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REDESIGN OF PATIENT WHEELCHAIR TYPE SM-8018 BASED ON ERGO-TOTAL FUNCTION DEPLOYMENT (ETFD) INTEGRATION

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Abstract. Manual wheelchairs remain widely used in Indonesian health-care facilities, yet their design often does not fully accommodate local anthropometric characteristics and work patterns. The SM-8018 patient wheelchair used at PT SPU is operated by caregivers, exposing both patients and caregivers to potential ergonomic risks. This study aims to evaluate and redesign the SM-8018 wheelchair using an integrated Ergo-Total Function Deployment (ETFD) and House of Ergonomics (HoE) approach within a Total Ergonomics framework. A pre–post experimental design was applied involving 32 adult users and caregivers with at least six months of experience using or pushing the SM-8018. Data collection included anthropometric measurements, musculoskeletal complaints using the Nordic Body Map (NBM), subjective fatigue using the Japan Association of Industrial Health (JAIH) questionnaire, boredom scores, satisfaction using the Minnesota Satisfaction Questionnaire (MSQ) and voice of customers (VoC). VoC and ergonomic findings were mapped into a HoE matrix to derive priority design specifications through ETFD. Results showed notable mismatches between user anthropometry and key wheelchair dimensions, particularly seat depth and width, backrest and headrest height and angle, and push-handle height, which were associated with high levels of discomfort in the lower back, buttocks, shoulders and upper arms and with considerable fatigue. The ETFD–HoE analysis identified four primary redesign priorities: adjustment of push-handle height, optimisation of backrest and headrest geometry, refinement of seat dimensions and improvement of front-wheel stability. Pre–post comparisons indicated that musculoskeletal complaints and fatigue remained relatively high and in some cases increased, whereas boredom and satisfaction tended to change in a more favourable direction. These findings suggest that the first iteration of the SM-8018 redesign, although guided by Total Ergonomics principles, requires further refinement and system-level support. Nonetheless, the study demonstrates the feasibility of integrating ETFD, HoE and Total Ergonomics to systematically guide the improvement of low-cost hospital wheelchairs in the Indonesian context.

Keywords : ETFD Integration, Redesign, The Patient Wheelchair Type SM-8018, Total Ergonomic

1. INTRODUCTION

Wheelchairs are assistive devices that enable individuals with permanent or temporary mobility limitations to move, carry out daily activities and participate in social life more independently [1][2]. In health-care facilities, manual wheelchairs remain the most widely used because of their simple construction, low maintenance cost and ease of repair, even though powered wheelchairs have been increasingly introduced in high-income settings [3][4]. The SM-8018 manual patient wheelchair is one of the commonly used models in Indonesian hospitals and clinics. This wheelchair is designed to be pushed by a caregiver rather than self-propelled by the patient, so that both the seated patient and the thruster are directly affected by the ergonomics of the product.

Field observations and preliminary evaluations at PT SPU indicate that several critical components of the SM-8018 wheelchair do not yet adequately accommodate the anthropometric characteristics and activity patterns of its users. The seat width, depth and height do not fully correspond to the body dimensions of typical Indonesian adult patients; the backrest and headrest are fixed and do not provide sufficient support for the upper back and cervical region; the push-handle height is not aligned with the elbow height of most caregivers; and the configuration of the front wheels may reduce stability when the wheelchair passes ramps or uneven floors. These design limitations may increase static muscular load and awkward postures during sitting and pushing, thereby contributing to musculoskeletal complaints, discomfort and fatigue for both patients and caregivers [5][6][7][8]. Inadequate comfort and safety in turn can negatively influence patients' perceived quality of life during treatment and rehabilitation [1][2].

From an ergonomic perspective, prolonged sitting in a constrained posture combined with repeated pushing tasks can trigger musculoskeletal disorders (MSDs), especially in the neck, back, shoulders, arms and buttocks. Such disorders are frequently assessed using instruments such as the Nordic Body Map (NBM) to identify the location and intensity of complaints [9]. In addition to physical complaints, indicators of mental and physiological load – including subjective fatigue, feelings of monotony or boredom, and job satisfaction – also play an important role in evaluating the acceptability of a work system and the design of the tools used [10][11][12][13]. The Japan Association of Industrial Health (JAIH) fatigue questionnaire, boredom scales and the Minnesota Satisfaction Questionnaire (MSQ) are widely used to capture these aspects in a systematic way.

