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Combination of Kansei Engineering and Ergonomic Function Deployment (EFD) in Designing Ergonomic Products: A Review Study

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ABSTRACT

Industrial competition encourages product development to focus not only on functionality but also on user satisfaction, comfort, and safety. The integration of Kansei Engineering (KE) and Ergonomic Function Deployment (EFD) has attracted significant attention in ergonomic product design research, as it enables the systematic translation of users' emotional needs into technical specifications. This article presents a literature review study that examines the application and integration of KE and EFD methods in ergonomic product design. The review is based on an analysis of national and international scientific journals addressing ergonomics, Kansei Engineering, and Ergonomic Function Deployment. The results indicate that the integration of KE and EFD effectively improves user comfort, safety, and satisfaction, while reducing the risk of musculoskeletal disorders and enhancing work productivity. Successful implementation is influenced by accurate identification of user requirements, the use of anthropometric data, ergonomic assessment tools, and close collaboration between designers and users. Furthermore, several studies highlight the importance of sustainable design by considering efficiency, occupational health, and product competitiveness. Overall, this review provides a comprehensive understanding of the potential and benefits of integrating Kansei Engineering and Ergonomic Function Deployment in ergonomic product design and offers a foundation for further research and practical implementation across various industrial sectors.

Keyword: *Kansei Engineering, Ergonomic Function Deployment, Ergonomic Product Design, Ergonomics, Literature Review*

ABSTRAK

Industri yang semakin ketat mendorong pengembangan produk tidak hanya berorientasi pada fungsi, tetapi juga pada kepuasan emosional, kenyamanan, dan keselamatan pengguna. Integrasi Kansei Engineering (KE) dan Ergonomic Function Deployment (EFD) menjadi perhatian penting dalam penelitian desain produk ergonomis karena mampu menghubungkan kebutuhan emosional pengguna dengan spesifikasi teknis secara sistematis. Artikel ini merupakan studi tinjauan pustaka yang membahas penerapan dan integrasi metode KE dan EFD dalam perancangan produk ergonomis. Kajian dilakukan dengan menelaah berbagai jurnal ilmiah nasional dan internasional yang membahas pengembangan produk berbasis ergonomi, Kansei Engineering, dan Ergonomic Function Deployment. Hasil review menunjukkan bahwa integrasi KE dan EFD efektif dalam meningkatkan kenyamanan, keselamatan, dan kepuasan pengguna, sekaligus menurunkan risiko gangguan muskuloskeletal dan meningkatkan produktivitas kerja. Keberhasilan penerapan metode ini dipengaruhi oleh identifikasi kebutuhan pengguna yang tepat, pemanfaatan data antropometri, penggunaan alat bantu analisis ergonomi, serta kolaborasi antara desainer dan pengguna. Selain itu, beberapa penelitian menekankan pentingnya pengembangan desain berkelanjutan dengan mempertimbangkan aspek efisiensi, kesehatan kerja, dan daya saing produk. Secara keseluruhan, studi ini memberikan pemahaman komprehensif mengenai potensi dan manfaat integrasi Kansei Engineering dan Ergonomic Function Deployment dalam desain produk

ergonomis serta membuka peluang pengembangan penelitian lebih lanjut di berbagai sektor industri.
Keyword: Kansei Engineering, Ergonomic Function Deployment, Desain Produk Ergonomis, Ergonomi, Literature Review

1. Introduction

Understanding and fulfilling individual user needs has long been recognized as a major challenge in product development across industries [1]. Intensifying industrial competition compels companies to continuously improve product quality and user satisfaction in order to maintain competitiveness in the market [2]. Today's consumers are presented with numerous alternatives offering similar functions and performance. Consequently, purchasing decisions are often based on perceived value, comfort, usability, and overall quality rather than solely on technical specifications [3]. To remain competitive, organizations must identify the factors that shape user perceptions and systematically translate these needs into concrete product design attributes and technical specifications [4].

