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(Research Article)

Analysis of physiological productivity levels in workers before and after ergonomics intervention of lightweight brick cutting tools

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Abstract

Brick cutting is a critical activity that requires precision and physical strength. Using brick-cutting tools that are not ergonomically designed often leads to unnatural working postures, such as hunching or bending over for prolonged periods. This study aims to analyze the effects of ergonomic interventions on reducing musculoskeletal complaints and increasing physiological productivity among lightweight brick-cutting workers. The sample consisted of five male workers, with an average age of 30, who worked 6 hours per day. Ergonomics interventions included redesigning the pedal switch for easy access, adding a footrest, and improving the work chair with a backrest and foam cushion. Results showed a 49.34% reduction in average musculoskeletal complaints (from 62.8 to 31.8) and a 4.08% increase in physiological productivity (from 275.2 to 286.4 pcs/6 hours). Improvements in tool design increase comfort, postural stability, and movement efficiency, thereby reducing physiological stress and increasing productivity. It was concluded that applying ergonomics principles to lightweight brick-cutting tools significantly improved comfort and work efficiency.

Keywords: Brick Cutting; Work Posture; Physiological Productivity; Ergonomics Interventions

1. Introduction

Brick cutting is a common activity in the construction industry, particularly in the manufacturing or sizing of building materials. This activity is generally performed manually using simple cutting tools, requiring physical strength and precision. Using less ergonomic tools often leads to fatigue, the risk of muscle injury, and decreased work productivity. Ergonomics plays a crucial role in designing tools and work systems that are suited to human capabilities and limitations. By applying ergonomics principles, it is hoped that physical workloads can be reduced, comfort increased, and work results optimized. Work is performed in unnatural postures, thus not in accordance with ergonomics principles. Musculoskeletal disorders and their exposure increase the risk of occupational injuries due to unnatural and unusual working postures [1, 2]. Therefore, ergonomic interventions are needed to improve brick-cutting tools to suit the operator's posture and abilities better.

Ergonomics plays a crucial role in adapting tools, environments, and work methods to human capabilities and limitations. Through ergonomic interventions, brick-cutting tools can be redesigned to support a more natural working posture —one that is comfortable, balanced, and in accordance with principles of human biomechanics. This change in working posture is expected to reduce excessive physical load, musculoskeletal complaints, and the risk of injury, and to improve worker comfort and performance. The decline in musculoskeletal disorders (MSDs) is currently widely

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attributed to ergonomic interventions, and ergonomic equipment categorization is needed to support specific-task and posture analyses [3, 4]. The IEA explains that design, in optimizing human well-being and overall system performance, is related to understanding the interaction between humans and other elements of a system, and that the profession is grounded in ergonomics [5]. Unnatural work postures increase musculoskeletal complaints, including fatigue, and the risk of muscle injury, and cause additional health costs, increased workloads, and decreased productivity [6, 7, 8, 9]. The emergence of musculoskeletal complaints due to non-ergonomic postures reduces productivity [10, 11].

Productivity encompasses both general and physiological productivity. Physiological productivity refers to the human body's ability to perform at optimal levels based on its physical condition and bodily functions. Unlike general productivity, which emphasizes work results or output, physiological productivity focuses more on the relationship between a worker's physical condition (such as muscle strength, fatigue, posture, and energy consumption) and the ability to produce work output. To increase productivity calculated physiologically, the design or redesign of work tools requires collaboration from different scientific fields. For example, the redesign of work tools involves cooperation between the fields of ergonomics and mechanical engineering, known as ergo-mechanical engineering. Ergo-mechanical applications can be used to address work problems related to work tools, ergonomics, and occupational health and safety [12]. Modifying work equipment with ergonomic interventions within the production process reduces unnecessary movements, physical demands, workers' compensation costs, and injury rates [13].

Figure 1 Worker working on a lightweight brick cutting machine before ergonomic intervention [14]

As in the lightweight brick cutting process shown in Figure 1, which causes musculoskeletal complaints with an average value above 60 [14]. Corrective action is needed for musculoskeletal complaints with a score of 50-70, which is in the moderate risk category [11]. Working postures, as shown in Figure 1, affect worker productivity. In this case, productivity is based on physiology, that is, productivity viewed from the perspective of the worker's physical and physiological abilities. This differs from general productivity, which focuses solely on output. General productivity is the ratio of output (work results) to input (resources), such as time, energy, costs, and materials. General productivity focuses on work results or performance, such as output per unit of time, work efficiency, and product quality. Meanwhile, physiological productivity focuses on the worker's physical condition, such as heart rate, muscle fatigue, energy consumption, physical workload, and work posture.

