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THE ASSOCIATION OF ERGONOMIC MISMATCH AND SELF-REPORTED PAIN AMONG STUDENTS OF A COLLEGE IN A PUBLIC UNIVERSITY IN THE PHILIPPINES

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Abstract: The main objective was to determine the association between ergonomic mismatch and self-reported pain among students from a college in a public university in the Philippines. The prevalence of ergonomic mismatch, self-reported pain, and pain qualities were also determined. The dimensions of the representative Auditorium, Wood-and-Metal, and Plastic chairs were compared with the anthropometric measurements taken while the students were sitting on the chairs to assert mismatch. Self-administered questionnaires were used to determine self-reported pain and its quality per body part. Logistic regression was utilized to establish the presence of an association between ergonomic mismatch and self-reported pain while accounting for confounders. All students were mismatched with the Auditorium chair, 88.68% with the Wood-and-Metal chair, and 89.10% with the Plastic chair. Sitting Shoulder Height to Backrest Height and Hip Breadth to Seat Width contributed the highest mismatch for all three chairs, and the most prevalent pain was heaviness in the back and neck. Association was established for the Plastic and Wood-and-Metal chairs, with mismatched students 54% and 29% more likely experiencing pain than matched students, respectively. For the Auditorium chair, association was established with mildly mismatched students 60% more likely to experience pain than severely mismatched students.

Keywords: Ergonomic Mismatch; Self-reported Pain

Introduction

Students spend a considerable number of hours in lecture classes, utilizing the room facilities, such as chairs and desks. As such, school furniture can have a significant effect on the posture condition of students, especially in the regions of the spine, knees, and neck (Da Silva *et al*, 2012). In this regard, furniture becomes an environmental constraint, as the possible postural positions are limited by the dimensions and design of the furniture (Karwowski *et al*, 2003).

Poor posture entails susceptibility to pain in different parts of the body. A seat too high can lead to discomfort in the knees, lower legs, and feet while a seat too low can bring about pain in the shoulders and neck (Grandjean *et al*, 1977). The pain results from prolonged muscle contraction while maintaining an unsupported sitting posture which then leads to the reduction of blood flow and accumulation of waste products in the muscles. Moreover, if developed as a habit, bad posture could lead to chronic conditions such as rheumatic diseases. Finally, posture is also an index of personality as it is one of the elements of nonverbal communication. Good posture suggests confidence, submissiveness, and openness while a bad posture conveys detachment, disinterest and hostility.

Studies have found a substantial degree of mismatch between school furniture and anthropometric measurements. A study in Michigan showed that less than 20% of the participating students have acceptable chair or desk combinations. Most pupils are sitting in chairs with sitting surfaces that are too high or too deep and at desks that are too high. In the same way, a recent study conducted in Bangladesh showed that both boys and girls used seats and desks which were too high for them. Since these studies conducted among students of different nationalities showed an established trend, the different procurement policy of furnishings and the body dimensions could potentially influence the compatibility on environmental and geographical contexts, hence the need for the execution of similar study in a public university in the Philippines.

Review of Related Literature

Classroom Furniture and Posture

Body posture is associated with school furniture design, particularly in their tendency to spend time in classrooms while leaning over the tablet arms or desks of their chairs. A study by Tirloni *et al* in 2014 investigating the influence of school furniture design and body posture found that 63.6% of students from five Higher Education Institutions in Santa Catarina, Brazil spend more than half of their time in class with their trunks leaning over the tablet arm or the desks of their arm chair. The study also involved comparison between the student's tendency to lean over the desks in chairs with armrests at the opposite side of the desk arm and those without. The study established an association between body posture and current classroom furniture design. 66.3% of students who used chairs without armrests tended to lean their trunks over the desks. On the other hand, 54.5% of those who utilized chairs with armrests did not lean their trunks over the desks.

Related Mismatch Analysis Studies

Several studies involving mismatch analysis of body measurements and chair dimensions have been conducted in various countries. A study on mismatch between furniture and anthropometric measurements of Bangladeshi primary school students evaluated the mismatch between classroom furniture dimension and anthropometric measurement of primary school students to assess the ergonomic orientation of the classrooms. The study found substantial mismatch between anthropometric measurements and school furniture dimensions.

In Ghana, a study on the mismatch in body-chair dimensions and the associated musculoskeletal pain among selected undergraduate students identified a high degree of incompatibility between chair dimensions and anthropometric measures. Mismatch was established between seat height and popliteal height, seat depth and buttock popliteal length, and seat width and hip breadth. Part of the study considered how the students rate the pain they felt from sitting on the chairs for two hours. 90.5% of the sample population attributed their pain to the ill-fitted chairs under study.