In many product development processes, however, insufficient attention is given to ergonomic aspects and users' emotional responses, which may result in discomfort, reduced usability, and long-term health risks for users. Products that fail to address ergonomic requirements often contribute to musculoskeletal disorders, decreased productivity, and lower user satisfaction, particularly in manual or semi-mechanized work systems [5]. Therefore, integrating ergonomic principles and emotional user needs into product design has become increasingly essential to ensure sustainable and user-centered product development.

Product design is a structured activity that begins with identifying user needs and market opportunities and culminates in the production, distribution, and use of the product [6]. Effective product design requires a systematic organization of product components to fulfill functional objectives while ensuring safety, comfort, accessibility, aesthetic appeal, and economic feasibility [7]. In this context, three fundamental aspects influence product success, namely the relationship between humans, products, and the environment [8]. Human-centered studies focus on physical, cognitive, and emotional needs; product-oriented studies emphasize functionality, safety, and comfort; while environmental studies consider contextual factors that affect product usage and performance [9].

In manufacturing and product development, the concept of Concurrent Engineering (CE) has been widely adopted as a systematic approach that integrates multiple disciplines throughout the product life cycle [10]. CE aims to reduce development time and cost while improving product quality by enabling parallel activities and cross-functional collaboration among departments such as marketing, design, and manufacturing [11]. Within this framework, various design-oriented approaches, commonly referred to as Design for X (DFX), have been developed to address specific objectives such as manufacturability, reliability, maintainability, and usability [12].

Among these approaches, Ergonomic Function Deployment (EFD) has emerged as a development of Quality Function Deployment (QFD), emphasizing the integration of ergonomic requirements into product design. EFD systematically translates user needs related to safety, comfort, and efficiency into technical design parameters through structured matrices such as the House of Ergonomics [13]. This method enables designers to prioritize ergonomic requirements while balancing technical feasibility and performance.

In parallel, Kansei Engineering (KE) has been widely applied to capture and quantify users' emotional responses toward products. KE focuses on translating subjective feelings, perceptions, and emotional preferences into design elements and specifications using psychological and statistical approaches [14]. By incorporating Kansei attributes such as comfort, attractiveness, safety, and ease of use, designers can create products that not only function effectively but also resonate emotionally with users.

In recent years, Kansei Engineering has experienced significant development through integration with artificial intelligence, digital human modeling, and smart product systems. Lu et al. in 2024 reported that Kansei Engineering has increasingly been applied in vehicle and smart interface design to capture complex

emotional responses and improve user interaction quality. Furthermore, Liu et al. in 2023 demonstrated that the integration of KE and Quality Function Deployment can support emotionally intelligent smart home interface design, emphasizing the relevance of KE in modern user-centered product development. These developments indicate that Kansei Engineering is evolving beyond conventional emotional product evaluation toward more intelligent and adaptive ergonomic design systems [30], [31].

The integration of Kansei Engineering and Ergonomic Function Deployment provides a comprehensive framework for ergonomic product design by combining emotional user needs with measurable technical requirements. While KE captures users' affective responses, EFD ensures that these responses are systematically transformed into ergonomic and technical specifications. Several studies have demonstrated that this integrated approach can enhance user satisfaction, reduce ergonomic risks, and improve overall product performance [15]. However, research on the combined application of KE and EFD remains fragmented across different product domains and industries.

Although previous studies have widely discussed Kansei Engineering (KE) and Ergonomic Function Deployment (EFD) independently, studies that systematically integrate both approaches in ergonomic product design remain limited [21], [22], [49]. Most existing research focuses either on emotional user perception without detailed ergonomic translation or on ergonomic specifications without considering users' affective responses [25], [29]. Consequently, there is still a gap in understanding how emotional and ergonomic requirements can be simultaneously transformed into technical product specifications within a unified framework [31], [42].

