship between car driver‘s anthropometric dimensions postural angles and seat adjustment is very important for seat development. [3] Seats should be easily adapted by users and controls are easy to reach. [5] Human search instinctively for the body posture which allows the lowest expenditure of energy within possible physiological and biochemical limits and which allows an ease and efficiency in task execution. [12] Shows that the sitting in the restricted position and in the effect of vibration is risk. This means that there is risk to sit on the car seat. [10] Showed that the car seat should optimize the muscular tension and reduce postural stress. [6] discovered the discrepancies between the compact car survey for 12 subjects and the contour characteristics scanned for those seat environments. The conclusion of this study was that ergonomics criteria could not be blindly applied for ensuring comfort automobile seats. [7] Published a paper on the development process of automobile seat comfort and restrictions associated with it. Through this study he initiated the framework to lead the investigative process related to seat comfort research. The aim of this framework is to produce theories and methods that could provide guidelines and further validate the comfort if automobile seat. The evolution of car seat started with bench seat in the earlier days to bucket seat in the present days. The purpose of car seat is to support the parts of human body/occupant which includes buttocks, the thighs, the back which (upper and lower back) and the head support. The main three parts of seat are seat back, the seat cushion and the headrest. Now a days most of the cars have all these parts. At the moment of car invention, the car seat is not comfortable as it may have now days. The design is based on adaptation of the horse dawn carriage. [8] Observe the ergonomics advantages of different car seat design considering the dynamic characteristics in three different driver postures. [2] shows that the dynamic and objective study are both necessary for automobile seat comfort. [14] identified the H-point and analyses the influencing factors of automobile driving comfort. [15] An ergonomically designed car reduces driver‘s fatigue. Anthropometric measurements of a driver and surrounding measurements of car controls affect traffic safety and driver‘s fatigue. [9] Ergonomically unsuitable car seat design is responsible for various pains and physiological fatigue in the body. Due to prolonged seating on unfit car seat design reduced the blood circulation in the buttocks and legs and produces stress in the lumbar back and the other parts of body. [13] There is difference between the anthropometric dimensions of people where the vehicle manufactured and that of user population in the countries where the vehicle are exported. Sedan cars are very popular in India. It can clearly be seen through above references that so many researchers are concerned over ergonomics issue of seat in a car. They also represent above car seat design, with different posture for foreign population. However the gap is visible in term of Indian population. Keeping this in view, sedan cars design parameters have been ergonomically evaluated for Indian population. These vehicles are imported in India since there is no manufacturing plant in India. An ergonomic evaluation of these cars is very important to determining their suitability for the people of India.

II. METHODOLOGY

The methodology adopted for this research includes:
Number of participant measured = 2
Age = 22 – 35 years
Weight = 50 – 65 kg
Gender = Male

Ergonomics evaluation of vehicle seats was conducted on three sedan cars which are popular in India. They are: Toyota corolla, Honda city and Hyundai accent. Three models (2004,2008 and 2012) of each sedan cars were considered on the basic of their design peculiarity. The selected vehicles had the similar features such as for adjusting the seat track, height and back rest angle. For this study, two individuals were participated representing the 5 and 95 percentiles of population. The average heights of population for percentiles of 5 and 95 of the Indian were 1537mm and1781mm. [13] Every participant is free to sit in his comfortable posture and allowed to adjust the seat according to his preference. Thereafter, [15] Anthropometric measurements were taken by direct method when the back rest was inclined at an angle 95. 105 and 125 which are seat position angle (Ψ). The input parameters for analysis of variance are different car seat modals and the responses are seven anthropometric parameters include:
Steering wheel clearance
Boot space
Head clearance
Sitting height
Knee angle
Foot angle
Elbow angle

Ergonomics evaluation of vehicle seats was conducted on three sedan cars which are popular in India. They are: Toyota corolla, Honda These anthropometric parameters are illustrated in Fig 1. Measurements were taken with the help of tape rule, protractor and a pair o f dividers. Analysis of variance test was carried out on the calculated data.

