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The integration of Ergonomics Ergo-System Framework (EESF) with the product design process in the innovation ergonomic seating support for scoliosis patients

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Abstract

Several researches in medical science have revealed that individuals who have scoliosis experience discomfort while sitting upright, leading to symptoms like leg pain, back pain, and claudication. These symptoms can limit their ability to perform certain tasks in the office. Thus, this paper utilized Ergonomics Ergo-System Framework (EESF) to design a innovative ergonomic seating support for scoliosis patients. Through the interview study conducted with a rehabilitation specialist, a physiotherapy expert, and three scoliosis patients in Malaysia, the EESF was integrated to identify patients design issues and needs. The result of solution components and design criteria obtained from the interview study highlights the parameters for the development of ergonomic seating support. The decision of innovative design of the ergonomic seating support incorporated the modular seating concept for office use, visually aesthetic with emotional design elements, and equipped with adjustable spinal support. To develop the semi-working ergonomic seating supporter concept model for future production, a design process was executed. It is hoped that the outcome of this study will contribute to demonstrating how the EESF can be utilized, integrated with the innovative product design process, and benefit scoliosis patients.

*Keywords: Ergonomics Ergo-System Framework, Design Thinking, Scoliosis, Erg*onomic, Product Design

1. Introduction

Scoliosis is a condition that occurs in mature patients with a spinal deformity where the Cobb angle in the coronal plane is greater than 10 degrees. Aebi (2005) has classified scoliosis into four major categories. The first type, as shown in **Figure 1**, is primary degenerative scoliosis, which is primarily caused by arthritis in the discs and/or facet joints. This leads to an asymmetrical impact on those structures and typically results in back pain indications. It frequently occurs with or without symptoms associated with spinal stenosis, both central and lateral stenosis. This curvature is referred to as "de novo" scoliosis (Benner & Ehni, 1979; Epstein et al., 1979; Fowles et al., 1978; Grubb et al., 1988; Grubb & Lipscomb, 1992; Korovessis et al., 1994; McKinley et al., 1977).

The second type of scoliosis, as depicted **in Figures 2, 3,** and **4,** is progressive idiopathic scoliosis that occurs during adulthood. The thoracic and/or lumbar spine are commonly affected by this scoliosis, which continues throughout adulthood. It frequently has a connection to secondary degeneration and/or imbalance (Kostuik & Bentivoglio, 1981; Ogilvie, 1992; Sponseller et al., 1987; Winter & Lonstein, 1983).

The third type of scoliosis, illustrated in Figure 5, is secondary degenerative scoliosis. It can develop as follows: (a) It may develop when a person has idiopathic, or another kind of scoliosis, or due to a pelvic obliquity caused by hip pathology, an imbalance in leg length or a lumbosacral transitional malformation. This scoliosis type o is mainly found in the thoracolumbar, lumbar, or lumbosacral spine. (b) Scoliosis can also be caused by metabolic bone disease, such as asymmetric, osteoporosis, arthritic disease, and/or spinal fractures (Bradford et

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al., 1999; Deyo et al., 1992; Healey & Lane, 1985; Robin et al., 1982; Velis et al., 1988)

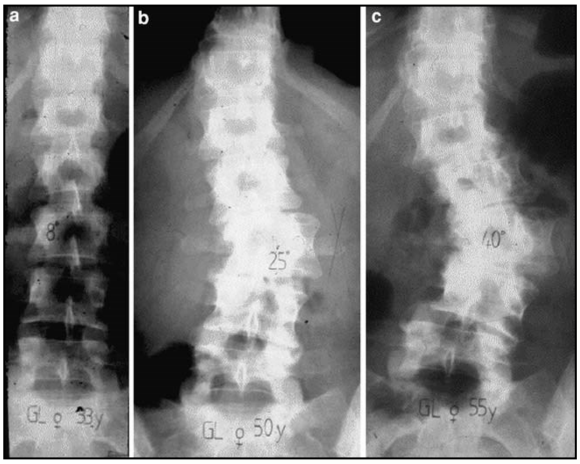

Figure 1. De novo scoliosis (type 1 adult scoliosis). **(a)** age 33 (8 degrees), **(b)** age 50 (25 degrees), and **(c)** age 55 (40 degrees), adopted from Aebi (2005).

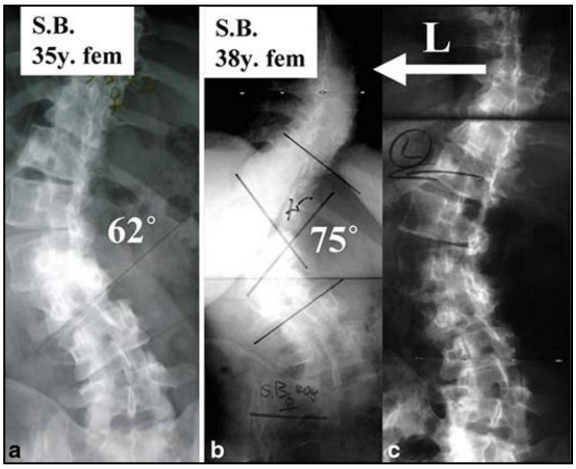

Figure 2. A young female with progressing idiopathic scoliosis occurred in adult life (type 2 scoliosis). **(a)** 62 degrees at age 35 **(b)** advanced to 75 degrees at age 38, and **(c)** left bending with minor correction, adopted from Aebi (2005).