In addition, previous review studies have generally discussed KE or EFD separately and have not comprehensively synthesized their combined application across various ergonomic product design contexts [18], [19], [51]. Therefore, this study contributes by providing a scientific synthesis of the integration between KE and EFD, identifying methodological trends, integration stages, advantages, limitations, and future research opportunities in ergonomic product development [28], [30].

This study also highlights the novelty of combining emotional design analysis through Kansei Engineering with ergonomic prioritization using Ergonomic Function Deployment in a literature review framework. The proposed synthesis provides a broader conceptual understanding for developing user-centered ergonomic products that consider both emotional satisfaction and ergonomic performance simultaneously [23], [31], [49].

Therefore, this study aims to systematically review and critically analyze previous studies related to the integration of Kansei Engineering and Ergonomic Function Deployment in ergonomic product design, identify research trends and methodological approaches, evaluate the reported ergonomic and emotional outcomes, and formulate research opportunities for future ergonomic product development studies. By examining trends, methodologies, and application outcomes reported in previous studies, this literature review seeks to provide a comprehensive understanding of the potential, benefits, and research gaps associated with the combined KE–EFD approach in designing ergonomic products.

2. Research Methodology

This study adopts a literature review approach to analyze and synthesize previous research related to the application and integration of Kansei Engineering (KE) and Ergonomic Function Deployment (EFD) in ergonomic product design. The methodology is structured to systematically review concepts, procedures, and outcomes reported in scientific publications, enabling the identification of trends, benefits, and research gaps in the combined KE–EFD approach.

This study does not focus on a single product object, but rather reviews various ergonomic product design studies that implement Kansei Engineering and Ergonomic Function Deployment across different industrial contexts. Therefore, the analysis emphasizes methodological integration, ergonomic evaluation, emotional design considerations, and reported outcomes presented in previous studies.

2.1. Literature Selection Procedure

The literature review process was conducted systematically through several stages, including identification, screening, eligibility assessment, and final article selection. Scientific articles were collected from reputable databases such as Google Scholar, Scopus, ScienceDirect, and Springer using keywords including "Kansei

Engineering", "Ergonomic Function Deployment", "ergonomic product design", "user-centered design", and "ergonomic product development". The literature search focused on studies discussing emotional design, ergonomic evaluation, and the integration of Kansei Engineering and Ergonomic Function Deployment in product development [18], [19], [30].

The inclusion criteria in this study consisted of:
a. Articles discussing Kansei Engineering (KE), Ergonomic Function Deployment (EFD), or the integration of both methods;
b. Articles published in national or international peer-reviewed journals;
c. Studies related to ergonomic product design and user-centered product development;
d. Articles published between 2011 and 2025;
e. Studies containing relevant discussions on emotional, ergonomic, or technical design evaluation.

Meanwhile, the exclusion criteria included:
a. Duplicate articles from multiple databases;
b. Non-peer-reviewed publications, editorials, and unpublished reports;
c. Studies not directly related to ergonomic product design;
d. Articles lacking sufficient methodological explanation or research findings relevant to this review.

A total of 78 articles were initially identified through database searching. After the screening process based on titles, abstracts, and relevance to the research topic, 52 articles met the eligibility criteria. Finally, 35 selected articles were comprehensively analyzed and synthesized in this review study to identify research trends, methodological approaches, integration frameworks, and reported outcomes related to the application of KE and EFD in ergonomic product design.

2.2. Kansei Engineering (KE)

Kansei Engineering is a product development method that focuses on translating users' emotional responses, feelings, and perceptions into concrete design elements and technical attributes. The primary objective of KE is to ensure that products are not only functional but also capable of satisfying users' psychological and emotional needs [25]. KE is commonly applied to support user-centered and emotion-oriented product design and is utilized for the following purposes, which is as [26]:
a. method to identify and quantify users' emotional needs related to comfort, safety, aesthetics, and usability.
b. structured approach to translate subjective Kansei attributes into measurable product design parameters.
c. decision-support tool to assist designers in selecting design alternatives that best reflect user preferences.

