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A Pilot Study of Seat Design in Public Transport for Elderly People in Taiwan

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Abstract: The proportion of elderly people in the population in Taiwan has been steadily increasing over the past decades. Mobility is most essential to maintain an independent life style for elderly people who make extensive use of public transport. Many elderly people have difficulty with rising (sit-to-stand) and sitting (stand-to-sit). However, current chair designs of public transport make little consideration for elderly users. The present study aimed to assess the requirements in chair designs of public transport for elderly people in Taiwan. Subjective assessment scales for chair-related determinants have been developed to evaluate the current chair design in Taipei Metro. The correlations between anthropometric characteristics and seat-related dimensions were analyzed and ANOVA was used to determine the effects of gender and obesity.

Key words: Sitting, rising, elderly people, ergonomics, chair design, public transport

INTRODUCTION

The elderly population in Taiwan has been steadily increasing over the past decades. Life expectancy in Taiwan reached a record high of 80.2 years in 2015 which is now at the same level as in Germany and Britain, higher than in the US, China, Malaysia and the Philippines and lower than in Canada, France, Japan, South Korea and Singapore. Furthermore, the lifespan of Taipei citizens reached an average 83.43 years in 2015, due to factors such as lifestyles and access to medical resources (Liu and Chen, 2016). The non-reversible trend in elder population change appears to be emerging in most economically developed countries. The main reasons for this are believed to be great improvements in medical technologies and health care delivery systems (Kothiyal and Tettey 2001; Rais *et al*., 2015a, b). Taiwan's National Health Insurance (NHI) may be generally acknowledged to be a high performing health care system compared with many other health care systems around the world (Cheng, 2015). Benefitted from Taiwan's NHI policy, people in Taiwan are living longer now than ever before. Besides, Taiwan's fertility rate of 0.9 in 2011 was the world's lowest. The nation's low birth rate has bounced back slightly since 2011, following the enactment of fertility policies. The birth rate in Taiwan is still too low with an estimated 30% of people born in the 1990s and later unlikely to have children and 40% unlikely to have grandchildren (Chen, 2016).

According to the World Health Organization, a society in which the proportion of people 65 years or older is 7% is known as an "aging society" 14% or higher is regarded as an "aged society" and 20% or higher is called a "hyper-aged" society. Taiwan became an aging society in 1993 and would become an "aged" society by 2018 and a "hyper-aged" society by 2025. In fact, Taiwan's accelerated rate of aging is more than twice that of European countries and United States. In only 24 years, Taiwan will have progressed from an aging society to an aged society. The time span for this transition in Taiwan is equal to that of Japan; however Taiwan will only take 7 years to progress to a hyper-aged society from an aged society which will be shorter than in Japan (Lin and Huang, 2015).

Facing these structural changes in the population, the ergonomic demands for the elderly should be further amplified (Annis, 1996; Hu *et al*., 2007; Kothiyal and Tettey, 2001; Putri *et al*., 2015). Mobility for elderly people is most essential in activities of daily living. With the loss of physiological capabilities and the fear of getting injured, the elderly would be likely to make use of public transport instead of using private cars especially in urban areas (Kothiyal and Tettey, 2001). However, many elderly people have difficulty with rising (sit-to-stand) and sitting (stand-to-sit). Current chair/seat designs of public transport make little consideration for elderly passengers. Dall and Kerr (2010) reported that normal people performed a daily average of 60 sit-to-stand movements with a rate of around 3/h. The ability to go from a sitting position to a standing position is an important skill for elderly people. Difficulty in rising from a chair can cause the elderly to rise less often and therefore to be less mobile and active in daily and social activities (Zacharkow, 1988). Elderly adults compared to younger

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adults often have difficulty rising from chairs. Suggested specifications for chair design have been based on anthropometric measurements (Wheeler *et al*., 1985). Whereas, there have been considerable studies on the influence of aging in physiology and biomechanics, little reliable anthropometric information with individuals aged 65 years and over is available worldwide (Annis, 1996). At present, there are no published data on the anthropometry of the elderly in Taiwan (Chen *et al*., 2010).

