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Journal of Advanced Research Design

Journal homepage:
https://akademiabaru.com/submit/index.php/ard
ISSN: 2289-7984

Potential Impact of Seat Tray Table's Height Adjustment on Aircraft Passengers' Comfort during In-Flight Activities

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ARTICLE INFO

Article history:
Received 14 February 2025
Received in revised form 3 March 2025
Accepted 30 June 2025
Available online 20 July 2025

Keywords:
Flight comfort; anthropometry; tray table; in-flight activity; seat pitch

ABSTRACT

Most aircraft passengers consider flight comfort as one of their primary selection criteria when choosing their travel option. When aircraft passengers can easily and comfortably perform their in-flight activities, their overall comfort level is also enhanced. In this case, since the seat tray table has been used to support many in-flight activities, the adequacy of its height is important. Furthermore, available legroom at the seat will also affect the required seat tray table height for aircraft passengers to comfortably perform their in-flight activities. Based on this notion, this study intends to establish the influence of seat pitch, seat tray table height and the passengers' anthropometry parameters on their in-flight comfort level by conducting an activity-based sitting comfort experiment. In this experiment, comfortable seat tray table height is recorded for three common in-flight activities at different seat pitch settings: eating, writing and using laptop. Based on the experimental results, the settings of seat tray table height and seat pitch are shown to notably affect the passengers' comfort during in-flight activities. Moreover, comfortable seat tray table height is also correlated with passengers' anthropometry. In comparison to typical height of seat tray table that is currently used in the aircraft cabin, which is 68 cm, the average resultant comfortable height is found to be higher. This indicates a clear mismatch of the seat tray table height and highlights the need for proper adjustment of the seat tray table height to improve passengers' flight comfort.

1. Introduction

Flight comfort is one of the major competitive aspects for airlines today. It has been indicated in numerous studies that most aircraft passengers select their travel options based on several different factors and comfort has been one of the key considerations [1-3]. In general, passengers' comfort is a rather complex matter and it has been differently approached by researchers. For instance, in its simplest definition, comfort is taken by some researchers as the state of a person in the absence of discomfort [4]. On contrary, some researchers have argued that such absence of discomfort does not always result in comfort because there are other factors that might influence the comfort level of a person. In this respect, a more comprehensive definition has viewed comfort as a complex and also

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https://doi.org/10.37934/ard.138.1.1425

a dynamic construct that is affected by person-centric elements that include physiological, physical, psychological and social, in addition to the situational and environmental elements [5]. Translating this into the specific context of aircraft passengers, it could be taken that their comfort experience will depend on their physical and mental state, their physical interactions with the cabin environment and the activities that they are engaged in.

To date, many studies have been conducted with regards to improving in-flight comfort of aircraft passengers. Researches have indicated that aircraft passengers' comfort is affected by physical cabin design including seat pitch and available legroom [6,7], passenger seat design [8,9] and also cabin arrangement [10]. Furthermore, several studies have highlighted the potential effects of passengers' body anthropometry and psychological state on their perception of flight comfort level [11,13]. In addition, it has also been indicated that the type of activities that the passengers do can affect their comfort, especially in combination with the effects from physical seat features [14]. This situation is demonstrated in experimental studies where different levels of comfort or discomfort have been observed for some typical in-flight activities of the aircraft passengers [15,16]. However, it should be noted that most of the previously conducted studies to improve aircraft passengers' comfort have been focused on enhancing the design of passenger seat and the cabin environmental factors.

For instance, a study is conducted to explore the use of human-contour shaped seat shell and cushioning to increase design comfort of aircraft passenger seat [17]. Moreover, another study has conducted ergonomic analysis on suitability of current aircraft seat design against passengers' anthropometry measurements [18]. Furthermore, there have been studies on effects of cabin environmental factors on aircraft passengers' comfort including cabin temperature [19], cabin vibration [20], cabin noise [21] and cabin lighting [22]. Most of these studies do not take into account the influences of the passengers' in-flight activities since the comfort assessment have been performed with assumption of a static posture or sitting position. This is an identified research gap that needs to be addressed since there is a lack of flight comfort studies that are carried out with activity-based assessment approach [16].