Significant mismatch between anthropometric measurements and seat dimensions was also identified among Iranian high school students, particularly for seat height, seat width, and desktop height which exhibited greater levels of mismatch than the other dimensions analyzed. The study took into account the factor of sex, as it concluded that seats were too high for majority of lower grade boys, and were too narrow for most girls. Desk height was also determined to be too low for both sexes. Furthermore, the study stated that conditions of mismatch may lead to discomfort and tend to increase the risk for development of musculoskeletal problems among the students.

Pain Associated with Ergonomics

Back pain is a multi-factorial problem resulting from an interaction of different risk factors, such as age, family clinical history, back pain injury, female sex, time spent watching television, stress, and anxiety. As earlier established, children and adolescents spend a great part of their day time at school where they remain in a sitting position for long periods of time. The sitting posture that they adopt during class might be related to furniture design. If a chair is ill-fitted to the user, it can result to increased stress in spinal structures. Thus, the mismatch of school furniture and the anthropometric characteristics of the students may be related to the experience of musculoskeletal symptoms. McCulloch and Transfeldt suggest that for children over ten, low backache is due to poor posture or overuse with more serious conditions requiring medical diagnosis and treatment. Children seem to be suffering from postural discomfort in schools.

A mismatch between school furniture and anthropometric characteristics causes some detrimental effects. For example, this mismatch may induce fatigue and discomfort resulting in poor posture habits as well as preventing focused learning. Assunção *et al* found that a greater mismatch between anthropometric measurements (elbow height and desk height) increased the probability of adolescents experiencing upper back pain.

Inappropriate seat and anthropometric measurements in instances where the seats of chairs are too low or too high may also be contributory to pain. Here, there may either be a lack of thigh supports or the seat design may not be able to support their feet on the floor. This may then result to increased pressure on the posterior surface of the knee and back. When there is inadequate support such as in these cases, the students make certain postural adjustments to compensate for the mismatch. These adjustments may result to the accumulation of physical stress, and consequently, pain (Bello & Sepenu, 2013).

Possible Confounders on the Association between Ergonomic Mismatch and Self-Reported Pain

The dimensions of lecture facilities remain fixed through time. However, anthropometric measurements change due to various factors which can possibly affect the relationship between the two variables, leading to mismatch. Similarly, they can have an effect on musculoskeletal pain. Therefore, they are regarded as possible confounders to the relationship between mismatch and pain.

Anthropometric measurements change with age due to normal development. Meanwhile, back pain results from different risk factors including age. The prevalence of benign back pain appears to decrease with increasing age, after a peak in the sixth decade, but that of severe back pain continues to increase with increasing age.

More differences in physical characteristics of males and females are introduced during puberty, such as widening of hips in females. This leads to varying body measurements which can affect mismatch. Moreover, females are reported to have low back pain more often than males due to pain modulation by estrogen.

In the mismatch analysis study in Ghana involving undergraduate students, pain intensities due to the ergonomic mismatch varied among year levels. Those in second year reported the highest pain intensities compared to those in the third and fourth levels. Possible explanations for this may be attributed to tissue adaptation as a result of longer stay in the school environment.

General Objective of the Study

Determine the association between ergonomic mismatch and self-reported pain among third year and fourth year students from a college in a public university in the Philippines

Specific Objectives of the Study

1. Determine the prevalence of mismatch between the dimensions of chairs (Auditorium, Wood-and-Metal, and Plastic) in lecture rooms with the anthropometric measurements of students
    a. Buttock popliteal length to seat depth
    b. Popliteal height to seat height
    c. Thigh clearance to seat-to-desk clearance
    d. Sitting shoulder height to backrest height
    e. Sitting elbow height to desk height

f. Hip breadth to seat width

2. Determine the prevalence of self-reported pain among students with ergonomic “Mismatch” and “Without Mismatch” in the neck, shoulders, arms, back, hips, thighs and legs
3. Describe the qualities of self-reported pain among students with ergonomic “Mismatch” and “Without Mismatch” in the neck, shoulders, arms, back, hips, thighs and legs
4. Determine the association between ergonomic mismatch and self-reported pain in the neck, shoulders, arms, back hips, thighs, and legs

An analytical cross-sectional study design was done to determine the association between exposure to the ergonomic mismatch of the students and the outcome, namely, self-reported pain.

Definition of Major Study Variables

The independent variable in the study is the presence or absence of mismatch in the dimensions of the chairs and the body measurements of the students. Anthropometric measurements of each student were related to the dimensions of the representative chair of each type to identify whether mismatch was present or not.

Ergonomic mismatch refers to a discrepancy between the student’s anthropometric measurements and the seat dimensions. For the purpose of this study, a discrepancy established in at least one of the student's anthropometric measure and seat dimension comparison categories is defined as a mismatch. This decision was made with the knowledge that the body conforms and adjusts accordingly when there is postural and positional stress. Table 1 shows the match criteria for the different comparison categories considered in this study.