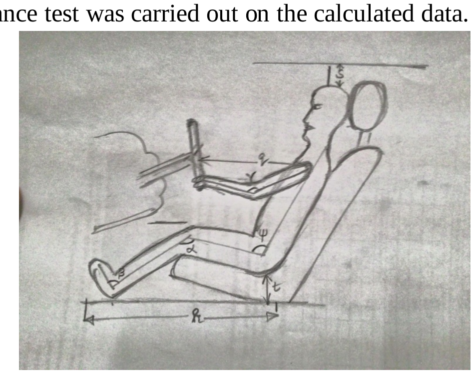

Fig1: Ergonomics factor of vehicle seat position and anthropometric parameters

III. RESULTS

All as discussed in previous section one way analysis of variance (ANOVA) has been used the see the variation in seven anthropometric parameters. The ANOVA also assigns the source of variation (i.e models of cars). The results are tabulated in tables. Table 1 shows the anthropometric parameters measurement. Table 2 to 7 shows the average values of the anthropometric measurements of short and tall individuals for three sedan cars with their different year models. The parameters include: steering wheel clearance(q), boot space(r), head clearance(s), sitting height(t), knee angle(α), foot angle(γ) and elbow angle(φ).

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TABLE I
ANTHROPOMETRIC DATA OF SELECTED SEDAN CARS

Toyota Corolla 2004 model							
Ψ(deg)	q(mm)	r(mm)	s(mm)	t(mm)	α (deg)	γ (deg)	φ (deg)
95	350	930	100	150	101	110	91
105	475	930	105	150	101	110	105
125	580	930	125	150	101	110`	120
AVG	468.3	930	110	150	101	110	105.3
Toyota corolla 2004 model							
Ψ(deg)	q(mm)	r(mm)	s(mm)	t(mm)	α (deg)	γ (deg)	φ (deg)
95	480	930	130	150	108	92	100
105	590	930	180	150	108	92	127
125	600	930	220	150	108	92	140
AVG	556.7	930	176.7	150	108	92	122.3

Toyota Corolla 2008 model							
Ψ(deg)	q(mm)	r(mm)	s(mm)	t(mm)	α (deg)	γ (deg)	φ (deg)
95	400	940	80	180	97	105	85
105	510	940	90	180	97	105	125
125	620	940	95	180	97	105	136
AVG	510	940	88.3	180	97	105	115.3
Toyota Corolla 2008 model							
Ψ(deg)	q(mm)	r(mm)	s(mm)	t(mm)	α (deg)	γ (deg)	φ (deg)
95	390	940	95	180	133	118	107
105	520	940	100	180	133	118	143
125	630	940	115	180	133	118	149
AVG	513.3	940	103.3	180	133	118	133
Toyota Corolla 2012 Model							
Ψ(deg)	q(mm)	r(mm)	s(mm)	t(mm)	α (deg)	γ (deg)	φ (deg)
95	570	1030	80	220	102	111	99
105	600	1030	100	220	102	111	118
125	680	1030	120	220	102	111	137
AVG	616.6	1030	100	220	102	111	118
Toyota Corolla 2012 Model							
Ψ(deg)	q(mm)	r(mm)	s(mm)	t(mm)	α (deg)	γ (deg)	φ (deg)
95	550	1000	95	220	114	108	98
105	570	1000	120	220	114	108	120
125	660	1000	135	220	114	108	145
AVG	593.3	1000	116.6	220	114	108	121
Honda City 2004 model							
Ψ(deg)	q(mm)	r(mm)	s(mm)	t(mm)	α (deg)	γ (deg)	φ (deg)
95	480	920	50	200	101	95	93
105	490	920	60	200	101	95	99
125	510	920	75	200	101	95	107
AVG	493.3	920	61.6	200	101	95	99.6
Honda City 2004 model							
Ψ(deg)	q(mm)	r(mm)	s(mm)	t(mm)	α (deg)	γ (deg)	φ (deg)
95	515	920	65	200	113	99	103
105	520	920	80	200	113	99	111
125	540	920	90	200	113	99	133

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AVG	525	920	78.3	200	113	99	115.6