The general steps of Kansei Engineering applied in product design studies are as follows [27]:

a. Identification of Kansei words: Relevant Kansei words describing users' emotions, perceptions, and impressions toward a product are collected through literature studies, interviews, or questionnaires.

b. Classification and structuring of Kansei words: The collected Kansei words are grouped and structured to represent dominant emotional dimensions relevant to the product.

c. Linking Kansei words with product attributes: Relationships between emotional responses and physical or design attributes of the product are identified using qualitative or quantitative analysis techniques.

d. Analysis and interpretation: Statistical or analytical methods are used to determine the influence of product attributes on users' emotional perceptions.

e. Design concept development: The results are used as a basis for developing product design concepts that reflect user emotions and preferences.

2.3. Ergonomic Function Deployment (EFD)

Ergonomic Function Deployment is a systematic product development method derived from Quality Function Deployment (QFD), with a specific focus on incorporating ergonomic principles into product design. The goal of EFD is to ensure that products meet ergonomic requirements related to safety, comfort, efficiency, and health, thereby reducing ergonomic risks and improving user performance [28].

EFD is commonly used to translate user needs into technical specifications through structured matrices, often referred to as the House of Ergonomics. The main purposes of EFD include [29]:
a. Identifying and prioritizing ergonomic requirements based on user needs.
b. Translating ergonomic needs into measurable technical characteristics.
c. Supporting designers in making ergonomic-oriented design decisions.

The general steps of Ergonomic Function Deployment are as follows [30]:

a. Identification of user needs and ergonomic requirements: User needs related to posture, comfort, safety, and ease of use are identified through literature review, observation, or user feedback.

b. Determination of importance and priority levels: Each ergonomic requirement is weighted based on its level of importance to users.

c. Translation into technical specifications: Ergonomic requirements are transformed into technical parameters using the House of Ergonomics matrix.

d. Evaluation of relationships and correlations: The strength of relationships between ergonomic requirements and technical characteristics is evaluated.

e. Design improvement and final specification development: The results are used to propose ergonomic design improvements and finalize product specifications.

2.4. Integration of Kansei Engineering and Ergonomic Function Deployment

The integration of Kansei Engineering and Ergonomic Function Deployment provides a comprehensive framework for ergonomic product design by combining emotional and ergonomic aspects. In this integrated approach, Kansei Engineering is used to capture and quantify users' emotional responses, while EFD systematically translates these emotional and ergonomic needs into technical design specifications [31].

In this literature review, the integration process is analyzed based on the following stages:
a. Identification of emotional and ergonomic user needs from previous studies.
b. Mapping Kansei attributes into ergonomic requirements.
c. Translation of combined requirements into technical specifications using EFD matrices.
d. Evaluation of reported outcomes related to user satisfaction, ergonomic performance, and product effectiveness.

This structured methodology enables a comprehensive understanding of how the KE–EFD integration has been applied in various product design contexts and serves as a basis for identifying research gaps and future research opportunities.

3. Method's Integration

The research methodology entitled "Combination of Kansei Engineering and Ergonomic Function Deployment (EFD): A Review of Literature" was conducted using a systematic literature review approach to examine and describe the integration between Kansei Engineering and Ergonomic Function Deployment in ergonomic product design. This study carefully selected and evaluated relevant literature from reputable national and international journals to obtain a comprehensive understanding of the advantages, challenges, and potential synergies of integrating KE and EFD methods.

The research process involved the identification of research objectives, selection of information sources, and determination of inclusion and exclusion criteria. Through this approach, the study reviews recent developments related to the combined application of KE and EFD, highlighting how emotional user needs and ergonomic requirements are translated into technical design specifications. The stages of data collection and in-depth analysis of previous studies form the basis for synthesizing key findings into a coherent literature review, providing a comprehensive understanding of the role of KE–EFD integration in improving ergonomic performance, user satisfaction, and product effectiveness. The literature search process was conducted using relevant keywords that represent the scope of this study, such as Kansei Engineering, Ergonomic Function Deployment, ergonomic product design, and user-centered design [31].

