A Study on the Ergonomical Train Seat Design

Se Jin Park*, Hyun Ja Lee**, Chul Jung Kim*, Byung Chan Min*

* Korea Research Institute of Standards and Science

** Chung Nam National Univ.

The purpose of this study is to investigate the train seat dimensions suitable for keeping comfortable postures. We designed a special experimental seat of which the lengths and angles are adjustable separately. Seat dimensions keeping subjects comfortable were measured for the restricted posture and the extended posture. The significant differences of dimensions for two postures were analyzed, and the differences were found on backrest-seatpan angles, length of backrest and so on. The dimension differences for the levels of height and weight were also found out. Some dimensions were correlated with subjects' height and weight..

Introduction

Seat is very important factor to interface between human and a transport. Train seats must accommodate the drivers or riders who have diverse physique for the long hours. Especially the performance of suitable body support plays an important role in reducing the fatigue of passenger [1]. Many researches were performed to find out the seat dimensions suitable for comfort postures of driver in automotive [2, 3]. However, researches of train passenger seat were rare despite train seat is different from automotive seat on the user activities. Because passengers can perform various activities in train, for examples, adjustment of posture, reading, watching windows, sleeping and so on. Then, the train seat should be designed with consideration of these activities [4].

This study was conducted to find out the optimal dimensions of passenger seat for train, especially suitable for Korean. We designed experimental seat for the measurement. The required seat dimensions for supporting comfortable postures were directly measured. The differences of dimensions for the two postures and the body sizes of subjects were statistically analyzed. The correlation coefficients between seat dimensions and subjects' height and weight were also calculated.

Experimental Seat

The special experimental seat of which the lengths and angles are adjustable separately was designed for measurement. The adjustable ranges of lengths and angles were wide enough to include from 5th percentile to 95th percentile of Korean. The seat can be applied to another kinds of seats because of broad adjustable range and separable armrest. Backrest was cut on the 350mm place from seatpan and the upper slid upward and downward to

control the length of backrest. Seatpan was also cut on the 330mm location from backrest, and the fore moved forward and backward. Height of seatpan (the fore part and the rear part), length of backrest and height of footrest were operated with motors controlled with lever by subjects. Each angle of seat was fixed with screws and levers, but angle of seatpan was kept by the height difference of the fore and the rare. Dimensions of experimental seat were determined in consideration of the various seat dimensions and anthropometric data of Korean [5]. The dimensions are presented in table 1 and operating directions are shown in figure 1.

Table 1. Dimensions of Experimental seat

Dimensions of Experimental seat		Adjustable range	
		Length (mm)	angle (°)
headrest	height	230~260	0~180
backrest	height	587~712	90~180
	width	490	
seatpan	depth	410~580	0~22
	height	300~470	
	width	430	
armrest	height	320~800	-45~225
footrest	height	100~365	-35~227
	length	220	
	width	400	

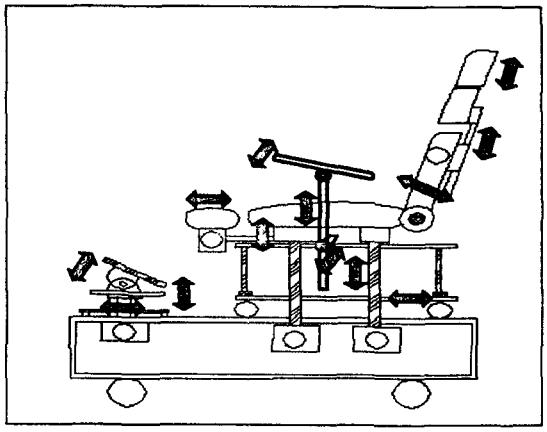

Figure 1. Operating directions of experimental seat

Experiments

Subjects were consisted with 20 males and 18 females. The distribution of their body sizes was broad from 5th percentile to 95th percentile. Subjects sat on the experimental seat set on default angle and length with relaxed posture (reading, conversation, etc) and extended posture (sleeping, etc) [4]. The postures are main postures taken by passengers on the train seats [6]. Subjects adjusted the experimental seat comfortable, and 20 lengths and 5 angles of seat parts were measured. The measures were length of backrest, depth of seatpan, backrest-seatpan angle and so on. The dimension differences for posture types were analyzed by paired t-test. The differences of dimensions were also analyzed by GLM (general linear model) for the height levels, the weight levels and height level * weight level. The levels of height (151.0~187.0cm) and weight (42.0~89.0kg) were divided equally 5 levels from minimum to maximum. The correlation coefficients (Pearson's r) between the dimensions and heights and weight of subjects were also calculated.