Table 1. Summary of Match Criteria

Anthropometric Measurement	Seat Dimension	Match Criterion
Popliteal Height (PH)	Seat Height (SH)	$(PH+3) \cos 30° \leq SH \leq (PH+3) \cos 5°$
Buttock Popliteal Length (BPL)	Seat Depth (SD)	$0.80\ BPL \leq SD \leq 0.95\ BPL$
Hip Breadth (HB)	Seat Width (SW)	$1.10\ HB \leq SW \leq 1.30\ HB$
Sitting Elbow Height (SEH)	Desk Height (DH)	$SEH \leq DH \leq SEH +5$
Sitting Shoulder Height (SSH)	Backrest Height (BH)	$0.60\ SSH \leq BH \leq 0.80\ SSH$
Thigh Clearance (TC)	Seat-to-desk Clearance (SDC)	$(TC+2) < SDC$

Anthropometry refers to the measurements and proportions of the human body. This is an important consideration in ergonomics where the basic principle is to adapt the facilities to the person. Table 2 shows the anthropometric measurements (Biswas, *et* al) accounted for in this study.

Table 2. Anthropometric measurements of students

Anthropometric Measurement	Description
Popliteal Height	Vertical distance from the posterior surface of the knee (popliteal space) to the resting surface of the foot
Buttock Popliteal Length	Horizontal distance from the posterior surface of the buttock to the popliteal space
Hip Breadth	Maximum horizontal distance between the right and left side of the pelvis
Sitting Elbow Height	Vertical distance from the bottom tip of the elbow (olecranon) flexed at 90° to the seat surface
Sitting Shoulder Height	Vertical distance from the acromion process at the shoulder to the seat

Thigh Clearance	Vertical distance from the sitting surface to the highest point of the thickest portion of the thigh

Measuring seat dimensions is an important step in determining mismatch. In the Philippines, school chairs usually have built-in desks. Table 3 shows the seat dimensions (Biswas *et* al) accounted for in this study.

Table 3. Dimensions of the chairs used by the students

Seat Measurement	Description
Seat Height	Vertical distance from the midpoint of the front edge of the seat to the floor
Seat Depth	Minimum horizontal distance from the front edge of the seat to its back edge
Seat Width	Horizontal distance between the right and left edges of the seat
Desk Height	Vertical distance from the top of the seat front edge to the top of the desk front edge
Backrest Height	Vertical distance from the top edge of the backrest to the seat
Seat-to-desk Clearance	Vertical distance from the lowest point of the desk to the top of the seat front edge

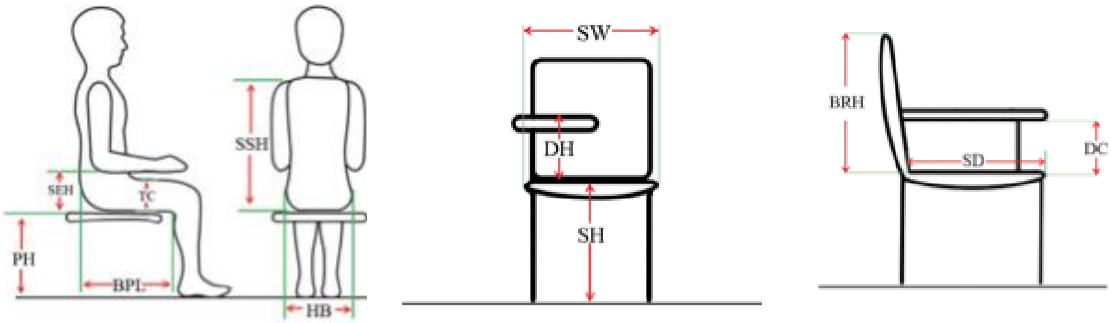

Figure 1 Illustration of the anthropometric and seat measurements considered in the study

The dependent variable in the study is the presence or absence of pain determined through a self-administered questionnaire. Pain is any discomfort related to the muscles, ligaments, and tendons. Pain in at least one of the selected body parts was recorded as having pain. In this study, pain was described further based on its quality:

- Numbness is described as "unfeeling" or "asleep."
- Tingling is described as "pins and needles."
- Cramping is described as "tight" or “firm.”
- Throbbing is described as "pounding" or "pulsing."
- Heaviness is described as "weighty" or "ponderous."

Study Population

The respondents were third year and fourth year students aged 18 to 22 years enrolled for the school year 2016-2017. Age 18-22 years was considered because this is the usual age range of the third year and fourth year students. The investigators were excluded to prevent bias. Moreover, students with pre-existing musculoskeletal conditions were excluded to ensure that the pain reported was due to mismatch.

