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Development of A Chair and Table to Support the Telbowmes Elbow Therapy Device

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Abstract

Stroke is a non-communicable disease that frequently causes motor impairments, particularly in the arm and elbow, requiring continuous rehabilitation to restore functional movement. Telbowmes is an elbow therapy device designed to support controlled joint-movement exercises; however, its use requires an ergonomic supporting chair and table that accommodate users' anthropometric characteristics. This study aimed to design and develop an ergonomic, safe, and economically feasible supporting chair and table for the Telbowmes elbow therapy device. The research involved anthropometric data collection followed by adequacy, normality, and uniformity tests, percentile determination, product design, manufacturing analysis, and production-cost evaluation. The results produced an adjustable table-surface height of 60.33–86.07 cm, a table length of 45.6 cm, a table width of 80.1 cm, a chair backrest height of 87.6 cm, and a seat dimension of 66.5 cm. The design integrates anthropometric considerations with structural stability, adjustable mechanisms, safety features, manufacturing requirements, and economic analysis. The manufacturing analysis also established a structured relationship among materials, components, production operations, and assembly activities. The estimated production cost was IDR 3,300,000 per unit, with an estimated selling price of IDR 3,960,000. The developed design provides an integrated ergonomic support system intended to improve user comfort, safety, and compatibility during elbow rehabilitation.

Keywords: *Anthropometry, Elbow Therapy Device, Ergonomic Product Design, Product Development, Telbowmes.*

INTRODUCTION

Universitas Diponegoro (UNDIP), as a research-oriented university progressing toward World Class University status, has established the Center for Biomechanics, Biomaterials, Biomechatronics, and Biosignal Processing (CBIOM3S) as a research center dedicated to the development of engineering-based healthcare technologies. CBIOM3S is one of the Centers of Excellence for Science and Technology in Higher Education (PUI-PT) at UNDIP, providing an interdisciplinary environment for research and innovation in biomedical engineering and healthcare technology. The global development of rehabilitation technology has increasingly moved toward engineering-based systems that support controlled, repetitive, and patient-oriented therapeutic movements, particularly for individuals experiencing functional impairment after stroke. Kuriakose and Xiao (2020) emphasize that stroke remains a major neurological condition requiring rehabilitation strategies capable of addressing persistent motor impairment and restoring functional capacity. Recent elbow rehabilitation research has demonstrated the integration of mechanical actuation, intelligent control, and Internet of Things technologies to improve the accuracy and adaptability of therapeutic movement (Demirsoy et al., 2024). The development of rehabilitation technology also increasingly considers the interaction between users and therapeutic systems rather than focusing exclusively on mechanical performance. Yeh and Chou (2023) indicate that user experience evaluation provides important implications for optimizing rehabilitation robots because usability, physical interaction, and user perception influence the practical effectiveness of rehabilitation technologies. Within this technological context, the Telbowmes elbow therapy device requires an appropriate supporting environment because the therapeutic mechanism cannot be optimally utilized when the user's sitting position and interaction with the device are not adequately accommodated.

Previous studies have demonstrated substantial progress in the development of elbow rehabilitation devices, particularly through the application of mechanical assistance and automated control mechanisms. Sasono et al. (2022) developed an elbow exoskeleton therapy device intended to assist stroke patients, demonstrating the potential of engineering-based systems to support upper-limb rehabilitation. Khumairoh et al. (2025) developed an assistive training device for hand and elbow movement in stroke patients with paresis, illustrating the continuing expansion of rehabilitation technology toward practical assistive applications. Jameel et al. (2024) demonstrated that low-cost elbow rehabilitation equipment can provide an alternative approach for increasing the accessibility of rehabilitation technologies. Sofwan and Santoso (2024) further incorporated artificial intelligence and Internet of Things technologies into elbow-fracture rehabilitation equipment to improve the quality of therapeutic processes. The L-CADEL development series illustrates that rehabilitation devices require iterative evaluation and design improvement because the optimization of mechanical assistance cannot be separated from the requirements emerging during actual interaction with users (Ceccarelli et al., 2024). Kotov and Ceccarelli (2025) similarly demonstrate that successive prototype development can improve the design of elbow-assisting devices through systematic refinement of their structural and functional configurations. These studies collectively establish that the development of rehabilitation technology has progressed beyond the creation of basic mechanical devices toward increasingly sophisticated systems, yet the supporting furniture that determines the user's physical relationship with the therapeutic mechanism remains comparatively underexplored.