Previous studies have shown that chair design has a great influence on performing Sit to Stand (STS) movement. Most researchers have focused on the effects of seat height. Decreasing the seat height can result in changing biomechanical demands and makes the STS movement more laborious and difficult (Arborelius *et al*., 1992; Hughes *et al*., 1994; Janssen *et al*., 2002; Munro *et al*., 1997; Schenkman *et al*., 1996; Su *et al*., 1998; Weiner *et al*., 1993). Chan *et al*. (1999) suggested that the chair with soft and thick cushion provides inadequate support and decrease the upward thrust when rising. The optimum seat height for comfort is not necessarily the same as the height required for ease of rising. Chen *et al*. (2010) use subjective rating to evaluate the perceived difficulty and safety for both sit-to-stand and stand-to-sit.

They suggested that rising was faster than sitting and the elderly relatively slower in both actions. It is also found that elder people preferred lowerseat height than young people did. In this study, we intended to evaluate the current chair design for the elderly in the Taiwan's rapid transit system and to make recommendations for future research.

MATERIALS AND METHODS

Subjects: Volunteers were recruited in taipei rapid transit system. A total 29 subjects (16 male and 13 female) participated in the experiment. The age of volunteers was between 66 and 85 years. Subject selection was based on the subject being musculoskeletal injury free and healthy. The subjects were interviewed on the train of Songshan-Xindian Line (Green Line) of Taipei Metro. Prior to the experimentation, the research protocol was explained to the subjects in detail. Then the participant was asked to sign a consent form and provided certain demographic information such as age, height and weight. The anthropometric characteristics are shown in Table 1 and Fig. 1. The descriptive statics values present as mean±standard deviation.

Table 1: Anthropometric characteristics of the subjects

Variables	Ages (years)	Stature (cm)	Body mass (kg)
Male (N = 16)	73.3±4.9	168.6±8.00	75.3±11.00
Female (N = 13)	71.9±4.3	155.0±8.20	62.1±8.000
Total (N = 29)	72.6±4.6	162.5±10.5	69.38±11.7

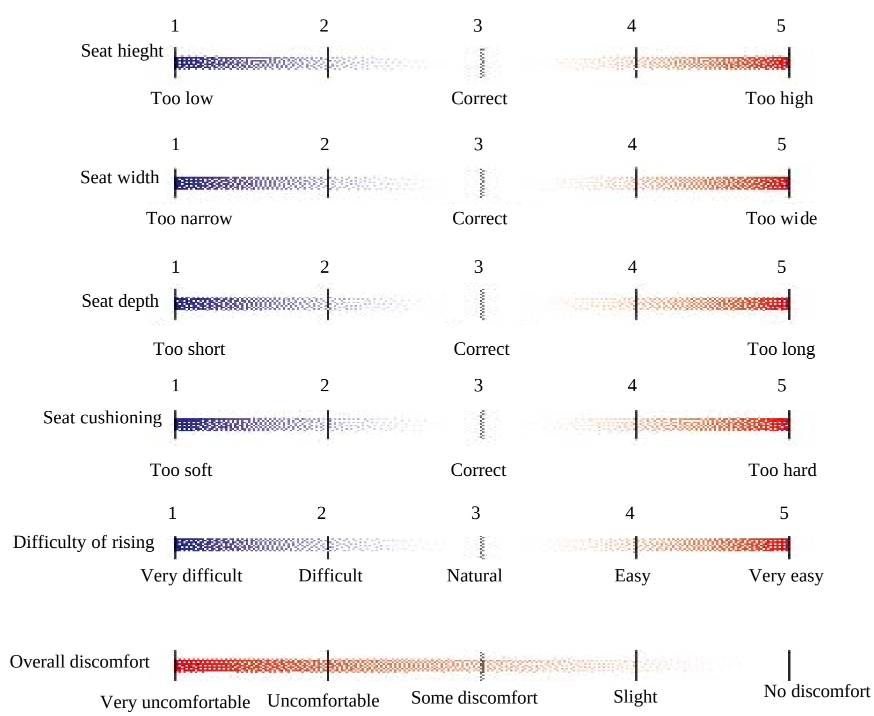

Fig. 1: Assessment scale and questionnaire

Subjective evaluation: Chairs have been widely evaluated subjectively (Chen *et al*., 2010; Goonetilleke and Feizhou, 2001; Li *et al*., 2017), the subjective assessment used in this study is well established and adapted from the literature (Goonetilleke and Feizhou 2001; Drury and Coury, 1982). Using a five-point semantic differential scale, the elderly volunteers required to rate six dependent variables including seat height, seat width, seat depth, seat cushioning, difficulty of rising and overall discomfort.

