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INTEGRATING ERGONOMICS AND COGNITIVE SYSTEMS ENGINEERING FOR OCCUPATIONAL SAFETY IN HEALTHCARE WORK SYSTEMS: AN EXPLORATORY STUDY

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Background. Healthcare work is shaped by a combination of physical effort and cognitive workloads. Prolonged exposure to these demands can contribute to musculoskeletal strain, fatigue, and risks to both patient and staff safety. Although Human Factors and Ergonomics (HFE) have been applied in healthcare for some time, less attention has been paid to the interaction between ergonomic conditions and Cognitive Systems Engineering (CSE) in everyday clinical work.

Purpose. This study aimed to explore how frontline healthcare professionals experienced ergonomic changes in relation to physical strain, cognitive load, and their ability to adapt to demanding clinical work environments.

Findings. This exploratory single-case study focused on ergonomic improvement initiatives implemented during 2022–2023 in a public general hospital in China and combined semi-structured interviews with non-participant observations involving 15 frontline healthcare professionals (7 doctors and 8 nurses) from five hospital units. The data were interpreted through an integrated ergonomics-CSE lens using thematic analysis. Three themes were identified: perceived reduction in physical workload, redistribution of cognitive load, and adaptation to stressful situations. Overall, 80.0% of the participants reported lower physical strain after the ergonomic changes. Nurses tended to highlight improvements in patient transfer and bedside care, whereas doctors more frequently cited fewer workflow interruptions and better concentration during procedures.

Implications. The integrated ergonomics-CSE perspective provides a useful way to understand the connections among physical working conditions, cognitive demands and adaptive practices in routine clinical work. In this single-case study, ergonomic initiatives were linked to safer task performance, enhanced task focus, and improved adaptation to demanding hospital environments. These findings indicate that this perspective can complement a broader sociotechnical framework when hospital managers make decisions on equipment procurement, workflow redesign, staff support, and ergonomic training priorities.

Keywords: Cognitive Engineering, Decision-Making, Ergonomics, Human-System Interaction, System Performance.

1. Introduction.

Human Factors and Ergonomics (HFE), also known as ergonomics, examines the interactions among people, tasks, technologies, and work environments to improve safety, health, and performance. Healthcare is an area where humans are often required to meet a range of physical and cognitive demands. Therefore, it is appropriate to study the effects of these requirements on individuals working in healthcare settings. Furthermore, various methods exist for studying these relationships in healthcare, each with its own focus and benefits.

In healthcare research, different human factor traditions have often been used for various analytical purposes. Ergonomics has commonly focused on physical workload and equipment design; socio-technical approaches have examined coordination and work system conditions; the Systems Engineering Initiative for Patient Safety (SEIPS) model has provided a broad framework for linking work system design to patient safety; FRAM has been used to examine variability and emergence; Cognitive Systems Engineering (CSE) and Cognitive Work Analysis (CWA) have offered more fine-grained accounts of distributed cognition in demanding clinical settings.

Although it is common to discuss the physical and cognitive demands of healthcare work separately, these factors are interrelated in the healthcare environment. Each of these physical factors can affect the cognitive aspects of healthcare work, and the cognitive aspects of the work can affect the physical aspects. Any occupational hazards arising from these factors are not limited to those related to the physical or cognitive demands on healthcare workers today but also include hazards arising from the interaction between these two types of demands.

In this study, Cognitive Systems Engineering (CSE) was not used as a replacement for SEIPS 2.0, the Functional Resonance Analysis Method (FRAM), or other comprehensive socio-technical frameworks but as a complementary interpretive lens. SEIPS is particularly useful for mapping the overall work system, whereas CSE is particularly helpful for examining how attention, tool use, and adaptation unfold in real time.

Therefore, integrating ergonomics with CSE enables a more focused examination of how physical conditions shape cognition during daily clinical work. Against this background, the present study aimed to investigate the ergonomic changes in healthcare work from an integrated perspective of ergonomics and CSE. The investigation will focus on healthcare professionals' experiences with ergonomic issues in their daily work. The questions investigated in this study were as follows:

RQ1: What are the experiences of healthcare professionals regarding the physical and cognitive demands of their work?

RQ2: How do they perceive the impact of ergonomic changes on their work?

RQ3: How can an integrated ergonomics-CSE perspective inform future safety and adaptation initiatives in healthcare?

These questions address on the ergonomics of healthcare work.

2. Literature Review.

The term ergonomics was first introduced by Jastrzębowski (1997). Subsequently, Murrell (1973) established ergonomics into a field related to the workplace. Beyond the workplace, ergonomics has developed into a field related to work, well-being, and human flourishing (Norman, 2013). International developments in ergonomics include the principle of "fitting the job to the worker", which later enabled its application in healthcare and other fields (Karwowski, 2006).