Results

The maximum, minimum, mean and standard deviation of measures were presented in table 2 and table 3 and paired t-test results, tested the dimension differences for posture types, were also summarized.

As the results, the range of backrest-seatpan angle was from 98° to 133°. Backrest-seatpan angle, armrest-floor angle, seatpan depth, height of fore seatpan, length of ischial tuberosity-backrest and armrest length at extended posture were significantly larger than at relaxed posture (α=o.o5). On the other side, backrest-seatpan length, scapula-seatpan length, height of lumbar support and height of armrest were significantly smaller. Consequently, the dimensions of backrest, seatpan and lumbar support were changed with posture types. Therefore, these changes have to be reflected on seat design.

Pearson's correlation coefficients between body sizes and dimensions were shown in table 4 and table 5. The GLM results of the dimension differences for levels of height and weight were also presented (α=.05). Armrest-floor angle was correlated with height and weight. Length and width of backrest, seatpan depth, footrest-seatpan distance and etc. were correlated with heigth, and length and width of backrest, seatpan width, elbow-backrest distance and etc. with weight. Significant differences for heights were shown on a few angles, and weights on some lengths.

Table 2. Preferred angles on the relaxed posture and extended posture and results of t-test

Angles	Relaxed Posture (°)				Extended Posture (°)				p-value
	Min.	Max.	Mean	S. D.	Min.	Max.	Mean	S. D.	(α=.05)
Headrest - backrest	118.0	159.0	140.1	11.5	117.0	158.0	137.7	12.2	.094
Backrest - seatpan	98.0	116.0	106.6	4.6	106.0	133.0	121.5	5.8	.000
Seatpan - floor	8.0	15.0	11.6	1.6	7.0	16.0	11.7	2.4	.522
Armrest - floor	-8.0	30.0	10.3	9.1	-7.0	44.0	19.3	11.5	.000
Footrest - floor	27.0	46.0	35.6	4.4	23.0	55.0	34.5	6.7	.317

Table 3. Preferred lengths (heights or widths) on the relaxed posture and extended posture and results of t-test

Lengths	Relaxed Posture (mm)				Extended Posture (mm)				p-value
	Min.	Max.	Mean	S. D.	Min.	Max.	Mean	S. D.	(α=.05)
Headrest – backrest	135.0	238.0	189.1	24.4	117.0	270.0	196.1	31.5	.567
Width of backrest reqiured	370.0	474.0	419.6	27.4	370.0	493.0	424.5	31.4	-
Length of backrest	480.0	600.0	550.5	32.4	460.0	594.0	528.6	37.5	.001
Height of scapula – seatpan	351.0	473.0	414.2	32.5	317.0	452.0	376.6	33.7	.000
Width of seatpan required	297.0	410.0	347.8	28.7	297.0	410.0	347.8	28.7	-
Depth of seatpan	387.0	491.0	437.3	27.7	405.0	495.0	454.5	24.4	.000
Rear height of seatpan	334.0	384.0	354.9	12.1	324.0	387.0	353.0	14.3	.424
Fore height of seatpan	384.0	441.0	410.4	15.4	379.0	446.0	414.7	17.5	.010
Ischial tuberosity - backrest	82.0	217.0	138.6	26.2	82.0	176.0	129.2	21.7	.025
Distance of hip sliding – backrest	20.0	67.0	42.9	12.1	13.0	73.0	39.4	13.5	.147
Height of lumbar support – seatpan	125.0	240.0	185.8	27.1	67.0	225.0	149.0	43.9	.000
Thickness of lumbar support	47.0	64.0	55.2	4.2	46.0	88.0	55.0	6.9	.622
Height of armrest	158.0	250.0	205.8	24.6	128.0	260.0	193.9	34.7	.027
Distance between two arms	475.0	692.0	581.3	59.2	480.0	685.0	582.1	59.4	.899
Elbow-backrest	81.0	200.0	131.9	32.6	56.0	228.0	137.6	44.4	.485
Length of armrest	286.0	418.0	350.7	34.5	318.0	435.0	372.8	33.2	.001
Width of armrest required	56.0	95.0	75.5	9.7	56.0	95.0	75.5	9.7	-
Footrest-seatpan	397.0	588.0	491.7	51.3	400.0	605.0	483.9	54.5	.386
Height of footrest	103.0	124.0	111.4	5.8	103.0	131.0	113.7	7.2	.186
Distance between two feet	245.0	418.0	336.2	40.5	280.0	444.0	350.6	40.0	.165

Conclusion

In this study, the train seat dimensions suitable for supporting comfortable postures were investigated using a special experimental seat of which the lengths and angles were separately adjustable. Comfortable seat dimensions were measured for the two postures, those were the restricted posture and the expanded posture. The significant differences of dimensions for two postures were analyzed, and the differences were found on backrest-seatpan angles, length of backrest and so on. The dimension differences for the levels of height and weight were also found out. Some dimensions were correlated with subjects' heights and weight. These results will be helps to advance comfort of train seats.