Statistical analysis: The data collected from questionnaires were statistically analyzed using SPSS Software. Frequency distributions of six dependent variables were obtained to clarify the potential problems for current seat design of MRT trains. The correlations between anthropometric characteristics and dependent variables were analyzed using pearson correlation coefficients. Also, Analysis of Variance (ANOVA) with a significance level of 0.05 was used to determine the effects of gender (2 levels) and obesity (4 levels) on seat ratings.

RESULTS AND DISCUSSION

Subjective ratings: The probability distributions of subjective ratings for seat features were computed separately by gender. As shown in Fig. 2a, the mean rating scores of the Seat Height (SH) were 2.54 and 1.94 for the female and male respectively. This implies that the current seat height is lower than expected especially for male participants. Similar tendencies are also found in the subjective ratings of the Seat Width (SW) and the Seat Depth (SD) as shwn in Fig. 2b and c. The seat dimensions are expected to be wider and deeper generally. Furthermore, the ideal seat cushioning, as can be seen in Fig. 2d should be softer than currently designed (NDC, 2012).

Figure 3 shows the results of perceived difficulty of rising and the overall discomfort. The mean rating scores of the difficulty of rising are around 2.7 for both female and male participants. However, 48.3% of the participants (53.8% female and 43.8% male) experienced some difficulties with rising (Fig. 3a). The results of overall discomfort rating are shown in Fig. 3b. Only 6.9% of the participants didn't have any discomfort but 27.6% of the participants felt uncomfortable. No significant differences are found in the rating of difficulty of rising or overall discomfort between men and women (Kirvesoja *et al*., 2000).

Correlations between independent and dependent variables: Bivariate correlations were analyzed by estimating pearson correlation coefficients between the