Method of Data Collection

Representative samples of the Auditorium, Wood-and-Metal, and Plastic chairs were chosen and measured using a self-retractable steel tape measure. After the signing of informed consent forms, the respondents were asked to line up to be measured. They were asked to remove their shoes, sit in an erect position, with their legs perpendicular to the floor. Anthropometric measurements relative to each chair type were obtained using a retractable steel tape measure, with the help of rulers that ensured proper alignment of the body parts measured. They were recorded in cm. After measuring, questionnaires on the presence of pain in the different body parts, and its quality were administered.

Results of the Study

The study population included 149 third year and fourth year students. From these, 148 complied to participate in the study. 15 from the 148 participants reported to have been diagnosed with musculoskeletal conditions, and were hence excluded. Seven other participants gave no response as to whether or not they have existing musculoskeletal conditions. Therefore, the study population consists of a total of 126 students.

Ergonomic Mismatch

Table 4. *Percentages of Students With and Without Mismatch in Different Chair Types*

	Auditorium (%)		Wood-and-Metal (%)		Plastic (%)	
	Mismatch	Match	Mismatch	Match	Mismatch	Match
BPL to SD	66.67	33.33	22.22	77.78	34.13	65.87
PH to SH	29.37	70.63	8.73	91.27	17.46	82.54
TC to SDC	28.57	71.43	0	100	0	100
SSH to BH	100	0	47.62	52.38	4.76	95.24
SEH to DH	48.41	51.59	29.37	70.63	50	50
HB to SW	96.83	3.17	77.78	22.22	75.4	24.6
TOTAL	**100**	**0**	**89.68**	**10.32**	**88.10**	**11.90**

Table 4 shows that all of the respondents were mismatched with the Auditorium chair. The aspect with the highest mismatch was in the Sitting Shoulder Height to Backrest Height (SSH-to-BH) with 100%. The Wood-and-Metal Chair was found to be mismatched with 89.68% of the respondents. Highest mismatch was between hip breadth and seat width (HB-to-SW). On the other hand, 88.10% of the respondents were mismatched with the Plastic chair. The aspect with the highest mismatch was found to be in the HB-to-SW. No mismatch was found with TC-to-SDC in both the wood-and-metal and the plastic chairs.

Self-Reported Pain

Table 5. *Percentage of Students who Experience Pain in Different Body Parts Using Different Chair Types*

	Auditorium (%)	Wood-and-Metal (%)		Plastic (%)	
	Mismatch	Mismatch	Match	Mismatch	Match
Neck	30.95	56.00	75.00	54.05	66.67
Shoulder	19.05	43.00	41.67	43.24	46.67
Arm	7.94	20.00	50.00	21.62	26.67
Back	30.16	66.00	66.67	54.95	66.67
Hip	10.32	40.00	33.33	24.32	20.00
Thigh	19.05	42.00	58.33	42.34	46.67
Leg	25.40	50.00	58.33	54.95	53.33

As seen in Table 5, pain was most frequently reported in the neck, and least frequently in the arm for the Auditorium chair. For the Wood-and-Metal chair, back pain was the most frequent among those mismatched while neck pain among those matched. For the Plastic chair, the highest prevalence of self-reported pain was in the leg and back among those mismatched, and in the neck and back among those matched.

Qualities of Pain

Table 6. *Percentages of Pain Quality in Different Body Parts of Students while using the Auditorium Chair*

	Numbing (%)	Tingling (%)	Cramping (%)	Throbbing (%)	Heaviness (%)
Neck	11.11	3.97	10.40	8.73	17.46
Shoulder	2.38	3.17	6.45	3.97	14.29
Arm	0.79	1.59	1.61	1.59	4.76
Back	8.73	9.52	8.00	7.14	15.08
Hip	5.56	0.79	0.80	2.38	4.76
Thigh	9.60	7.94	7.20	0.79	6.35
Leg	9.52	19.20	12.80	3.97	7.94

As shown in Table 6, heaviness was the most prevalent in the neck, shoulder, arm and back, numbing in the hip and thigh, and tingling in the leg for the Auditorium chair.

Table 7. *Percentages of pain quality in different body parts of students while using the Wood-and-Metal Chair*

	Numbing (%)		Tingling (%)		Cramping (%)		Throbbing (%)		Heaviness (%)	
	Mismatch	Match	Mismatch	Match	Mismatch	Match	Mismatch	Match	Mismatch	Match
Neck	25.00	41.67	14.00	8.33	18.00	8.33	14.00	8.33	37.00	50.00
Shoulder	17.00	16.67	4.00	16.67	15.00	16.67	11.00	16.67	33.00	33.33
Arm	8.00	8.33	5.00	16.67	5.00	16.67	3.00	8.33	7.00	33.33
Back	31.00	41.67	16.00	25.00	29.00	33.33	18.00	16.67	43.00	33.33
Hip	22.00	16.67	7.00	16.67	11.00	25.00	4.00	16.67	18.00	8.33
Thigh	28.00	41.67	19.00	25.00	14.00	25.00	6.00	8.33	20.00	33.33
Leg	30.00	25.00	29.00	33.33	26.00	33.33	4.00	25.00	20.00	25.00

In Table 7, it is shown that among those mismatched with the Wood-and-Metal chair, heaviness was the most prevalent in the neck, shoulder and back, and numbing in the arm, hip, thigh and leg. For those matched, heaviness was the most prevalent in the neck, shoulder, and arm, numbing in the back and thigh.