A number of previous studies have discussed the design and improvement of wheelchairs from mechanical, structural or basic anthropometric perspectives, focusing for example on strength, stability, manoeuvrability or simple dimensional fit between users and products [3][4][6]. Other research has applied Quality Function Deployment (QFD) or limited ergonomic checklists to translate the voice of customers into design specifications. However, these studies generally analyse either physical complaints or user preferences separately, and rarely integrate musculoskeletal complaints, fatigue, boredom and satisfaction into a single, comprehensive evaluation framework. Furthermore, there is still limited research that applies Total Ergonomics – integrating Appropriate Technology (AT) and the Systemic, Holistic, Interdisciplinary and Participatory (SHIP) approach – to low-cost manual hospital wheelchairs in the Indonesian context [5][7][8].

Consequently, several important gaps remain. First, the specific ergonomic shortcomings of the existing SM-8018 design, particularly in relation to Indonesian patients' and caregivers' anthropometry and patterns of use, have not been described in detail. Second, previous ergonomic and QFD-based studies on wheelchair design have not explicitly integrated multidimensional outcome measures (MSDs, fatigue, boredom and satisfaction) with an Ergo-Total Function Deployment (ETFD) or House of Ergonomics (HoE) approach. Third, the potential of Total Ergonomics (AT and SHIP) to systematically prioritise design improvements for hospital wheelchairs has not yet been fully explored.

To address these gaps, this study aims to redesign the SM-8018 manual patient wheelchair used at PT SPU based on an integrated Ergo-Total Function Deployment approach. Specifically, the objectives of this research are: (1) to evaluate the mismatch between the current SM-8018 wheelchair dimensions and the anthropometric characteristics, musculoskeletal complaints, fatigue, boredom and satisfaction of users and caregivers; (2) to construct a House of Ergonomics that translates the voice of customers and ergonomic risk findings into technical design requirements; and (3) to determine and prioritise key design modifications for the SM-8018 patient wheelchair within a Total Ergonomics (AT and SHIP) framework so as to enhance comfort, safety, health and efficiency for both patients and caregivers.

2. METHODS

2.1 Research design and setting

This study employed a pre–post experimental design to evaluate and redesign the SM-8018 manual patient wheelchair used at PT SPU, a medical equipment manufacturer and distributor in Indonesia. The pre–post design was chosen to enable direct comparison between the existing wheelchair configuration and the redesigned specifications in terms of anthropometric fit, musculoskeletal complaints, fatigue, boredom and user satisfaction. The ergonomic evaluation and measurement sessions were conducted in the wheelchair assembly and testing area under typical working conditions.

2.2 Participants

A total of 32 participants took part in this study. They consisted of adult users and caregivers who routinely operated or pushed the SM-8018 wheelchair at PT SPU and affiliated health-care facilities. Inclusion criteria were: (1) age ≥ 18 years, (2) experience in sitting in or pushing the SM-8018 wheelchair for at least six months, and (3) absence of acute musculoskeletal injury during the data collection period. Participants who reported severe pain requiring medical treatment or who were unable to complete the questionnaires were excluded. All participants were informed about the study procedures and provided written consent prior to participation.

2.3 Variables and instruments

To address the first objective—evaluating the mismatch between the current SM-8018 design and user characteristics—several groups of variables were measured:

