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ORIGINAL ARTICLE

Proposed Workstation Design in Laboratory for Musculoskeletal Disorder Complaints

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ABSTRACT

Introduction: Laboratory is a means of improving the effectiveness of learning. The problem faced by laboratory staff in performing their work (analysis and experimentation) is fatigue caused by long work time with inappropriate sitting posture and position. The use of a wooden chair without a backrest and with a seat height that is too high or too low can cause musculoskeletal disorders (MSDs). This study aims to provide a workstation design suggestion with attention to ergonomics to reduce complaints of musculoskeletal disorders. **Method:** This descriptive research used an observational method. The population in this research consisted of 31 female students of a feed laboratory user, and the sample consisted of 16 respondents at the SIKIA Laboratory. Data collection for this study was conducted from July to September 2022. The independent variable in this study was the dimension of the workstation, and the dependent variable was musculoskeletal complaints. **Result:** Anthropometric measurements on laboratory assistants of the SIKIA Laboratory showed that the average popliteal height was 53.25 cm. Assessment on musculoskeletal disorder complaints shows that most complaints are found on "Pain in the back" with a score of 36. A new chair and table design is proposed, where the width of the seat back is 39.75 cm. **Conclusion:** A new workstation design is proposed that focuses on ergonomics to reduce the complaints of musculoskeletal disorders.

Keywords: complaint, laboratory, musculoskeletal disorder, workstation design

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INTRODUCTION

To improve the effectiveness of education in the learning and teaching processes, it is necessary to obtain experimental simulations. As an appropriate learning facility, a laboratory was used to assist in the teaching process. The laboratory is an important support facility and is very strategic for the education system, especially in higher education. In general, laboratories carry out educational activities, research, and community services (Gunawan, 2019). A laboratory is a place to train users to understand concepts and improve their skills in scientific experimentation (Emda, 2017). The implementation of testing and analysis in the laboratory requires a set of tables and chairs as workstations. One of the problems faced by students in analyzing and experimenting is long working hours without the need for an ergonomic workstation.

In the laboratory, the principle of ergonomics is especially important for application in work systems to achieve the desired goals effectively, safely, and comfortably. In line with the regulation of the Health Ministry of the Republic of Indonesia Number 605/MENKES/SKNI1 of 2008 concerning the standards of the Health Laboratory, the Health Laboratory Center aims to ensure that each laboratory has good standards, including facilities, infrastructure,

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equipment, media, reagent, occupational safety and health, mutilation, and reporting standards (Fatimah and Indrawati, 2018).

SIKIA (Sekolah Ilmu Kesehatan dan Ilmu Alam) is an extension of the School of Health and Natural Sciences, which is under the auspices of the Universitas Airlangga in Banyuwangi, East Java. SIKIA consists of the Bachelor of Public Health, Bachelor of Veterinary Medicine, and Bachelor of Aquaculture Study Programs. The implementation of theory in class and verification of the compatibility between the theory and field conditions, namely the practicum, are inseparable; therefore, the laboratory is very important and is often used by students.

The workstation of the SIKIA Laboratory used a wooden chair without a backrest, where the seat height was too high, and the workbench was too low. The practicum conducted by the students required long working hours. Therefore, a sitting and bent working posture could potentially cause work fatigue that leads to complaints of musculoskeletal disorders (MSDs) in the laborer. From direct observation and discussion with the laboratory assistant as a user of the SIKIA Laboratory, it was found that the user experienced several complaints of back pain and uncomfortable buttocks during practicum because the chair base was too small and the table was too low.

Musculoskeletal complaints are complaints of the skeletal muscles felt by humans, ranging from mild complaints to severe pain. According to Rahdiana (2018), complaints of muscle fatigue result in muscle spasms, loss of balance, and sprains. Muscle fatigue can also lead to numbness (loss of sensation) in parts of the body that receive load.

