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The Ergonomics of Perry Chairs: Fit for Canadian University Students

Yu seon Chae[1]*, Aleisha Fernandes[1]

[1]Simon Fraser University, *Faculty of Health Sciences*

Abstract

The purpose of this study was to determine whether student seating (Perry chairs) are objectively and subjectively comfortable for Simon Fraser University students. Purposeful sampling occurred within an undergraduate Kinesiology class (BPK 303) to ensure students from both ends of the height range of university students were captured. Students were asked to rate their subjective comfort after sitting in Perry chairs for two hours. Subsequently, six key anthropometric measures were taken (hip breadth, buttock-to-scapula height, lumbar support height, hip angle, buttock-to-popliteal length and popliteal height) and compared to Perry chair dimensions to determine ergonomic fit. 25 BPK 303 students' anthropometrics were collected but only 16 had completed a subjective survey evaluating comfort during a two-hour lecture. Overall mean comfort ratings had a decreasing trend from 5.1/7 at the beginning of lecture to 3.1/7 after lecture. Results showed that only the seat breadth was found to provide adequate ergonomic fit. None of the participants were accommodated by all six of the chair dimensions. However, participants reported no significant change in their subjective comfort ratings before and after the lecture and participants' change in subjective comfort ratings were found to not be correlated to their anthropometric measures ($r = 0.1$; $p = 0.84$). In order to adequately assess the benefits of adjustable chairs and their ability to accommodate university students, future studies should increase the duration students are seated for and sample size, as well as make subjective comfort ratings more specific to the different affected body parts

Keywords — Ergonomics, Perry Chairs, Students, University, Anthropometry

1. Introduction

University students often sit for prolonged periods of time at school hence it is crucial that school furniture accommodate their wide range of anthropometrics. Sitting in inadequate furniture for extended amounts of time could lead to harmful sitting postures and result in poor health outcomes such as musculoskeletal disorders [1, 2, 3]. It has been found that musculoskeletal discomfort earlier in life is a significant risk factor of serious joint problems later in life [4]. Several studies have found linkages between prolonged sitting and back pain as well as a strong relationship between backrest height, chair to ground height and presence of lordosis in female students [5, 6, 7]. A study conducted in 2017 found that most seat heights in university settings were only optimal for 19.6% of participants and were often too low

*Corresponding Author. Contact: sarah_chae@sfu.ca

for participants causing an increase in kyphotic posture when writing [8]. This lack of good ergonomic fit is a significant concern for students' wellbeing.

Chairs have certain dimensions and ranges that must be satisfied in order to accommodate the diverse SFU student population. The literature identifies four chair dimensions which are critical in assessing the ergonomics of chair design. Seat pan width helps to provide stability for the legs, feet, and back for long periods of time [9]. To be ergonomically fit, the width of the seat pan is dependent on the largest individual so that it can accommodate the majority of the populations' hip breadth [10]. As females tend to have wider hip breadths, chairs are often based on the 95th percentile of female hip breadths [11]. Backrest height provides users support for their lumbar spine and reduces paraspinal muscle activation and muscle fatigue [12, 13]. Carcone and Keir [14] found that backrests can decrease the peak pressure on the back by 35% and lower the average pressure on the back by 20% when sitting on a chair with a backrest than without. It is believed that the height of the backrest should be below the scapula to allow arm and trunk movements and must fit the 5th percentile of females to be classified as ergonomically correct [15]. Lumbar support height (the point on the back that curves in the most) is believed to provide the most support when the height and the shape resembles the height and the curve of the user [16, 17, 18]. Lumbar support height has been discovered to reduce both the sitting load on the lumbar spine and the lumbar muscular activity [19]. Moreover, ergonomically correct lumbar support height reduces lower back and referred leg pain when compared to an unsupported backward slouching posture [18]. Seat pan angle between 90° to 110° is believed to result in a healthier retracted head and neck posture of individuals, improving the alignment of the upper body [10, 20]. As the hip flexion angle decreases, the greater the chances of developing hip abnormalities in the joints [20]. Hip angle is also dependent on popliteal height and buttock-to-popliteal length matching up with the chair's seat pan height and length. An ergonomically adequate hip angle is necessary to maintain and protect the natural curvatures of the spine and reduce the incidence of lower back pain. Although, there are various chair dimensions that must be accounted for, these are the most commonly researched measures in the literature and the biggest contributors to students' wellbeing.