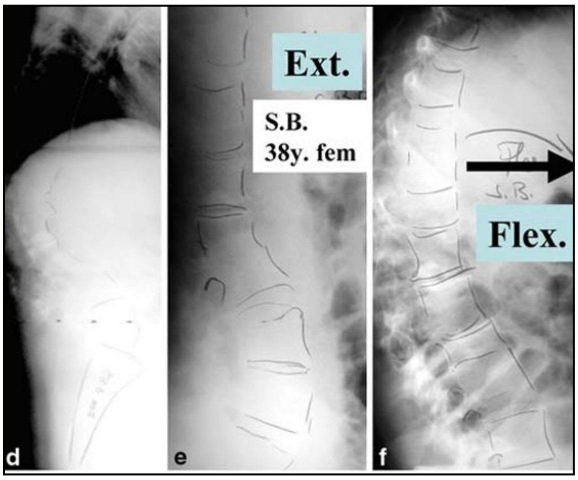

Figure 3. A young female with progressing idiopathic scoliosis occurred in adults. (type 2 scoliosis) **(d)** severe lumbar kyphosis; **(e)** partial extension correction; **(f)** thoracic spine flexion, adopted from Aebi (2005)

Figure 4. A young female with progressive idiopathic scoliosis occurred in adulthood (type 2). **(g) and (h)** 18 months post-operation, adopted from Aebi (2005).

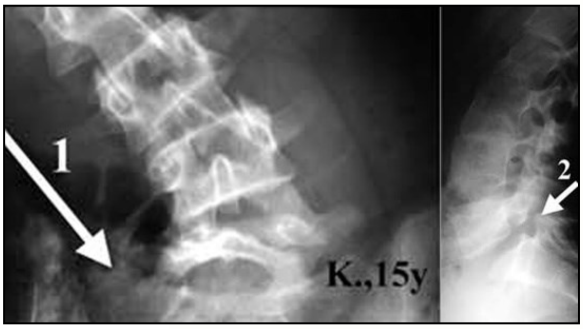

Figure 5. Scoliosis of type 3 in a female patient, age 25. Arrows **(1)** indicate a transitory abnormality while Arrows **(2)** indicate L5 spondylolysis, adopted from Aebi (2005).

Scoliosis may appear at any age and can either get worse or start to cause symptoms in adults. Alternatively, scoliosis can develop in adulthood without any prior history, referred to as "de novo" scoliosis. Aebi (2005) notes that the most common clinical groupings are secondary (type 3) and primary (type 1) degenerative adult scoliosis. Osteoporosis can exacerbate both types of scoliosis in older adults, including type 2 scoliosis. At some point, all three types of scoliosis can present as degenerative scoliosis, which is the primary form of adult scoliosis.

The exact cause of scoliosis with a primary location in the lumbar or thoracolumbar spine is difficult to identify, but once an asymmetric load or degeneration occurs, a predictable pathomorphology and pathomechanism can be observed, as noted by Aebi (2005). Asymmetric degeneration can lead to an increase in asymmetric load, which can cause the development of scoliosis and/or kyphosis as well as deformity. Osteoporosis, particularly in postmenopausal women, can also contribute to the progression of the curve. The facet joints, joint capsules, discs, and ligaments can all be affected and destroyed, resulting in mono or multisegmented instability, and eventually, spinal stenosis.

Ágústsson, Sveinsson, and Rodby-Bousquet (2017) suggest that scoliosis can be caused by the weakening of spinal muscles, leading to discomfort, deformity, and decreased cardio-respiratory function. Lephart and Kaplan (2015) assert that individuals with scoliosis may have difficulty sitting upright and may experience pain, potentially restricting their activities. Back pain is the most frequent indication, followed by leg pain and claudication, while neurological problems and concerns about appearance are rare. Once the muscle weakness is severe, the resulting deformity can be challenging to treat, making slowing the progression of the condition the most effective approach.

Seeger and Sutherland (1981) state that traditional wheelchair designs do not provide proper support to the spine due to the lack of stable pelvic position and resistance to sideways spine bending. Crytzer et al. (2016) found that the design of seating supports significantly affects seating comfort and functionality and lowers spinal strains and associated healthcare costs. Seeger and Sutherland (1981) hypothesized that custom-molded seating may improve sitting comfort and delay spinal curvature advancement in scoliosis patients, and aimed to develop low-cost, comfortable seating to aid spinal deformity treatment. The work on this subject has previously varied from merely cushioning the armrest to specially molded chairs to disperse force over the rib cage. Although the method was labor-intensive and therefore expensive, a variety of comfortable chairs were made by Seeger and Sutherland's (1981) early attempt at custom molding utilizing the bean bag expulsion and consolidation technique. In order to help correct spinal deformity, they set out to build a low-cost method of enabling comfortable seating. Utkan, Fredericks, and Butt (2011) conducted a study using the Scoliometer, an inclinometer that determines any trunk asymmetries or axial trunk inclination (ATI) in the torso flexion, to investigate the impact of self-selected back support on adults with scoliosis during seating. It was discovered that all respondents opted to pick support that was not uniform throughout the lower back based on the 35 diodes in the low back that they self-selected to adjust for their support needs. The study highlights the importance of further assessment of seating issues and ergonomic seating support design for adult scoliosis patients.