The general framework of the integration between Kansei Engineering and Ergonomic Function Deployment is illustrated in Figure 1.

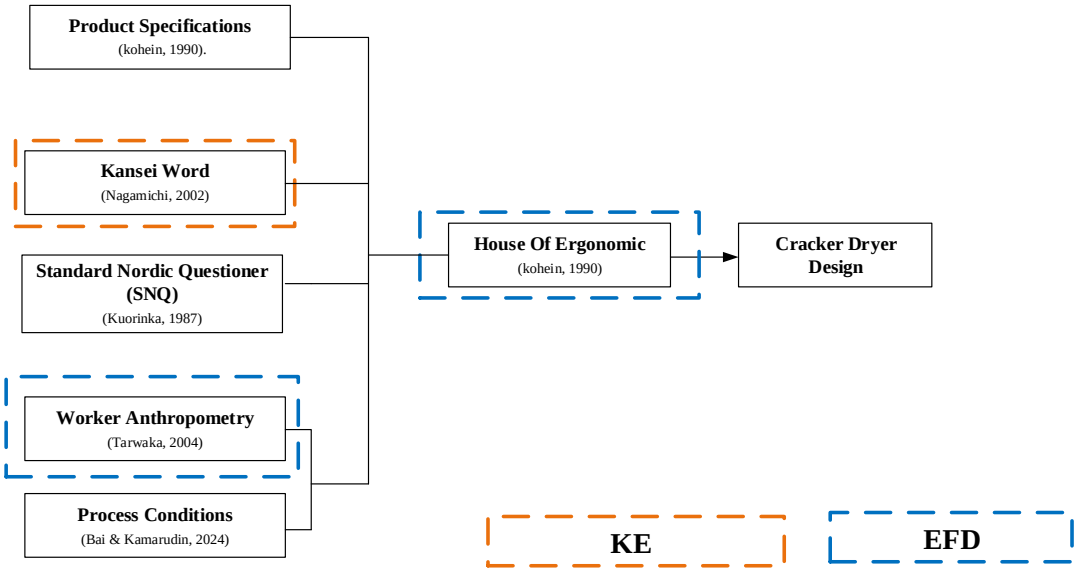

Figure 1. Integration Framework of Kansei Engineering and Ergonomic Function Deployment

Based on Figure 1, the steps of KE–EFD integration are described as follows:

1. Identification of User Needs and Kansei Attributes: At this stage, users' emotional responses, perceptions, and impressions toward products are identified using Kansei Engineering concepts. Kansei words representing comfort, safety, attractiveness, usability, and satisfaction are collected from literature sources, questionnaires, or previous empirical studies [32]. This step aims to capture the emotional dimension of user needs as the foundation of ergonomic product design.

2. QFD-Based Ergonomic Analysis (House of Ergonomics): A structured Ergonomic Function Deployment analysis is conducted using a QFD-based approach. The first phase focuses on translating user needs and Kansei attributes into ergonomic requirements, such as posture suitability, reachability, force exertion, and safety [33]. The second phase determines critical technical characteristics that require priority improvement in order to fulfill both emotional and ergonomic requirements [34].

3. Design Concept Development: Based on the results of KE and EFD analysis, an initial design concept is developed. This stage defines the product structure, materials, dimensions, and functional elements while considering ergonomic principles and emotional user preferences [35]. The design concept serves as an early identification of potential ergonomic issues and design constraints.

4. Evaluation of Ergonomic and Emotional Design Attributes: An evaluation of the proposed design is conducted by reviewing previous studies that applied KE–EFD integration. Questionnaire-based assessments, ergonomic evaluation tools, and comparative analyses reported in the literature are examined to identify dominant factors influencing user satisfaction and ergonomic performance [36].