Perry chairs are a type of chair commonly offered on university campuses in study areas, libraries, classrooms, etc. (Fig. 1). Due to their high prevalence on site, they are used regularly and for long periods of time by students. Unfortunately, there is a lack of literature available on whether these chairs are ergonomically fit for university students' anthropometry. In this study, we examined whether Perry chairs are subjectively and objectively ergonomically adequate for university students at SFU based on the seat pan width, backrest height, lumbar support height, and hip angle when seated. We gathered anthropometric measures of students and compared them to the dimensions of the Perry chair. We hypothesized that the seat pan width would be ergonomically adequate, but backrest height, lumbar support height, and height and length of seat pan would not be. We also compared students' objective measures and subjective comfort ratings to Perry chairs, to determine whether the ergonomics of chair dimensions can influence the comfort ratings of the user. We hypothesized that SFU students will report lower comfort ratings as class progresses, especially for individuals who are less ergonomically fit for the chair.

2. Materials and Methods

2.1. Study Population

SFU students enrolled in BPK 303 class from January 2020 to April 2020 were recruited for the study. They ranged from 18 to 30 years of age which was consistent with the demographics of university students attending SFU. 25 subjects were purposely selected to ensure at least 10(3/25) of the sample consisted of tall individuals and another 10% (3/25) consisted of shorter individuals. The remaining 19 individuals consisted of individuals in the middle to ensure a normal distribution. Unfortunately, due to the COVID-19 pandemic, our data collection was interrupted, causing some participants to have incomplete data for subjective measures.

2.2. Procedures

A survey was created to determine whether students subjectively perceived Perry chairs as comfortable. Students were asked to fill out a quick survey throughout a BPK 303 lecture to rate how comfortable they felt sitting in Perry chairs before the lecture, during the break, and after the lecture. The rating was done on a seven-point Likert scale with one representing very uncomfortable, four representing neutral, and seven representing very comfortable. Change in comfort ratings over time were calculated per person and for the overall population.

Participants were able to get up and leave the chair during the mid-lecture break, which was 10-minutes long. Students who did stand up during the break had to report how long they left their seat for. Participants' anthropometric measures were collected to evaluate the ergonomic fit of the Perry chairs. The chosen anthropometric measures were based on the landmarks endorsed by the International Society for the Advancement of Kinanthropometry and previous research studies to ensure quality and uniformity [21]. Six anthropometric measures were taken: hip breadth, buttock-to-scapula height, lumbar support height, hip angle, buttock-to-popliteal length and popliteal height. Each of the measurements were taken three times and the median value was used for data analysis. All six measurements, except for the hip angle, were taken on a seating surface that allowed the participants' knees to be at 90°. Hip angle was measured when participants sat on a Perry chair. When collecting the data, participants were asked to wear loose fitting clothing and remove their shoes to provide access to essential landmarks used in measurements and increase accuracy. Perry chair measurements and the corresponding sample anthropometrics were compared to determine whether the Perry chairs are ergonomically fit for students (Table 3). Based on the optimal seat dimensions, the proportion of students that fit the criteria was assessed to determine if at least 95% of the sample was accommodated by the Perry chairs.