Analysis of lightweight brick-cutting tools before and after an ergonomic intervention is an important step in assessing the extent to which tool design improvements can increase productivity. Productivity in this context can be measured by the number of bricks successfully cut in a given time, the accuracy of the cuts, and the level of operator musculoskeletal complaints. Reducing risks in physical work is achieved through ergonomic assessments, which increase productivity [15]. The test results will serve as a basis for evaluating the effectiveness of the implemented ergonomic interventions and provide input for the development of more efficient and safer work tools. Therefore, this research aims to analyze differences in brick-cutting tool performance before and after the implementation of ergonomic interventions, using productivity indicators, to determine the extent to which the interventions improve work outcomes and operator well-being.

2. Materials and methods

This study was conducted among lightweight brick cutting workers, and measurements were taken at baseline (before the ergonomic intervention) and at follow-up (after the intervention), with each subject serving as his or her own control. The sample consisted of 5 workers who performed lightweight brick cutting. The workers were male, aged 18–55 years, with ≥ 6 months of work experience. The workers were in good health and had no history of serious cardiovascular/respiratory disease, acute musculoskeletal injuries, or use of drugs that affect heart/energy function.

Ergonomics interventions are carried out based on workers' participation and anthropometric data for lightweight brick cutting work. Anthropometric databases can help design appropriate workplaces and equipment, thereby reducing work disorders and accidents [16]. Meanwhile, the participatory approach used in ergonomics offers an effective means to redesign manual tasks and reduce physical workloads. It benefits from the procurement of work tools [17, 18]. The results of the level of musculoskeletal complaints after ergonomics intervention through redesign of the lightweight brick-cutting tool, based on previous research by Susana et al. [14], are shown in Figure 2.

Figure 2 Work tools after ergonomics intervention [14]

Anthropometric measurements were taken from workers seated because lightweight brick cutting is performed in this position. This study involved redesigning the lightweight brick-cutting tool, focusing on modifying the pedal switch and work chair, and adding a footrest. Before the improvements, the pedal switch (see Figure 1) was positioned too far out of reach of the worker's feet, resulting in pain in the left leg. Therefore, the pedal switch was redesigned with adjustments to its location and dimensions to suit the user's anthropometric range. Furthermore, a footrest was added to support the worker's feet, preventing them from hanging down or falling into the channel beneath the work area. The worker's chair design was also improved through dimensional adjustments and the addition of armrests and foam padding to enhance comfort and reduce fatigue. Based on these results, a physiological productivity analysis of workers was conducted to assess the effectiveness of ergonomics interventions implemented for lightweight brick cutters. The physiological productivity levels were compared before and after the ergonomic intervention. Physiological productivity was calculated based on Equation 1.

$$P = \frac{O}{I \times t} \qquad \ldots\ldots\ldots\ldots (1)$$

P = physiological productivity (pcs/hour); O = output in the form of number of units or units of goods (pieces or pcs); I = input in the form of level of musculoskeletal complaints; and t = length of working time (hours).

3. Results and discussions

The study involved a sample of 5 lightweight brick cutting workers, with an average age of 30 years (range: 26-33 years) and male gender. All respondents worked in a sitting posture for an average of 6 hours per day, with working hours from 09.00-16.00 and a 1-hour break time at 12.00-13.00. Based on research by Susana et al., worker anthropometric data were used to redesign pedal switching, add footrests, and adjust the dimensions of work chairs [14]. Improvements included moving the pedal switch closer for easier access, adding a footrest to support the feet, and upgrading the work chair with armrests and foam padding to increase comfort and postural stability. Data on the level of musculoskeletal complaints are presented in Table 1.

Table 1 Level of workers' musculoskeletal complaints before and after ergonomics intervention

No	Workers	Before the ergonomics intervention		After the ergonomics intervention		Reduction in musculoskeletal complaints after work (%)
		Before work	After work	Before work	After work	
1	S1	30	66	28	32	51.52
2	S2	29	63	29	33	47.62
3	S3	28	62	28	31	50
4	S4	29	61	29	31	49.18
5	S5	31	62	30	32	48.39
Average		29.4	62.8	28.8	31.8	49.34