Among aircraft passengers' in-flight activities while seated at their seat include resting, sleeping, eating and drinking, watching in-flight entertainment, using laptop or tablet, reading and also writing [23,24]. It can be anticipated that each of these different activities will correspond to different sitting position or body posture for the aircraft passengers as depicted in Figure 1, which in turn affects the comfort level of the passengers. Another important thing to note is the common usage of seat tray table during most of these activities. The seat tray table's height will influence the sitting position or posture of passengers according to their body anthropometry.

Fig. 1. Observed different sitting postures of passengers while using the seat tray table [24]

Additionally, the settings of the cabin seat pitch will also affect the sitting position or posture during in-flight activities because the effective positioning of the seat tray table is changed with

different seat pitch. This situation is demonstrated in a previous study where the current height of seat tray table is causing unnatural neck posture and discomfort among aircraft passengers [25]. This clearly indicates negative effects of improper height of seat tray table on aircraft passengers' flying comfort. Taking all these into consideration, it is of a big interest to establish the relationship between the comfortable seat tray table's height for in-flight activities with both cabin seat pitch and passengers' body anthropometry parameters. Thus far, there is a clear lack of studies being done on assessing the adequacy of seat tray table's height for improving passengers' comfort.

Based on this notion, this study is intended to demonstrate such flight comfort relationship. To achieve this, an activity-based experiment is done using an aircraft cabin mock-up where the comfortable seat tray table's height is recorded for three different common in-flight activities: eating, writing and using the laptop. The seat pitch is varied throughout the experiment and the relevant anthropometry parameters of the participants in the experiment have been measured and recorded. The collected data is analysed to indicate underlying relationship between the comfortable seat tray table's height, cabin seat pitch and passengers' body anthropometry.