2.3. Statistical Analysis

Descriptives were taken for objective and subjective measures and a statistical analysis was conducted to determine whether there was a correlation between subjective and objective measures. Histograms were made to examine the trend in the change in comfort ratings over time for all participants and within participants. The mean and standard deviation (sd) were reported. For the objective measures, Perry chair measurements were compared against anthropometric measures to determine whether Perry chairs were ergonomically adequate or objectively comfortable for the 95th to 5th percentile of BPK 303 students. The mean, sd, 5th and 95th percentiles were reported for hip breadth, buttock-to-scapula height, lumbar support height, hip breadth, hip angle, popliteal height and buttock-to-popliteal length. Histograms were also made to examine where the distribution of anthropometrics fell. An alpha level of $p \leq 0.05$ was used as the criterion for statistical significance. Data analysis was conducted using IBM SPSS statistics (version 25.0) and Microsoft Excel 2019.

3. Results

Overall, there were eight males and 17 females that had anthropometric data collected. However, due to missing data, there were only four males and 12 females who had their anthropometric measures linked with their subjective comfort ratings. Participants all ranged from 20 to 25 years of age. Age distribution amongst the total number of participants and linked participants were similar. Females tended to be younger, while males tended to be slightly older. Overall, the age of participants fell into a normal distribution with a mean of 22.3 years ± 1.3 for the total number of participants and 22.4 years ± 1.0 for linked participants (Tab. 1).

Table 1: *Age and gender distribution of sample population. Linked participants are the participants whose anthropometric measures were able to be linked to their subjective measures from the in-class survey.*

	Age (Female)		Age (Male)		Age (Mixed)	
Total Number of Participants (N = 95)	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
	22	1.13	23.2	1.37	22.4	1.3
Linked Participants	**Age (Female)**		**Age (Male)**		**Age (Mixed)**	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
	22.1	1.12	22.6	0.78	22.3	1.04

Participants were asked to rate their comfort on a scale of one (very uncomfortable) to seven (very comfortable) at three separate times during the lecture (at the beginning, during the break and after the lecture). Before the lecture, most participants reported high comfort ratings (75%) with a mean of 5.1 ± 0.9 and range of 3 to 6 (Tab. 2). For those who stood during the break, participants reported high comfort ratings with a mean of 4.8 and those who did not stand had a mean of 4.5. During the lecture, most participants reported a comfort rating of three or four (81%) with a mean of 3.4 ± 0.8 and a range of two to five (Tab. 3). For those who stood during the break, participants reported a mean comfort rating of 3.2 and 3.7 for those who did not stand. After the

Table 2: *Mean and standard deviation of subjects' comfort rating at different times of the lecture.*

Time Measure Was Taken:	Mean Comfort Rating		
	Total (N=16)	Standing (N=9)	Not Standing (N=7)
Before Lecture	5.1	4.8	5.4
During Lecture	3.4	3.2	3.7
After Lecture	3.1	2.7	3.7

lecture, most participants reported a comfort rating of three or four (69%) with a mean of 3.1 ± 1.2 and a range of one to five (Tab. 2). For those who stood during the break, participants reported a mean comfort rating of 2.7 and 3.7 for those who did not stand. Overall, thedistribution for after lecture is very similar to the distribution of comfort ratings taken during the lecture.

For the overall sample, on average, the change in comfort ratings over time was -2.0 for after lecture to before lecture. However, there was only a -0.3 decrease between after lecture and during lecture and a -1.7 decrease in comfort ratings between during and before lecture. Over time, participants showed an overall decreasing trend in comfort ratings throughout the duration of the lecture. Students were also provided a ten minute break during the halfway mark and students had the option to remain in their seats or stand up. 43% (7/16) of participants did not stand up during the break. Three individuals stood up for five minutes, three individuals stood up for seven minutes and three individuals stood up for ten minutes. A Spearman's rank-order correlation was calculated to determine whether there was a significant difference for changes in comfort rating within individuals and how long individuals stood up during the break. Results showed a correlation of $r = 0.38$ ($p = 0.15$) which was deemed non-significant.