Human factors and ergonomics encompass cognitive, physical, and organisational aspects. Authors such as Wickens et al. (2004), Sanders and McCormick (1993), Karwowski (2006), and Dul and Weerdmeester (2003) have all discussed the importance of human capabilities in ergonomics. These authors considered the individual differences in humans and their anatomical and physiological characteristics. Furthermore, authors such as Vicente (1999), Rasmussen (1983), Hancock and Warm (1989), and Reason (1990) have focused on the cognitive aspects of human factors and ergonomics. These studies addressed human factors related to cognition in complex environments and tasks, as well as errors that occur during those tasks.

Helander (2005), Salvendy (2012), Stanton et al. (2013), Proctor and Van Zandt (2008), Wickens and Hollands (2021), and Kirlik (2018) have discussed the workload, team cognition, and dynamic work aspects of human factors. Three CSE-related concepts were used to make the physical-cognitive link explicit. Cognitive allocation refers to the way a clinician allocates attention among patients, equipment, body posture, and competing task demands. Adaptive strategies are practical adjustments that employees make when job pressure, physical stress, or equipment constraints change. Reallocation of attention refers to the shift in mental focus that occurs when ergonomic conditions reduce or exacerbate a physical discomfort. These concepts help explain how physical ergonomic conditions affect cognitive tasks in clinical practice. Vicente and Rasmussen (1992) and Guastello (2023) studied the interface between humans and technological devices and the errors that arise in complex technological environments.

Jacquier-Bret and Gorce (2023) demonstrated that ergonomic interventions alone can reduce strain among healthcare workers, although musculoskeletal disorders are prevalent among healthcare workers. Abdul Halim et al. (2023b) conducted a review of interventions to reduce musculoskeletal strain among healthcare workers and found that the most effective interventions incorporate ergonomic considerations into recommendations for healthcare workers. Abdul Halim et al. (2023a) found that although various patient transfer devices can help reduce nurses' strain and be effectively integrated into nursing workflows, which benefits the workers.

Recent studies have also found that tasks related to patient transfer and bedside care place the greatest strain on healthcare workers (Vinstrup et al., 2024). Early nursing ergonomics research has also linked patient handling, ongoing work demands, and clinical workload to musculoskeletal complaints in healthcare workers (Engels et al., 1996; Nelson et al., 2003; Trinkoff et al., 2002), while broader ergonomics research continues to identify gaps in musculoskeletal disease prevention (Rempel & Krause, 2021). Thus, approaches that address various aspects of nursing and healthcare may help reduce the strain on workers.

Therefore, these frameworks are better understood as complementary rather than competing. SEIPS 2.0 offers a strong macro-level account of the socio-technical structure in healthcare, whereas CWA/CSE provides a closer view of cognitive work and adaptation. What remains comparatively underdeveloped in empirical hospital studies is an analysis that explicitly traces how local ergonomic conditions, bodily strain, and moment-to-moment cognitive demands are experienced simultaneously in frontline work.

The integrated ergonomics-CSE lens used here is intended as a focused interpretive combination for that purpose rather than as a claim that broader systems models do not exist. Recent work on occupational fatigue and healthcare control centres likewise points to the value of linking work-system conditions with staff experience and adaptation (Watterson et al., 2023; Paterson et al., 2024). Table 1 presents human-factor models relevant to healthcare work, along with the reasons for integrating ergonomics and CSE concepts.

Table 1. Comparison of Human Factors Frameworks and Their Relevance to Healthcare Work.

Framework	Focus	Strengths	Limitations in Healthcare
SEIPS / SEIPS 2.0 (Carayon et al., 2006; Holden et al., 2013)	Work system and patient safety	Strong socio-technical focus; widely applied in healthcare	Broad socio-technical scope; less emphasis on how local ergonomic conditions shape distributed cognition during frontline tasks
FRAM (Hollnagel, 2012)	Variability and emergence	Captures complexity and resilience in socio-technical systems	Minimal attention to ergonomics or healthcare-specific design
CSE / CWA (Vicente, 1999; Rasmussen, 1983)	Cognition and decision-making	Rich insights into distributed cognition	Less explicit attention to musculoskeletal strain and organisational ergonomics unless combined with ergonomic analysis
Proposed CSE–Ergonomics Approach	Integrated cognitive and physical ergonomics	Bridges decision-making, workload, and ergonomic design in healthcare	Requires empirical validation across diverse clinical contexts

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3. Methodology.