Table 4. Correlation coefficients and significance of angles on the two postures

Angles	Relaxed Posture				Extended Posture			
	Height		Weight		Height		Weight	
	Corr. Coef.	Sig.	Corr. Coef.	Sig.	Corr. Coef.	Sig.	Corr. Coef.	Sig.
Headrest - backrest	0.050	$p < 0.05$	-0.191	Not sig.	0.169	Not sig.	-0.011	Not sig.
Backrest - seatpan	0.100	$p < 0.05$	0.262	Not sig.	-0.216	$p < 0.05$	0.139	Not sig.
Seatpan - floor	-0.145	Not sig.	-0.195	Not sig.	0.082	Not sig.	0.063	Not sig.
Armrest - floor	-0.388*	Not sig.	-0.351*	Not sig.	-0.434*	Not sig.	-0.279	Not sig.
Footrest - floor	0.217	Not sig.	0.154	Not sig.	0.148	Not sig.	0.081	Not sig.

** correlation is significant at the 0.01 level and * is significant at the 0.05 level

Table 5. Correlation coefficients and significance of lengths on the two postures

Lengths	Relaxed Posture				Extended Posture			
	Height		Weight		Height		Weight	
	Corr. Coef.	Sig.	Corr. Coef.	Sig.	Corr. Coef.	Sig.	Corr. Coef.	Sig.
Headrest – backrest	0.177	Not sig.	0.131	Not sig.	0.151	Not sig.	0.280	Not sig.
Width of backrest reqiured	0.644**	Not sig.	0.752**	$p < 0.05$	0.620**	Not sig.	0.807**	$p < 0.05$
Length of backrest	0.478**	Not sig.	0.537**	$p < 0.05$	0.378*	Not sig.	0.411*	Not sig.
Height of scapula – seatpan	0.315	Not sig.	0.320	Not sig.	0.186	Not sig.	0.248	Not sig.
Width of seatpan required	0.213	Not sig.	0.473**	$p < 0.05$	0.213	Not sig.	0.473**	Not sig.
Depth of seatpan	0.520**	Not sig.	0.367*	Not sig.	0.436**	Not sig.	0.224	$p < 0.05$
Rear height of seatpan	0.267	Not sig.	0.116	Not sig.	0.105	Not sig.	0.025	Not sig.
Fore height of seatpan	0.408*	Not sig.	0.160	Not sig.	0.275	Not sig.	0.121	Not sig.
Ischial tuberosity - backrest	0.287	Not sig.	0.485**	Not sig.	-0.170	Not sig.	-0.097	Not sig.
Distance of hip sliding - backrest	0.142	Not sig.	0.080	Not sig.	0.132	Not sig.	-0.117	Not sig.
Height of lumbar support	-0.193	Not sig.	-0.039	Not sig.	-0.120	Not sig.	-0.100	Not sig.
Thickness of lumbar support	0.398*	Not sig.	0.281	Not sig.	-0.009	Not sig.	-0.030	Not sig.
Height of armrest	-0.105	Not sig.	-0.003	Not sig.	-0.057	Not sig.	0.031	Not sig.
Distance between two arms	0.349*	Not sig.	0.304	Not sig.	0.216	Not sig.	0.282	Not sig.
Elbow-backrest	0.329*	Not sig.	0.496**	Not sig.	0.315	Not sig.	0.281	Not sig.
Length of armrest	0.400*	Not sig.	0.314	Not sig.	0.017	Not sig.	0.007	Not sig.
Width of armrest required	0.464**	Not sig.	0.685**	$p < 0.05$	0.464**	Not sig.	0.685**	$p < 0.05$
Footrest-seatpan	0.763**	Not sig.	0.657**	Not sig.	0.645**	Not sig.	0.631**	Not sig.
Height of footrest	-0.344*	Not sig.	-0.276	Not sig.	-0.009	Not sig.	-0.116	Not sig.
Distance between two feet	0.063	Not sig.	-0.022	Not sig.	0.112	Not sig.	0.250	Not sig.

** correlation is significant at the 0.01 level and * is significant at the 0.05 level

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