The Perry chair has a backrest height of 40.2cm. Participants' buttock-to-scapula height had a mean of 44.5cm ± 4.3. The 5th percentile of the buttock-to-scapula height distribution was 33.5cm and the 95th percentile was 50.9cm (Tab. 3). The Perry chair was found to not be ergonomically adequate as it did not accommodate the 5th percentile. However, it accommodated 96% of the sample. In terms of lumbar support height, the sample had a mean height of 29.9cm ± 3.7 (Fig. G-7). The 5th percentile of the lumbar support height distribution was 23.1cm and the 95th percentile was 38.4cm (Tab. 3). Lumbar support height of the chair was 26.3cm and matched up with 12% of the sample (3/25). The Perry chair was found to not be ergonomically adequate for the 5th to 95th percentile.

Three measurements were taken to assess the seat pan: hip breadth, buttock-to-popliteal length, and popliteal height. The sample had a mean hip breadth of 28.5cm ± 4.0. The 5th percentile of the hip breadth distribution was 22.5cm and the 95th percentile was 37.5cm (Tab. 3). After adding an additional 10% for thigh width to the sample's hip breadth measures, Perry chairs were found to be ergonomically adequate for all participants in terms of seat width. For popliteal height, the sample had a mean of 43.1cm ± 3.0. The 5th percentile of the distribution was 38.6cm and the 95th percentile was 49.4cm (Tab. 3). The seat pan height was 45.6cm. Therefore, the Perry chair was found to not be ergonomically adequate as it accommodated only 40% of the sample and not the 5th percentile (10/25) in terms of seat height. Buttock-to-popliteal length of the sample had a mean length of 47.2cm ± 5.5. The 5th percentile of the buttock-to-popliteal length distribution was 32.9cm and the 95th percentile was 54.1cm (Table 3). The seat pan length of the Perry chair was 45.6cm. Therefore, the Perry chair was found to not be ergonomically adequate as it did not accommodate the 5th percentile for seat pan length. Buttock-to-popliteal length only accommodated 72% of the sample (18/25). The final measure, hip angle, was determined by measuring participants' natural hip angle when seated. The 5th percentile of the hip angle distribution was 88° and the 90th percentile was 116°. The mean of 104° ± 7.7, the chair's seat angle only accommodated 64% of the sample (16/25) (Tab. 3). Thus, the seat pan was found to be ergonomically inadequate in all dimensions except for seat pan width.

Table 3: *Descriptive Statistics for Anthropometric Measurements.*

Chair Dimensions	Anthropomorphic Measure	Mean	SD	5th Percentile	95th Percentile	Chair Dimension	Optimal Chair Dimension	Fit (Y/N)
Chair Seat Pan Width	Hip Breadth	28.5 cm	4.0 cm	22.5 cm	37.5 cm	46.4 cm	41.25 cm	Y
Chair Backrest Height	Buttock-to-Scapular Height	44.5 cm	4.3 cm	33.5 cm	50.9 cm	40.2 cm	<33.5 cm	N
Chair Lumbar Support Height	Lumbar Support Height	29.9 cm	3.7 cm	33.5 cm	38.4 cm	26.3 cm	Same as participants	N
Chair Angle	Measured Hip Angle	104°	7.7°	88°	116°	100°	90-100°	N
Chair Seat Pan Length	Buttock-to-Popliteal Length	47.2 cm	5.5 cm	32.9 cm	54.1 cm	45.6 cm	32.9 cm	N
Chair Seat Height	Popliteal Height	43.1 cm	3.0 cm	38.6 cm	49.4 cm	45.6 cm	36.67 cm	N