3.1. Theoretical Orientation.

The study was informed by Cognitive Systems Engineering (CSE) as an interpretive lens within a broader ergonomics perspective. CSE conceptualises cognition as distributed across individuals, tools, tasks, and the surrounding work environment. In this study, the perspective was applied to examine how participants described the interplay among physical workload, cognitive demands, and adaptation in routine clinical work.

The analysis centred on three aspects: (a) cognitive allocation between different tools and products, (b) adaptive strategies adopted under pressure, and (c) reallocation of attention when physical limitations change. These aspects informed the coding process and helped explain how ergonomic adjustments shaped the immediate decision-making. To make this relationship more explicit, Figure 1 summarises the three-level conceptual model that explains the link between body ergonomic conditions, cognitive work processes, and adaptive safety outcomes.

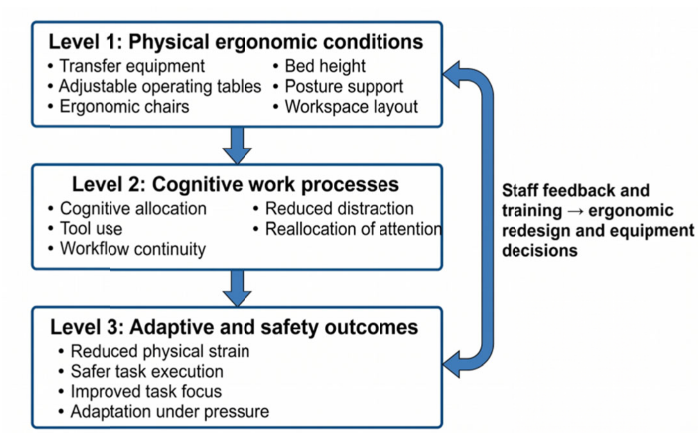

Fig. 1. Three-level Conceptual Model of Physical-Cognitive Interconnections in Ergonomic Healthcare Work Systems.

3.2. Study Design.

This study adopted a qualitative exploratory single-case design at a public general hospital in China. Defining the study as a single case enabled an in-depth examination of staff experiences with ergonomic changes within a single organisational context. Semi-structured interviews and non-participant observations were selected because the study aimed to interpret staff experience and practice, not to test hypotheses, estimate intervention effects, or build a formal, grounded theory. In line with the exploratory aim, this study did not include standardised workload scales or formal pre-and post-intervention measures.

3.3. Setting and Participants.

This study was conducted at a public general hospital in China.

The participants were healthcare professionals working in several hospital units, namely the Emergency Department (ED), the Intensive Care Unit (ICU), the Operating Room (OR), the General Medical/Surgical Ward, and Rehabilitation/Geriatric/Long-term Care-related units. These units were included because patient care delivery in these settings requires both physical and cognitive demands. During 2022-2023, the hospital introduced several ergonomic improvement initiatives, such as electric patient transfer equipment (emergency room, intensive care unit), adjustable-height operating tables (operating room), and ergonomic office chairs (general ward). These renovation measures reflected part of the ergonomic investment made in some Chinese public hospitals and offered a bounded case through which systematic, rather than piecemeal, ergonomic renovation could be examined.

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Purposive sampling was used to recruit participants who could provide detailed accounts of clinically demanding work involving both physical and cognitive requirements. The final sample consisted of 15 frontline healthcare professionals, including 7 doctors and 8 nurses, whose work experience ranged from 3 to 16 years. For this bounded qualitative case, the sample size was determined by information power and thematic sufficiency rather than numerical representativeness (Malterud et al., 2016). Recruitment was discontinued when recurring patterns appeared across the two professional groups and the selected units, and when further accounts did not substantially expand the core themes.

The findings were analysed across cases rather than used for unit-specific comparisons. The inclusion criteria required participants to be actively engaged in frontline clinical work, have at least 2 years of professional experience, and encounter both physical and cognitive demands in their jobs (Table 2).

Participants were deliberately recruited based on professional role, frontline experience and qualifications during the study, rather than to achieve unit-level proportionality or gender balance. The uneven gender distribution in some units (e.g., operating theatres and intensive care units) reflects the limited number of qualified frontline staff in these settings. It should not be used as a basis for gender comparisons.

Table 2. Summary of Participant Characteristics.