The design of the workstation must be improved to achieve an effective, safe, and comfortable learning process. This can be done by including ergonomic factors to reduce complaints from laboratory staff. Ergonomic factors are expected to improve the comfort of people or laboratory staff when using the laboratory for practicum, so that their focus is improved and complaints of the aches they experience are reduced. Based on the above description, we propose a new workstation design based on the anthropometry of the staff to provide comfort, safety, and health to the staff.

METHOD

This research is a descriptive observational study that describes the phenomenon found in the form of risk factors without an analysis of how and why the phenomenon can occur, but uses statistical mean values (mean, median, mode) with standard deviation and percentage proportions. Determinants must be considered when designing a workstation that is adapted to the population.

The population in this study comprised 31 female users of laboratory feed. Random sampling was then performed. The research subjects were 16 respondents at the SIKIA Laboratory. Data were collected from July to September, 2022. In this study, the independent variable was the dimensions of the workstation and the dependent variable was musculoskeletal complaints.

Several data were collected during the data collection phase, namely the dimension of the workstation, dimension of the table, dimension of the laboratory anthropometric, and risk of musculoskeletal disorders (MSDs). The chair dimensions were the height of the chair and the circumference of the base of the chair. The dimensions of the table included the height, width, and length of the table, and the distance between the seat and bottom step. Laboratory anthropometric measurements included popliteal height, hip width, popliteal length, sitting shoulder height, shoulder width, elbow height in the sitting position, distance from the tip of the elbow to the fingertips, and extension of the reach of the hand forward from the shoulder to the fingertips. Data regarding the risk of musculoskeletal disorders (MSDs) were collected through observation and interviews using the Nordic Body Map instrument. A questionnaire with a score range of 1-4 was used, where 1 meant "no pain," 2 meant "feel quite the pain," 3 meant "feel the pain," and 4 meant "feel severe pain". The collected data will be used as a reference to redesign the workstation of the SIKIA Laboratory. This research was conducted based on an ethical test conducted by the Faculty of Dentistry, Universitas Airlangga No.451/HRECC. FODM/VII/2021.

RESULT

Existing Design of Workstation

Data collection was conducted by measuring the existing or initial design of the laboratory workstation. The dimensions of the table and chair were measured using a simple length measuring device. The results of the measurements were as follows:

Student Anthropometric

The anthropometric of students at SIKIA Laboratory SIKIA included the average popliteal height of 53.25 cm with a standard deviation of 3.231, while the average height of the elbow in the sitting position was 32.06 cm with a standard deviation of 2.28. Anthropometric measurements are presented in Table 2.

Nordic Body Map

Assessment of musculoskeletal disorder complaints using the Nordic Body Map on 16 respondents was conducted based on the questionnaire, classifying the complaint levels into "no pain" (1), "feel quite the pain" (2), "feel the pain" (3), and "feel severe pain" (4). The results are as follows:

The following chart shows Muscle complaints (MSDs) coming from the students. The highest score of complaint is found on the "Pain in the back" with a score of 36 while the lowest score of complaint is found on the "Pain in the left wrist" with a score of 17.

Table 1. Initial Data of Laboratory Workstation Design

Dimension of the body	Measurement Basis	Size (cm)
Body height in a sitting position measured from the floor to the inner knee	Seat Height	56
Hip Width	Seat Base Width	29
Thigh length up to the knee	Seat Base Length	-
Sitting shoulder height (TBD), measures the vertical distance from the surface of the seat mat to the end of the outermost shoulder bone.	High Backrest Seating	-
Shoulder width	Seat Back Width	-
Elbow height in sitting position	Table Height	78
Elbow tip to fingertip distance	Table Length	316
Length of hand reach forward from shoulder to fingertips	Table Width	132

Workstation Design

The anthropometric data in Table 4 were used to design a new workstation to replace the old workstation.