Several Spearman's rank-order correlations were calculated to determine whether there was a correlation between comfort rating changes within individuals and the number of anthropometric measures that were ergonomically fit for the Perry chair. Participants' anthropometric measures that fell in the ergonomically adequate range for the Perry chair dimensions were coded as 1, and those who fell outside of the range were classified as 0. Change in comfort ratings were based on the change in comfort rating from after lecture and right before lecture began. A correlation of $r = 0.1$ ($p = 0.8$) was found for all six anthropometric measures. The change in reported comfort ratings and how ergonomically fit participants were, was found to be non-significant for both. Seven independent Spearman's rank-order correlations were calculated to determine whether there was a significant difference between comfort rating changes for individuals and their specific anthropometric measures. Analysis obtained correlations ranging from $0.01 \leq r \leq 0.3$ ($0.67 \leq p \leq 0.2$) (Tab. 4). Although none of the anthropometric measures were found to be significantly correlated to comfort ratings, there was a moderate correlation for lumbar support height ($r = 0.3$, $p = 0.3$) and buttock-to-popliteal length ($r = 0.3$, $p = 0.2$) (Tab. 4). Popliteal height was also found to have a weak correlation to comfort ratings ($r = 0.13$, $p = 0.63$) (Ta. 4). Additional Spearman's rank-order correlations were calculated to determine whether there was a significant difference between comfort rating changes and demographics. Analysis obtained for gender found a correlation of -0.46 ($p = 0.07$) which was moderate but non-significant. Analysis obtained for age found a correlation of -0.06 ($p = 0.84$) which was non-significant.

4. Discussion

The aim of this study was to determine whether Perry chairs are ergonomically fit for students both objectively and subjectively. The results of this study show that when sitting on a Perry chair for over a two-hour period, there was no significant change in

Table 4: *Results of Spearman's Rank Order Correlation Coefficients for the change in comfort and anthropometric measures.*

Anthropomorphic Measure	Spearman's Rank Order Correlation Coefficients	P-Value
Buttock-to-Scapula Height	0.059	0.827
Lumbar Support Height	0.297	0.265
Hip Angle	-00116	0.669
Popliteal Height	0.130	0.631
Buttock-to-Popliteal Length	-0.331	0.210

terms of subjective comfort for participants. However, in terms of anthropometric measures, students were only adequately accommodated by seat pan width. Furthermore, the ergonomics of chair design were not correlated to the subjective comfort ratings. Due to the COVID-19 pandemic that unexpectedly interrupted our data collection, we could not collect survey responses concerning subjective comfort levels from all participants that provided us with anthropometric measures. Additionally, we couldn't achieve a normal distribution with our data set due to the participants with missing anthropometric and subjective measures being taller individuals. Change in subjective comfort ratings and demographics was found to be non-significant, while there was a moderate correlation for gender. Male participants reported a minor change while females tended to report a greater change in their comfort ratings. However, our sample may not be representative of males due to the small sample size. Nevertheless, future analysis should consider gender as a possible confounding factor in subjective comfort ratings.

4.1. Subjective Comfort Ratings

The results of this study show that there was a decrease in participants' overall and individual comfort ratings throughout the lecture, although this decrease was not significant. However, it is important to consider potential for biases from participants when collecting subjective measures. For example, there may be human error in participants self-reporting their comfort ratings, such as forgetting to record the comfort rating or the length of time they spent standing during the break. Additionally, individuals may unintentionally record a trend in their comfort rating since they are informed of the aims of the study prior to their participation. There may be other factors that hinder the accuracy of the comfort rating such as the desk height and the eye height when sitting on the Perry chair. As our survey only asked students for comfort ratings of the chair, it fails to address other elements of the classroom as well as the specificity of the chair. Future research is recommended to identify Perry chairs' compatibility to other university furniture as well as include a section where participants can record their comfort ratings for certain body parts to allow for more specificity.