1. Anthropometric dimensions
   Key body dimensions relevant to wheelchair design were recorded, including: popliteal height, buttock–popliteal length, hip breadth, elbow height in standing and sitting, shoulder height, and body mass and stature. Measurements were taken using a standard anthropometer, measuring tape and digital scale, following conventional anthropometric procedures. These data were later compared with the existing dimensions of the SM-8018 seat, backrest, armrest, headrest and push handle.
2. Musculoskeletal complaints (MSDs)
   Musculoskeletal complaints were assessed using the Nordic Body Map (NBM) questionnaire. Participants reported the presence and intensity of discomfort or pain in different body regions (e.g., neck, shoulders, back, buttocks, arms and legs) after using or pushing the wheelchair. Scores for each body part were coded and summed to generate an overall MSD index, and the percentage of participants reporting discomfort in each region was calculated.
3. Subjective fatigue
   Subjective fatigue was measured using the Japan Association of Industrial Health (JAIH) fatigue questionnaire, which consists of multiple items covering general, physical and mental fatigue symptoms. Responses were recorded on a Likert-type scale and converted into an overall fatigue index. Higher scores indicated higher perceived fatigue.
4. Boredom / monotony
   Feelings of monotony or boredom related to the activity of sitting in or pushing the wheelchair were captured using a boredom scale that assessed the extent to which participants experienced repetitive, unchallenging or monotonous tasks. The items were rated on a Likert scale, and an average boredom score was computed for each participant.
5. Satisfaction
   User satisfaction with the SM-8018 wheelchair was evaluated using the Minnesota Satisfaction Questionnaire (MSQ) adapted to the context of assistive device use. Items addressed comfort, ease of use, perceived safety and overall satisfaction. Responses were transformed into a satisfaction index, where higher scores represented higher satisfaction.
6. Voice of customers (VoC) and ergonomic requirements
   In addition to the standardized instruments above, semi-structured interviews and open-ended questions were used to collect the voice of customers (VoC) from both patients and caregivers. The VoC data captured qualitative perceptions regarding comfort, safety, handling, stability on ramps or uneven surfaces, and suggestions for improvement. These qualitative inputs were then translated into ergonomic requirements and technical characteristics within the Ergo-Total Function Deployment (ETFD) framework.

2.4 Procedure

Data collection was carried out in two main stages corresponding to the pre–post design.

1. Pre-intervention (baseline) stage
   a) Participants were first familiarised with the purpose of the study and the measurement instruments.
   b) Anthropometric measurements were taken once for each participant.
   c) Participants then used or pushed the existing SM-8018 wheelchair while performing typical patient transport activities (e.g., moving along corridors, turning, passing ramps or uneven floor transitions) for a specified duration.
   d) Immediately after the activity, participants completed the NBM, JAIH fatigue, boredom and MSQ satisfaction questionnaires, and provided qualitative feedback (VoC) on perceived problems and desired improvements.
2. Design development stage using ETFD and House of Ergonomics (HoE)

a) The baseline anthropometric data, MSD, fatigue, boredom and satisfaction indices, along with VoC information, were consolidated to identify ergonomic problems and potential mismatches between the existing SM-8018 design and user needs.
b) These findings were mapped into a House of Ergonomics (HoE), in which the "customer ergonomic requirements" (comfort, safety, health, efficiency, stability and ease of handling) were linked to "ergonomic design characteristics" such as seat width and depth, backrest and headrest height and angle, push-handle height, wheelbase and front-wheel configuration.
c) The HoE matrix was used to calculate relationship weights and priorities, forming the core of the Ergo-Total Function Deployment (ETFD) process and generating a set of prioritized design specifications.

3. Post-intervention (prototype evaluation) stage
   a) Based on the prioritized specifications from ETFD, redesign recommendations for the SM-8018 wheelchair were formulated, focusing on adjustments to seat dimensions, backrest and headrest configuration, push-handle height and wheel stability.
   b) A prototype or detailed redesign concept reflecting these specifications was then evaluated by the same group of participants under similar task conditions.
   c) After using or pushing the redesigned wheelchair, participants once again completed the NBM, JAIH fatigue, boredom and MSQ satisfaction questionnaires and provided feedback on the redesigned features.

2.5 Data analysis

Descriptive statistics (mean, standard deviation, minimum, maximum and percentiles) were calculated for all anthropometric variables and compared with the corresponding dimensions of the existing SM-8018 wheelchair to identify mismatches and inform the redesign. For the subjective outcome measures (MSDs, fatigue, boredom and satisfaction), pre- and post-intervention scores were computed for each participant.

Prior to inferential analysis, the normality of the difference scores was examined using the Shapiro–Wilk test. When the data satisfied the normality assumption, paired sample t-tests were applied to compare pre- and post-intervention means for each outcome variable at a significance level of $\alpha = 0.05$. For variables that did not meet normality assumptions, the non-parametric Wilcoxon signed-rank test was considered. In addition, percentage changes in MSDs, fatigue, boredom and satisfaction indices were calculated to facilitate interpretation of the practical impact of the redesign.