Ergonomic and anthropometric principles provide an important foundation for addressing this limitation because the dimensions of a product must correspond to the physical characteristics of its intended users. Anthropometric characteristics vary across individuals according to factors such as age, sex, ethnic background, and patterns of daily activity, creating substantial challenges for the development of universally appropriate product dimensions. Andriani et al. (2026) demonstrate that anthropometric information can be integrated with user-oriented design considerations to develop assistive devices that are more compatible with human physical characteristics. Research concerning office-chair design similarly establishes that anthropometric evaluation is necessary to determine whether chair dimensions adequately accommodate users and support appropriate body positioning (Fitrianto et al., 2025). The relationship between chair height, table height, reach distance, and upper-limb position becomes particularly important when a user must maintain a relatively stable posture while interacting with therapeutic equipment. Hidayatullah et al. (2024) demonstrate that ergonomic redesign of chairs and tables can improve the suitability of workstations by incorporating anthropometric considerations into product dimensions. Ayuningtyas et al. (2025) further demonstrate that redesigning tables and chairs based on ergonomic principles can reduce subjective fatigue among workers. These findings establish that chairs and tables should not be regarded merely as complementary furniture because their dimensions directly influence posture, physical comfort, and the manner in which users interact with equipment.

Despite the development of increasingly sophisticated elbow rehabilitation devices, a significant conceptual and empirical gap remains concerning the integration of rehabilitation mechanisms with anthropometrically appropriate supporting furniture. Existing studies on elbow rehabilitation have primarily emphasized actuator systems, movement control, sensing mechanisms, and mechanical assistance rather than the design of the chair and table that determine the user's physical position during therapy. Setiono et al. (2019) developed a Continuous Passive Motion system controlled using electromyographic signals, highlighting the importance of technological control in upper-limb rehabilitation while providing limited attention to the anthropometric configuration of the supporting workstation. Nisrina and Asi (2026) similarly developed an Arduino-based Continuous Passive Motion rehabilitation system, with emphasis placed on therapeutic functionality rather than the ergonomic integration of the device with supporting furniture. Kurniawan and Ariswati (2025) focused on motor gearbox control for improving angular accuracy in an elbow Continuous Passive Motion tool, illustrating how technical precision continues to dominate the engineering development of rehabilitation devices. Ergonomic research, in contrast, has demonstrated that inappropriate workstation configurations can contribute to undesirable working postures and physical loading. Purwaningsih et al. (2017) showed that workstation and posture design based on biomechanical analysis can reduce static loads and musculoskeletal complaints. Siska and Harahap (2022) similarly demonstrated that ergonomic intervention can improve body posture through systematic assessment of workplace risks.

The separation between these two research streams indicates that the ergonomic requirements of the supporting environment for elbow rehabilitation devices have not yet received proportional attention.

