

The application of ergonomics to improve work productivity

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ABSTRACT

Ergonomics in the workplace is an aspect that must be considered, because it has potential hazards such as work position, inappropriate body posture when doing work, design of work tools, workplaces that are not in accordance with labor anthropometry, and lifting loads that exceed work capacity. By implementing ergonomics in the workplace, a safe and comfortable work system, work environment, and work equipment will be created for all workers. So that workers can avoid injury or accidents while working, but it can also avoid occupational diseases. Therefore, work facilities must be designed ergonomically so that it has an impact on increasing work productivity.

Keywords: *Ergonomics, work facilities, work productivity*

INTRODUCTION

The rapid development of technology in this era of globalization has led to equipment becoming a fundamental necessity in the workplace. Consequently, occupational health and safety issues have become more complex, such as work-related diseases (WRD) and work-related accidents (WRA) (Indah, 2000). Work activities take up 1/3 of the time per day. If the position when working is not good, it can cause work-related skeletal muscle disorders such as fatigue, neck pain, shoulder pain, back pain, lower back pain, forearm muscle pain, wrist pain, vascular disorders, headaches and other disorders (NIOSH, 2010). This literature review explains its importance the application of ergonomics in the workplace so that workers avoid these problems. Working ergonomically creates a work system, work environment, and work equipment that is safe and comfortable for all workers. Therefore work facilities must be designed ergonomically so that it has an impact on increasing work productivity. Ergonomics is a science that studies the compatibility between humans, work, and the environment. Its aim is to ensure harmony between workers, equipment, work processes, and the work environment, reducing discomfort during work and ultimately achieving optimal work productivity (Suma'mu, 2014). According to the National Institute for Occupational Safety and Health (NIOSH), ergonomics involves the application of scientific knowledge to design facilities, tools, and equipment in accordance with the anatomical, physiological, biomechanical, perceptual, and habitual characteristics of humans (NIOSH, 2010).

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The application of ergonomics in the workplace can prevent early fatigue from escalating into chronic and fatal conditions. Ergonomics plays a crucial role in enhancing occupational health and safety factors and improving work efficiency, thus increasing worker productivity (Indah, 2000). This principle is reflected in labor laws and regulations, such as the Labor Law No. 13 of 2003, which emphasizes the need for workplace safety measures to protect workers' safety and achieve optimal work productivity (Presiden RI, 2003). Similarly, the Law No. 1 of 1970 states that occupational safety is a primary means to prevent accidents, disabilities, and fatalities resulting from workplace accidents (Presiden RI, 1970).

Ergonomics plays a significant role in improving occupational health and safety factors, for instance: design of a work system to reduce pain in the musculoskeletal system, design of a workstation for visual displays. This is to alleviate visual discomfort in working postures, design of a working tool to reduce work fatigue, design of an arrangement of instruments and control systems for optimal information transfer processes by generating quick responses while minimizing work risks and the occurrence of errors, as well as achieving optimization, work efficiency, and reduction of health risks due to inappropriate working methods (Nurmianto, 2008).

ERGONOMICS OBJECTIVES

The objectives of applying ergonomics in the workplace include: 1) Preventing WRD and WRA through work system/method redesign and administrative control, such as job rotation, shift work, and break scheduling, 2) Achieving productive work systems with good work quality, combined with comfort, ease, and efficiency (Nurmianto, 2008; Iridiastadi, 2014; Santoso, 2004).

APPLICATION OF ERGONOMICS

According to Tarwaka (2008), ergonomic principles should be applied while working: 1) Maintain a normal posture/position, 2) Reduce the workload, 3) Ensure equipment is within reach, 4) Align work according to body dimensions, 5) Minimize repetitive and excessive movements, 6) Minimize static movements, 7) Consider load points, 8) Consider spatial distances, 9) Create a comfortable work environment, 10) Perform light exercises and stretches while working, 11) Ensure displays and instructions are easily understandable, 12) Reduce work-related stress. The application of ergonomics in the workplace is as follows:

1. Job position

According to Iridiastadi (2014), a job position is a human body posture that can depict the body's position from head to toe in relation to the type of work activity. Job position is greatly influenced by the type and workload that the worker undertakes. Each job position has a different impact on bodily health. Job positions or workstations can be divided into three main types: sitting workstations, standing workstations, and a combination of both (sit/stand workstations). Sitting position involves the legs not bearing the body weight and maintaining a stable position during work. This position is the most commonly used choice in companies and is considered the most comfortable and least tiring. Sitting job positions can be the preferred choice when one of the following conditions is met: a) Jobs that only involve the use of hands and do not require significant muscular effort, b) Objects needed during work can be easily reached even while sitting and are within arm's reach in a sitting

job position, c.) The most common use of the sitting job position is in office tasks such as writing, typing, etc.