2.6 Integration of ETFD and Total Ergonomics

To address the second and third objectives—constructing the HoE and prioritising key design modifications within a Total Ergonomics framework—the ETFD results were analysed using the principles of Appropriate Technology (AT) and the Systemic, Holistic, Interdisciplinary and Participatory (SHIP) approach. Customer ergonomic requirements and technical characteristics were interpreted in terms of the ECSHE dimensions (Effective, Comfortable, Safe, Healthy and Efficient).

The final redesign priorities were determined by combining: (1) the quantitative priority weights obtained from the ETFD/HoE matrix, (2) the magnitude and statistical significance of changes in MSDs, fatigue, boredom and satisfaction, and (3) qualitative feedback from participants. This integrated analysis produced a ranked list of critical design features—such as push-handle height, backrest and headrest geometry, and front-wheel stability—that should be modified in order to improve comfort, safety, health and efficiency for both patients and caregivers when using the SM-8018 patient wheelchair.

3. RESULTS AND DISCUSSION

3.1 Description of the existing SM-8018 patient wheelchair

The SM-8018 manual patient wheelchair used at PT SPU is designed to be pushed by a caregiver rather than self-propelled by the patient. Figure 1 shows the standard components of a manual wheelchair together with the main elements of the SM-8018 model, including the seat, backrest, armrests, footrests, headrest, push handles and wheel configuration. Figure 2 illustrates the SM-8018 wheelchair when in use during typical patient transport activities such as moving along corridors, turning and passing ramps or uneven floor transitions.

(a) (b)

Figure 1. a) Standard manual wheelchairs and their parts [7][10], and b) dimensions of the patient wheelchair type SM-8018 production result of PT SPU

Figure 2. The Design of the SM-8018 Patient Wheelchair When in Use

Field observations during the baseline stage indicated several practical limitations of the existing design. The fixed backrest and headrest do not adequately support the upper back and cervical region for many users, and the seat dimensions do not fully match the anthropometric characteristics of typical Indonesian adults. For caregivers, the push-handle height appears lower or higher than their natural elbow height, which forces them to bend forward or elevate their shoulders while pushing. These qualitative observations are consistent with the initial complaints reported by participants and motivated the need for a more systematic ergonomic evaluation and redesign of the SM-8018 wheelchair.

3.2 House of Ergonomics and ETFD results

The voice of customers (VoC) collected from patients and caregivers was translated into ergonomic requirements and mapped into a House of Ergonomics (HoE) matrix (Figure 3). In this HoE, customer ergonomic requirements—such as comfort during sitting, perceived safety, stability on ramps, ease of handling, postural support and ease of maintenance—were positioned on the left side of the matrix, while technical/ design characteristics—such as seat width and depth, seat height, backrest and headrest height and angle, push-handle height, wheelbase and front-wheel configuration—were placed along the top.

Table 1. Summary of Participants' Responses to the ECSHE Variable Characteristics and Assessment of Wheelchair Components

Variable	Attribute	Wheelchair Parts	Wheelchair Evaluation
Effective (E)	Performance Functional	Stability (Static & Dynamic)	When in a fixed state, it performs well, but within a moving or adaptable framework, it remains less stable if the user's body weight is overweighed
		Transporting patient wheelchair (simple to transfer between locations, simple to use, simple to transport a mobility chair)	It functions well, however, the front tire continues to spin, pivot, and halt independently if it encounters a minor obstruction.
Comfortable (C)	Holder and Postural supports	Dimensions (Greatest dimensions, breadth, overall stature, height of the seat, width of the seat from the flooring, height of the armrests relative to the seat, length of the seat, elevation of the backrest, maximum weight capacity for wheelchairs,	The quality is acceptable, but the elevation of the back support is inadequate; it needs to reach the level of the head or headrest. The chair's rear support is not designed for proper posture, being both shorter and less inclined

