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Effects of long-duration sitting with limited space on discomfort, body flexibility, and surface pressure

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ABSTRACT

The objective of this work is to analyze the effect of long-duration sitting on a seat with the limited space on discomfort, body flexibility and surface pressure, and the changes of discomfort, surface pressure and body flexibility with the sitting time. The experiment was that eighteen healthy subjects seated for long-duration (3 h) in three different seat pitches (32 inches, 30 inches and 28 inches) conditions in the laboratory. The discomfort, pressure, and body flexibility parameters have been measured during the experiments. Comparing the data between three seat conditions during the sitting time, the results show that there is a significant difference in the overall discomfort ratings and pressure variances between three different seat conditions after 3 h, and significant effects were found among the three different seat pitches for the discomfort rating of shoulder, middle back and low back after 3 h. No significant findings were seen in lumbar and hamstring flexibility. The relationship between subjective ratings and objective measurements has been analyzed with spearman analysis. The correlation analysis suggest that differences in arm and middle back discomfort were significantly negatively correlated to Sit-Reach(3) scores (Correlation Coefficients: 0.492 and −0.527; p values of 0.038 and 0.025, respectively). Differences in overall discomfort, thigh and knee were significantly correlated to average pressure (Correlation Coefficients: 0.562, 0.833 and 0.520; p values of 0.004, 0.001.and 0.027, respectively).

Relevance to industry Nowadays many forms of public transport, especially prolonged flight, involve sitting in the seat with a confined sitting space for long time, which may have bad effects on the user's flexibility and discomfort perception. The survey of passenger's subjective perception for different seat pitches and their physiological changes is helpful to find a relationship between subjective perception and objective measurement and understand how seat pitch to influence the discomfort, and the result can provide a reference for determining the appropriate distance of seat pitch.

1. Introduction

Over the years, air travel has become a common mode of transportation, especially the development of low cost carriers (LLC) (Brundrett, 2001; Kremser et al., 2012). Compared to full service carriers (FSC), LLCs often have a lower level of comfort and service. Passenger comfort is one of the customer's priorities when people go to travel by airplane. Passengers spend all their time sitting on their seats, except several minutes when they have to go to washroom. Seat comfort already becomes one of the most important parts which have an impact on passenger comfort during the flight (Richard and Jacobson, 1975). Prolonged sitting in a constrained or fixed posture exposes a person to long term static loading of the body which is generally seen as a risk factor for the development of musculoskeletal complaints and discomfort (Aldington et al., 2008; Cascioli et al., 2011; Fazlollahtabar, 2010; Healy et al., 2010; Luttmann et al., 2010). It has been argued that prolonged seated work is a potential risk to spinal and paraspinal discomfort and disorders (Aldington et al., 2008; Healy et al., 2010). As airlines seek to boost profits, by squeezing more seats aboard airplanes and increasing passenger capacity, the average economy-class seat pitch and passenger legroom has declined over the years. Passengers in the middle of the three-abreast seating with the shared armrest would cause undue physical contact with passengers in window or aisle seat. Passengers in widow or middle seat

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inevitably disturb passengers in aisle seat during ingress/egress. The shrinking seat space on airplanes is surely uncomfortable, but it might also be dangerous for passengers' health. Cramped seating restricts physical activity and makes it difficult to leave the seat for regular exercise, cause health problems, such as swell and ischemia of the lower limbs (Hinninghofen and Enck, 2006). During long flights, passengers keep being immobilized in tight seats, cramped seats and inadequate legroom restricts effective body movement, passengers have a high risk for deep vein thrombosis, blood clot forms, typically in a leg vein.

One of the most important factors influencing aircraft sitting comfort in economy class is seat pitch and legroom. Seat pitch is the distance between the back of one seat to the same point on the back of the seat in front. This distance is not the full space allocated to the passenger as the thickness of the seat upholstery takes up some of the space. So the legroom is affected by the seat pitch and the thickness of the seat back. Legroom has a very high influence on aircraft interior comfort. The correlation coefficient between legroom and comfort score is 0.72 from the 10,032 passengers trip reports (Vink et al., 2012). The legroom is the seat pitch subtracts the thickness of the backrest. The depth and the contour of the backrest reduce seat pitch to the available legroom (Quigley et al., 2001; Vink and Brauer, 2011). Slimline seat is thinner backrest design and is supposed to be another good choice to enlarge the legroom without sacrificing travelers' comfort or airlines' passenger numbers (http://www.ausbt.com.au/photo-tour-do-slimline-economy-seats-deserve-the-extra-legroom-hype). Another factor influencing aircraft seating comfort is the reclining backrest. The conflicts between passengers are increasing because the front passenger reclining seats results the legroom of the rear passenger to shrink. There were several reports about that the flight diverted because of the passengers' conflicts on the reclining backrest (http://www.theguardian.com/business/2014/aug/26/plane-diverted-as-passengers-fight-over-seat-reclining?commentpage=1, Retrieved May 5, 2016). There is a debate about the seat recline or not in economy class. The two main concerns in this paper is long-duration and limited seating space. The experimental setting simulated the seat in the flight.