This research paper is focused on the integration of ergonomics EESF with the product design process in the innovation of ergonomic seating support for scoliosis patients. It highlights the importance of incorporating human factors in product design, which involves studying human behavior, identifying obstacles and expectations, and conducting research and development to develop innovative products that offer increased value to users. This approach is currently considered a crucial aspect of product design (Abdullah Sani et al., 2019; Chumiran et al., 2020; Kamil et al., 2018, 2019a, 2019b; Kamil & Abidin, 2013; Li & Mohamed Kamil, 2022; Mohamed Kamil et al., 2020; Mohamed Kamil, Ho Wan Ying, et al., 2022; Mohamed Kamil, Hua, et al., 2022; Mohamed Kamil & Abdullah Sani, 2021; Mohamed Kamil & Abidin, 2014; Mohamed Kamil & Shaukat, 2023; Mohamed Kamil & Zainal Abidin, 2014, 2015; Sani et al., 2020).

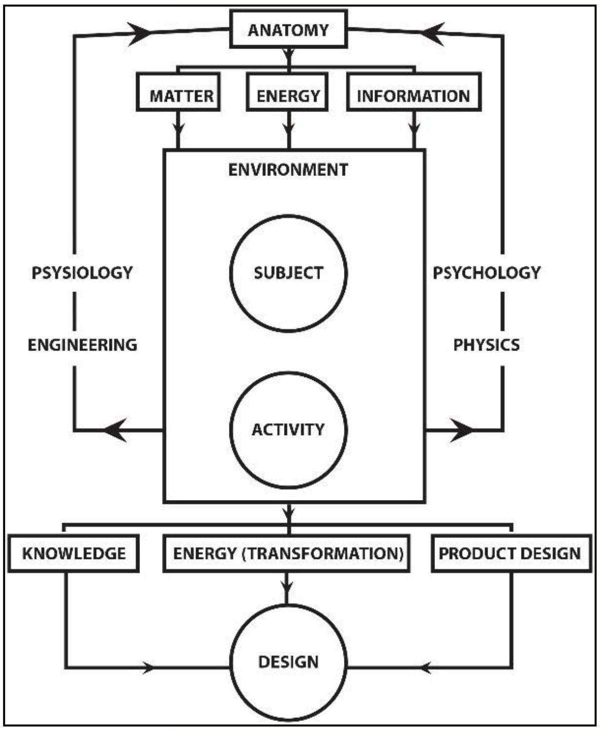

Figure 6. Scoliosis of type 3 in a female patient, age 25. Arrows **(1)** indicate a transitory abnormality while Arrows **(2)** indicate L5 spondylolysis, adopted from Aebi (2005).

The main objective of the study is to explore the potential for theoretical investigation that complements design practices, to create innovative product designs that meet the needs of users. As proposed by Bridger (2008), the EESF is typically employed to enhance system performance but has been adapted here for product design practice, specifically to develop an ergonomic seating supporter for scoliosis patients (see Figure 6). The framework consists of five elements drawn from the fields of ergonomics: anatomy, and engineering. physiology, psychology, and physics. The five elements interact with each other and the environment, with the synchronization of "people" and "machine" interactions forming the foundation of the framework to generate a specific output. The input of supplementary variables, material, design needs, and facts, varies depending on the stage of human factors study. In this study, the framework is employed to support designers' design thinking from the initial levels of empathizing with the user's needs, through brainstorming and ideation, to prototyping and testing. The user's synchronization with the context is the foundation of the system. Understanding the user's condition or circumstance in a particular context or location is essential to comprehending the relationship. The subject's condition or circumstance will provide insight into their thoughts on the physics of their environment and how it impacts their psychology and needs. Academically, this research also aims to broaden the understanding of the importance of ergonomics and design thinking and to present the product design process. It is hoped to broaden knowledge and motivate future investigation in design research by embracing cross-disciplinary studies with relevance to physiology.

2. Methodology

In this study, the development of an ergonomic seating supporter for scoliosis patients was conducted based on previous research that integrated ergonomics, behavior, and product design needs (Bruno et al., 2016; Chen & Chu, 2012; Demirbilek & Sener, 2003; Kamil & Abidin, 2013; Matos et al., 2014; Mohamed Kamil et al., 2020; Mohamed Kamil, Hua, et al., 2022; Sani et al., 2020; Schütte, 2005). The main objective of the study was to identify the design elements needed by scoliosis patients, incorporating the ideal design feature for the ergonomic seating supporter, to improve their physical comfort while sitting. To achieve this, a semi-structured interview was held with three scoliosis patients, a rehabilitation expert, and a physiotherapy expert, with each interview session lasting 45 minutes at the Advanced Medical and Dental Institute in Penang, Malaysia. The five sets of ergonomics scientific elements - physiology, anatomy, physics, engineering, and psychology, were proposed in the ergonomics ergo system framework and served as the basis for the construction of the interview questions. For example, the physiology expert was interviewed to obtain a professional opinion on issues related to scoliosis, such as its symptoms and diagnosis (anatomy), its impact on physical well-being (physiology), its impact on patients' emotional state (psychology), and available treatment options (physiology). The rehabilitation expert was interviewed to gain a deeper understanding of the rehabilitation technology available for scoliosis (engineering) and the variation of physical treatment (physics), while the interview with scoliosis patients aimed to assess design requirements based on their difficulties and psychological responses to existing ergonomic seating (psychology and physics).