On the other hand, a standing job position can be defined as a work position where the legs are not burdened by body weight and a stable position is maintained while working. Additionally, the standing job position relies more on leg muscles. Types of jobs that involve a standing job position include: a) Jobs that require handling heavy goods/materials, b) Jobs that involve reaching for distant objects frequently, c) Jobs that require a relatively high level of mobility.

2. Antropometri

When sitting in the office, you will feel uncomfortable if: 1) the chair you use to sit is too low or too high, too wide or too narrow; 2) Employees will feel uncomfortable when using tools that are too small or too large; 3) Employees cannot reach an object if it is too high or too far from their work desk. Incompatibility between the design outcomes and human body dimensions will result in discomfort in using the design, leading to fatigue and work-related stress. If this persists for a prolonged period, it will lead to mistakes in performing tasks and even worse, workplace accidents. By knowing the dimensions of workers' bodies, work equipment designs, workstations, and products can be created that align with workers' body dimensions, thus creating comfort and facilitating users in their activities, ultimately enhancing work capacity, which in turn impacts increased work productivity (Purnomo, 2013).

According to Pulat (1992) and Wickens (2004), the application of anthropometric data in the design process is as follows: a) Determine the user population of the design product or workstation. Different individuals within age groups have distinct physical characteristics and needs. The same applies to gender, race, ethnic groups, civilian or military populations; b) Identify the body dimensions estimated to be important in the design (e.g., eye height when seated, toe height, hip width, popliteal height, etc.). For instance, when designing an entrance, the height and maximum shoulder width of users must be considered. Meanwhile, seating design should accommodate the user's hip width; c) Select a percentage of the population to accommodate in the design. It's not feasible for a design to accommodate 100% of the user population; d) For each body dimension, determine the relevant percentile values by referring to anthropometric tables. If percentiles are not available in the table, then use the mean and standard deviation of the dimension from anthropometric data; e) Provide allowances for existing data if necessary. Clothing is one of the factors that must be considered when making allowances. Allowances are also needed for accessories such as shoes, gloves, masks, and head coverings; f) Use mock-ups or simulators for design testing. Designers need to evaluate whether the design meets the requirements. Simulators can be employed to test the design using a sample of users to conduct simulations.

3. Design Both

Human-machine system design and workstation design are interdependent aspects of design. The goal of this design is to achieve high comfort to enhance work productivity. For example, the use of computers in offices aims to improve worker performance. However, if the design of the human-machine system, in this case, workers interacting with computers, is not ergonomic, it can lead to musculoskeletal disorders and early fatigue, resulting in decreased worker performance. If this issue is not addressed and persists, it can lead to significant losses for both workers and the company (Purnomo, 2013). In the design process, it's essential to consider who the users of the design are. Therefore, designers must

have a clear understanding of the design's users to ensure that the design outcomes align with expectations. The concept of using range estimation, through percentile values, is frequently employed. The commonly used percentile values are the 5th percentile (small percentile) and the 95th percentile (large percentile) (Eastman Kodak Company and Ergonomics Group, 1986).

The things that need to be considered in design:

A. Range Dimension

The use of the range dimension in control design is expected to accommodate users with the shortest arm span in the population. If individuals with shorter arm spans can use it, those with longer arm spans can also use it (Eastman Kodak Company and Ergonomics Group, 1986).

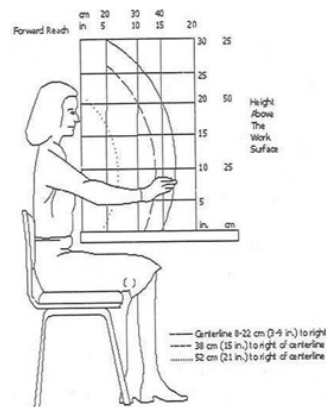


Figure 1. Range area with 5th percentile for female workers
(Source: Eastman Kodak Company, 1986)

Figure 1 illustrates the concept of range using the 5th percentile, where in this concept, workers can comfortably reach tools or work objects without the need to bend, thus avoiding stretching. If a larger percentile is used, then the shortest individuals in the population will face difficulties in accessing items (Panero, 1979).