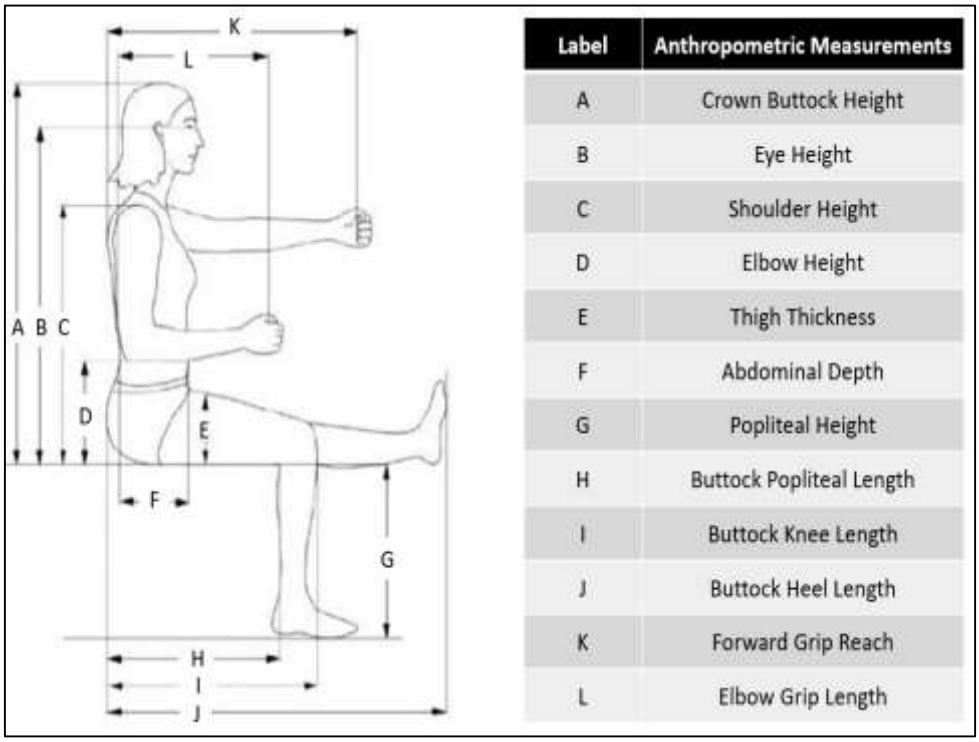
2. Methodology

In this study, the activity-based experiment is conducted using the aircraft cabin mock-up that is available at Department of Aerospace Engineering, Universiti Putra Malaysia, as depicted in Figure 2. It should be noted that this aircraft cabin mock-up is comprised of two rows of refurbished aircraft passengers' seats that had been previously used in the economy class seating of Boeing B737-400 aircraft [26]. Moreover, this aircraft cabin mock-up has been equipped with the capability to adjust the pitch between the seat rows and the height of the seat tray table.

Fig. 2. Aircraft cabin mock-up used for the comfort experiment

A total of 132 people has participated in the experiment and they all are gathered through public calls made for the volunteers on social media outlets including Facebook and WhatsApp. Before each participant went through the experimental session, their anthropometry measurements were first recorded. Since this study is focused on the passengers' comfort during their in-flight activities while seated, only the measurement of the participants' sitting anthropometry parameters has been taken as shown in Figure 3. After their body anthropometry has been measured and recorded, participants have been tasked to sit in the cabin mock-up and performed three considered in-flight activities using the seat tray table: eating, writing and using a laptop. Although there are also other in-flight activities of aircraft passengers that can be considered, these three activities have been chosen for this study

since they are the common ones by most passengers [16]. In the experiment, foods were prepared for the participants during their eating activity. On the other hand, for the activities of writing and using a laptop, the participants have been tasked to write and type a provided short paragraph of written text, respectively.



Label	Anthropometric Measurements
A	Crown Buttock Height
B	Eye Height
C	Shoulder Height
D	Elbow Height
E	Thigh Thickness
F	Abdominal Depth
G	Popliteal Height
H	Buttock Popliteal Length
I	Buttock Knee Length
J	Buttock Heel Length
K	Forward Grip Reach
L	Elbow Grip Length

Fig. 3. Measured human sitting anthropometry parameters of the participants [7]

In its standard definition, seat pitch is measured as the distance from one point on the seat to the same point on the seat in the front or back row from it. During the experiment, the seat pitch is varied between 71.12 cm to 86.36 cm, which is the common range of the seat pitch used in economy class passenger cabin of many commercial passengers' transport aircraft [6,7]. The seat pitch is varied by 2.54 cm at a time between this range during the experiment. At each setting of the seat pitch, the seat tray table's height is then adjusted until the participant felt at their most comfortable level for each specific activity.

In total, there are seven seat pitch settings and three in-flight activities, which accumulates to a total of 21 experimental sessions for each participant. It should be noted that the change in seat pitch has been done in randomized order to reduce the possibility of any order effects in the participants' comfort assessment. Figure 4 depicts some pictures taken during the experiment. It should be noted that the conduct of this sitting comfort experiment closely follows similar procedures that have been applied in other flight comfort studies [6,27,28]. Nevertheless, necessary adjustments have been made to better tailor the experimental procedure with the aircraft cabin mock-up used and the study objective. The collected data is further analysed to establish the potential of improving passengers' comfort during in-flight activities by a proper setting of seat pitch and height of seat tray table.