The unresolved issue has important scientific and practical consequences because the effectiveness of a rehabilitation device depends not only on its ability to generate or control therapeutic movement but also on whether users can interact with the device in an appropriate physical configuration. An elbow therapy device supported by an unsuitable table may require excessive reaching, inappropriate elbow positioning, or prolonged postural adjustment, potentially reducing comfort and interfering with the intended therapeutic interaction. Kusuma et al. (2020) demonstrate that ergonomic redesign of tables and chairs can improve working posture by modifying the physical configuration of the workstation according to ergonomic requirements. Pratama and Setiawan (2020) similarly demonstrate the relevance of ergonomic principles in the development of physical assistive equipment designed around the characteristics of users. The problem is more specific in rehabilitation settings because the dimensions of the supporting furniture must accommodate both the human body and the geometric requirements of the therapeutic mechanism. A supporting system that is appropriate from a conventional furniture perspective may not necessarily provide suitable positioning for an elbow rehabilitation device because the user's arm must remain spatially aligned with the therapeutic mechanism. This condition creates a need for a design process that translates anthropometric measurements into specific chair and table dimensions while simultaneously considering the operational requirements of Telbowmes. Research and Development (R&D) provides a suitable methodological framework because product development can proceed through systematic identification of needs, design formulation, development, and evaluation rather than relying solely on subjective design decisions. The resulting approach can connect anthropometric evidence with engineering design requirements and produce a physical support system that is more closely aligned with the intended rehabilitation application.

The present study is positioned within the intersection of rehabilitation engineering, ergonomics, anthropometric design, and product development by focusing on the development of a chair and table specifically intended to support the Telbowmes elbow therapy device. The research originates from the observation that the existing supporting table does not adequately correspond to the anthropometric dimensions required for an ergonomic interaction between the user and the therapeutic device. The study therefore treats the chair and table as an integrated component of the therapeutic system rather than as independent furniture surrounding the device. Anthropometric measurements are used as the principal empirical basis for determining appropriate dimensions, while the configuration of the Telbowmes device is considered in establishing the spatial requirements of the supporting system. The objective of this study is to determine how anthropometric measurement can be applied to the design of the Telbowmes working system and how the resulting data can be processed into dimensional specifications for an ergonomic chair and table. The methodological contribution is the development of a structured product-design procedure that connects human-body measurements with engineering specifications for rehabilitation-device support. The practical contribution is the development of a chair-and-table configuration intended to improve user positioning, ergonomic compatibility, and interaction with the Telbowmes elbow therapy device. At the theoretical level, the study contributes to a human-centered rehabilitation engineering perspective by positioning the therapeutic device and its supporting workstation as interconnected components within a single ergonomic system.

RESEARCH METHODS

This study employed an empirical Research and Development (R&D) approach conducted at the CBIOM3S Laboratory, Semarang, focusing on the development of a chair and table to support the Telbowmes elbow therapy device. The R&D approach was selected because the research involved a sequence of needs identification, data collection, product design, prototype development, testing, and product refinement based on empirical findings (Sasono et al., 2022). The first stage involved identifying problems associated with the existing supporting table, followed by a literature review and collection of anthropometric data as the basis for determining the product dimensions. The conceptual design included the determination of chair and table dimensions, seating configuration, user movement space, selection of strong and relatively lightweight materials, and an adjustable-height mechanism to accommodate variations in user body dimensions (Andriani et al., 2026). Anthropometric data were used to determine the principal product dimensions so that the relationship among the user's body, elbow position, chair, table, and therapy device could be ergonomically configured (Fitrianto et al., 2025). After the design was established, a physical prototype was fabricated and integrated with the Telbowmes elbow therapy device to produce a supporting system that could be directly used in a therapeutic-use simulation. The complete development process was organized into a research flow diagram to ensure that problem identification, data collection, design, fabrication, testing, and product refinement were conducted systematically.