2.1 Phase 1: Assessing the design needs.

In order to establish a clear design direction, the design thinking and the EESF had to be integrated, and the interview analysis played a significant role in the design process. During the first phase of the interview data analysis, the focus was on gaining a better understanding of the respondents, their challenges, and design requirements. In this research, the EESF forms the basis of the researcher's cognitive process, ensuring alignment between the respondents and their contextual surroundings. Employing this framework, the study seeks to investigate the circumstances and conditions of participants, offering insights into how the environment impacts their psychology and requirements (Mohamed Kamil & Abdullah Sani, 2023). This all-encompassing approach considers the dynamic interplay among anatomy, engineering principles, physiological aspects, psychological factors, and the laws of physics, fostering an in-depth comprehension of the experiences of individuals with scoliosis. For instance, in the study of activities leading to back discomfort among scoliosis patients, the anatomical aspect of the EESF plays a pivotal role in understanding the physical configuration of scoliosis patients, particularly the curvature of the spine and its influence on posture and movement. Simultaneously, the physiological component of the ESSF is imperative for recognizing how the physiological aspects of patients' conditions impact bodily functions and comfort, encompassing the evaluation of muscle activity, blood flow, and respiratory patterns. This gathered information is then utilized to customize the design to accommodate the physiological variations associated with scoliosis.

The interview analysis followed the three coding steps described by Creswell (2009) and Saldaña (2009), including open coding, axial coding, and selective coding, to systematically analyze and organize the transcriptions of the interview data into categories of information. In a study to identify activities that may have caused back discomfort among the participants, the researcher employed a method known as open coding, which involves the identification of descriptive labels or speech analysis features from the respondents' utterance. The components of the respondents' speech were then separated out and categorised by the researcher, as indicated in Table 1. In order to create axial codes, which are more conceptual categories, the resultant open codes were further abstracted. Through selective coding, comparable coded data were grouped into conceptual categories that were derived from the open codes. The axial codes were adjusted to achieve the best match, and more than one axial code may have been created during this process. Additionally, data that was "divided" or "fractured" during the open coding process was reconstructed. The axis represents a category that was created from open coding at this level, and identifying these dimensions and organizing the available codes along them is a primary objective of early coding. For instance, based on their connections to one another, the open codes shown in Table 1 were given new names and rearranged. The researcher might have to repeat the process and recode the data after choosing a category or dimension depending on the newly developing notion that is encapsulated in the category or dimension. Muller and Kogan (2010) suggest that selecting which codes to develop further requires a choice of issues to research. Selective coding involves extracting data by examining the links between the groups created by axial coding (Creswell, 2009). The chosen coding only retains variables that are applicable and relevant to the key variables of the procedure, in order to produce explicit information. The core category, or axial coding, was identified and then classified and recoded as selected codes to provide a clear representation of the information. This process may need to be repeated several times to establish the relationship between the codes and develop the most plausible explanation.

Table 1. Sample of coding on respondents' activities that may have caused back discomfort.

Index	Respondent 1	Respondent 2	Respondent 3
Protocol Time	13:30	15:12	11:45
Transcriptions	"...I often feel back discomfort when I handle big goods and spend a lot of time standing, walking, or even sitting... My waist carries a lot of weight..."	"It usually appears to me that doing a lot of work makes my body weak and hurts my back..."	"…I don't think I can stand or walk for long periods of time without my back hurting..."
Attributes	1. Lifting heavy objects 2. Spending a lot of time standing, walking and sitting	1. Doing a lot of work	1. Standing for a long periods of time 2. Walking for a long period of time
Open Codes: Categories of information	Handling a lot of weight for an extended period of time including standing, walking, and sitting became a burden for the waist and resulted in back discomfort.	Doing a lot of work caused back pain.	Walking and standing for a long period of time caused the back pain.
Axial Codes	Scoliosis patients feel the back pain as a result of carrying a lot of weight, standing, walking, and sitting for a lengthy period of time.	Scoliosis patients feel back pain when they do a lot of work.	Scoliosis patients feel back pain from walking or standing for long periods of time.
Selective Codes	Carrying a lot of weight repeatedly including walking, standing, and sitting for a lengthy period of time causes back pain to scoliosis patients.		

3. Results

In this study, the coding technique used to analyze interview data started with empathizing with the situation that was being investigated. The study evaluated design requirements for scoliosis patients by considering five elements of ergonomics science: physiology, psychology, physics, anatomy, and engineering, within the ergonomics ergo system framework. During the interview, respondents provided information about the state or status of scoliosis patients, specifically how their circumstances and environment affect their needs. By understanding the anatomical and physiological requirements, it was possible to identify the significant design features and facts that could be improved further in the ergonomic seating supporter design process. The results of the interview were summarized into three descriptions of design needs and solution components, as shown in **Table 2**.

Table 2. Sample of coding on respondents' activities that may have caused back discomfort.

Descriptions of Design Needs	Solution Components
Patients sit in their office for half of the day. Therefore, the design of the ergonomic sitting should be modular and compatible with standard office chair designs.	Modular seating design for office users.
Most ergonomic seating supporter already on the market was poorly designed and gave the appearance of having health issues, which made patients feel less confident. Therefore, the aesthetic component of the ergonomic design should aid in regaining the confidence of patients.	Visually aesthetic design
Each patient has a unique spinal issue and curvature. Hence, ergonomic sitting should be flexible to accommodate spinal conditions, especially for an extended period of time of sitting.	Adjustable support

3.1 Phase 2: Generating design ideations.

The three descriptions of design needs and solution components were previously developed as a result of interview analysis. While this is happening, the next process involves generating design criteria for the ergonomic seating supporter using the three elements of solutions (see **Table 3**).

Table 3. Sample of coding on respondents' activities that may have caused back discomfort.