DISCUSSION

In this study, workstation dimensions, laboratory anthropometric data, and complaints of musculoskeletal disorders were used to create an ergonomic workstation design. This research is in line with other research that redesigns chairs and lecture tables to provide customized and ergonomic lecture workstations to users (Sinaga, Siboro and Marbun, 2021). This research is also in line with the other research conducted by Denaneer (2022), which shows that there is a meaningful relationship between chair ergonomics and musculoskeletal complaints in workers at Company X in Jambi. Dinar (2018) also showed that there was a significant relationship between the ergonomics of the chairs used when working with musculoskeletal complaints, namely, the length of the chair and the buttocks and popliteal.

Table 2. Anthropometric Measurement Data of student in the SIKIA Laboratory (n=16)

Size	Calculation				
	AVERAGE	SD	PER 5	PER50	PER95
Popliteal Height	53.25	3.23	48.44	53.25	58.6
Hip Width	42.56	3.84	36.29	42.56	48.92
Popliteal Length	50.56	3.62	45.1	50.56	56.57
Sitting Shoulder Height	59.25	2.98	54.83	59.25	64.21
Shoulder Width	39.75	3.09	35.16	39.75	44.88
Elbow Height in Sitting Position	32.06	2.28	28.82	32.06	35.86
Elbow Tip to Fingertip Distance	41.13	1.58	39.04	41.13	43.77
Length of Hand Reach Forward from Shoulder to fingertip	67	3.28	62.11	67	72.44

Anthropometric Measurement

In Table 2, the anthropometric measurements were adjusted to what was needed for designing tables and chairs, namely by measuring only the popliteal height, hip width, popliteal length, shoulder width, sitting shoulder height, and elbow tip-to-fingertip distance of the laborer. Anthropometry plays a role in designing a workstation by considering the body dimensions of the people who use the workstation (Fitra, Desyanti and Suhaidi, 2020). The anthropometric method is used as a reference for adjusting products related to humans, such as workstations. The use of anthropometry in the workplace aims to provide comfort and safety for workers to improve productivity and quality, which will provide an effective and efficient work influence (Windari *et al*., 2018).

Table 3. The Result of Nordic Body Map Questionnaire

Location	Total Score of Complaints
Pain in the upper neck	26
Pain in the lower neck	30
Pain in the left shoulder	23
Pain in the right shoulder	23
Pain in the left upper arm	20
Pain in the back	36
Pain in the right upper arm	18
Pain in the waist	35
Pain in the buttock	27
Pain in the bottom	28
Pain in the left elbow	21
Pain in the right elbow	20
Pain in the left lower arm	20
Pain in the right lower arm	18
Pain in the left wrist	17
Pain in the right wrist	18
Pain in the left hand	19
Pain in the right hand	20
Pain in the left thigh	24
Pain in the right thigh	24
Pain in the left knee	22
Pain in the right knee	23
Pain in the left calf	21
Pain in the right calf	21
Pain in the left ankle	19
Pain in the right ankle	19
Pain in the left foot	19
Pain in the right foot	19
Total Score	630
Average	22.5

Complaints Nordic Body Map

From the answers of 16 respondents obtained through the Nordic body map questionnaire, eight locations of musculoskeletal disorders were identified. A high score of complaints was found in the back with a total score of 36, waist with a total score of 35, bottom of the neck with a total score of 30, bottom of the buttock with a total score of 28, buttock with a total score of 27, top of the neck with a total score of 26, and right and left thighs with a total score of 24.

This research is in line with the research conducted by Djaali (2019), who used the Nordic body map questionnaire and found that the respondents (employees) felt pain in the waist, 12.43% in the lower neck at 9.84%, and 10.36% in the upper neck. Pain in the waist was felt because the laboratory chair was not ergonomic and the working hours were long. Uncomfortable conditions cause the body to become depressed, resulting in lumbago and aches.