Profession	Department/Unit	Gender (F/M)	Years of Experience (2–5 / 6–10 / 11+)
Doctors (n = 7)	Emergency Department (ED)	1/1	1/1/0
Doctors (n = 7)	Intensive Care Unit (ICU)	1/1	0/1/1
Doctors (n = 7)	Operating Room / Perioperative Unit	0/1	0/0/1
Doctors (n = 7)	General Medical/Surgical Ward	0/1	1/0/0
Doctors (n = 7)	Rehabilitation / Geriatric / Long-term Care Unit	1/0	0/1/0
Nurses (n = 8)	Emergency Department (ED)	1/1	1/0/1
Nurses (n = 8)	Intensive Care Unit (ICU)	1/0	0/1/0
Nurses (n = 8)	Operating Room / Perioperative Unit	2/0	1/1/0
Nurses (n = 8)	General Medical/Surgical Ward	2/0	1/0/1
Nurses (n = 8)	Rehabilitation / Geriatric / Long-term Care Unit	0/1	0/1/0

3.4. Data Collection.

Data were collected from two sources: semi-structured interviews and non-participant observations of routine clinical work. All participants completed individual semi-structured interviews. The interviews addressed bodily strain, cognitive demands, equipment use, workflow interruptions, and suggestions for improving hospital ergonomics.

The observation sessions were conducted in the participants' work units. As routine care activities unfolded, the researcher documented the postures, equipment use, task flow, and adaptive strategies in real time. The observer did not participate in the work process or interfere with the clinical tasks. The observation duration was typically approximately 45-60 minutes, with variation depending on the department's workflow needs and patient care activities.

3.5. Data Analysis.

Interview transcripts and observation notes were reviewed and coded manually to identify recurring themes related to physical strain, cognitive workload, equipment use, workflow disruption, and adaptation. The material was reviewed repeatedly to become familiar with the data. Segments related to bodily strain, attentional demand, equipment use, workflow disruption, and adaptation were coded and analysed. These first-cycle codes were subsequently organised into broader categories and compared across the interview and observation materials to examine similarities, differences, and areas of overlap.

Table 3 presents how excerpts moved from initial coding to categories and themes. Because the dataset was small and confined to a bounded case, the analysis did not rely on dedicated qualitative data analysis software.

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A formal inter-rater reliability coefficient was not calculated, as the aim was interpretive theme development rather than quantifying coder agreement. To maintain analytic consistency, the codes and themes that emerged during the analysis were checked against the full dataset. Revisions were made when the category boundaries were insufficiently clear or not adequately supported by the original material. For excerpts that could reasonably be placed in more than one category, the researcher returned to the wider interview or observation context and compared them with similar excerpts before making the final coding decisions. Ambiguous cases were noted analytically and reconsidered during subsequent thematic refinement until the coding framework captured the participants' meanings with adequate accuracy.

Theme counts, when included, refer to participants who mentioned a given theme at least one time. Their purpose is limited to describing relative prominence in the dataset; they are not used as statistical tests or as outcome measures. Methodological rigour and transparency were supported by following Braun and Clarke's (2006) six-phase thematic analysis framework.

The process involved: (1) familiarisation with the data through repeated reading of interview transcripts; (2) generation of initial codes capturing both semantic (explicit) and latent (interpretive) content; (3) development of candidate themes by systematically collating and reviewing codes; (4) review of candidate themes to assess their internal coherence and distinctiveness across the full dataset; (5) refinement, definition, and naming of final themes to represent salient and meaningful patterns; and (6) construction of a cohesive analytic narrative grounded in empirical evidence.

In line with the interpretive character of qualitative enquiry and established qualitative standards, inter-rater reliability coefficients were not calculated. Instead, four complementary trustworthiness strategies were implemented: (a) negative case analysis, which involved systematically identifying and examining disconfirming instances, such as the three participants who reported no reduction in physical strain, followed by contextual exploration, such as shared equipment use, to refine thematic boundaries; (b) researcher reflexivity, supported by a comprehensive analytic audit trail that recorded decisions, evolving assumptions, and the rationale for coding and thematic revisions; (c) peer debriefing, in which two independent qualitative researchers unaffiliated with the study reviewed emerging themes and critically challenged potential interpretive biases; and (d) data triangulation, through which interview-derived insights were cross-verified against contemporaneous observational field notes to assess convergence between reported experiences and observed behaviours.

Table 3. Example of the Coding Process.

Illustrative excerpt	Initial code	Category	Theme	Analytic interpretation
Since we began using the lifting device, my back pain has decreased considerably, and long shifts have become easier to manage with less strain.	Lifting device reduced back pain and long-shift strain	Ergonomic support for patient handling	Perceived reduction in physical workload	Equipment reduced bodily strain during routine care tasks.
The adjustable operating tables and chairs help us pay more attention to the patient instead of being distracted by discomfort.	Adjustable workstation improved focus on the patient	Reduced disruption in procedure workflow	Redistribution of cognitive load	Physical adjustment of the workspace supported attention allocation.
Even on night shifts, the new equipment makes it easier to continue working safely without becoming overly exhausted.	New equipment sustained safe work during night shifts	Support for work under pressure	Adaptation to stressful situations	Ergonomic changes were linked to sustained safe performance in demanding conditions.