Table 8. Percentages of Pain Quality in Different Body Parts in Students while using the Plastic Chair

	Numbing		Tingling		Cramping		Throbbing		Heaviness	
	Mismatch	Match	Mismatch	Match	Mismatch	Match	Mismatch	Match	Mismatch	Match
Neck	18.92	26.67	8.11	6.67	17.12	13.33	9.91	6.67	38.74	40.00
Shoulder	12.61	6.67	4.50	0	12.61	6.67	8.26	6.67	29.73	33.33
Arm	5.41	6.67	7.21	6.67	4.50	0	0.92	0	10.91	13.33
Back	25.23	26.67	10.81	0	18.02	20.00	11.82	13.33	33.33	20.00
Hip	10.91	13.33	3.64	6.67	5.50	6.67	2.73	7.14	10.09	0

Thigh	24.32	26.67	20.72	20.00	16.22	13.33	8.18	6.67	12.73	20.00
Leg	30.91	28.57	34.55	46.67	26.13	20.00	11.82	6.67	15.32	20.00

Among those mismatched with the Plastic Chair, heaviness was the most prevalent in the neck, shoulder, arm, and back, and numbness in the hip, thigh and leg. The most frequently reported in the neck, shoulder and arm among those who matched was heaviness. For pain reported in the back, hip, and thigh, the most prevalent was numbness. Tingling was the most prevalent in the leg for respondents who matched with the chair.

Association between Ergonomic Mismatch and Self-Reported Pain

To establish the association between ergonomic mismatch and self-reported pain, logistic regression was used. In this analysis, ergonomic mismatch was identified as having a mismatch in at least one of the anthropometric measurements and seat dimensions while pain reported in at least one body part was considered as having pain.

No comparison group could be formed in the Auditorium chair because of the 100% mismatch. To enrich data analysis, the respondents were divided into having “Mild” and “Severe” Mismatch based on the number of mismatched aspects. Mild mismatch was defined as having one to three mismatched aspects, and severe mismatch as having four to six mismatched aspects. Those with severe mismatch were considered as exposed.

Table 9. Screening for Confounders (Auditorium Chair)

	Odds Ratio	p-value	Remarks
Age	1.61	0.048	PROBABLE confounder
Sex	0.973	0.829	NOT a probable confounder
Duration	0.767	0.031	PROBABLE confounder

Unadjusted OR = 0.60

Sex was not a probable confounder to the association of severe ergonomic mismatch and self-reported pain for the Auditorium chair. The p-value for probable confounders is set at less than 0.25. The p-value obtained for sex was greater than 0.25, hence, it was not considered a probable confounder. The p-values of age and duration of use were 0.048 and 0.031 respectively so they were considered probable confounders. The unadjusted Odds Ratio obtained for the association was 0.60.

Table 10. Identifying Specific Confounders (Auditorium Chair)

	OR full	OR reduced	% change	Remarks
Age	0.56	0.557	0.49	NOT a significant confounder
Duration	0.56	0.595	6.28	NOT a significant confounder

Analysis proceeded to the assertion of the significance of age and duration of use. The % change-in-estimate for age and duration of use were 0.49% and 6.28% respectively. Since these values are less than 10%, age and duration of use were not significant confounders and must be removed from the model. The unadjusted Odds Ratio obtained for the association was 0.60. Hence, students with mild mismatch in the Auditorium chair were 60% more likely to report pain in the different body parts than those with severe mismatch.

Table 11. Screening for Confounders (Wood-and-Metal Chair)

	Odds Ratio	p-value	Remarks
Age	0.76	0.506	NOT a probable confounder
Sex	0.75	0.217	PROBABLE confounder
Duration	1.13	0.857	NOT a probable confounder

Unadjusted OR = 0.96

Age and Duration of Use were not probable confounders to the association of ergonomic mismatch and self-reported pain for the Wood-and-Metal chair. The p-values obtained for the two were greater than 0.25, hence, they were not considered probable confounders. The p-value of sex was 0.217, therefore it was considered as a probable confounder. The unadjusted Odds Ratio obtained for the association was 0.96.