The results of the research conducted by Santosa and Ariska (2018) stated that muscle strength in women is 2/3 of male muscle strength, so that women experience complaints of musculoskeletal disorders more than men. Another study conducted on cleaning service workers in Semarang City Hospital also found that MSDs complaints occur more frequently in women than in men.

This research is also in line with the research conducted by Jaelani *et al*. (2022). They found that the workers of Yuriko Indonesia who performed the process of printing, cutting, and gluing materials

Table 4. The Data of Laboratory Workstation Proposed Design

Workstation Dimension	Percentile	Size (cm)
Seat height	95	58.6
Width of Seat Base	95	48.92
Seat Base Length	95	56.57
High Backrest Seating	95	64.21
Seat Back Width	50	39.75
Table Height	95	35.86
Table Length	95	43.77
Table Width	95	72.44

in UD also felt pain (especially in the left and right legs). The pain was caused by non-ergonomic workstations, such as chairs and tables, that were not proportional to the workers' bodies.

Complaints caused by a long sitting position with no seat flexible movement and transfer of view that causes disorders of the back and neck cause the spine to curve.

Workstation Design

Table 4 describes the new workstation, including the reduction of the height and length of the table to 35.86 cm and 43.7 cm. The ergonomic design of the workstation for laboratory staff is obtained by considering the student anthropometric data so that the result of the redesign is in line with the needs of its users. The design of this workstation must follow the dimensions of the population that will use the workstation (Sokhibi, 2017).

Workstation is an important component in the workplace because it can provide comfort for the user and help workers avoid discomfort (Denaneer, 2022) . If the workstation does not match the dimensions of the user, the resulting physical fatigue and discomfort will be significant (Wulandari D, 2018)

Seat Height

The height of the chair was adjusted to the height of the body in a sitting position, measured from the floor to the inner knee, with a percentile of 95. The original chair size was 56 cm. The size needs to be increased by 2.60 cm so that the final size is 58.60 cm, rounded to 59 cm for seat height. This addition is expected to provide comfort for students with long legs. According to Himarosa (2019), chair height should be adjusted to the popliteal dimensions, enabling the knee to bend at an angle of 30° relative to the vertical axis. By contrast, Sokhibi (2017) designed the height of a chair using the 50th percentile with a value of 42.6 cm. The mismatch between the height of the chair and table in the biomedical laboratory room is associated with a low risk of musculoskeletal disorders (Tjahayuningtyas, 2019).

Width of Seat Base

To provide support to the lower thighs and hips, the width of the chair is determined using the hip width because the plane on the seat must be able to accommodate the size of the hip bone width and enable it to be easily swung back. Hip width data on student took the 95th percentile with a value of 48.92 cm or rounded to 49 cm with a square shape (originally a 29 cm circle) to increase the comfort level of students. The use of the 95th percentile value is reinforced by Mesra (2017), who stated that large men can use a chair and even small men can use it. The base of the chair was equipped with a soft cushion to reduce pain in the buttocks.

The seat cover must be wider than that of the hips to fulfill the room capacity and chair model criteria (Suryatman, 2019). Wibowo (2012) stated that the seat base should be determined using wide waist measurements for ease of use.

Seat Base Length

The length of the thigh to the knee using the 95th percentile was 56.57 cm or rounded to 57 cm. The length of the base of the chair was designed based on anthropometric measurements of the length of the thigh to the knee, to support most of the buttock and thigh area. This is in line with research (Wibowo, 2012) which stated that the length of the seat base is based on popliteal measurements for ease of use. The length of the chair base must have a difference of 1.24 greater than the data obtained from anthropometric calculations (Suryatman, 2019).

The initial design of the chair was round in shape, which caused pain in the right and left thighs of the laboratory worker, as shown in Table 3. Therefore, the length of the chair must be increased so that laboratory workers feel comfortable when sitting with their legs, forming 900. This is in line with research (Fitri, Adelino and Putra, 2021) where the design of a chair with a short base length was replaced with a longer chair to provide comfort for the user. However, the previous chair was not ergonomic.