Based on the data in Table 1, it can be seen that after implementing ergonomics interventions on the lightweight brick cutting tool, the level of musculoskeletal complaints decreased among all workers in this study, namely, from sample 1 (S1) to sample 5 (S5). The average reduction in musculoskeletal complaints after work reached 49.34%, from an average of 62.8 to 31.8. This is a result of ergonomics intervention, with workers' postures becoming more natural than before. This research aligns with the results of Pratiwi et al., who found that natural work postures minimize musculoskeletal injuries [19]. On the other hand, unnatural work postures resulting from a mismatch between the work tool and the worker cause musculoskeletal complaints. Unnatural work postures during job performance are associated with an increased risk of musculoskeletal complaints, including pain in the hands, wrists, upper and lower back, neck, shoulders, knees, elbows, and ankles, as well as an increased risk of work injuries [1, 2, 20]. A decrease in musculoskeletal complaint scores indicates that workers perceived a lighter workload after the equipment redesign. Comfort improved because the pedals and seat were now positioned within body reach, reducing the need for repetitive stretching and excessive pressure on the left leg. Adding a footrest helps stabilize the foot position, reduces static pressure on the lower leg, and improves blood circulation. Additionally, improving the work chair with a foam backrest and cushioning reduces contact pressure and improves long-term sitting comfort. This condition aligns with ergonomics theory, which holds that physical comfort and good work posture directly influence movement efficiency and work endurance [21]. By reducing muscle tension and pain, workers can maintain their work pace without experiencing premature fatigue. Reducing musculoskeletal complaints increases productivity, both through physiological mechanisms (reduced muscle fatigue) and psychological mechanisms (improved work comfort and motivation). This is shown in Table 2.

Table 2 Worker physiological productivity before and after ergonomics intervention

No	Workers	Before intervention	After intervention	Physiological productivity increase (%)
		(pcs/6 hours)	(pcs/6 hours)	
1	S1	270	282	4.44
2	S2	281	290	3.20
3	S3	274	287	4.74
4	S4	268	280	4.48
5	S5	283	293	3.53
Average		275.2	286.4	4.08

Based on physiological productivity measurements of workers over six working hours, the number of lightweight bricks cut increased after ergonomics interventions were implemented on the cutting tool. Detailed data are shown in Table 2. From the table, it is evident that all workers experienced an increase in productivity after implementing the redesigned cutting tool. Productivity values before the intervention ranged from 268 to 283 pcs/6 hours, with an average of 275.2 pcs/6 hours. After the intervention, productivity increased to 280-293 pcs/6 hours, with an average of 286.4 pcs/6 hours. The average increase in physiological productivity was 4.08%, with individual increases ranging from 3.20% to 4.74%. The worker with the highest increase was worker 3 (S3) at 4.74%, while the lowest increase was in worker 2 (S2) at 3.20%. This increase in productivity indicates that ergonomics interventions, such as redesigned pedal switching, the addition of footrests, and improved seating, have had a positive impact on work efficiency. Workers become more comfortable and able to maintain a work rhythm without experiencing excessive fatigue. Physiologically, this improvement indicates a decrease in internal workload (e.g., heart rate and muscle fatigue), thereby increasing actual work capacity. Thus, ergonomics interventions not only improve comfortable working postures but also directly impact worker productivity. This aligns with the research by Santosa and Bawa Susana, which indicates that productivity, as measured by workload, suggests that workers perform their work more comfortably and efficiently [22]. The prevalence of musculoskeletal disorders among workers is reduced due to a significant reduction in ergonomics risk factors resulting from engineering interventions [23]. Work tools designed with worker participation in mind are applications that place humans at the center. Human-machine integration, as a crucial factor, underscores the importance of the human factor for adaptability and innovation [24].

The increase in productivity following the intervention indicates that ergonomically improved working conditions can enhance the efficiency of lightweight brick-cutting activities. In the context of repetitive, daily work, this 4.08% figure is quite significant because it represents an increase in output without additional work time or labor. This increase in movement efficiency reduces work cycle time and increases cutting speed, ultimately impacting total productivity. From an ergonomics perspective, more comfortable working conditions that align with the worker's anthropometry will reduce physiological stress, resulting in less energy expended per work cycle and achieving more optimal results. The application of ergonomics principles to lightweight brick-cutting tools significantly increases work productivity by improving movement efficiency and reducing fatigue during the work process.

4. Conclusion

The application of ergonomics interventions to lightweight brick-cutting equipment, including redesigned pedal switching, footrests, and improved work chairs, has been proven to have a positive impact on workers' physiological conditions and productivity. The study results showed a 49.34% decrease in musculoskeletal complaints and a 4.08% increase in physiological productivity. The reduction in musculoskeletal complaints indicates that work postures after the intervention became more natural and comfortable, reducing muscle workload and the risk of fatigue. Ergonomic working conditions improve movement efficiency, postural stability, and long-term sitting comfort. The increased productivity achieved without additional time or effort demonstrates that applying ergonomic principles significantly improves worker efficiency and performance. Therefore, ergonomics interventions through improved tool design can be an effective solution to improve occupational health, comfort, and worker productivity in the lightweight brick-cutting industry.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare no conflict of interest.

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