		modifying the anthropometric measurements to fit the Indonesian population)	
		Holder (Seat type, seat cushion, seat material, seat cushion material)	The padding on the seat is inadequate, causing it to indent when you sit, resulting in discomfort for the backside
		Adjustable and Ergonomic Factor (Beckrest, footrest, armrest, rear wheels, push handle)	Not ideal, particularly in the lower backrest area (there is indeed a headrest), the push handle has not been modified, resulting in cramps, discomfort, and fatigue from pushing.
Safe (S)	Strength, Durability and Safety	Strong material (Hard frame material)	Already well
		Endurance (Chair framei, push handle)	It works well; it continues to shake even if the person using it is overweight, but the handle for pushing cannot be modified.
		Flammability (Not flammable, Corrosion resistant)	Already well
		Surface safety (Flat surface, tire cover, have reflective stickers)	Already well
		Brake effectiveness (Stopped on the descent, did not come off suddenly)	Unsuitable for descending, ascending, and uneven terrain conditions.
Healthy (H)	MSDs	Reduce musculoskeletal complaints	There are still musculoskeletal complaints
	Fatigue	Reduces fatigue	Tired of pushing especially the push handle
	Boredom	Reduces boredom	It can reduce boredom
	Satisfaction	Increase satisfaction	Not yet satisfied
Efficient (E)	Economic	Affordable product prices	Prices can be pressed again
	Maintenance	Easy to care for	Already well
	Raw Material	Raw material are strong and durable	The structure still appears delicate when the individual is overweight. Certain components are prone to damage (such as brake pads)

The relationships between customer requirements and technical characteristics were scored and weighted within the Ergo-Total Function Deployment (ETFD) framework. This analysis produced priority weights indicating which design attributes contributed most strongly to comfort, safety, health and efficiency (ECSHE). As summarised in Table 1, participants consistently highlighted issues of comfort (particularly in the back and buttocks), safety and stability when passing ramps, and physical effort required when pushing the wheelchair. These complaints were strongly associated, in the HoE matrix, with the geometry of the seat and backrest, the headrest configuration, the push-handle height and the stability of the front wheels.

The ETFD results, integrated with the Total Ergonomics perspective (Appropriate Technology and SHIP), are further detailed in Tables 2 and 3. Table 2 indicates how each proposed design change respects Appropriate Technology principles—being simple, affordable and maintainable in the PT SPU context—while Table 3 shows how the redesign aligns with the Systemic, Holistic, Interdisciplinary and Participatory (SHIP) approach. Overall, the ETFD–HoE analysis identified four main redesign priorities: (1) adjustment of push-handle height, (2) optimisation of backrest and headrest height and angle, (3) refinement of seat dimensions (width and depth) to match user anthropometry, and (4) improvement of front-wheel stability when the wheelchair passes ramps or uneven surfaces.

Table 2. Use of AT in Ergonomics Total Case Study the Patient Wheelchair Type SM-8018 Product Redesign

No.	Aspects of AT	Problem Solving Description
1.	Technically	Holder and postural supports the patient wheelchair type SM-8018 product redesign to find the root cause of ergonomics is not too difficult
2.	Economical	Redesign of holder and postural supports the patient wheelchair type SM-8018 product does not require high cost investment so that PT SPU can immediately follow up
3.	Ergonomics	Redesign of the potential for ergonomics of the patient wheelchair type SM-8018 product redesign with improved holder and postural supports to improve patient quality of life
4.	Socio-culturally	The holder and postural supports improvements have no implications for socio-cultural interactions between patients with of the patient wheelchair type SM-8018 product redesign pushers and the general social community
5.	Energy efficient	The redesign does not require energy that exceeds the threshold value and does not have an impact on excessive energy utilisation. the energy expended from pushing of the patient wheelchair type SM-8018 product redesign and patient also decreases
6.	Environmentally friendly	The patient wheelchair type SM-8018 product redesign has no impact on causing environmental pollution and supports sustainability

Table 3. Use of SHIP Approach in Ergonomics Total Case Study the Patient Wheelchair Type SM-8018 Product Redesign