Table 12. Identifying Specific Confounders (Wood-and-Metal Chair)

	OR full	OR reduced	% change	Remarks
Sex	1.29	0.96	25.58	SIGNIFICANT confounder

Analysis proceeded to the assertion of the significance of sex. The % change-in-estimate calculated for sex was 25.58%. Since this value is greater than 10%, sex was identified to be a significant confounder and therefore must be retained in the model. In the full model including the exposure, outcome and the confounder, the computed odds ratio was 1.29. Thus, adjusting for the confounding effect of sex, students who were mismatched with the Wood-and-Metal chair were 29% more likely to report pain than those who were matched.

Table 13. Screening for Confounders (Plastic Chair)

	Odds Ratio	p-value	Remarks
Age	0.71	0.351	NOT a probable confounder
Sex	1.04	0.871	NOT a probable confounder
Duration	0.88	0.546	NOT a probable confounder

Unadjusted OR = 1.54

Age, Sex, and Duration of Use were not probable confounders to the association of ergonomic mismatch and self-reported pain for the Plastic chair. The p-value for probable confounders is set at less than 0.25. The p-values obtained were all greater than 0.25, hence, they were not considered probable confounders. The unadjusted Odds Ratio obtained for the association was 1.54. Hence, students who were mismatched with the Plastic chair were 54% more likely to report pain in the different body parts than those who were matched.

Discussion

The three chairs considered in this study were the Auditorium, Wood-and-Metal type, and Plastic types. Each has its own attributes that may have contributed to the occurrence of ergonomic mismatch or self-reported pain. The Auditorium chair has a cushioned sitting surface and backrest that extends at a considerably greater height compared to the other two chairs. It has a foldable seat and a retractable desk. Its sides from the armrest down to the sitting surface are closed with no space for movement of the body. The Wood-and-Metal chair has interspaced wooden planks as backrest. Its rigid seat surface is curved at the front edge. It has a non-retractable desk but includes a space from the armrest down to the sitting surface. Also, it has a compartment below the seat alternatively used as footrest. Lastly, the Plastic chair follows a convex shape as it goes towards the the sitting surface. Similar with the Wood-and-Metal chair, it has a non-retractable desk.

Moreover, it has an armrest on the left side. The chair is made entirely of smooth plastic and has curved edges on all corners.

Ergonomic Mismatch - Auditorium

Results show that 100% of the respondents were ergonomically mismatched with the Auditorium type chair. This was mainly due to the mismatch in the aspect of the SSH-to-BH. Mobility of the trunk and arms is important when sitting, therefore it is recommended that the backrest height be lower than or at most, on the upper edge of the scapula (Agha, 2010). This was violated by the auditorium chair because all the students' scapulae considerably lower than the backrest. This could prevent full extension of the trunk and arms.

A large proportion of mismatch was also observed in the comparison of the HB-to-SW. An optimal seat width must be selected for the chairs to ensure that it will allow for a wide range of hip breadths. SW should be at least 10% (to accommodate hip breadth) and at most 30% (for space economy) larger than the HB (Biswas, *et al*). The seat should be wide enough to allow the student to sit comfortably, but narrow enough to enable the use of the armrests without stretching too far. It was observed that mismatch was due to the seat being too wide for the students, thus tending them to stretch too much or lean to only one side, predisposing them to poor posture.

Ergonomic Mismatch – Wood-and-Metal

Results show that 89.68% of the respondents were ergonomically mismatched with the Wood-and-Metal chair. The aspect with the greatest mismatch was the HB-to-SW at 77.78%. It is important for the seat width to be sufficiently large to accommodate the widest of hips and permit space for various lateral movements. However, it should also be narrow enough to provide adequate support for the body, not causing any major postural adjustments due to the increased space available for movement. Data show that the extensive seat width of the Wood-and-Metal chair was the reason for the mismatch among most of the students.

On the other hand, no mismatch was recorded in the TC-to-SDC. SDC must be greater than TC to permit leg movement. Wood-and-metal chairs have a huge allowance from the seat surface to the lowest point of the desk, giving a lot of area for movement and changes in leg position.

Ergonomic Mismatch – Plastic

Data show that 88.10% of the respondents were ergonomically mismatched with the Plastic chair. Highest mismatch was recorded in the HB-to-SW aspect at 75.4%. Like in the two other chairs, this may be due to the fact that the seat is too wide and does not provide enough support for the body, specifically the hips.

It can be noted that low mismatch was recorded in the SSH-to-BH aspect at 4.76% compared to that of the Auditorium chair and Wood-and-Metal chair where 100% and 47.62% of students were mismatched in this same aspect respectively. No mismatch was also recorded with the TC-to-SDC aspect, same with that of the wood-and metal chair. It was observed that the Plastic chairs leave a lot of room for movement of the legs due to the large SDC that may accommodate thigh clearances of various measurements.