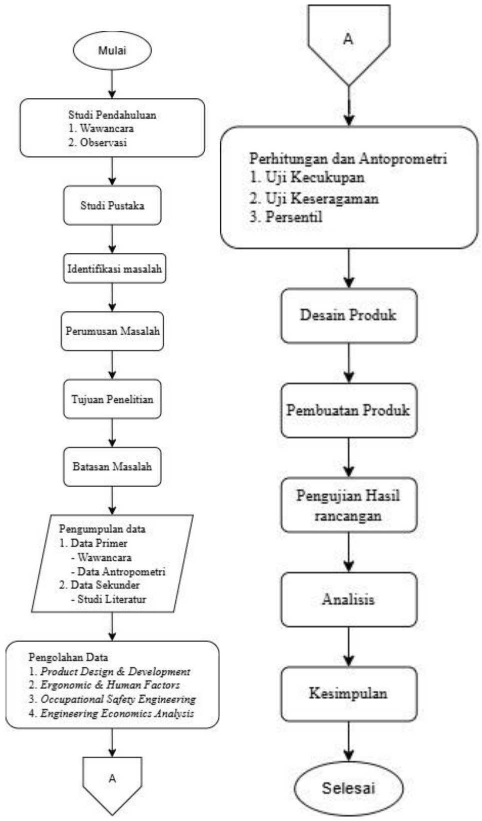

Figure 1. Research Flowchart

At the testing stage, the developed chair and table prototype was used together with the Telbowmes device through a simulated therapeutic-use procedure involving patients or users with characteristics corresponding to the intended user population. The testing focused on dimensional suitability, structural stability, sitting comfort, accessibility of the therapy components, and the ability of the supporting system to maintain an appropriate user position during therapy. Ergonomic validation was conducted by comparing the actual dimensions of the prototype with the anthropometric measurements of the users to determine whether the chair height, table height, and working position corresponded to the users' physical characteristics (Hidayatullah et al., 2024). Postural conditions were also observed during the simulation because an inappropriate workstation configuration can increase static biomechanical loading and contribute to undesirable working postures (Purwaningsih et al., 2017). Functional validation was performed through direct inspection and use of the prototype to verify its ability to support the therapy device, maintain structural stability, and allow the user's elbow to remain appropriately positioned during therapeutic movement. The evaluation metrics comprised anthropometric dimensional compatibility, structural stability, height-adjustment capability, user seating comfort, and functional integration between the chair-table system and the Telbowmes device. The testing results were subsequently used to identify necessary modifications to the dimensions, component positions, adjustable mechanism, or frame construction before establishing the final design, consistent with rehabilitation-device research emphasizing human–device interaction as an important component of design optimization (Yeh & Chou, 2023).

RESULTS AND DISCUSSION

Data Collection and Anthropometric Requirements

The initial data collection was conducted to identify the functional, dimensional, structural, and ergonomic requirements of the chair and table supporting the Telbowmes elbow therapy device at the CBIOM3S Laboratory, Semarang. The data were obtained by examining the existing therapy-device configuration and identifying the physical characteristics required for safe and comfortable interaction between the user and the rehabilitation system. The Telbowmes system was designed for elbow and arm rehabilitation, particularly for stroke patients, making the user's sitting posture and upper-limb positioning important considerations in the supporting-product design. Rehabilitation technology for stroke patients requires appropriate therapeutic positioning because functional recovery depends not only on the movement mechanism but also on the conditions under which repetitive rehabilitation activities are performed (Adityasiwi et al., 2025). The collected specifications indicate that the supporting system requires an adjustable seating height, a dedicated therapy surface, stable structural components, and materials capable of supporting the intended load. The resulting requirements are summarized in Table 1 to establish the technical baseline for subsequent anthropometric analysis and product development.

Table 1. Data Collection of the Telbowmes Elbow Therapy Device

No.	Criteria	Specification
1	Chair Dimensions	Seat height: 45–55 cm
2	Table Dimensions	Length: 30 cm, Width: 25 cm, Height: 5 cm
3	Frame Material	Hollow iron / Acrylic
4	Surface Material	Plywood + foam
5	Load Capacity	Maximum 160 kg
6	Height Adjustment System	Gas lift
7	Ergonomics	Adjusted to anthropometric data of stroke patients
10	Finishing	Powder coating / varnish
11	Target Users	Stroke patients (elbow & arm rehabilitation)
12	Safety Standards	No sharp edges, stable structure