No.	Aspects of AT	Problem Solving Description
1.	Systemic	An approach that considers the system as a whole, including human, technological, and environmental factors, to improve worker performance, safety, and health. system analysis, problem identification, system design, system implementation, and system evaluation have solved the problem of holder and postural supports the patient wheelchair type SM-8018 product redesign
2.	Holistic	Understand the system as a single entity consisting of many interrelated components. Solve problems without creating new ones
3.	Interdisplinary	Combining knowledge from various disciplines, such as psychology, physiology, engineering, and design to the patient wheelchair type SM-8018 product redesign
4.	Participatory	Involve workers and other stakeholders in the system design and implementation process of the patient wheelchair type SM-8018 product redesign

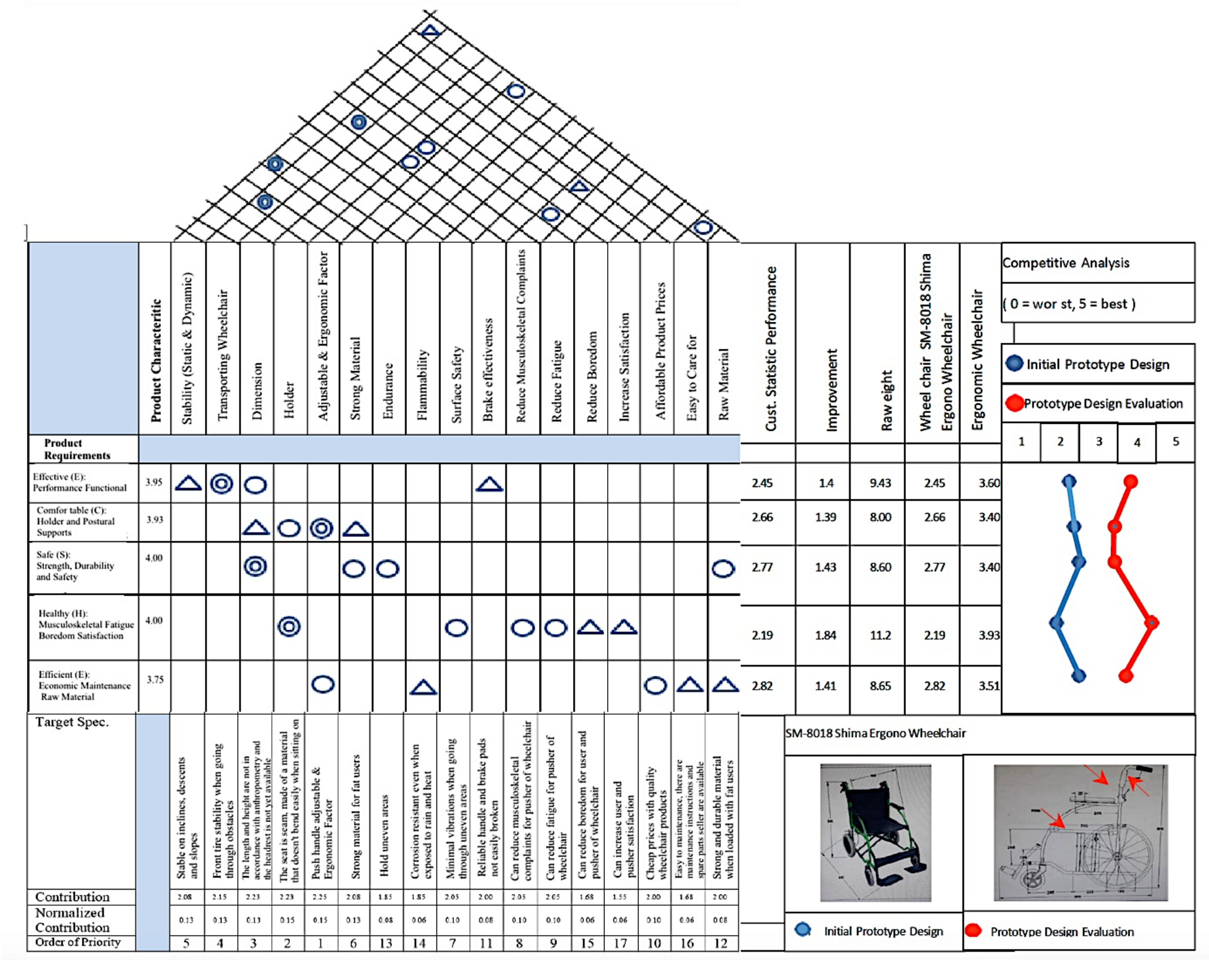

Figure 3. House of ergonomic of the patient wheelchair type SM-8018 protoype product