Self-Reported Pain - Auditorium

Based on the data gathered, pain was most frequent in the neck and back among the respondents. This may be because of the limited neck and spine movement brought about by the increased backrest height. This may have hindered the neck and back to move freely, causing pain and discomfort. Back pain may also be due to the poor posture brought about by the high mismatch in the HB-to-SW aspect. The least prevalent pain experienced while sitting on the Auditorium chair was arm pain. The mismatch in the SEH-to-DH was relatively low with 48.41%, thus may have contributed on the low experience of pain in the arm.

Self-Reported Pain – Wood-and-Metal

HB-to-SW and SSH-to-BH were the two aspects with the highest prevalence of mismatch in this chair. Mismatch was due to the seat being too wide for the hips. Together with the fixed desk, these can predispose the students to assume awkward positions for long periods due to the incompatibility of the structure of the chair. This could then lead to pain in various parts of the body.

The highest prevalence of pain for this chair was back pain followed closely by neck pain. Correspondingly, there was a high prevalence of mismatch for SSH-to-BH. Based on the mismatch analysis, the backrest of this chair was too high for the students which may affect their sitting postures, eventually lead to pain. The spine is a complex structure made up of vertebrae, muscles, nerves, and ligaments. The muscles of the spine attach to the neck and extend until the skull, therefore pain experienced in one of these areas could radiate to the rest. Improper posture and body rigidity can cause a tremendous amount of stress and inflammation on the back muscles. Over time, these muscles could become weak and inflexible, leading to pain in the back, neck and head. The high prevalence of mismatch in HB-to-SW along with the high backrest could have forced the respondent to sit in a position leading to poor and unsupported posture because the respondent would have to compensate for the dimensions of the seat. This may also account for the pain experienced in the back and neck because the seat and back surfaces were both highly mismatched and mainly affecting these body parts.

Self-Reported Pain - Plastic

The high prevalence of mismatch in the HB-to-SW was due to the seat being too wide for the hips of the students. This could have led them to slouch towards the desk, leading to pain. At the same time, the wide seat permits movement and adjustment of posture. The user can then change position freely to alleviate the feeling of pain, and this could explain why there was a relatively low prevalence of hip pain despite the high mismatch.

While there was high prevalence of mismatch for SEH-to-DH, there was also a high prevalence of pain in the shoulder. This could be due to the awkward positions the students were subjected to when resting their elbows on the desks that were found to be too high for them. The BPL-to-SD aspect also exhibited high prevalence of mismatch. Highest pain was recorded in the leg and this could be due to the seat being too long. The seat depth should be enough so that the backrest of the seat can support the lumbar spine without compression of the popliteal surface. Non-compliance to this could lead to leg pain due to compression and radiate to the back and the neck because of the connection of the seat depth to the backrest.

For both cases of matched and mismatched measurements, the leg, back and neck were consistently the highest in terms of the presence of pain. The incompatibility of the seat with the hips of the students, and the presence of the fixed desk may have led to pain in different parts of the body especially the back and consequently, the neck.

Qualities of Pain

In general, heaviness was the most prevalent pain quality experienced in the neck, shoulder and arm. The heavy sensation can be attributed to the accumulation of lactic acid in the muscles (Sahlin, 1986) or as a result of many other sensations in the long run. The body parts forced to hold non-neutral positions experience static loading where they constantly exert effort, therefore lactic acid may be accumulated leading to fatigue, or heaviness.

Numbing was commonly reported in the hip and thigh. This is usually caused by nerve impingement occurring when too much pressure is applied by surrounding tissues. External pressure from holding the body in one position for long periods could reduce blood flow in the vessels supplying the nerve. This causes local ischaemia affecting the transmission of action potentials. Moreover, pressure on a nerve root exiting the spine may cause neck or low back pain. It may also cause pain to radiate from the neck into the shoulder and arm (cervical radiculopathy), or into the leg and foot (lumbar radiculopathy or sciatic nerve pain).

Cramping was reported in the back. External pressure may compress the blood vessels, leading to compromised blood flow. This can cause overexcitement of nerves and involuntary contraction of muscles. This can also occur due to insufficient adenosine triphosphate causing the myosin fibers to not fully detach from actin.

Tingling was the most prevalent in the leg. It is caused by pressure on the nerves as with crossing the legs or lying on one's arm while sleeping. On the other hand, throbbing was the least frequent sensation felt across all three chairs in all body parts. This sensation may have a vascular origin, resulting from physical exertion.

Association between Ergonomic Mismatch and Self-Reported Pain – Auditorium

Students with mild mismatch in the Auditorium chair were 60% more likely to report pain in the different body parts than those with severe mismatch. This is contrary to the common knowledge that a severe mismatch will more likely lead to pain than a mild one. A possible explanation for this is the need for whole body compensation. In the case of the Auditorium chair, the 100% mismatch in the SSH-to-BH may require compensation not only of the back but also of the other body parts to facilitate easier adjustment to the chair.