Honda City 2008 Model							
Ψ(deg)	q(mm)	r(mm)	s(mm)	t(mm)	α (deg)	γ (deg)	φ (deg)
95	510	930	80	230	103	99	97
105	550	930	100	230	103	99	99
125	560	930	115	230	103	99	105
AVG	540	930	98.3	230	103	99	100.3
Honda City 2008 Model							
Ψ(deg)	q(mm)	r(mm)	s(mm)	t(mm)	α (deg)	γ (deg)	φ (deg)
95	540	910	105	230	109	97	105
105	590	910	120	230	109	97	113
125	630	910	140	230	109	97	127
AVG	586.6	910	121.6	230	109	97	115
Honda City2012 model							
Ψ(deg)	q(mm)	r(mm)	s(mm)	t(mm)	α (deg)	γ (deg)	φ (deg)
95	520	1010	120	240	119	101	99
105	590	1010	150	240	119	101	127
125	710	1010	175	240	119	101	151
AVG	606.6	1010	148.3	240	119	101	125.6
Honda City2012 model							
Ψ(deg)	q(mm)	r(mm)	s(mm)	t(mm)	α (deg)	γ (deg)	φ (deg)
95	560	980	139	240	109	97	103
105	610	980	170	240	109	97	130
125	680	980	195	240	109	97	155
AVG	616.6	980	168	240	109	97	129.3
Hyundai Accent 2004 Model							
Ψ(deg)	q(mm)	r(mm)	s(mm)	t(mm)	α (deg)	γ (deg)	φ (deg)
95	450	1020	80	250	113	98	92
105	490	1020	100	250	113	98	113
125	530	1020	125	250	113	98	131
AVG	490	1020	101.6	250	113	98	112
Hyundai Accent 2004 Model							
Ψ(deg)	q(mm)	r(mm)	s(mm)	t(mm)	α (deg)	γ (deg)	φ (deg)
95	530	920	100	250	119	101	99
105	610	920	127	250	119	101	118
125	670	920	153	250	119	101	143
AVG	603.3	920	126.66	250	119	101	120
Hyundai Accent 2008 Model							
Ψ(deg)	q(mm)	r(mm)	s(mm)	t(mm)	α (deg)	γ (deg)	φ (deg)
95	530	1000	85	280	115	103	105
105	580	1000	115	280	115	103	125
125	620	1000	130	280	115	103	137
AVG	576.6	1000	110	280	115	103	122.3
Hyundai Accent 2008 Model							
Ψ(deg)	q(mm)	r(mm)	s(mm)	t(mm)	α (deg)	γ (deg)	φ (deg)
95	585	870	105	280	110	97	118
105	605	870	115	280	110	97	128
125	630	870	135	280	110	97	143
AVG	606.6	870	118.3	280	110	97	129.66

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Hyundai Accent 2012 Model							
Ψ(deg)	q(mm)	r(mm)	s(mm)	t(mm)	α (deg)	γ (deg)	φ (deg)
95	610	930	95	330	120	113	112
105	630	930	105	330	120	113	133
125	660	930	135	330	120	113	150
AVG	633.3	930	111.6	330	120	113	131.6
Hyundai Accent 2012 Model							
Ψ(deg)	q(mm)	r(mm)	s(mm)	t(mm)	α (deg)	γ (deg)	φ (deg)
95	600	890	110	330	111	103	118
105	620	890	120	330	111	103	135
125	645	890	150	330	111	103	160
AVG	621.6	890	126.6	330	111	103	137.6

TABLE 2
MODEL 2004 AVERAGE VALUES OF ANTHROPOMETRIC DATA for TALL PERSON

Brand	q(mm)	r(mm)	s(mm)	t(mm)	α (deg)	γ (deg)	φ (deg)
Toyota Corolla	468.3	930	110	150	101	110	105.3
Honda City	493.3	920	61.6	200	101	95	99.6
Hyundai Accent	490	1020	101.6	250	113	98	112

TABLE 3
MODEL 2004 AVERAGE VALUES OF ANTHROPOMETRIC DATA for SHORT PERSON

Sedan Brand	q(mm)	r(mm)	s(mm)	t(mm)	α (deg)	γ (deg)	φ (deg)
Toyota Corolla	556.7	930	176.7	150	108	92	122.3
Honda City	525	920	78.3	200	113	99	115.6
Hyundai Accent	603.3	920	126.66	250	119	101	120

TABLE 4
MODEL 2008 AVERAGE VALUES OF ANTHROPOMETRIC DATA for TALL PERSON

Sedan Brand	q(mm)	r(mm)	s(mm)	t(mm)	α (deg)	γ (deg)	φ (deg)
Toyota Corolla	510	940	88.3	180	97	105	115.3
Honda City	540	930	98.3	230	103	99	100.3
Hyundai Accent	576.6	1000	110	280	115	103	122.3

TABLE 5
MODEL 2008 AVERAGE VALUES OF ANTHROPOMETRIC DATA for SHORT PERSON

Sedan Brand	q(mm)	r(mm)	s(mm)	t(mm)	α (deg)	γ (deg)	φ (deg)
Toyota Corolla	513.3	940	103.3	180	133	118	133
Honda City	586.6	910	121.6	230	109	97	115
Hyundai Accent	606.6	870	118.3	280	110	97	129.66