Design Criteria	Descriptions
Modularity	The ergonomic seating supporter would serve as a modular supporter that should be compatible with a variety of office seat designs.
Emotional element	The ergonomic seating supporter should boost the patient's sense of confidence overall.
Adjustable spinal support	Longer periods of comfortable sitting should be possible with ergonomic seating supporter. The ergonomic seating supporter should be assistive to reduce spinal dullness and stress.

Based on the stated descriptions of design needs, the modular concept, emotional element, and adjustable spinal support will be incorporated into the ergonomic seating supporter design. The ergonomic seating supporter is intended to be created as a modular supporter that can work with different seat designs. This is to ensure that potential users who spend a lot of time sitting at their desks can use products that complement different office chair designs. Additionally, it is believed that including an emotional component in the design will increase the patient's confidence. As outlined in the EESF, the psychological aspect is integrated during the study to comprehend the mental and emotional aspects of living as scoliosis patients, and how these factors influence their perceptions of comfort and discomfort. This knowledge contributes to the development of a seating supporter that addresses not only physical but also psychological well-being. Hence, the design's improved aesthetics would make potential users feel emotionally comfortable using the product. Aligned with the physics component within the EESF, the design will integrate adjustable spinal support features to provide flexibility and adaptability, catering to the unique spinal conditions and curvature exhibited by each scoliosis patient. This strategic incorporation is intended to mitigate spinal tension and alleviate the dullness associated with extended periods of sitting, thereby enhancing the product's effectiveness in addressing the specific needs of users.

Then, a sketching activity (Figure 7) was conducted to initiate the design ideation. With the term "idea" referring to a core thought that might be visual, physical, or abstract, design ideation may be characterized as the process of producing and exchanging ideas. Sketching, which has long been recognized as a crucial conceptual tool in this process, may help to fully comprehend the visual structure and composition of form design, as well as how form aesthetics operate and how form ingredients are organized. Components made from design requirements were utilized to visualize various stages of the ergonomic seating supporter development.

Figure 7. Design ideation process.

3.2 Phase 3: Model making process.

As illustrated in Figure 8, using the Autodesk Inventor 3D Design software, the result of the sketching process was transformed into a three-dimensional (3D) design. Over time, 3D modelling design software has demonstrated its ability to speed up the design process, especially in terms of effectiveness, job quality, and the final product. A realistic enhancement was made to the design's size and visual qualities (Mohamed Kamil & Abdullah Sani, 2020; Zhuopeng et al., 2023). The 3D design outcome makes it simpler to comprehend all aspects of the ergonomic sitting supporter design, including features, colors, and product measurements.

Figure 8. Three-dimensional (3D) design development.

In this phase, the engineering aspect of the EESF is utilized during the model-making process to construct design solutions capable of tackling the challenges presented by scoliosis. This involves a comprehensive consideration of the structural elements and material properties inherent in seating supporters. The envisioned design outcome aims to furnish substantial support, ensuring comfort, and facilitating the promotion of correct spinal alignment. The model-making process was initiated after the completion of 3D development. In this process, the research team can ensure that a concept is viable by creating a model to show how the real product would look. This required using a 3D printer called an Ender using the created 3D files. Throughout the procedure, the Ender 3D printer's Polylactic Acid (PLA) filament spool was inserted and fuelled directly into the head for extrusion to the printer's nozzle (see Figure 9). The motor then enables the filament to melt and pushes it through the 0.4mm printer nozzle after bringing it to the necessary temperature (approximately 200–210 °C). The extrusion nozzle moves in accordance with the mapped coordinates, causing the blackened material to harden on the plate.

Figure 9. 3D printing process and the printed outcome.

Then, a metal structure was fabricated, the spinal support adjuster was installed, and memory foam upholstery was completed (see Figure 10 and Figure 11). The technical elements of the model were continuously investigated throughout the process to be certain that all flaws in the design were corrected. The limitations of the ergonomic seating supporter and what actual users would behave, believe, and perceive when using the final design were preliminarily identified during this stage.

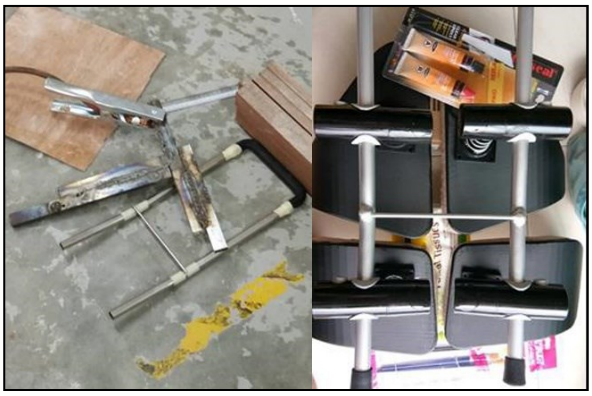

Figure 10. The fabrication of metal structure, and the installation of the spinal support adjuster.

Figure 11. The installation of memory foam upholstery.

After the serial iteration processes, which involve numerous adjustments to match the appropriate comfort, the final semi-working model is finished (see Figure 12). The aesthetic characteristics that distinguish the current ergonomic chair design trend including the practical issues underlining how possible users would act, think, and feel when handling the final product are among the most significant qualities of the semi-working model.

Figure 12. The final semi-working prototype.