5. Identification of Design Improvements and Optimization: At this stage, design attributes are identified for improvement, modification, or optimization based on ergonomic risks and emotional response priorities. The integration of KE and EFD enables designers to balance emotional satisfaction and ergonomic feasibility by refining product dimensions, layout, and functional features [37].

6. Assessment of Ergonomic Effectiveness and Design Performance: The effectiveness of the integrated design approach is evaluated through reported outcomes in the literature, such as improvements in comfort, reduction of musculoskeletal disorder risks, increased productivity, and enhanced user satisfaction. Several studies also employ efficiency indicators or ergonomic performance metrics to assess design improvements [38].

7. Simulation and Validation: Some reviewed studies include simulation and validation stages, such as digital

human modelling, posture analysis, or stress analysis using computer-aided design tools. These simulations are used to evaluate ergonomic performance under realistic usage conditions and to validate the effectiveness of the proposed ergonomic design solutions [39].

4. Results and Discussion

Several previous studies highlight the importance of integrating emotional and ergonomic aspects in product design to enhance user satisfaction and product performance. Nagamachi in 2011 states that Kansei Engineering is effective in translating users' emotional responses into design parameters, enabling designers to understand subjective user perceptions such as comfort, safety, and attractiveness in a structured manner [41]. Furthermore, KE emphasizes iterative improvement, as emotional preferences may evolve based on user experience and product usage.

Research by Schütte in 2015 shows that Kansei Engineering can be integrated with systematic design approaches to improve user-centered product development. The study emphasizes that KE is not only applicable to aesthetic design but also to functional and ergonomic aspects of products, particularly when supported by quantitative analysis tools [42]. In addition, KE has been widely applied in industrial product design to bridge the gap between emotional user needs and technical decision-making processes [43].

Several studies also emphasize the role of Ergonomic Function Deployment in ensuring that ergonomic requirements are effectively incorporated into product design. Helander and Lin in 2002 describe EFD as a structured method that extends Quality Function Deployment by focusing on ergonomic factors such as posture, reach, force, and safety [44]. EFD enables designers to prioritize ergonomic requirements and systematically translate them into technical specifications. Research by Hartono and Tan in 2011 demonstrates that EFD contributes to improved comfort, reduced musculoskeletal disorder risks, and increased productivity in product usage [45].

The integration between Kansei Engineering and Ergonomic Function Deployment has been discussed in several recent studies. Junior and Borsato in 2020 emphasize that KE and EFD are complementary methods, where KE captures users' emotional needs while EFD translates these needs into measurable ergonomic and technical parameters [46]. This integration allows product designers to consider both subjective and objective user requirements simultaneously. Similarly, Pudi in 2023 highlights that understanding user needs—both emotional and ergonomic—is a key factor in improving product quality and reducing redesign costs, particularly when KE and EFD are applied within a concurrent engineering framework [47].

Research conducted by Ginting et al. in 2019 shows that the integration of ergonomic analysis and user perception assessment can significantly improve design efficiency and user comfort. The study indicates that prioritizing ergonomic requirements through EFD while incorporating emotional satisfaction through KE leads to more comprehensive design improvements [48]. Meanwhile, Guo and Sun in 2022 report that product attributes such as geometry, dimensions, and material selection play a critical role in fulfilling ergonomic and emotional requirements identified through KE–EFD integration [49]. Table 1 presents a summary of previous studies reviewed in this research, highlighting the combination of Kansei Engineering and Ergonomic Function Deployment and their reported outcomes.

Based on Table 1, the integration of Kansei Engineering and Ergonomic Function Deployment provides several significant benefits, including improved ergonomic performance, increased user satisfaction, reduced risk of musculoskeletal disorders, and enhanced design effectiveness. The reviewed studies indicate that KE plays a crucial role in capturing emotional user needs, while EFD ensures that these needs are systematically translated into ergonomic and technical specifications.