Figure 2. Range of Short Body Dimensions at a High Percentile
(Source: Purnomo H, 2013)

The above Figure 2 demonstrates that using a higher percentile in the design of medicine box placement would be challenging for individuals with shorter reach within the population. Therefore, it is necessary to use a lower percentile so that individuals with shorter reach can also access the medicine (Purnomo, 2013).

B. Space Dimension

The space dimension is essential in design implementation, such as door height and width. Designing door height aims to allow the tallest individuals to pass through the door safely without head-door collisions. Even door height requires sufficient clearance to accommodate factors that might increase body height, such as shoes or tall hats (Purnomo, 2013).



Figure 3. Door Height and Width with a High Percentile
(Source: Purnomo H, 2013)

The above Figure 3 illustrates that when the door height and width are designed using a higher percentile, individuals with both tall and short stature can easily pass through the door (Purnomo, 2013).

C. Seating Design

Regarding the seated working position, the chair should be designed ergonomically. This is closely related to other facilities, requiring alignment between the facilities and the chairs being used. This alignment ensures that workers enjoy their tasks and remain productive over extended periods (Panero, 1979). When a designer is tasked with creating a chair, the first step involves identifying spatial dimensions and reach dimensions. Chair height falls into the reach dimension category, while the width of the seat pan is classified as a spatial dimension. The use of percentiles in these calculations is adjusted based on their respective categories. Spatial dimensions employ a higher percentile, whereas reach dimensions utilize a lower percentile (Purnomo, 2013).

The seating design is as follows:

a. Chair Height

The chair height is determined using the female popliteal height. This choice is based on the fact that female popliteal height is shorter compared to males. Selecting popliteal height is essential for designs emphasizing reach dimensions, where the shortest individuals should be able to use the design. Meanwhile, the seat pan width uses male hip breadth because male hip breadth is generally greater than that of females. In this context, it is recommended to use a broader hip breadth to accommodate the widest individuals in the population (Purnomo, 2013).

Popliteal height refers to the vertical distance from the floor surface to the inner knee with the knee angle at 90°. The population's popliteal height (T_{po}) varies significantly,

necessitating accurate measurements for seat height design. To accommodate all users in the population, a small percentile is used, for example, the 5th percentile from anthropometric data. The 5th percentile is chosen because lower seat heights tend to be more comfortable than excessively high ones. The male Tpo value is 43.5 cm with a standard deviation of 2.8 cm, while the female Tpo value is 39.9 cm with a standard deviation of 2.1 cm. If the 5th percentile is used, the chair height for males would be 38.9 cm, and for females, it would be 36.4 cm. Figure 4 below illustrates the sitting positions when the seat base is too high or too low (Panero, 1979).

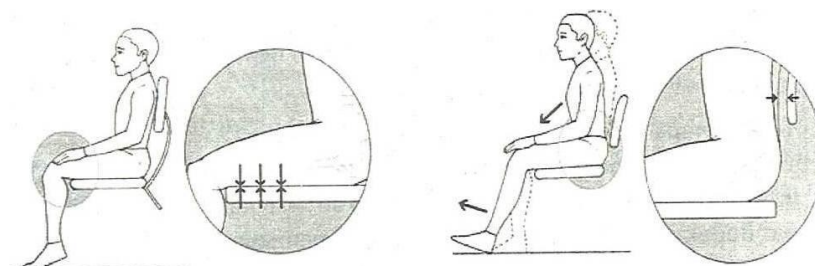


Figure 4. Seating that is Too High and Too Low
(Source: Purnomo H, 2013)

Based on the above Figure 4, if the chair height is not suitable for the user, it can lead to various challenges during work activities. An excessively high seat height, exceeding the user's popliteal height, can create pressure on the lower thighs, reducing blood circulation in the lower extremity muscles, causing tingling and swelling in the legs. Moreover, a seat that is too high prevents the feet from fully touching the floor surface, weakening body stability. On the other hand, a seat that is too low causes the knees to bend. To cope with this posture, individuals might scoot forward or bend their lower legs backward. When the seat is too low: 1) One's back will hunch forward due to the sharp angle formed between the thighs and the back; 2) It becomes difficult to stand up and sit down; 3) More space is needed for the legs (Pheasant and Haslegrave, 2006).

b. Seat Length

The seat length refers to the length of the seat pan, measured from the front edge to the back edge. Using inaccurate anthropometric data for designing seat length can result in a seat length that doesn't match the body dimensions. The body dimension used here is the popliteal-buttock length (Ppp), which is the distance from the buttocks to the inner knee. The recommended seat length should support the buttocks and a significant portion of the thighs. The use of percentiles for seat length depends on user requirements, as using either the 5th percentile or the 95th percentile remains within tolerance limits. If using the mean values, the Ppp is 43.9 cm for males and 43.4 cm for females (Panero, 1979).