High Backrest Seating

The height of the seatback is determined by the anthropometric data of sitting shoulder height, which measures the vertical distance from the surface of the seat to the end of the outermost shoulder bone. The height at the 95th percentile was 64.21 cm or rounded to 64 cm. The initial design of the chair did not include a backrest. This leads students to complain about back pain. Therefore, a good backrest height should be able to hold 60-80% of the height of the worker's shoulder when sitting.

The shape of the backrest should be adjusted to the shape of the arch on the spine, and the height of the backrest should be able to rest the entire back, namely, up to the cervical vertebrae (Kautsar and Dewi, 2020). The provision of foam on seatback provides comfort during the learning process (Fitri, 2021). The backrest should be able to support the back of the head (Irma Puspitasari, 2017).

Seat Back Width

The width of the seatback was designed based on the width of the upper shoulder. According to Pheasant (2019), the back of the chair must accommodate the entire back of the user to facilitate comfortable learning. Based on anthropometry data using the 50th percentile, the width was 39.75 cm or rounded to 40 cm. The 50th percentile value is chosen to cover the worker with a percentile value of less than 50 so that the comfort level of the laboratory worker increases, and also to provide the freedom of movement of the elbow by making the back not too wide (Noviarmi and Ningtiyas, 2018).

The width of the backrest is required to match the anthropometric back of the chair user/worker, and the angle of the backrest is tilted back more to provide a comfortable impression to the chair user (Irma Puspitasari, 2017). In contrast to previous research (Wibowo, 2012), the width of the seatbacks of the land over chair is smaller than the average person's shoulder width, which is unable to fully support the passenger shoulders and causes discomfort to the user.

Table Height

The table height was determined based on the elbow height in the sitting position (35.86 cm plus a popliteal height of 58.6 cm. With the 95th percentile, the table height was 94.46 cm or rounded to 95 cm. The addition of the table height is expected to facilitate more comfort and ease of use of the table.

According to Muis *et al*. (2022), the height of the table must be adjusted by the operator without having to change the position, and the table is used as a place to lean and provide comfort to the user.

For a craftsman, the height of the workstation must be increased to 70 cm to provide a healthy, safe, and comfortable work environment according to anthropometric data (Soewarno, 2017). The ideal table height makes it easier for the user to see the monitor without feeling fatigued and injuring the body above the neck (Qurthuby, 2019).

Table Length

From anthropometry, the elbow tip-to-fingertip distance for the new design of 44.22 cm or rounded to 44 cm is expected, with the use of 95 percentile. The long range provided by the table increases user comfort during the practicum. For example, Rama Jaya Motor Workshop workers feel comfortable after being given a long table according to the anthropometry of the workers, and consequently, decrease their work complaints (Ockyta, Darsini and Ahya, 2020).

The length of the table is taken from the anthropometry of shoulder width using the 95th percentile, so that people with a shoulder width above the average can use the table comfortably (Qurthuby, 2019). The laboratory table is different from a gaming table, where the height of the table legs and table leveling can be adjusted according to the user's height. The initial height of the table was 75 cm, which could be raised to 82 cm. The leveling on the table could be raised to 15 cm (Aprillina *et al*., 2019).