TABLE 6
MODEL 2012 AVERAGE VALUES OF ANTHROPOMETRIC DATA for TALL PERSON

Sedan Brand	q(mm)	r(mm)	s(mm)	t(mm)	α (deg)	γ (deg)	φ (deg)
Toyota Corolla	616.6	1030	100	220	102	111	118
Honda City	606.6	1010	148.3	240	119	101	125.6
Hyundai Accent	633.3	930	111.6	330	120	113	131.6

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TABLE 7
MODEL 2012 AVERAGE VALUES OF ANTHROPOMETRIC DATA for SHORT PERSON

Sedan Brand	q(mm)	r(mm)	s(mm)	t(mm)	α (deg)	γ (deg)	φ (deg)
Toyota Corolla	593.3	1000	116.6	220	114	108	121
Honda City	616.6	980	168	240	109	97	129.3
Hyundai Accent	621.6	890	126.6	330	111	103	137.6

Tables 8 to 23 show the result of analysis of variance for seven anthropometric parameters. For each type and model of vehicle, analysis of variance was conducted on the data for the tall and short individual separately.

ANOVA = analysis of variance

SS = sum of square

MS = mean sum of square

df = degree of freedom

TABLE 8
STEERING WHEEL CLEARNCE (q) for TALL PERSON

	Sum of squares	df	Mean square	F	Sig.
Between Groups	1850.73	2	925.00	0.1941	0.829
Within Groups	2.8599E+04	6	4767.27		
Total	3.0449E+04	8			

TABLE9
STEERING WHEEL CLEARNCE (q) for SHORT PERSON

	Sum of squares	df	Mean square	F	Sig.
Between Groups	4797.23	2	2399.	1.855	0.236
Within Groups	7760.14	6	1293.		
Total	1.2557E+04	8			

TABLE10
BOOT SPACE (r) for TALL PERSON

	Sum of squares	df	Mean square	F	Sig.
Between Groups	1356.43	2	677.8	0.2641	0.2641
Within Groups	1.5400E+04	6	2567.4		
Total	1.6756E+04	8			

TABLE11
BOOT SPACE (r) for SHORT PERSON

	Sum of squares	df	Mean square	F	Sig.
Between Groups	6289.	2	3144.57	2.695	0.146
Within Groups	7000.	6	1167.31		
Total	13289E+04	8			

TABLE12
HEAD CLEARANCE (s) for TALL PERSON

	Sum of squares	df	Mean square	F	Sig.
Between Groups	104.8	2	52.39	0.077	0.927
Within Groups	4082.	6	680.3		
Total	4186	8			

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TABLE13

HEAD CLEARANCE (s) for SHORT PERSON

	Sum of squares	df	Mean square	F	Sig.
Between Groups	117.9	2	88.98	7.6802E-02	0.927
Within Groups	6951.	6	1158		
Total	7129	8			

TABLE14

SITTING HEIGHT (t) for TALL PERSON

	Sum of squares	df	Mean square	F	Sig.
Between Groups	1.6289E+04	2	8144	7.404	0.0029
Within Groups	6600.	6	1100		
Total	2.2889E+04	8			

TABLE15

POST HOC ANALYSIS OF SITTING HEIGHT USING TUKEY HSD, for TALL PERSON

(I)model	(J) model	Mean Difference	Critical q	Std. Error	95% confidence interval	
					Lower Bound	Upper Bound
Toyota	Honda	-40.00	4.339	19.14	-82.65	43.05
	Hyundai	-103.40	4.339	19.14	-186.45	-20.35
Honda	Toyota	40.00	4.339	19.14	-43.05	123.05
	Hyundai	-63.40	4.339	19.14	-146.45	19.65
Hyundai	Toyota	103.40	4.339	19.14	20.35	186.45
	Honda	63.40	4.339	19.14	-19.645	146.95
The mean difference is significant at the 0.005 level						

TABLE16

SITTING HEIGHT (t) FOR TALL PERSON

	Sum of squares	df	Mean square	F	Sig.
Between Groups	1.6289E+04	2	8144	7.404	0.0029
Within Groups	6600.	6	1100		
Total	2.2889E+04	8			