4. Discussion

In this study, the EESF was utilized to incorporate the five sets of ergonomics science elements, including physiology, psychology, physics, anatomy, and engineering, which are crucial in addressing the specific requirements of scoliosis patients. The integration of EESF served as a design model that guided the research process through conducting a semi-structured interview study with rehabilitation experts, physiotherapy experts, and scoliosis patients. The interview data were analyzed using a three-step coding process, including open coding, axial coding, and selective coding. Open coding involves creating descriptive labels or speech analysis features to categorize the interview data. Axial coding was then used to create more abstract conceptual categories based on the open codes. Finally, selective coding involved sorting and relabeling the coded data to identify the design needs and solution components. Through the coding analysis of the interview data, it was found that extended periods of sitting can have an adverse effect on the comfort, posture, and overall well-being of scoliosis patients. Especially in an office environment, patients spend roughly 8 hours a day. The design of ergonomic seating should be modular and compatible with standard office chair designs to ensure that the ergonomic seating can seamlessly integrate into typical office environments without the need for significant changes or adaptations. Patients should be able to integrate their standard office chairs with these ergonomic alternatives easily. Hence, a modular seating design for office use is suggested as part of the solution component. In addition, the interview data also underscores the importance of the aesthetic component in the design of ergonomic seating supporters, particularly for patients with scoliosis. The data outcome suggests that many existing ergonomic seating options on the market are poorly designed and may give off an impression of being unattractive or unappealing, which can negatively impact the confidence of scoliosis patients. According to the interview, unattractive or poorly designed seating options make patients feel self-conscious about their health issues. Particularly for individuals with visible conditions like scoliosis, the seating may draw attention to their condition in an unflattering way. The aesthetic component of ergonomic design should play a role in regaining the confidence of patients. The visual appeal of the seating is not just about aesthetics for the sake of it; rather, it is a means to enhance the psychological well-being of patients. Therefore, a visually aesthetic design is suggested as a solution component as well. Furthermore, the outcome of the interview data also highlights the importance of flexibility and adjustability in the design of ergonomic seating, particularly for scoliosis patients with unique spinal issues and varying degrees of curvature. Since each patient's spinal condition is unique, the ergonomic seating should be adaptable to accommodate these conditions, especially during extended periods of sitting. An adjustable support allows scoliosis patients to personalize their seating experience. They can fine-tune the chair to align with their unique spinal curvature, providing optimal comfort and support. In detail, the ability to adjust the seating promotes better posture and spinal alignment, reducing the risk of discomfort and pain associated with prolonged sitting. It can also help alleviate pressure points and distribute body weight more evenly. Due to that, adjustable support is also suggested as a component of the solution. Overall, the research process involved assessing the design needs for the ergonomic seating support through interviews and coding analysis, guided by the EESF. This procedure provided valuable insights into the requirements of scoliosis patients, which informed the subsequent design and development phases of the study.

Once the description of the design need was obtained, the generation of design ideations for the

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ergonomic seating support was conducted. The process involved transforming the design criteria derived from the interview analysis into tangible design concepts. To initiate the design ideation process, a sketching activity was employed, allowing for the visualization of form, structure, aesthetics, and composition of the intended ergonomic seating support. The sketch development was based on the design criteria and aimed to explore various possibilities and variations for ergonomic seating support. This involved the variations of gestalt form of the intended ergonomic seating support, variations of the adjustable support mechanism, and variations color of memory foam upholstery. The output of the sketching activity was then translated into 3D designs using Autodesk Inventor 3D Design software. It enables our research team to construct a more realistic representation of the gestalt form of intended ergonomic seating support, adjustable support mechanism, and color variations of memory foam upholster. This process facilitates a better understanding of its dimensions, features, colors, and overall aesthetics of the product. In addition, the 3D design process also enables our research team to continuously refine and iterate the design ideations to ensure they meet the specific requirements of scoliosis patients. Feedback and input from the research team, experts, and potential users of the ergonomic seating support were incorporated into the iterative process. Overall, the process of generating design ideations was crucial in exploring different design possibilities and refining the concepts for ergonomic seating support.

Once the outcome of generating design ideations was obtained, the model-making process was conducted to create a physical representation of the ergonomic seating support design. This enables our research team to ensure the viability of the design concept and provide a tangible visualization of how the final product would look. The model-making process involved the use of an Ender 3D printer and Polylactic Acid (PLA) filament. Our research team utilized the generated 3D files to guide the printing process. During the printing process, the PLA filament was inserted into the 3D printer and fed into the extrusion head assembly, where it was melted and pushed through the printer nozzle. The extrusion nozzle followed the designated coordinates, allowing the material to solidify and form the desired shape on the printing plate. After the 3D printing process, a metal structure was fabricated, and the spinal support adjuster was installed. Additionally, memory foam upholstery was completed to enhance the comfort of the seating support. Throughout the model-making process, continuous investigations of the technical features of the model were conducted to address any design issues. The iterative nature of the model-making process allowed for adjustments and refinements to be made based on the feedback received and the identified limitations of the ergonomic seating support. This iterative approach ensured that the final model met the necessary comfort and functional requirements for potential users. The final semi-working model was achieved after several iterations, incorporating alterations to optimize user comfort. The model showcased the visual aspects that distinguished the ergonomic seating support design and demonstrated how potential users would interact with the product. Overall, the model making process played a crucial role in validating the design concept and refining the ergonomic seating support for scoliosis patients. It provided valuable insights into the technical feasibility and user experience of the design, paving the way for further improvements and the eventual development of a functional and effective product.

Figure 13. The panel design.