Economy class seats of aircrafts were investigated through a field survey and literature searching in which the dimensions of various seat components were measured. The range for seat pitch in economy class is from 28 to 33 inches, which covers typical economy class of FSC and LLC. The common seat width is 17–18 inches. The size of chair used in the experiment is 18 inches (width) × 26 inches (total depth). Seat cushion depth is 17.5 inches and seat height is 18 inches. The seatback angle is 110°. These dimensions are generally consistent with the actual aircraft seat. In this sense, the office chair is acceptable and it can be used to simulate the seat in the experiment. This research adopted office chairs to do the experiment.

There are several definitions and models of comfort and discomfort available in the literature (Corlett and Bishop, 1976; De Looze et al., 2003; Zhang et al., 1996). Comfort and discomfort have been defined as independent entities associated with different factors (Zhang et al., 1996). Since discomfort and comfort are based on independent factors, a reduction of discomfort does not necessarily bring about feelings of comfort (Helander and Zhang, 1997). Comfort is not simply the absence of discomfort, and indeed both can occur at the same time. Comfort and discomfort need to be treated as different and complementary entities in ergonomic investigations. Additionally, no or low levels of comfort can be perceived if a high level of discomfort exists (Helander and Zhang, 1997; Zhang et al., 1996). It can be concluded from the literature that comfort corresponds with positive state, and can be described by such words as relief, well-being, satisfaction, enjoyment; discomfort corresponds with negative state, and can be described by such words as suffering, pain, fatigue, anxiety (Yang et al., 2009). Only discomfort is studied in this study. Several factors influence feelings of discomfort, passenger discomfort cannot be considered purely physical, psychological state was rated as the most influential factor in the discomfort (Ahmadpour et al., 2016; De Looze et al., 2003; Helander, 2003). External factors, such as visual input, smell, noise, temperature, humidity, vibration, pressure/touch, posture and movement, can also form an important part of the evaluation of discomfort. The objective of the study is to analysis the degree to which discomfort provided by seat and sitting space can be quantified, and not the feelings of discomfort experienced by a person. Thus, the discomfort resulted from visual input, smell, noise, temperature, humidity and vibration is not considered in this study. Comfort is a subjective construct that is difficult to interpret, measure, and specifically define due to its psychophysical nature (Shen and Parsons, 1997). Discomfort is a construct that is proposed to lie on the opposite end of a continuum and is thought to be easier for subjects to identify a degree of affliction. It is also important to note that feelings of comfort/discomfort change with sitting duration. Therefore, sitting comfort/discomfort was divided into initial sitting comfort/discomfort, short-term comfort/discomfort (up to 30 min), and long-term comfort/discomfort (after 30 min) (Zenk et al., 2006). The long-duration sitting related to discomfort have not been studied thoroughly.

Pressure distribution appears to be the objective measure with the most clear association with the subjective comfort and discomfort ratings (De Looze et al., 2003). These studies (Fujimaki and Mitsuya, 2002; Groenesteijn et al., 2009; Vergara and Page, 2000) analyzed that discomfort reported a relationship with pressure parameters, whereas one study (Carcone and Keir, 2007) could not find a relation between discomfort and pressure measurements. Pressures have been used in the evaluation of car seats (Franz et al., 2012; Milivojevich et al., 2000; Zenk et al., 2012), wheelchairs (Brienza et al., 2001; Geyer et al., 2001; Shaw, 1993) and workstation (Fujimaki and Mitsuya, 2002), for which comfort and function are very important. Long term evaluation of body pressure variation has been performed applied to cars and office chairs, workstation, wheelchairs and bicycles, although there has not been a great deal of work in the airplane seat. According to De Looze et al. (2003), a higher pressure resulted in more discomfort. This is because a high surface pressure can compress the blood vessels in tissues, restricting circulation and causing discomfort. Consequently, a better understanding of the long-duration sitting including body flexibility, and surface pressure may help to design protocols and devices aiming at reducing discomfort.

Discomfort has been assumed to be imposed by the physical constraints of the subject's workstation or cramped position. A subject's perception of discomfort is caused by physical constraint, stiffness or reduced mobility. In previous studies, word descriptors of discomfort are associated with "cramped", "stiff", "soreness and numbness" (Christiansen, 1997; Monette and Weiss-Lambrou, 1999; Shackel et al., 1969). Therefore, this study will explore that whether body flexibility can be used as an indicator of the discomfort degree. As an objective measurement, body flexibility will be used to improve the assessment of chair design and allow for a better understanding of which combination of seat adjustments are required to improve the seats performance. Body flexibility referring to neck flexibility, hamstring flexibility and lumbar flexibility is measured by Cervical Range of Motion,Sit-reach test, and Schöber's test (Cascioli et al., 2011; Grenier et al., 2003).

Based on the above, it seems reasonable to expect that subjects who sit on a chair of basic design with limited sitting space for long time may be more likely to experience reduced flexibility, a higher