3.6. Trustworthiness and Ethical Considerations.

Trustworthiness was enhanced through the triangulation of interview and observation data, purposive recruitment of experienced frontline staff, and repeated comparison of emerging interpretations with the original material. The observational data were not treated as independent outcome measures. Instead, they were used as contextual evidence to help corroborate, refine, or, in some cases, challenge interview accounts.

This iterative process across data sources strengthened the credibility of the final themes and reduced the risk of interpreting individual quotations out of context. Before data collection, each participant was informed of the purpose of the study and provided written informed consent.

Data were managed and reported in a manner that protected confidentiality, and no personally identifiable information was included in the study or data set. Since observations were conducted in active clinical settings, observer effects cannot be completely ruled out. This issue is revisited in the limitations section.

4. Results.

The final analysis identified three closely connected themes: (1) perceived reduction in physical workload, (2) redistribution of the cognitive load, and (3) adaptation to stressful conditions. Table 4 presents a descriptive summary of the frequency with which these themes appeared across the sample and between the two groups. These counts were used to indicate relative prominence in the dataset rather than serving as statistical indicators.

Table 4. Distribution of Themes by Professional Group.

Theme	Total (n = 15)	Doctors (n = 7)	Nurses (n = 8)	Typical emphasis
Perceived reduction in physical workload	12 (80.0%)	5 (71.4%)	7 (87.5%)	Nurses: patient transfer, bedside care, bodily strain; Doctors: posture and procedural comfort
Redistribution of cognitive load	10 (66.7%)	6 (85.7%)	4 (50.0%)	Reduced distraction, smoother workflow, and improved concentration during procedures
Adaptation to stressful situations	9 (60.0%)	4 (57.1%)	5 (62.5%)	Safer performance during long shifts, night work, and high-pressure situations

Note. Counts indicate the number of participants who mentioned each theme at least once. Participants could mention more than one theme. Percentages are descriptive only and are not intended for statistical inference.

4.1. Perceived Reduction in Physical Workload (Theme 1).

Participants commonly reported that ergonomic modifications reduced the physical demands of their routine tasks. This theme emerged in 12 of the 15 accounts (80.0%), specifically, 5 of the 7 doctors (71.4%), and 7 of the 8 nurses (87.5%). Nurses tended to attribute the perceived improvement to patient handling, bedside care, and long shifts, whereas doctors more frequently emphasised better posture and increased comfort during procedures. One nurse explained that, after starting to use the lifting device, long shifts had become less stressful to manage (study participant, nurse).

A similar view was expressed by a ward-based participant, who described routine ward duties as considerably less exhausting than before (study participant working in the ward).

Across units, participants consistently framed ergonomic tools not merely as comfort aids but as practical means of supporting safer task performance. These accounts were corroborated by observation notes, which documented frequent bed-height adjustments and reliance on transfer aids prior to patient handling. The findings were consistent with the participants' descriptions of reduced back and shoulder strain.

4.2. Redistribution of cognitive load (Theme 2).

The second theme concerns how ergonomic adjustments may alter attention management at work. Participants reported fewer interruptions attributable to poor posture, discomfort, and repeated equipment adjustments. Physicians most commonly associated this pattern with surgery, workstation adjustment, and the ability to maintain focus on the patient rather than physical discomfort.

One doctor noted that the adjustable operating tables and chairs enabled greater attention to the patient rather than discomfort (doctor participant). Another explained that, given the equipment's largely ergonomic design, less mental energy was devoted to minor physical difficulties (doctor participant). Echoing this, a participant from the perioperative unit observed that the workflow had become smoother once repeated readjustments were no longer required (perioperative participant). Collectively, these findings suggest that ergonomic design indirectly influences cognition by reducing bodily interference and workflow disruption. Descriptively, the theme was identified in 10 of the 15 accounts (66.7%) and was more prevalent among doctors than nurses (85.7% versus 50.0%). Consistent with these accounts, observations in the OR and ICU revealed fewer posture readjustments around adjustable workstations and a more continuous task flow when ergonomic equipment was available (Table 4).