Critically, the reviewed studies reveal that most applications of Kansei Engineering primarily focus on emotional evaluation without fully integrating ergonomic risk assessment [21], [25], [30]. Conversely, studies applying Ergonomic Function Deployment tend to emphasize technical and ergonomic specifications while paying limited attention to users' emotional perceptions [20], [40], [51]. This separation indicates that many ergonomic product development approaches still partially address user-centered design principles and have not comprehensively integrated emotional and ergonomic considerations simultaneously [49].

Table 1. Summary of Previous Studies on the Integration of Kansei Engineering and Ergonomic Function Deployment

Reference	Research Focus	Methods Used	Main Findings	Contribution
Nagamachi (2011)	Emotional product design	Kansei Engineering	KE translates emotional responses into design parameters	Introduced emotional-based product design approach
Hartono & Tan (2011)	Ergonomic product improvement	KE and EFD	Integration improved comfort and productivity	Demonstrated effectiveness of KE–EFD integration
Junior & Borsato (2020)	User-centered product development	KE and EFD	Emotional and ergonomic needs are complementary	Strengthened integrated user-centered design
Liu et al. (2023)	Smart home interface design	KE and QFD	Emotional design improved user interaction quality	Expanded KE application in smart systems
Zhang et al. (2025)	Digital ergonomic modeling	Ergonomic simulation	Posture prediction improved ergonomic validation	Supported digital ergonomic assessment

From a theoretical perspective, the integration of Kansei Engineering and Ergonomic Function Deployment aligns with human-centered design principles proposed in ISO 9241-210, which emphasize that product development should consider users' physical, cognitive, and emotional characteristics simultaneously [23]. The reviewed studies demonstrate that combining emotional analysis through KE with ergonomic prioritization using EFD enables more comprehensive product development outcomes compared to applying each method independently [22], [29], [42].

Furthermore, the literature indicates that the KE–EFD integration contributes not only to ergonomic improvements but also to sustainable product competitiveness. Products developed through this integrated approach tend to achieve better usability, comfort, emotional acceptance, and operational efficiency [18], [31], [49]. However, several limitations remain, particularly regarding the lack of standardized integration procedures and the limited use of advanced digital simulation tools to simultaneously validate ergonomic and emotional performance [30], [54].

Therefore, future research should focus on developing more standardized integration frameworks and incorporating digital human modeling, artificial intelligence, and real-time ergonomic evaluation systems to improve the effectiveness and scalability of KE–EFD implementation across various industrial sectors [10], [25], [54].

However, despite the demonstrated advantages, the integration of KE and EFD remains limited in many product design studies. Most research applies these methods independently, resulting in partial consideration of either emotional or ergonomic aspects. The findings suggest that a structured integration framework—such as the one illustrated in Figure 1—can enhance the effectiveness of ergonomic product design. By identifying user needs through Kansei Engineering and prioritizing ergonomic requirements using Ergonomic Function Deployment, designers can determine critical design attributes that require improvement. This integrated approach enables the modification, optimization, or elimination of design elements that negatively affect comfort, safety, and user satisfaction, ultimately leading to ergonomic products that are more user-centered and competitive.

5. Conclusions

This review demonstrates that the integration of Kansei Engineering and Ergonomic Function Deployment provides a comprehensive approach for ergonomic product development by combining emotional user perception with ergonomic and technical requirements. The reviewed studies consistently indicate improvements in comfort, usability, safety, and user satisfaction when both methods are applied simultaneously. The integration framework also supports more systematic decision-making in translating user needs into product specifications while reducing ergonomic risks and improving product effectiveness. In addition, the findings highlight the importance of interdisciplinary collaboration, ergonomic evaluation tools, and user-centered design principles in achieving successful product development outcomes. Despite its

potential, the implementation of KE–EFD integration remains limited and lacks methodological standardization across industries. Therefore, future studies are recommended to develop more standardized integration models and incorporate digital technologies such as simulation systems and intelligent ergonomic analysis tools to strengthen ergonomic product design practices.

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