5. Conclusion

This research has successfully developed Scoolis, an ergonomic seating support as its design proposal to provide sitting comfort by reducing spinal dullness, and stress due to prolonged sitting among scoliosis patients. In accordance with the EESF, the five sets of ergonomics science elements (physiology, psychology, physics, anatomy, and engineering) were investigated through interview sessions with a rehabilitation expert, a physiotherapy expert, and three scoliosis patients. The results of the interview study provided three descriptions of design requirements, each of which covered components of ergonomics science. Before the three descriptions of design criteria (modularity, emotional element, and adjustable spinal support) were successfully attained, the solution components to match the descriptions of design needs were derived. Through the design process, sketching and 3D modeling techniques are employed to explore various possibilities and refine the Scoolis design concepts. The process highlights the importance of visualization and conceptualization in the design process. Followed by model making process, the physical representation of Scoolis was created using 3D printing technology, metal structure, and memory foam upholstery. The iterative nature of this process allows for continuous refinement and improvement of the design, taking into account technical features. The final semi-working model of Scoolis demonstrates the visual aspects and functional considerations of the design, providing valuable insights into user behavior and comfort. In the future, Scoolis might be enhanced and manufactured in huge volumes. Implementing the suggested design criteria will help with this. More crucially, the suggested design would enable us to promote the development for health and wellbeing. The drawback of this study is that more user testing and product performance assessment will soon be required to fully assess the applicability of the recommended ergonomic seating support.

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References

Abdullah Sani, M.N. et al. (2019). The Assessment of the Clubfoot Children's Orthotic Need for the Development of the Foot Abduction Orthosis (FAO) Prototype Design, International Journal of Advances in Science Engineering and Technology, 7(1), 20–24.

Aebi, M. (2005). The adult scoliosis, European Spine Journal, 14(10), 925–948.

Ágústsson, A., Sveinsson, Þ. & Rodby-Bousquet, E. (2017). The effect of asymmetrical limited hip flexion on seating posture, scoliosis and windswept hip distortion, Research in Developmental Disabilities, 71,18–23.

Benner, B. & Ehni, G. (1979). Degenerative lumbar scoliosis, Spine, 4(6), 548–552.

Bradford, D.S., Tay, B.K.B. & Hu, S.S. (1999). Adult scoliosis: surgical indications, operative management, complications, and outcomes, Spine, 24(24), 2617.

Bridger, R. (2008). Introduction to Ergonomics, Boca Raton, Crc Press.

Bruno, S. et al. (2016). The conceptual design of a mechatronic system to handle bedridden elderly individuals, Sensors, 16(5), 1–11.

Chen, L.C. & Chu, P.Y. (2012). Developing the index for product design communication and evaluation from emotional perspectives, Expert Systems with Applications, 39(2), 2011–2020.

Chumiran, M.H., Abidin, S.Z. & Kamil, M.J.M. (2020). Pre post observation research fosters a preliminary study in product form identity, Proceedings of the 22nd International Conference on Engineering and Product Design Education E&PDE 2020, 1, 1–6.

Creswell, J.W. (2009). Research Design: Quantitative, Qualitative, and Mixed Methods Approaches, SAGE Publications, Inc.

Crytzer, T.M. et al. (2016). Identifying characteristic back shapes from anatomical scans of wheelchair users to improve seating design, Medical Engineering and Physics, 38(9), 999–1007.

Demirbilek, O. & Sener, B. (2003). Product design, semantics and emotional response, Ergonomics, 46(13–14),1346–1360.

Deyo, R.A. et al. (1992). Morbidity and mortality in association with operations on the lumbar spine. The influence of age, diagnosis, and procedure, The Journal of bone and joint surgery, 74(4), 536–543.

Epstein, J.A., Epstein, B.S. & Jones, M.D. (1979). Symptomatic lumbar scoliosis with degenerative changes in the elderly, Spine, 4(6), 542–547.

Fowles, J. V et al. (1978). Untreated scoliosis in the adult, Clinical orthopaedics and related research, 134,212–217.

Grubb, S.A. & Lipscomb, H.J. (1992). Diagnostic findings in painful adult scoliosis, Spine, 17(5), 518–527.

Grubb, S.A., Lipscomb, H.J. & Coonrad, R.W. (1988). Degenerative adult-onset scoliosis, Spine, 13(3), 241–245.

Healey, J.H. & Lane, J.M. (1985). Structural scoliosis in osteoporotic women, Clinical orthopaedics and related research, 195, 216–223.

Kamil, M.J.M. & Abidin, S.Z. (2013). Unconscious Human Behavior at Visceral Level of Emotional Design, Procedia - Social and Behavioral Sciences, 105, 149–161.

Kamil, M.J.M, Abidin, S.Z. & Hassan, O.H. (2019a). Assessing Designers' Perception, Analysis, and Reflective Using Verbal Protocol Analysis, Chakrabarti, A. (ed.) Research into Design for a Connected World, Singapore, Springer Singapore, 51–61.

Kamil, M.J.M., Abidin, S.Z. & Hassan, O.H. (2019b). Assessing the Attributes of Unconscious Interaction Between Human Cognition and Behavior, In Everyday Product Using Image-Based Research Analysis, Chakrabarti, A. (ed.) Research into Design for a Connected World, Singapore, Springer Singapore, 63–73.

Kamil, M.J.M., Zainal Abidin, S. & Hasdinor Hassan, Os. (2018). The Investigation of Designers' Reflective Practice Activity Using Verbal Protocol, International Conference on Engineering and Product Design Education 6 & 7 September 2018, Dyson School of Design Engineering, Imperial College, London, United Kingdom, 363–368.

Korovessis, P. et al. (1994). Adult idiopathic lumbar scoliosis. A formula for prediction of progression and review of the literature, Spine, 19(17), 1926–1932.