4.3. Adaptation to stressful situations (Theme 3).

The third theme concerned how ergonomic support helped the staffs maintain safe working practices under pressure. The issue was raised by 9 participants (60.0%), comprising 4 of the 7 doctors (57.1%) and 5 of the 8 nurses (62.5%). This was particularly evident in accounts from the ED, ICU, and OR, where long shifts, time pressure, and physically demanding tasks were commonly reported.

One doctor noted that even during night shifts, the new equipment made it easier to continue working safely without becoming exhausted (doctor participant).

A nurse described a similar experience, noting that although fatigue still arose on busy shifts, long shifts had become considerably more manageable (nurse participant). For participants, ergonomic support was associated not only with comfort but also with the capacity to sustain performance during long shifts, demanding tasks and time-pressured situations. Several studies have advocated for wider access to patient transfer devices and ergonomic training to extend these benefits.

Consistent with these accounts, observation notes from high-pressure units indicated that the staff used ergonomic equipment to maintain a safer posture and a steadier work pace during prolonged or physically demanding tasks.

5. Discussion.

Taken together, the interviews and field observations suggest that the participants did not regard ergonomic change merely as an improvement in comfort. Rather, they linked it to the organisation of physical effort, attention, and safe task performance in everyday clinical work.

The first finding was that participants perceived ergonomic changes as reducing physical strain in their daily work. Their accounts centred on tasks, equipment, and workstation arrangements that made patient handling, prolonged standing, and other physically demanding activities more manageable. From this perspective, the value of ergonomics extends beyond comfort to safer task performance. This pattern is consistent with recent evidence indicating that patient transfer and bedside care rank among the most physically demanding tasks in healthcare and those ergonomic measures can reduce musculoskeletal strain when incorporated into routine workflows (Abdul Halim et al., 2023a; Abdul Halim et al., 2023b; Vinstrup et al., 2024).

The second finding was that participants described ergonomic changes as reducing disruptions in work processes. When less effort was required to compensate for discomfort or awkward equipment, staff reported being able to direct more attention to the patient and the immediate demands of care.

This pattern aligns with the CSE perspective, which conceptualises cognition as being shaped by interactions among workers, tools, tasks, and the surrounding environment (Hollnagel & Woods, 1983; Vicente, 1999; Nemeth et al., 2004).

Comparisons between professional groups further revealed differences in role-related emphasis. Nurses more frequently discussed bodily strain associated with patient handling and bedside care, whereas doctors more often emphasised reduced distraction, smoother procedures, and improved concentration. These patterns underscore the importance of examining physical and cognitive demands jointly rather than as separate domains. In this regard, the integrated ergonomics-CSE lens complements broader socio-technical frameworks, such as SEIPS, by highlighting how local ergonomic conditions are embedded in cognition and adaptation during care delivery.

Third, participants associated ergonomic improvements with their ability to work safely during long shifts, physically demanding tasks, and high-pressure situations. Although resilience was not directly measured, the findings suggest that ergonomic support may strengthen adaptive capacity by making demanding work sustainable. This interpretation is consistent with systems-oriented discussions of adaptation in complex healthcare settings (Hollnagel, 2012; Waterson, 2009).

From a practical standpoint, integrating ergonomics with CSE in healthcare involves more than introducing equipment. Ergonomic initiatives need to be aligned with local workflows, coordination requirements, and the specific task demands of different units. Recent socio-technical work on occupational fatigue and healthcare control centres makes a similar point: tools, staffing conditions, coordination, and local operating pressures need to be understood together rather than in isolation (Watterson et al., 2023; Paterson et al., 2024). These findings also inform ergonomics training courses for healthcare administrators and unit managers by highlighting how equipment decisions, workflow redesign, and employee feedback can be considered during the implementation.

Departments such as the ED, ICU, and OR may therefore benefit most from this integrated approach, and staff feedback should be incorporated during implementation to ensure that ergonomic changes align with local practices.

This study had several limitations. It was conducted in a single hospital and drew on a relatively small, purposively selected sample; therefore, the findings should be regarded as analytically transferable rather than statistically generalisable. Some units were represented by only one or two participants, which made the dataset better suited to cross-case pattern identification than to unit-by-unit comparison. The study also relied on interview accounts and non-participant observation rather than on standardised instruments such as National Aeronautics and Space Administration Task Load Index (NASA-TLX) or Borg-type ratings; the reported changes should accordingly be interpreted as experienced and observed patterns rather than as calibrated workload measures. As part of the evidence rested on self-reported ergonomic improvements, the findings may additionally be subject to response bias, including social desirability and retrospective interpretations of changes.