(a) (b) (c)

Fig. 4. Conducted sitting comfort experiment in the aircraft cabin mock-up (a) Eating (b) Writing (c) Using laptop

3. Results and Discussion

Before any of the participants started the experimental session, the measurements of their sitting anthropometry parameters were taken and recorded. Table 1 shows the descriptive statistics of the participants' anthropometry measurements. Based on the data in Table 1, it can be taken that male participants are generally taller and have relatively slenderer body than the female participants. In the sitting comfort experiment, participants have been instructed to sit on the designated seat inside the aircraft cabin mock-up. Each participant went through a total of 21 different sessions that roughly lasted about five minutes for each session. At each setting of the seat pitch, participants are tasked to perform three in-flight activities and the height of the seat tray table is gradually adjusted up until it reached their perceived most comfortable position for each activity. It should be noted that no instruction was imposed on participants' sitting posture during the entire experiment and they were free to change their posture according to their most comfortable position.

Table 1
Descriptive statistics of anthropometry measurements (in cm) for the participants

Anthropometry parameters	Male (n = 88)		Female (n = 44)	
	Mean	Standard deviation	Mean	Standard deviation
Stature	170.49	8.10	161.75	6.70
Forward grip reach	74.75	4.92	71.09	4.25
Elbow grip length	38.84	3.00	36.91	2.81
Crown buttock height	85.46	3.98	81.76	2.94
Sitting eye height	74.13	3.62	70.43	2.97
Sitting shoulder height	56.21	4.14	53.11	3.47
Sitting elbow height	20.35	3.18	20.56	2.97
Abdominal depth	21.31	3.82	20.99	3.72
Thigh thickness	14.57	2.81	14.52	2.64
Buttock popliteal length	47.59	3.85	44.21	3.50
Buttock knee length	58.44	3.74	55.99	4.25
Buttock heel length	104.50	6.24	98.83	5.48
Popliteal height	45.64	3.32	45.53	2.76

Subsequently, Table 2 shows the average of recorded comfortable height of the seat tray table for the eating, using laptop and writing activities from the experiment. It is good to note that majority of participants were Malaysians and only 27 of them were from other countries. To study whether there is any significant difference in the comfort trends between Malaysians and the other nationalities, the collected data presented in Table 2 has been segregated in terms of the participants' nationality as well.

Table 2
Comfortable seat tray table height for common in-flight activities

Seat pitch (cm)	Nationality	Average comfortable seat tray table height (cm)					
		Eating		Writing		Using laptop	
		Male	Female	Male	Female	Male	Female
71.12	Malaysian	73.45	73.10	73.39	73.38	73.18	73.16
	International	73.91	75.38	73.89	74.13	73.96	74.13
	Overall	73.57	73.31	73.52	73.44	73.38	73.25
73.66	Malaysian	73.58	73.41	73.64	73.55	73.63	73.54
	International	74.24	75.63	74.24	74.25	74.00	74.25
	Overall	73.75	73.61	73.80	73.61	73.73	73.61
76.20	Malaysian	74.03	73.69	73.99	73.86	73.89	73.88
	International	74.30	75.50	74.30	74.63	74.09	74.63
	Overall	74.10	73.85	74.07	73.93	73.94	73.94
78.74	Malaysian	74.41	74.06	74.39	74.19	74.20	74.30
	International	74.80	76.13	74.52	74.63	74.67	74.63
	Overall	74.51	74.25	74.43	74.23	74.32	74.33
81.28	Malaysian	74.79	74.53	74.47	74.31	74.63	74.59
	International	75.09	76.00	74.61	74.75	74.83	74.50
	Overall	74.86	74.66	74.51	74.35	74.68	74.58
83.82	Malaysian	74.99	75.10	74.85	75.14	74.97	74.86
	International	75.59	76.63	74.70	77.00	74.89	76.88
	Overall	75.15	75.24	74.81	75.31	74.95	75.05
86.36	Malaysian	75.09	75.26	75.02	75.33	75.11	75.16
	International	75.44	78.13	75.04	77.25	75.07	77.13
	Overall	75.18	75.52	75.02	75.50	75.10	75.34

Figure 5 plots the data for eating activity and it can be observed that the comfortable seat tray table height for this activity follows an increasing trend with increasing seat pitch. This situation might be due to the reaching capability of the aircraft passengers while they are seated. As the seat pitch is increased, the horizontal distance from the back of front seat where the seat tray table is attached and the body of passengers in their seat is also increased. Hence, having the seat tray table at higher vertical height can help to enhance their reachability and convenience while using the seat tray table for support during their activities while seated.