Kostuik, J.P. & Bentivoglio, J. (1981). The incidence of low-back pain in adult scoliosis, Spine, 6(3), 268–273.

Lephart, K. & Kaplan, S.L. (2015). Two Seating Systems Effects on an Adolescent with Cerebral Palsy and Severe Scoliosis, Pediatric Physical Therapy, 27(3), 258–266.

Li, Z. & Mohamed, M.J. Kamil (2022). Research on the design of Chaoshan intelligent tableware based on digital image processing technology, CIBDA 2022 3rd International Conference on Computer Information and Big Data Applications, 626–630.

Matos, D. et al. (2014). Contribution of Design in the Developmental Process of External Prosthetic Medical Devices, Proceedings of the 5th International Conference on Applied Human Factors and Ergonomics AHFE 2014, Poland 19-23 July 2014, 2482–2487.

McKinley, L.M., Gaines, R.W. & Leatherman, K.D. (1977). Adult scoliosis: recognition and treatment, The Journal of the Kentucky Medical Association, 75(5), 235–238.

Mohamed, M.J. Kamil & Abdullah, M.N. Sani (2021). The Challenges and Initiatives of Teaching Product Design's Course Online During the COVID-19 Pandemic in Malaysia, Asia Pacific Journal of Educators and Education, 36(1), 113–133.

Mohamed, M. J. Kamil, & Abdullah, M. N. Sani (2023). Re-evaluation of the Cerebral Palsy ' s orthotic need in Adaptive Seating Orthosis (ASO) design, Journal of Graphic Engineering and Design, 14(4), 13–23.

Mohamed, M.J. Kamil & Abidin, S.Z. (2014). The Value of Unconscious Human Behavior in Product Design Innovation, 2nd International Conference on Technology, Informatics, Management, Engineering & Environment Bandung, Indonesia, 123–127.

Mohamed, M.J. Kamil, Ho, G. Wan Ying & Abdullah, M.N. Sani (2022). Product design activity as a process to develop a therapeutic toy for self-managed depression among adolescents, Journal of Graphic Engineering and Design, 13(4), 5–12.

Mohamed, M.J. Kamil, Hua, C.E. & Abdullah, M.Na. Sani (2022). Adaptation of smart-object dimensions in the product design process to reduce household food waste, Journal of Graphic Engineering and Design, 13(3), 5–17.

Mohamed, M.J. Kamil, Li Shi, S.M. & Abdullah Sani, M.N. (2020). Re-assessing the Design Needs of Trans-Radial Amputees in Product Design Innovation, Wacana Seni Journal of Arts Discourse, 19, 61–71.

Mohamed, M.J. Kamil & Shaukat, S.A. (2023) 'The implementation of polycaprolactone (PCL) as an eco-friendly material in toy design development', Journal of Graphic Engineering and Design, 14(1).

Mohamed, M.J. Kamil & Zainal, S. Abidin (2014). Unconscious Human Behaviour in Product Design: Designers' Perception, Analysis, and Reflection, 1st International Conference on Creative Media, Design and Technology, REKA2014, 109–114.

Mohamed, M.J. Kamil & Zainal, S. Abidin (2015). Unconscious Interaction Between Human Cognition and Behaviour in Everyday Product: A Study of Product Form Entities Through Freehand Sketching Using Design Syntactic Analysis, International Conference on Engineering and Product Design Education, Loughborough University, Design School, Loughborough, UK, 369–374.

Muller, M.J. and Kogan, S. (2010). Grounded Theory Method in HCI and CSCW, Cambridge, IBM Center for Social Software, 28(2), 1–46.

Ogilvie, J.W. (1992). Adult scoliosis: evaluation and nonsurgical treatment, Instructional course lectures, 41, 251–255.

Robin, G.C. et al. (1982). Scoliosis in the elderly: a follow-up study, Spine, 7(4), 355–359.

Saldaña, J. (2009). The coding manual for qualitative researchers, The coding manual for qualitative researchers, Thousand Oaks, CA, Sage Publications Ltd.

Sani, M.N.A. et al. (2020). The appropriation of product design as solution to minimise risk of exertional heat illness among Marathon runners, International Journal of Human Movement and Sports Sciences, 8(6), 63–67.

Schütte, S. (2005). Engineering emotional values in product design: Kansei engineering in development, Institutionen för konstruktions-och produktionsteknik.

Seeger, B.R. & Sutherland, A.D. (1981). Modular seating for paralytic scoliosis: Design and initial experience, Prosthetics and Orthotics International, 5(3), 121–128.

Sponseller, P.D. et al. (1987). Results of surgical treatment of adults with idiopathic scoliosis, The journal of bone and joint surgery, 69(5), 667–675.

Utkan, F., Fredericks, T.K. & Butt, S.E. (2011). The effect of scoliosis curvature on lumbar support for task seating., Proceedings of the 2011 Industrial Engineering Research Conference.

Velis, K.P., Healey, J.H. & Schneider, R. (1988). Osteoporosis in unstable adult scoliosis, Clinical orthopaedics and related research, 237, 132–141.

Winter, R.B. & Lonstein, J.E. (1983). Adult scoliosis, Instructional course lectures, 32, 170–191.

Zhuopeng, L., & Mohamed, M. J. Kamil (2023). Incorporating The Influence of Regional Culture in Tableware Design: The Case Study of Chaoshan Area, Wacana Seni Journal of Arts Discourse, 22, 17–33.

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