Furthermore, because observations took place in active clinical settings, the Hawthorne effect may have influenced the behaviour. Finally, formal inter-rater reliability statistics were not used for manual coding. Future research could build on these findings by combining qualitative analysis with validated workload measures, broader sampling, and explicit comparative designs. This study suggests that occupational safety in healthcare can be better understood when ergonomics is examined alongside the cognitive demands of clinical work.

6. Conclusions.

This study examined how ergonomic changes in healthcare work can be understood from an integrated ergonomics-CSE perspective. Participants described ergonomic interventions as beneficial for reducing physical and cognitive workloads and supporting sustained safe performance in demanding clinical environments.

Specifically, 80.0% of the participants reported a reduction in physical load, 66.7% described a redistribution of cognitive load, and 60.0% noted improved adaptability to stressful situations. Nurses more often linked ergonomic changes to patient transfers and bedside pressure, whereas physicians linked them to smoother procedures and better concentration. These findings underscore the value of integrating CSE into discussions on ergonomics and occupational safety in healthcare.

Future research should extend this work through more diverse samples, longitudinal designs, and objective indicators, such as motion analysis, electromyography, NASA-TLX, the Borg Rating of Perceived Exertion, or related measures of physical and cognitive demand. This study clarifies how perceived ergonomic improvements relate to measurable changes in workload, safety, and performance over time.

Ethical Approval.

Ethical approval for this study was obtained from the Academic Ethics Committee of Shanghai Lixin University of Accounting and Finance (Approval No. 2025007).

Conflict of Interest Statement.

The authors have declared no conflict of interest.

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AI Use Statement.

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REFERENCES

Abdul Halim, N. S. S., Ripin, Z. M., & Ridzwan, M. I. Z. (2023a). Effects of patient transfer devices on the risk of work-related musculoskeletal disorders: A systematic review. International Journal of Occupational Safety and Ergonomics, 29(2), 494–514. https://doi.org/10.1080/10803548.2022.2055908

Abdul Halim, N. S. S., Ripin, Z. M., & Ridzwan, M. I. Z. (2023b). Efficacy of interventions in reducing the risks of work-related musculoskeletal disorders among healthcare workers: A systematic review and meta-analysis. Workplace Health & Safety, 71(12), 557–576. https://doi.org/10.1177/21650799231185335

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. Qualitative Research in Psychology, 3(2), 77-101. https://doi.org/10.1191/1478088706qp063oa

Carayon, P., Schoofs Hundt, A., Karsh, B. T., Gurses, A. P., Alvarado, C. J., Smith, M., & Flatley Brennan, P. (2006). Work system design for patient safety: The SEIPS model. Quality & Safety in Health Care, 15(Suppl 1), i50–i58. https://doi.org/10.1136/qshc.2005.015842

Dul, J., & Weerdmeester, B. (2003). Ergonomics for beginners: A quick reference guide (2nd ed.). CRC Press.

Engels, J. A., van der Gulden, J. W., Senden, T. F., & van 't Hof, B. (1996). Work related risk factors for musculoskeletal complaints in the nursing profession: Results of a questionnaire survey. Occupational and Environmental Medicine, 53(9), 636–641. https://doi.org/10.1136/oem.53.9.636

Guastello, S. J. (2023). Human factors engineering and ergonomics: A systems approach. CRC Press. https://doi.org/10.1201/9781003359128

Hancock, P. A., & Warm, J. S. (1989). A dynamic model of stress and sustained attention. Human Factors, 31(5), 519–537. https://doi.org/10.1177/001872088903100503

Helander, M. (2005). A guide to human factors and ergonomics (2nd ed.). CRC Press. https://doi.org/10.1201/b12385

Holden, R. J., Carayon, P., Gurses, A. P., Hoonakker, P., Hundt, A. S., Ozok, A. A., & Rivera-Rodriguez, A. J. (2013). SEIPS 2.0: A human factors framework for studying and improving the work of healthcare professionals and patients. Ergonomics, 56(11), 1669–1686. https://doi.org/10.1080/00140139.2013.838643

Hollnagel, E. (2012). FRAM: The functional resonance analysis method: Modelling complex socio-technical systems. CRC Press. https://doi.org/10.1201/9781315255071

Hollnagel, E., & Woods, D. D. (1983). Cognitive systems engineering: New wine in new bottles. International Journal of Man–Machine Studies, 18(6), 583–600. https://doi.org/10.1016/S0020-7373(83)80034-0

Jacquier-Bret, J., & Gorce, P. (2023). Prevalence of body area work-related musculoskeletal disorders among healthcare professionals: A systematic review. International Journal of Environmental Research and Public Health, 20(1), 841. https://doi.org/10.3390/ijerph20010841

Jastrzębowski, W. (1997). An outline of ergonomics, or the science of work. Ergonomics, 40(9), 865–870. (Original work published 1857).