3.3 Anthropometric Fit and Musculoskeletal Complaints

Anthropometric data collected from the 32 participants revealed mismatches between the existing SM-8018 dimensions and the body dimensions of users. For many participants, the seat depth exceeded their buttock–popliteal length, which may increase pressure in the popliteal area and promote slouched sitting. Likewise, the seat width did not always provide sufficient lateral support, and the backrest height did not reach a recommended level relative to shoulder and cervical height. The push-handle height often fell below or above the elbow height in standing, forcing caregivers to adopt non-neutral postures when pushing.

These mismatches were reflected in the musculoskeletal complaints measured using the Nordic Body Map (NBM). A large proportion of participants reported discomfort or pain in the lower back and buttocks, as well as in the shoulder and upper arm regions after using or pushing the wheelchair. Complaints were particularly concentrated in body segments that directly interact with the wheelchair components (seat, backrest, headrest and push handles). From an ergonomic perspective, these findings indicate that the current design of the SM-8018 wheelchair does not yet provide adequate postural support and load distribution during prolonged sitting and pushing tasks.

The patterns of musculoskeletal complaints observed in this study are consistent with previous ergonomic investigations that link non-optimal seat and backrest geometry with increased low-back and buttock discomfort, and associate inappropriate handle height with shoulder and upper-back strain [7][9][10]. They support the need to adjust the SM-8018 dimensions based on Indonesian anthropometric data, as recommended in the Total Ergonomics approach [14][15][16][17].

3.4 Fatigue, Boredom and Satisfaction Outcomes

Subjective fatigue measured by the JAIH questionnaire, boredom scores and satisfaction indices (MSQ) provided a more comprehensive view of the impact of the SM-8018 design on users and caregivers. In the baseline (pre-intervention) condition, participants reported noticeable levels of fatigue after performing typical wheelchair-related tasks, as well as feelings of monotony in repetitive pushing activities and only moderate levels of satisfaction with comfort, stability and ease of handling.

Following the ETFD-based redesign and evaluation of the prototype, the statistical analysis of pre–post data showed that musculoskeletal complaint indices and fatigue scores remained relatively high and, in some cases, increased significantly, whereas boredom and satisfaction scores changed in the opposite direction. In other words, although the redesign addressed several priority dimensions identified in the HoE, the short-term impact on physical load was not yet fully favourable, while some aspects of perceived monotony and satisfaction showed a tendency to improve or at least change in a more positive direction.

This pattern contrasts with the results of previous ergonomic interventions conducted by Setiawan and co-workers in other industries. For example, in a study on redesigning wet blanket workstations in a crumb rubber factory, the integration of ergonomic principles led to a substantial reduction in worker fatigue [18]. Similarly, an intervention applying a comprehensive ergonomic work system at a tofu factory resulted in a marked decrease in fatigue complaints [19][20][21][22][23], and an ergonomics-based improvement programme for freight workers at the 16 Ilir Market in Palembang produced a notable increase in satisfaction levels [24].

Compared with these earlier interventions, the present study suggests that the first iteration of the SM-8018 redesign—although guided by ETFD and Total Ergonomics—may still require further refinement, particularly in relation to load distribution during pushing and the dynamic stability of the wheelchair. The persistence or increase of musculoskeletal complaints and fatigue indicates that some critical constraints, such as overall weight, rolling resistance, or the interaction between seat/backrest geometry and pushing technique, have not yet been fully resolved.

3.5 Integrated Discussion in the Total Ergonomics Perspective

The combined results of anthropometric evaluation, NBM, fatigue, boredom and satisfaction measurements, and ETFD–HoE analysis highlight the complexity of designing an ergonomically sound manual patient wheelchair in a realistic industrial context. On the one hand, the HoE and ETFD framework successfully translated the voice of customers and ergonomic findings into a set of clear technical priorities, namely the adjustment of push-handle height, optimisation of backrest and headrest design, refinement of seat dimensions and improvement of front-wheel stability. These priorities are consistent with the ECSHE dimensions (Effective, Comfortable, Safe, Healthy and Efficient) and with the principles of Appropriate Technology and SHIP.