TABLE17

POST HOC ANALYSIS OF SITTING HEIGHT USING TUKEY HSD, for TALL PERSON

(I)model	(J) model	Mean Difference	Critical q	Std. Error	95% confidence interval	
					Lower Bound	Upper Bound
Toyota	Honda	-40.00	4.339	19.14	-82.65	43.05
	Hyundai	-103.40	4.339	19.14	-186.45	-20.35
Honda	Toyota	40.00	4.339	19.14	-43.05	123.05
	Hyundai	-63.40	4.339	19.14	-146.45	19.65
Hyundai	Toyota	103.40	4.339	19.14	20.35	186.45
	Honda	63.40	4.339	19.14	-19.645	146.95
The mean difference is significant at the 0.005 level						

TABLE 18

KNEE ANGLE (α) for TALL PERSON

	Sum of squares	df	Mean square	F	Sig.
Between Groups	384.2	2	192.1	4.912	0.055
Within Groups	234.7	6	39.11		
Total	618.9	8			

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TABLE 19: KNEE ANGLE (α) for SHORT PERSON

	Sum of squares	df	Mean square	F	Sig.
Between Groups	98.00	2	49.00	.7350	0.518
Within Groups	400.00	6	66.67		
Total	498	8			

TABLE20: FOOT ANGLE (Γ) for TALL PERSON

	Sum of squares	df	Mean square	F	Sig.
Between Groups	162.9	2	81.44	3.132	0.117
Within Groups	156.0	6	26.00		
Total	318.9	8			

TABLE 21
FOOT ANGLE (Γ) for SHORT PERSON

	Sum of squares	df	Mean square	F	Sig.
Between Groups	108.7	2	54.33	0.8923	0.458
Within Groups	365.3	6	60.89		
Total	474.0	8			

TABLE 22
ELBOW ANGLE (Φ) for TALL PERSON

	Sum of squares	**df**	**Mean square**	**F**	**Sig.**
Between Groups	**282.2**	**2**	**141.6**	**1.179**	**0.370**
Within Groups	**720.6**	**6**	**120.1**		
Total	**1004.0**	**8**			

TABLE 23
EBLOW ANGLE (Φ) for SHORT PERSON

	Sum of squares	df	Mean square	F	Sig.
Between Groups	126.4	2	63.20	1.017	0.417
Within Groups	372.9	6	62.16		
Total	499.4	8			

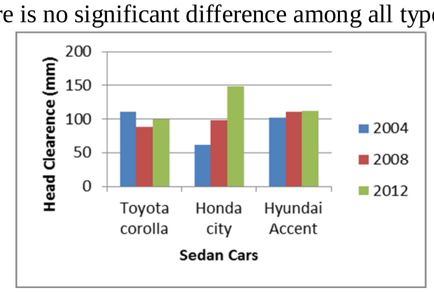
Criterion Standard

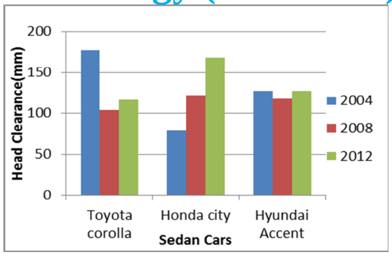
If the F- calculated value from the result is less than F- distribution table value, there is no significant difference.

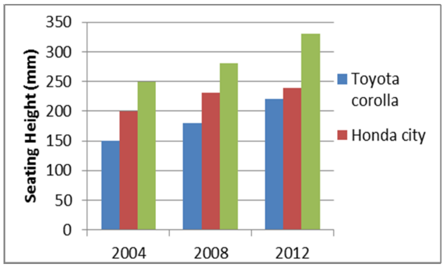
If the significant level in the calculated value from the result is greater than significant criterion alpha, α= 0.05, there is no significant difference.

IV. DISCUSSION

The analysis of variance for sitting height reveal that there is significant difference between the Toyota Corolla, Honda city and Hyundai Accent. There is no specific difference between the Toyota Corolla and Honda City in terms of sitting height. But Toyota Corolla is most ergonomically suitable in all the three model considered due to its sitting height. Tall people can comfortably sit down and it is also possible for short people to adjust the seat to suit them.The analyses of variance for other anthropometric parameters reveal that there is no significant difference among all types of sedan cars in terms of parameters.







V. CONCLUSION

An ergonomics evaluation of different vehicle seats were conducted on Toyota Corolla, Honda City and Hyundai Accent. Results showed there is no significant difference in steering wheel clearance, head clearance, knee angle, foot angle and elbow angle in all models of sedan cars. However , Honda City has highest head clearance favours tall individuals. In terms of boot space and sitting height Toyota Corolla is most ergonomically suitable of all sedan cars were considered.

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