Karwowski, W. (2006). The discipline of ergonomics and human factors. In W. Karwowski (Ed.), International encyclopedia of ergonomics and human factors (2nd ed., pp. 1–4). CRC Press.

Kirlik, A. (2018). Requirements for Psychological Models to Support Design: Toward Ecological Task Analysis. CRC Press.

Malterud, K., Siersma, V. D., & Guassora, A. D. (2016). Sample size in qualitative interview studies: Guided by information power. Qualitative Health Research, 26(13), 1753–1760. https://doi.org/10.1177/1049732315617444

Murrell, K. F. H. (1973). Ergonomics: Man in his working environment. Chapman & Hall.

Nelson, A., Fragala, G., & Menzel, N. (2003). Myths and facts about back injuries in nursing. The American Journal of Nursing, 103(2), 32–40. https://doi.org/10.1097/00000446-200302000-00021

Nemeth, C. P., Cook, R. I., & Woods, D. D. (2004). The messy details: Insights from the study of technical work in healthcare. IEEE Transactions on Systems, Man, and Cybernetics. Part A, Systems and Humans, 34(6), 689–692. https://doi.org/10.1109/tsmca.2004.836802

Norman, D. A. (2013). The design of everyday things (Rev. & expanded ed.). Basic Books.

Paterson, E., Chari, S., McCormack, L., & Sanderson, P. (2024). Application of a human factors systems approach to healthcare control centres for managing patient flow: A scoping review. Journal of Medical Systems, 48(1), 62. https://doi.org/10.1007/s10916-024-02071-1

Proctor, R. W., & Van Zandt, T. (2008). Human factors in simple and complex systems (2nd ed.). CRC Press.

Rasmussen, J. (1983). Skills, rules, and knowledge: Signals, signs, and symbols, and other distinctions in human performance models. IEEE Transactions on Systems, Man, and Cybernetics, SMC-13(3), 257–266. https://doi.org/10.1109/TSMC.1983.6313160

Reason, J. (1990). Human error. Cambridge University Press.

Rempel, D. M., & Krause, N. (2021). Ergonomics and musculoskeletal disorders: Research priorities and gaps. Applied Ergonomics, 92, 103341. https://doi.org/10.1016/j.apergo.2020.103341

Salvendy, G. (Ed.). (2012). Handbook of human factors and ergonomics (4th ed.). Wiley.

Sanders, M. S., & McCormick, E. J. (1993). Human factors in engineering and design (7th ed.). McGraw-Hill.

 e-ISSN 2786-8958
ISSN-L 2616-7107

Stanton, N. A., Salmon, P. M., Rafferty, L. A., Walker, G. H., Baber, C., & Jenkins, D. P. (2013). Human factors methods: A practical guide for engineering and design (2nd ed.). CRC Press.

Trinkoff, A. M., Lipscomb, J. A., Geiger-Brown, J., & Brady, B. (2002). Musculoskeletal problems of the neck, shoulder, and back and functional consequences in nurses. American Journal of Industrial Medicine, 41(3), 170–178. https://doi.org/10.1002/ajim.10048

Vicente, K. J. (1999). Cognitive work analysis: Toward safe, productive, and healthy computer-based work. CRC Press.

Vicente, K. J., & Rasmussen, J. (1992). Ecological interface design: Theoretical foundations. IEEE Transactions on Systems, Man, and Cybernetics, 22(4), 589–606. https://doi.org/10.1109/21.156574

Vinstrup, J., Jakobsen, M. D., Nielsen, A. B., & Andersen, L. L. (2024). Ergonomic challenges in healthcare: Mapping physical load during patient transfers using electromyographic field measurements. Frontiers in Public Health, 12, 1459595. https://doi.org/10.3389/fpubh.2024.1459595

Waterson, P. (2009). A critical review of the systems approach within patient safety research. Ergonomics, 52(10), 1185–1195. https://doi.org/10.1080/00140130903042782

Watterson, T. L., Steege, L. M., Mott, D. A., Ford II, J. H., Portillo, E. C., & Chui, M. A. (2023). Sociotechnical work system approach to occupational fatigue. The Joint Commission Journal on Quality and Patient Safety, 49(9), 485–493. https://doi.org/10.1016/j.jcjq.2023.05.007

Wickens, C. D., & Hollands, J. G. (2021). Engineering psychology and human performance (5th ed.). Routledge.

Wickens, C. D., Lee, J. D., Liu, Y., & Becker, S. E. G. (2004). An introduction to human factors engineering (2nd ed.). Pearson.