Considering only the presence of mismatch (100%), it was observed that the prevalence of self-reported pain was relatively lower in the Auditorium chair. This can be explained by the presence of cushion, retractable desk, and armrests. The cushion allows for even weight distribution. It is able to adapt according to the body shape of the user. Furthermore, the presence of retractable desk gives the students extra space for posture adjustment to prevent pain. The armrests in both sides of the chair also provide support to the arms.

Association between Ergonomic Mismatch and Self-Reported Pain – Wood-and-Metal

Sex was a significant confounder to the association between mismatch and pain. Adjusting for its confounding effect, students ergonomically mismatched with the Wood-and-Metal chair were 29% more likely to report pain in the different body parts. However, other factors affecting the presence of self-reported pain may still exist.

First, the wooden seat does not follow the contours of the body. Its rigidity is a source of pressure under the buttocks. This may have led to compression of the hip and butt which results to pain. Second, the backrest does not cover the entire back and is composed of interspaced wooden planks. As a result, students may tend to lean forward with their lower back extended to the space on the backrest. This prolonged stooping position can cause pain. Third, the non-retractable nature of the desk limits movement and posture adjustment. This may hinder the person to compensate properly and mitigate forced adjustments into non-neutral positions. Fourth, the compartment under the seat may have been used as an alternative footrest. However, instead of helping to ease leg discomfort, it may have caused compression of leg muscles as the feet are elevated for prolonged periods.

Association between Ergonomic Mismatch and Self-Reported Pain – Plastic

Students ergonomically mismatched with the Plastic chair were 54% more likely to report pain in the different body parts. This was a stronger association than in the Wood-and-Metal chair, but factors aside from ergonomic mismatch may still be present. The sitting surface is plastic and may contribute to the pressure exerted on the hip and butt area of the students. The smoothness of plastic may also tend the user to slide down to an awkward position. Meanwhile, the seat curvature can cause the thighs to be pressed, leading to compromised blood flow in the legs. It can also cause the legs to be hanging since the distal part of the thigh is higher. The feet are therefore unable to rest completely on the ground, leading to muscle strain. The non-retractable desk affects the student's motion and posture. In addition to this, the armrest can provide support to the forearm of the user.

Conclusion

All the respondents were mismatched with the Auditorium chair, with 100% mismatch in the SSH-to-BH. Neck pain (30.95%) was the most prevalent while arm pain (7.94%) was the least. The 100% mismatch with the Auditorium chair resulted in the lack of a comparison group so mismatched respondents were further divided into having "Mild" and "Severe" Mismatch based on the number of mismatched aspects. Students with mild mismatch were found to be 0.60 times more likely to report pain than those with severe mismatch.

89.68% of the respondents were mismatched with the Wood-and-Metal chair, with the highest mismatch in the HB-to-SW (77.78%) and none in the TC-to-SDC. Back pain (66%) and neck pain (75%) were the most common for the mismatched and matched students, respectively. Sex was a significant confounder. After adjusting for its effect, it was found that students with mismatch were 1.29 times more likely to report pain than those without.

88.10% of the respondents were mismatched with the Plastic chair, with the highest mismatch in the HB-to-SW (75.4%) and none in the TC-to-SDC. Both the neck and back pain were the most prevalent for those mismatched and matched. No significant confounder was found, thus students with mismatch were 1.54 times more likely to report pain than those without. For the three chairs, heaviness was the most prevalent pain quality in the neck and back, followed by numbness. Tingling was the most common for the leg.

Recommendations

Findings of this study may be considered in acquiring new chairs and desks, especially taking into account the aspects most frequently mismatched. Breaks during long lectures may also be incorporated to allow stretching and postural adjustments. This will improve vascular flow and reduce risk for nerve impingement.

A number of adjustments can be done to improve the quality of future studies. The use of standard measuring equipment can be touched upon to minimize variability in the manner of measuring the students. Several areas not touched on by this study can be considered for future research. The auditorium chair used degrees of mismatch to proceed further in the data analysis, yielding unexpected findings where the mildly mismatched were more likely to report pain than the severely mismatched. This result serves new questions and considerations for tackling the association between ergonomic mismatch and pain anew.

Since the study focused on mismatch between the chairs and respondents, the ergonomic design of the chairs themselves were not analyzed. This may include the presence of cushioning, the material of the chair, and the nature of the desks. Greater insight may be gleaned from analyzing these designs. On a larger scope, studies looking at ergonomics as a system could be pursued. Other factors like lighting, ventilation, relative position of chairs can be studied not only individually but as a system altogether. The study also set the scope of the analysis on pain to presence and absence. A similar form of analysis but with the severity of pain may yield greater understanding on the correlation of pain and ergonomic mismatch. The possibility of using a case-control study design to observe the effects of using specific chair types may also be explored. Other ergonomic mismatch studies that may be done can involve laboratory furnishings which may or may not be limited to the stools, as well as the office furnishings of the faculty and staff.

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