Additionally, it is also seen in Figure 5 that the plots for male and female are consistently close to one another. The average comfortable seat tray table's height for male passengers in this eating activity is slightly higher than that for female passengers for low values of seat pitch but the situation appears to be reversed when the seat pitch continues to be increased. One of the reasons for this situation could be contributed to different body anthropometry measurements between genders that affect their sitting posture and reachability. Nonetheless, since the difference of average comfortable seat tray table's height seems to be rather insignificant (i.e. less than 0.35 cm), it can therefore be taken that the effects of gender is negligible. Moreover, similar observation and conclusion can also be made for the writing and using laptop activities as well, as depicted in Figures 6 and 7, respectively.

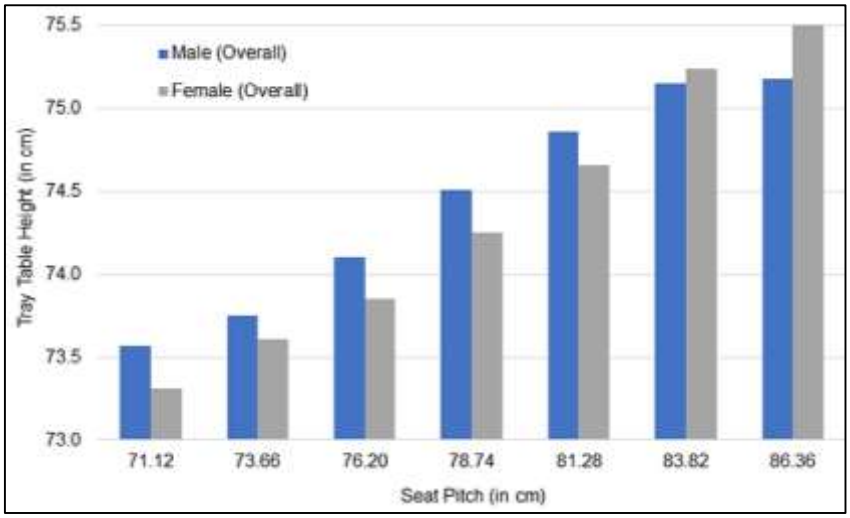


Fig. 5. Overall average comfortable height of seat tray table for eating activity by gender

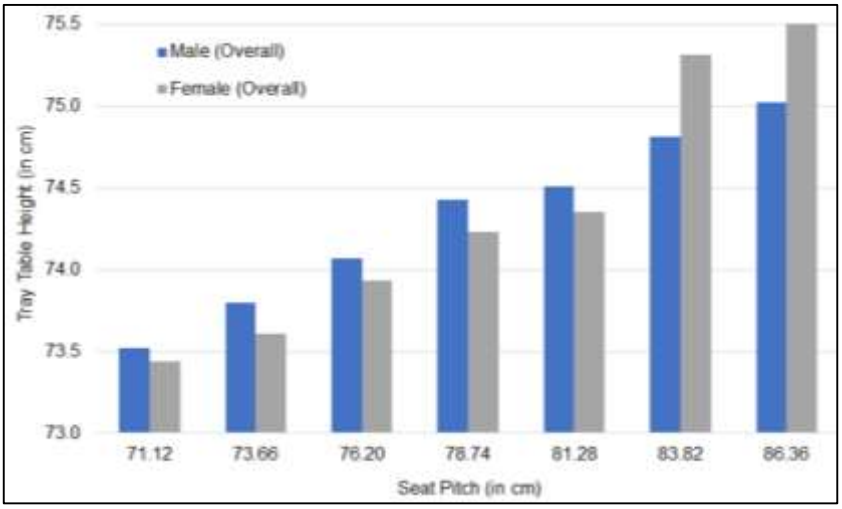


Fig. 6. Overall average comfortable height of seat tray table for writing activity by gender