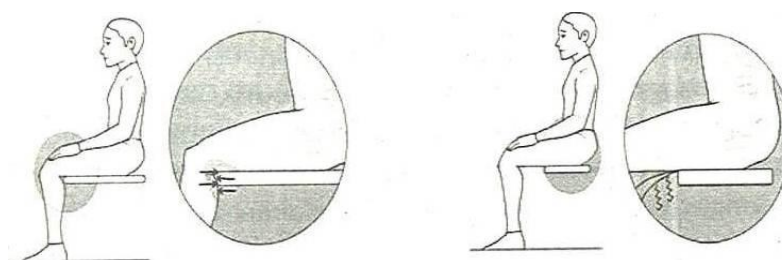


Figure 5. Seating that is Too Long and Too Short

(Source: Purnomo H, 2013)

Figure 5 illustrates the problems caused by chairs that are either too long or too short. This discrepancy can lead to serious issues. A chair that is too long can press against the inner knees, disrupting blood circulation in the legs. If this occurs repeatedly, it can lead to circulatory issues. To alleviate this, individuals might adjust their sitting positions by leaning forward to reduce pressure on the back of the knees. However, this compromises body stability as it becomes challenging to comfortably rest against the backrest. Conversely, a chair that is too short causes discomfort during use. This discomfort arises from the reduced seat area to support the thighs. In this scenario, users might feel as if they are slipping off the seat, causing their upper bodies to tilt forward. This stance weakens body balance, making individuals susceptible to gravity-induced tipping. An uncomfortable seat length design can disrupt work activities, leading to decreased (Panero, 1979).

c. Seat Width

The width of the seat is an important aspect to consider in seat design. The reference variable for measuring seat width is hip breadth (Lp). The seat width design should accommodate the widest individuals in the population, ensuring the comfort of those with greater size. A seat that is too narrow can cause discomfort for larger individuals or those using armrests. Thus, the design concept for seat width should use a larger percentile, such as the 95th percentile up to the 99.5th percentile. The Lp value is 35.8 cm with a standard deviation of 4.9 cm for males, and 35.4 cm with a standard deviation of 2.9 cm for females. Using the 95th percentile, the seat width for males would be 43.9 cm, while for females, it would be 40.2 cm (Panero, 1979).

d. Backrest

Most chairs are equipped with backrests, the function of which varies depending on their purpose. Office chairs typically feature low and medium backrest sizes. A low backrest design supports the lower lumbar and thoracic areas, while a medium-sized backrest supports the upper back up to the shoulders. High backrest designs are intended to support the entire back and head. To ensure comfortable sitting, the backrest is designed to be flexible, allowing for reclining. Comfort hinges on the angle formed between the thighs and the spine. A larger angle shifts the spine's load onto the backrest, reducing compression between the spine and pelvis and improving lumbar lordosis. Commonly, the backrest angle for office work ranges from 100° to 110° (Pheasant and Haslegrave, 2006).

e. Armrest

The armrest design is intended to support the arms during activities like office work or computer usage. It also aids in comfortable sitting and standing, particularly for larger individuals, the elderly, and pregnant women. Armrests help maintain body stability and prevent leaning forward. Obstetric clinics could consider using chairs with armrests for pregnant women. Additionally, industries with a predominantly female workforce could provide armrest-equipped chairs to support pregnant workers (Hirao and Kajiyama, 1994).

The size of the armrest is based on the body dimension called seated elbow height (Tsd). Tsd is measured from the seat surface to the bottom of the elbow. Precise measurement is crucial because seated elbow height varies significantly. If the armrest is too high, an individual might raise their shoulders, leading to quick fatigue during activities. Short armrests are easier to address compared to tall ones. Hence, careful consideration of

percentiles is needed. The use of percentiles, ranging from the 5th percentile to the 50th percentile, is recommended for designing armrest height. The range is from the 5th percentile as the lower limit to the 70th percentile as the upper limit, resulting in an armrest height of approximately 17.8 cm to 25.4 cm (Panero, 1979).