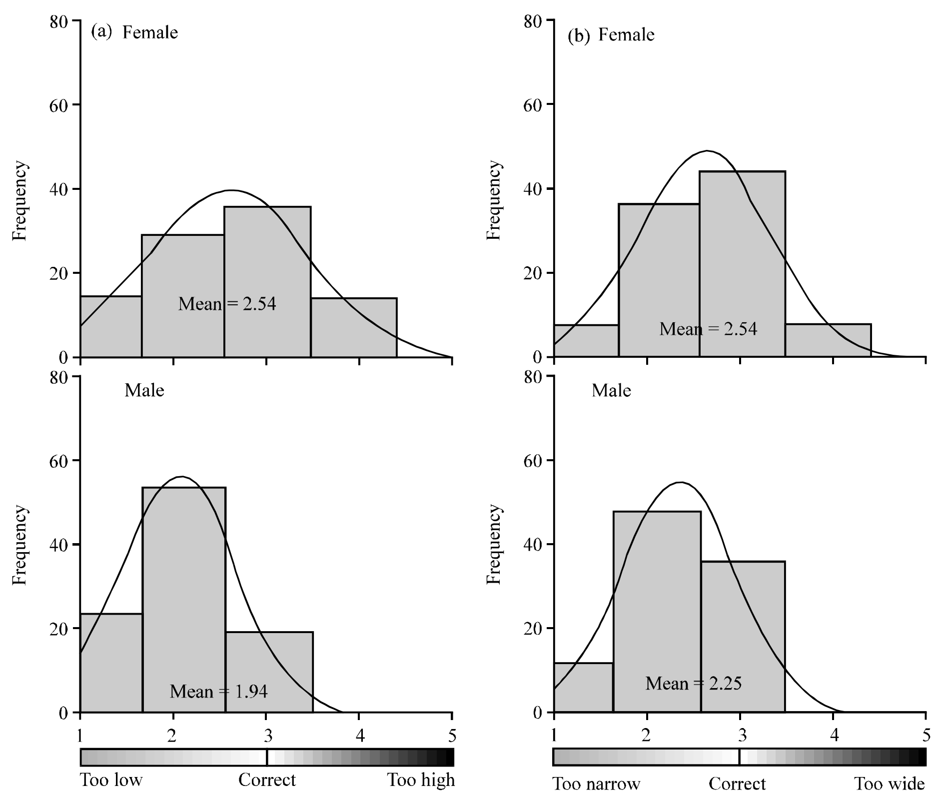

Fig. 2: Countinue

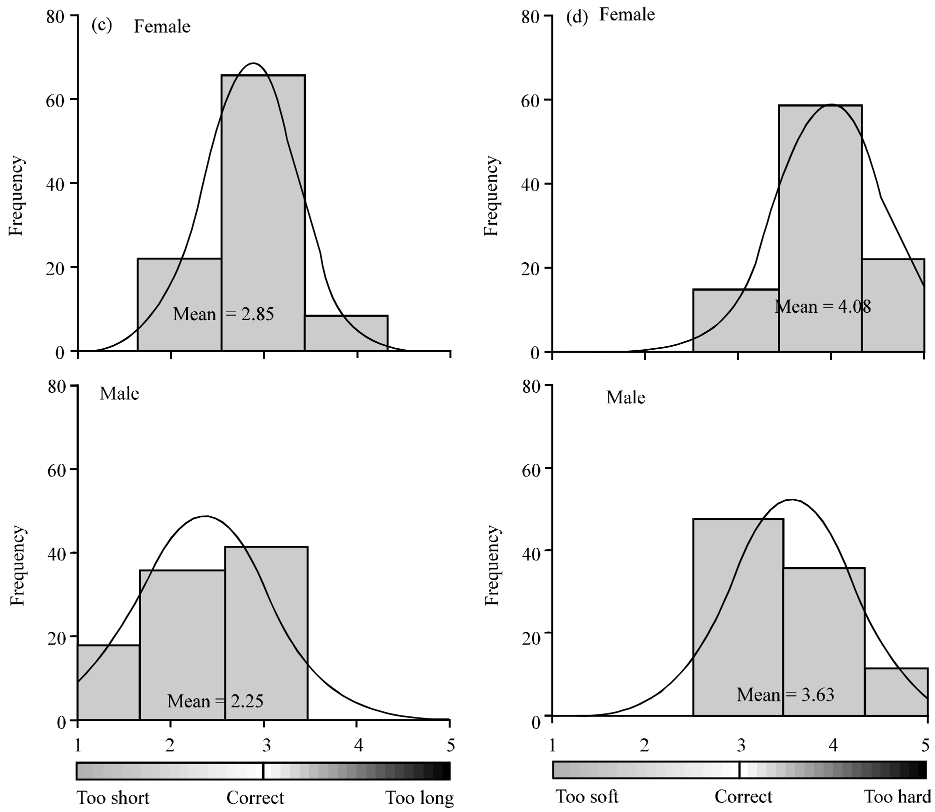

Fig. 2: Frequency distributions of subjective ratings of seat features: a) Seat height; b) Seat width; c) Seat depth; d) Seat cushioning