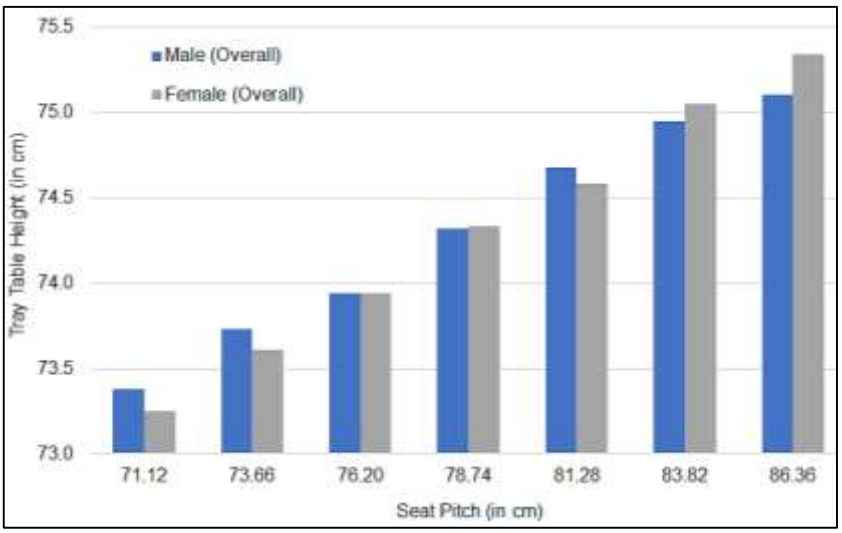


Fig. 7. Overall average comfortable height of seat tray table for using laptop activity by gender

Moreover, Figure 8 highlights the comparison of the overall average comfortable height of seat tray table for all considered in-flight activities. It is noted that Figure 8 also includes the comparison of average comfortable seat tray table's height trend with changing seat pitch between the Malaysian and non-Malaysian participants. It is observed that the average comfortable height of seat tray table for all three in-flight activities is slightly higher for non-Malaysians compared to that for Malaysians. However, the difference is very small and never exceed more than 1 cm for each activity. Based on this observation, it can be taken that the effect of nationality of participants on the comfortable seat tray table's height is rather negligible. This is a preferred situation since it implies that the findings of this study can be extended and applicable to the other populations as well and not only specific to Malaysians.

Furthermore, a similar observation for the average comfortable seat tray table's height between the different considered in-flight activities could also be seen in Figure 8. Therefore, it can be perceived that a fixed seat tray table height might be acceptable to accommodate the different types of in-flight activities, as long as it has been optimally set to provide proper passengers' comfort. Comparison between overall average comfortable seat tray table's height for all considered in-flight activities, irrespective of gender and also nationality of the participants, is shown in Table 3.