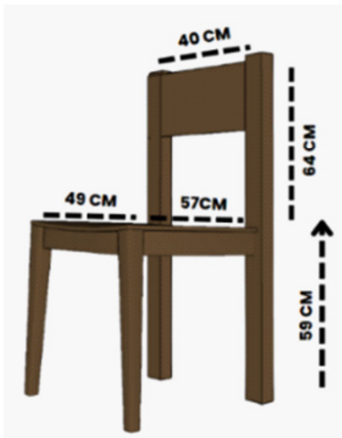

Figure 1. The New Design of the Laboratory Chair

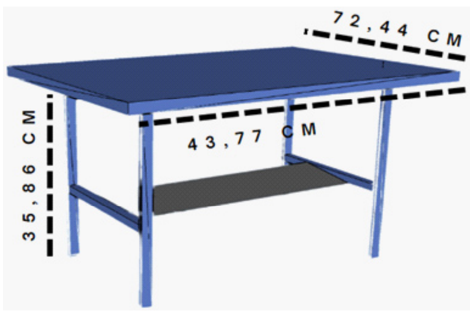

Figure 2. The New design of the Laboratory Table

Table Width

The width of the table was determined on the basis of the anthropometric length of the hand reaching forward from the shoulder to the fingertips of the laboratory worker. With the 95th percentile, the table width of 72.89 cm or rounded to 73 cm was expected to provide more free hand movement when conducting the practicum. This is in line with previous research conducted by (Aras, Rahmatika, Putra, 2019) in cerebral palsy, where the students can reach the keyboard with a comfortable sitting position by adjusting the table width to the anthropometric data of the user.

The width of the table is adjusted to the user's anthropometry for people who have below-average hand reach to reach the equipment properly (Qurthuby, 2019). The width of the table must accommodate special equipment for playing games such as mice, mousepads, keyboards, headsets, and gaming monitors (Aprillina *et al*., 2019).

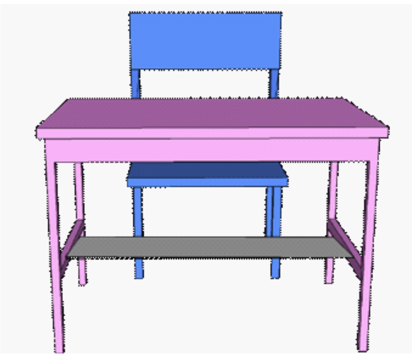

Figure 3. The New Design of the Laboratory Table (Front View)

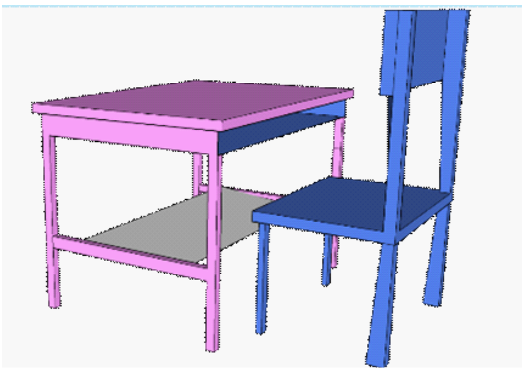

Figure 4. The New Design of Laboratory Table (Side View)

Footrest

The latest footrest was designed with a slope of 150 (Noviarmi and Ningtiyas, 2018). A footrest or step is needed so that a user with a small posture can sit comfortably. A sufficient leg space can provide comfort to the user. This can be achieved by using a footrest that can be reached by the foot/leg of the user when sitting (Irma Puspitasari, 2017). Unreachable footrest may cause swelling of the feet, pain in the ankles, and sore thighs due to pressure from the edge of the chair (Setyaningsih, 2019).

Workstation Design

The new workstation was designed based on anthropometric data. The new dimensions of the table and chair were obtained. The design of the workstation is selected by considering the wishes of the users and the ergonomic aspects to provide comfort and increase concentration during the learning process (Fitri, Adelino and Putra, 2021).

In the new workstation design, the width of the seat exceeded the average butt and hip widths for comfort. A backrest is also equipped with a design that provides comfort to the user's spine. Meanwhile, in the new design of the table, the height of the table is lowered to make it easier for laboratory assistants to conduct practicums, and the length of the table is shortened to make it easier for users to reach objects in the table area.

CONCLUSION

Based on the analysis, the existing workstations commonly used by laboratories are not suitable for use and cause musculoskeletal complaints in users. Therefore, the workstation was improved using anthropometric data from the laboratory to meet user standards. The new workstation design is expected to improve occupational health so that laboratories can be protected from various occupational diseases.

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