4.2. Anthropomorphic Measures

The results of this study show that the Perry chair was not ergonomically fit for most of the dimensions that we measured students for. Perry chair seat pan width can accommodate the 100th percentile of participants' hip breadth, however, the other dimensions measured in this study were not able to accommodate students. Hip angle is highly dependent on how the subject sits and if they are able to reach the backrest comfortably. It is also possible that there might have been some bias due to the Hawthorne Effect as individuals may exhibit better posture in the lab than in real world settings [22]. Shoes were also asked to be taken off to allow accurate measurements however, this may imply that our results are not representative of real-world applications as students typically wear shoes when seated in Perry chairs. Participants may have even bigger differences in their hip angle, than what is observed, outside of a lab setting. Majority of participants were also not accommodated by the popliteal height and the buttock-to-popliteal length which can affect hip angle. When the popliteal height is smaller than the height of the seat pan, the subject will have a hip angle that is greater than 90°. Additionally, participants will have hip angles significantly greater than 90° if they are sitting at the front of the chair as they tend to lean towards the backrest. As Perry chairs implement a sloped edge seat pan, it allows a natural increase in hip angle for those who do not fulfill the popliteal height requirement [23]. However, this sloped edge still is not able to accommodate the majority of students. In terms of the seat backing of the chair, the results of this study show that the Perry chair backrest height does not meet the ergonomic standard for accommodating the sample's buttock-to-scapula height and lumbar support height. Many studies have identified the backrest height of university furniture to not be ergonomically fit for university students [15, 24]. Backrest as part of a chair design is considered appropriate when it is below the scapula because it allows the movement of arms and trunk [15]. Failure to accommodate the smallest individual, or the 5th percentile, may result in decreased effects on both student performance and physical responses [1]. Another key aspect of the backrest is lumbar support height which has been shown to reduce both the sitting load on the lumbar spine and the lumbar muscular activity when lumbar support height matches the chairs' lumbar support height [19]. It is recommended that chairs should allow for adjustability in the lumbar support depth and height to allow the sitter to match it to their lumbar curves. However, lumbar support height is something that is hard to accommodate everyone with through non-adjustable equipment hence, our results show that no one was accommodated by the chairs' lumbar support height. As students in university range in heights and distributions, exploration of adjustable chairs prior to future furniture decisions should be made to reflect the need for back support that is adjustable for the diverse body types of SFU students.

5. Conclusion

Overall, our study showed that Perry chairs may not be ergonomically adequate for SFU university students as hip breadth was the only measure considered to have adequate ergonomically fit. Buttock-to-popliteal length and buttock-to-scapula height were found to be ergonomically adequate for 96% of all participants in the study. However, none of the participants were accommodated by all of the Perry chair dimensions investigated in the study. Furthermore, we found that participants' subjective comfort ratings were not correlated to anthropometric measures and there was no specific anthropometric measure that had a higher impact on subjective ratings of comfort. Future studies may wish to examine the change in comfort ratings between various chair types or examine the impact of various chair materials on subjective comfort ratings, as well as other furniture such as desks and tables. Future studies should also look at a larger and more representative sample with a longer sitting period when investigating trends in subjective comfort ratings. Additionally, adjustable seating in universities should be investigated as it has the potential to accommodate the diverse student population [14, 16, 17, 19]. Measures like lumbar support height are not easily accommodated in static chair designs. Wang et al. [16] found that adjustment functions of chairs can enhance comfort and decrease risk of musculoskeletal injuries. Similarly, Coleman et al. [17] found that a significant number of participants would adjust the lumbar support height to meet the ergonomic recommendations when the option was provided. They also advised that the adjustment tool should be made accessible and user-friendly for the sitter. Overall, our study found that Perry chairs at SFU may not ergonomically accommodate the majority of students and that further research should be done to ensure better health outcomes and satisfaction for students.

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7. Appendix

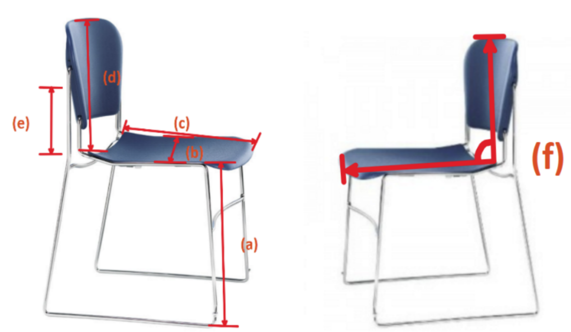

Figure 1: *Visual representation of: (a) Chair Seat Height, (b) Chair Seat Pan Width, (c) Chair Seat Pan Length, (d) Chair Backrest Height, (e) Chair Lumbar Support Height, (f) Chair Angle.*