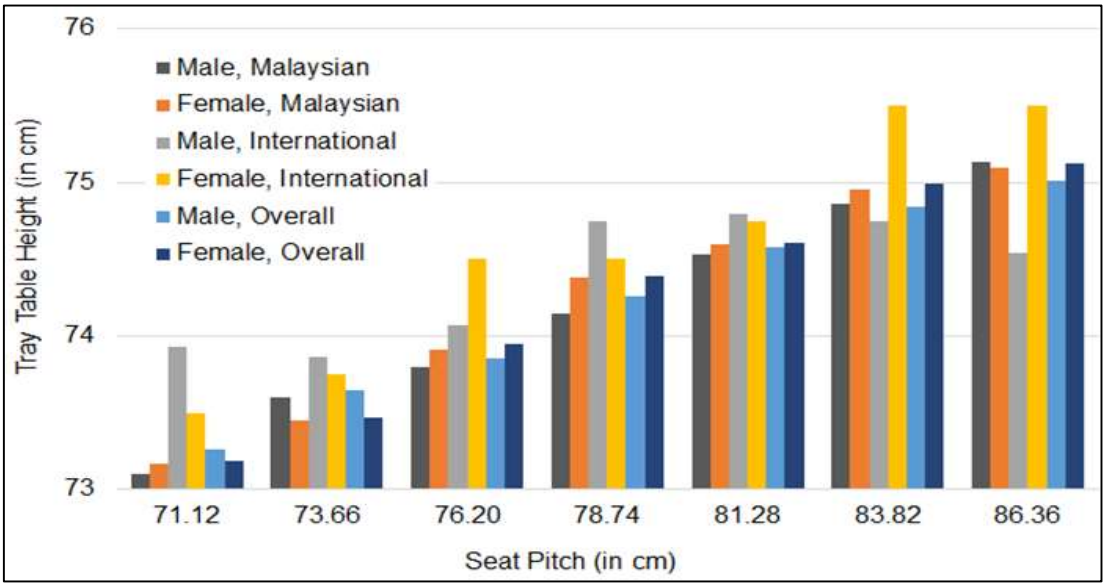


Fig. 8. Average seat tray table height for all different in-flight activities

Table 3
Overall comfortable seat tray table's height for in-flight activities

Seat Pitch (cm)	Overall average comfortable seat tray table height (cm)		
	Eating	Writing	Using Laptop
71.12	73.485	73.492	73.337
73.66	73.705	73.735	73.687
76.20	74.019	74.023	73.942
78.74	74.424	74.360	74.323
81.28	74.795	74.455	74.648
83.82	75.178	74.973	74.981
86.36	75.295	75.182	75.178

Recall that previously observed slight difference of comfortable seat tray table's height between genders and nationalities of participants has been attributed to their different body anthropometry measurements. To support this assertion, correlation analysis is conducted between anthropometry

measurements of the participants and their corresponding comfortable seat tray table's height at the given seat pitch settings of 71.12 cm and 86.36 cm. Results of this analysis are presented in Table 4, which indicate that the passengers' body anthropometry does significantly affect the required seat tray table's height for their comfort during the in-flight activities. A few anthropometric parameters have higher correlation with comfortable seat tray table's height than several others. Furthermore, it should be noted that the correlation coefficients also change when seat pitch is changed. This can be taken to infer that there is a combined effect on the comfortable seat tray table's height between the anthropometry measurements of aircraft passengers and the seat pitch setting.

Table 4
Correlation analysis results at seat pitch of 71.12 cm and 86.36 cm

Anthropometry parameters	Seat pitch (cm)	Pearson correlation coefficient		
		Eating	Writing	Using Laptop
Stature	71.12	0.340	0.258	0.201
	86.36	0.218	0.203	0.213
Forward grip reach	71.12	0.195	0.094	0.073
	86.36	0.256	0.257	0.219
Elbow grip length	71.12	0.150	0.126	0.155
	86.36	0.118	0.159	0.160
Crown buttock height	71.12	0.239	0.201	0.168
	86.36	0.115	0.070	0.063
Sitting eye height	71.12	0.261	0.190	0.180
	86.36	0.159	0.104	0.136
Sitting shoulder height	71.12	0.280	0.231	0.211
	86.36	0.162	0.109	0.115
Sitting elbow height	71.12	0.327	0.342	0.293
	86.36	0.253	0.234	0.151
Abdominal depth	71.12	0.163	0.143	0.119
	86.36	0.125	0.145	0.119
Thigh thickness	71.12	0.215	0.202	0.188
	86.36	0.242	0.246	0.235
Buttock popliteal length	71.12	0.132	0.037	-0.030
	86.36	0.035	-0.005	0.048
Buttock knee length	71.12	0.247	0.175	0.084
	86.36	0.195	0.144	0.172
Buttock heel length	71.12	0.213	0.134	0.085
	86.36	0.239	0.233	0.211
Popliteal height	71.12	-0.177	-0.114	-0.082
	86.36	-0.238	-0.084	-0.018