On the other hand, the pre–post comparison of subjective outcomes indicates that modifying a subset of design parameters alone is not always sufficient to reduce musculoskeletal load and fatigue in the short term. In the SM-8018 case, it is possible that the redesigned configuration alters the way caregivers push and control the wheelchair, leading to temporary changes in muscle activation patterns and perceived effort. Furthermore, some contextual factors—such as floor conditions, frequency and duration of wheelchair use, and work-organisation aspects including rest pauses and task rotation—may still be sub-optimal and continue to contribute to fatigue and discomfort.

From a Total Ergonomics standpoint, these findings emphasise that product redesign must be integrated with broader system-level changes. In addition to refining the SM-8018 geometry based on the present ETFD priorities, future interventions should consider: (1) optimising the rolling resistance and overall mass of the wheelchair, (2) providing training for caregivers on optimal pushing techniques and posture, (3) improving environmental conditions such as floor smoothness and ramp design, and (4) revisiting work-organisation policies to ensure adequate rest breaks and task variation.

Despite these limitations, the present study demonstrates the feasibility of applying the Ergo-Total Function Deployment and House of Ergonomics approach to a low-cost hospital wheelchair in Indonesia. The integration of quantitative anthropometric and subjective outcome measures with a participatory, SHIP-based design process offers a structured pathway for progressively improving the SM-8018 wheelchair. Subsequent design iterations, validated with larger samples and complemented by objective measures of posture and force, are expected to achieve reductions in musculoskeletal complaints and fatigue closer to those observed in previous Total Ergonomics interventions in other sectors [25][26][27][28].

4. CONCLUSION

This study applied an integrated Ergo-Total Function Deployment (ETFD) and House of Ergonomics (HoE) approach within a Total Ergonomics framework to evaluate and redesign the SM-8018 manual patient wheelchair used at PT SPU. By combining anthropometric measurements, musculoskeletal complaints (NBM), subjective fatigue (JAIH), boredom and satisfaction (MSQ) with the voice of customers (VoC), the research aimed to identify mismatches between the existing design and user needs, translate ergonomic requirements into technical specifications and prioritise key design modifications.

The results indicate that the current SM-8018 wheelchair does not yet adequately accommodate the anthropometric characteristics of Indonesian patients and caregivers. Seat depth and width, backrest and headrest height and angle, as well as push-handle height, showed notable mismatches with user body dimensions. These discrepancies were reflected in musculoskeletal complaints concentrated in the lower back, buttocks, shoulders and upper arms, and in considerable levels of subjective fatigue after typical wheelchair-related tasks. The HoE and ETFD analysis confirmed that comfort, safety, stability and ease of handling are strongly linked to the geometry of the seat, backrest and headrest, push-handle height and front-wheel configuration.

The pre–post comparison of subjective outcomes following the ETFD-based redesign revealed that musculoskeletal complaints and fatigue remained relatively high and in some cases increased, whereas boredom and satisfaction scores showed a tendency to change in a more favourable direction. These findings suggest that the first iteration of the SM-8018 redesign, although guided by ergonomic priorities and Total Ergonomics principles, is not yet sufficient to substantially reduce physical load in the short term. Product-level improvements need to be complemented by further optimisation of seat and backrest support, push-handle ergonomics, wheelchair mass and rolling resistance, as well as by system-level changes in work organisation, environmental conditions and caregiver training.

Despite these limitations, the study demonstrates the feasibility and usefulness of integrating ETFD, HoE and Total Ergonomics (AT and SHIP) for the systematic improvement of low-cost hospital wheelchairs in the Indonesian context. The approach produced a clear set of redesign priorities—namely adjustment of push-handle height, optimisation of backrest and headrest geometry, refinement of seat dimensions and enhancement of front-wheel stability—that can guide subsequent design iterations at PT SPU. Future research should involve larger and more diverse samples, incorporate objective measures of posture and force, and evaluate long-term effects of the redesigned wheelchair on musculoskeletal load, fatigue, boredom and satisfaction in real clinical settings.

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