The height of the armrest is around 20 cm to 25 cm. The Tsd value for males is 23.4 cm with a standard deviation of 2.7 cm, while for females, it is 23.3 cm with a standard deviation of 3.0 cm. Using the 5th percentile, the lower limit of the armrest height is 18.9 cm for males and 18.4 cm for females. Therefore, the armrest height ranges from 18.9 cm to 23.4 cm for males and 18.4 cm to 23.3 cm for females. The variation in armrest height is influenced by the user population. Consequently, understanding the user population is crucial when designing armrest height. European and American body dimensions differ from those of Indonesians, which affects design differences (Purnomo, 2013).

4. Workplace Layout:

The workspace display should be clearly visible when performing work activities. International symbols are commonly used more frequently than words (Depkes RI, 2011).

5. Lifting Loads:

Lifting activities have the potential to cause workplace accidents, involving coordination between the body's control systems, such as hands, feet, brain, muscles, and spine. Excessively heavy loads can cause injuries to the spine, muscle tissues, and joints due to excessive movement. Loads lifted should not exceed the ILO-defined regulations: a) Adult males 40 kg; b) Adult females 15-20 kg; c) Adolescent males (16-18 years) 15-20 kg; d) Adolescent females (16-18 years) 12-15 kg (Depkes RI, 2011)

CONCLUSION

The implementation of ergonomics plays a crucial role in enhancing work productivity. Ergonomics helps create a work environment that aligns with the physical and psychological needs of employees, thus reducing the risks of injuries and fatigue, while also improving comfort and efficiency in work. Through adjustments in equipment design, proper posture, and optimal spatial arrangements, ergonomics can alleviate the physical and mental burdens on employees, enabling them to work better and more productively. By prioritizing employee well-being through an ergonomic approach, companies can achieve long-term benefits, including increased productivity, improved work quality, and reduced costs associated with injuries or absenteeism. Therefore, the integration of ergonomics into human resource management strategies and workplace design is crucial in creating an environment that supports optimal productivity and the well-being of all individuals involved.

REFERENCES

- Depkes RI. Ergonomi. <http://www.depkes.go.id/downloads/Ergonomi.PDF>, 2011
- Eastman Kodak Company, Ergonomics Group. Ergonomic design for people at work. New York: Van Nostrand Reinhold; 1986.
- Hirao N & Kajiyama M. Seating for pregnant workers based on subjective symptoms and motion analysis. In Lueder R and Noro K., (Eds). Hard fact about soft machines: The ergonomics of seating. London: Taylor & Francis; 1994.

- Indan E. Ilmu kesehatan masyarakat. Bandung: PT. Citra Aditya Bakti; 2000.
- Iridiastadi H. Ergonomi suatu pengantar. Bandung: PT Remaja Rosdakarya; 2014.
- NIOSH. Musculoskeletal disorder dan workplace factors, A critical review of epidemiologic evidence for work-related MSDs of the neck, upper extremity and low back. US: Department of Health and Human Service; 2010.
- Nurmianto E. Ergonomi: Konsep dasar dan aplikasinya. 2nd. Surabaya: Guna Widya; 2008.
- Panero JP & Zelnik M. Dimensi Manusia dan Ruang Interior. Jakarta: Penerbit Erlangga; 1979.
- Pheasant S & Haslegrave CM. Bodyspace, Anthropometry, Ergonomics and The Design of Work. London: Taylor & Francis; 2006.
- Presiden RI. Undang-Undang Republik Indonesia nomor 13 tahun 2003 tentang Ketenagakerjaan. Jakarta: Sekneg RI; 2003.
- Presiden RI. Undang-Undang nomor 1 tahun 1970 tentang Keselamatan Kerja. Jakarta: Sekneg RI; 1970.
- Pulat BM. Fundamentals of Industrial Ergonomics. New Yersey, USA: Hall International, Englewoods Cliffs; 1992.
- Purnomo H. Antropometri dan Aplikasinya. Yogyakarta: Graha Ilmu; 2013.
- Santoso G. Manajemen K3. Surabaya: Prestasi Pustaka; 2004.
- Suma'mur. Higene Perusahaan dan Kesehatan Kerja. Jakarta: Sagung Seto; 2014.
- Tarwaka. Keselamatan dan Kesehatan Kerja. Manajemen dan Implementasi K3 di Tempat Kerja. Surakarta: Harapan Press; 2008.
- Wickens CD, Lee JD, Liu Y, Becker SEG. An Introduction to Human Factors Engineering. New Jersey: Prentice Hall; 2004.