All in all, based on the collected experimental data, it can be concluded that seat pitch and height of seat tray table have significant effects on passengers' comfort level during their in-flight activities. Additionally, it has been effectively shown that passengers' anthropometry measurements have an influence on the determination of the right setting of both seat pitch and seat tray table height that provides adequate comfort level for them to perform their in-flight activities. On the other hand, the effects of genders or nationalities of aircraft passengers on the comfortable height of seat tray table for in-flight activities can be taken as negligible.

Moreover, it also seems that the types of in-flight activities also do not significantly affect the corresponding comfortable height of seat tray table for a given seat pitch. Based on this notion, a fixed seat tray table's height that can adequately provide comfort for all types of in-flight activities to the passengers is essential to be determined. Lastly, it should be noted that the current fixed height of seat tray table in many economies class aircraft cabin today is around 68 cm [24], which is

clearly shown to be lower than the average comfortable height of seat tray table found in this study, which has been presented in Table 3. This indicates that many aircraft passengers might find that the current seat tray table is too low for their comfort, which is consistent with some of their complaints.

4. Conclusions and Future Study

With the big expansion of air transportation market, competition level between operating airlines has increased. Numerous studies have shown that flight comfort is one of primary selection factors by aircraft passengers when choosing their flight services. A good and comfortable flying experience usually makes the passengers more inclined to repeat the services from the same airlines. In general, an aspect of flight comfort is the ease and comfort for aircraft passengers to perform their in-flight activities. It is observed that typical in-flight activities for aircraft passengers mostly involve the use of seat tray table. Therefore, appropriate height of the seat tray table becomes a significant factor to ease the passengers to do the activities and also increase their comfort level. Moreover, the amount of the available legroom also affects the required height of the seat tray table for the activities as this can dictate the knee height of the passengers while seated and the distance of seat tray table from them.

Based on this notion, this study is conducted to explore and establish the possible effects of seat pitch, seat tray table height and passengers' body anthropometry on their comfort level while performing their in-flight activities. To accomplish this, an activity-based comfort experiment is done with 132 volunteers. The experiment, which has been done in an aircraft cabin mock-up, considered three common types of in-flight activities: eating, writing and using laptop. In this experiment, the comfortable height of seat tray table of each activity for each participant is recorded at each varying seat pitch setting. Based on the results, it has been demonstrated that height of the seat tray table and seat pitch do have significant effects on the aircraft passengers' comfort level during their in-flight activities. This has been reflected by the different comfortable seat tray table's height for each considered in-flight activity at the different seat pitch settings. Moreover, the comfortable seat tray table's height is found to be correlated with the participants' body anthropometry parameters, which implies that passengers with different anthropometry measurements might require a different seat tray table's height to comfortably conduct the same in-flight activity.

In addition, in comparison to the fixed height of seat tray table that is currently used in most economy class of many commercial transport aircraft, which is 68 cm, the experimental results show a notable mismatch whereby it can be taken that most passengers find this current height is too low for their comfort. Overall, findings from this study have clarified the potential to improve aircraft passengers' flight comfort with proper setting of seat pitch and height of seat tray table, taking into account the anthropometry parameters of the passengers. The next stage of the research study is to effectively model this relationship in order to optimize the height of the seat tray table for better passengers' flight comfort. Given the seat pitch and the sitting anthropometry of target passengers' population, such relationship model is useful to effectively assist and guide aircraft cabin designers to decide on the optimal fixed height of the seat tray table that will be comfortable for majority of the target aircraft passengers.

Acknowledgement

The authors acknowledge that this study has been essentially funded by Ministry of Higher Education Malaysia through their Fundamental Research Grants Scheme (FRGS) with the corresponding project number: FRGS/1/2018/TK09/UPM/2/1 and the vot number: 5540074.

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