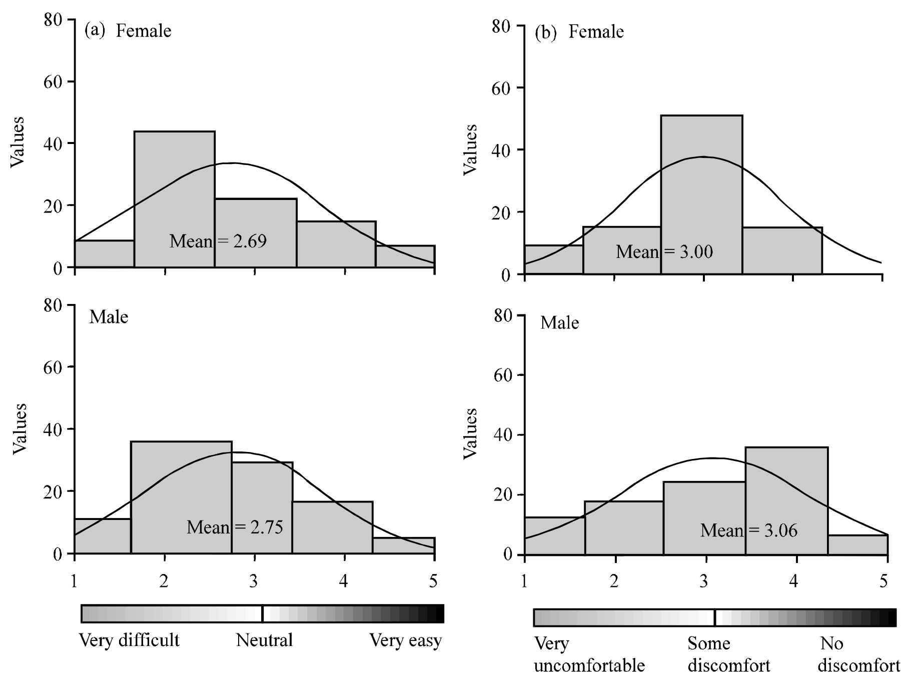

Fig. 3: Results of perceived difficulty of rising and overall discomfort: a) Difficulty of rising; b) Overall siscomfort

Table 2: Correlations between independent and dependent variables

Anthropometric variables	Seat height	Seat width	Seat depth	Seat cushioning	Difficulty of rising	Overall discomfort
Age	0.002	-0.263	0.080	0.250	-0.365	-0.224
Stature	-0.831**	-0.255	-0.845**	-0.412	-0.748**	-0.342
Weight	-0.560**	-0.667**	-0.435	-0.056	-0.510**	-0.473

**Correlation is significant at the 0.01 level (2-tailed)

Table 3: ANOVA results with the F-value and the probability (in parenthesis)

Variables	Seat height	Seat width	Seat depth	Seat cushioning	Difficulty of rising	Overall discomfort
Gender	4.94 (0.035)	NS	5.423 (0.028)	NS	NS	NS
Obesity	NS	7.416 (0.001)	NS	4.033 (0.018)	4.298 (0.014)	NS

NS: No-Significance

anthropometric characteristics and the ratings of seat features. From Table 2, it can be seen that the seat height rating is significantly correlated to the subject's stature and weight. Similar results are observed for the relationships between the rating of difficulty of rising and the subject's stature and weight. Stature is especially well correlated with those dimensions oriented along the longitudinal axis such as buttock-knee length and sitting height (Annis, 1996). It is believed that higher subjects generally have higher popliteal heights and thus tend to accept a higher seat height.

As shown in Table 2, the subject's weight is also highly correlated with the ratings of the seat height and the difficulty of rising. However, weight is a three dimensional measure and depends on depths, breadths and surface contour measurements associated with volume change. The correlation results for the subject's weight are suspicious and require to be further verified. To our knowledge no similar suggestion has been found in the reviewed literature.

It is also clear that age is poorly correlated with all other seat ratings. From the data analyzed in this study, the ratings of seat cushioning and overall discomfort may not be significantly correlated with anthropometric variables.

Effects of gender and obesity on seat ratings: The effects of gender and obese condition on seat ratings were examined by using ANOVA. Instead of using the factor body mass (weight), obese condition was taken into the analysis with 4 levels: level 1 (Underweight; BMI<18.5), level 2 (Normal; 18.5<BMI<25), level 3 (Overweight; 25<BMI<30) and level 4 (Obese; BMI >30).

As shown in Table 3, the ratings of the seat height and seat depth are significantly affected by gender. The same results can also be concluded from the Fig. 2a and 2c. It is shown that there are notable differences between the means of the rating scores of female and male subjects. It is noted that the average height difference is 13.6 cm between both sexes (Table 1).

It is not surprising that the obesity has a great influence on the ratings of the seat width the seat cushioning and the difficulty of rising. In other words, obese subjects, typically with larger cross-sectional dimensions and higher sitting pressure, can be expected to require more sitting space and softer cushioning as well as to experience more difficulty in rising.

CONCLUSION

This study was conducted to evaluate the current chair design for the elderly in Taipei Metro. Subjective assessment scales for seat height, seat width, seat depth, seat cushioning, difficulty of rising and overall discomfort were developed and 29 elderly volunteers (16 male and 13 female) were recruited to participate the research study. The preliminary results indicated that current seat dimensions are relatively low, narrow and short for the elderly passengers. Most of the participants felt uncomfortable to a certain degree and about half of them experienced some difficulties in rising. Stature is strongly correlated with the ratings of seat height, seat depth and difficulty of rising. In addition, the obesity also has a great influence on the ratings of the seat width the seat cushioning and the difficulty of rising.

In this study, the sampling size was relatively small and might not represent the elderly population in Taiwan. To validate the results of our pilot study, further and broader investigations are necessary in the future.

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