The specifications in Table 1 indicate that the existing supporting configuration provides several functional requirements but still requires dimensional adaptation to accommodate variations in user anthropometry. The chair height of 45–55 cm and the use of a gas-lift mechanism provide an initial basis for adjustability, although the appropriate adjustment range must be determined against measured body dimensions rather than assumed furniture standards. Anthropometric adaptation is particularly relevant for assistive devices because differences in body dimensions can affect the physical relationship between the user and the device during operation (Andriani et al., 2026). The use of a hollow-iron or acrylic frame provides structural alternatives, while plywood and foam provide a surface configuration intended to combine structural support with user comfort. The maximum load specification of 160 kg establishes a basic structural requirement that must be maintained when modifying the dimensions of the chair and table. The absence of sharp edges and the requirement for structural stability were retained as fundamental safety criteria because rehabilitation equipment involves direct and repeated physical contact with users. These specifications were therefore treated as design constraints rather than merely descriptive characteristics of the existing product.

Anthropometric data were subsequently collected to translate the physical characteristics of the intended users into measurable design requirements for the chair and table. Five anthropometric dimensions were selected because they directly influence seating height, table positioning, working reach, back support, and the longitudinal dimensions of the seat. The selection of sitting elbow height and popliteal height was intended to establish an appropriate vertical relationship between the seated user and the therapy surface. Shoulder breadth was considered in determining the longitudinal dimension of the table and the width required to support the user's upper body comfortably. Forward hand reach was used to determine the accessible working area when the user's arm is positioned toward the therapy device, while normal sitting height and popliteal length were used to establish backrest and seat dimensions. The functional relationship between each anthropometric measurement and the corresponding product dimension is presented in Table 2.

Table 2. Anthropometric Data Collection

No.	Anthropometry	Function
1.	Sitting Elbow Height and Popliteal Height	To determine the height of the table surface from the bottom to the top when a person is seated.
2.	Shoulder Width	To determine the appropriate table length and chair width to optimally support the back and provide comfort.
3.	Forward Hand Reach	To determine the table width when the hand is positioned forward.
4.	Normal Sitting Height	To determine sitting height from the seat surface to the top of the head.
5.	Popliteal Length	To determine the seat length so that the thigh is optimally supported without pressing the knee fold.

The selection presented in Table 2 reflects a human-centered dimensional strategy in which each measurement is connected to a specific functional requirement of the therapeutic workstation. Sitting elbow height is particularly important because the therapy surface must permit the user's elbow and forearm to interact with Telbowmes without requiring excessive elevation or depression of the upper limb. Popliteal height provides a reference for the vertical relationship between the floor, seat, and upper-limb working position, while popliteal length determines whether the seat can support the thigh without excessive pressure behind the knee. Shoulder breadth provides a relevant basis for determining lateral accommodation, whereas forward hand reach establishes the maximum practical working distance for the therapy interaction. Similar anthropometric considerations have been applied in ergonomic chair evaluation, where body dimensions are used to assess compatibility between furniture geometry and users (Fitrianto et al., 2025). The combined use of these dimensions provides a more comprehensive representation of the seated user's interaction with the therapeutic workstation than relying on a single body measurement.

The anthropometric framework also reflects the specific functional demands of rehabilitation equipment, where the user is not merely seated but must maintain an appropriate relationship between the upper limb and the therapeutic mechanism. An unsuitable chair or table dimension can alter elbow alignment, restrict reach, or require compensatory postural adjustments that may interfere with the intended rehabilitation activity. Research on ergonomic chair and table redesign has shown that anthropometric-based dimensional adjustment can improve the suitability of workstations and support more appropriate physical interaction (Hidayatullah et al., 2024). The present data collection therefore establishes two interconnected requirements: the structural specifications of the Telbowmes support system and the anthropometric characteristics required for its users. Their integration provides the empirical foundation for the subsequent statistical processing of anthropometric data and determination of product dimensions. The collected measurements also provide a basis for developing an adjustable configuration capable of accommodating variation among users rather than designing the product around a single assumed body size. This approach is consistent with the principle that assistive-device development should account for human characteristics as an integral part of product functionality. The resulting dataset was subsequently processed through adequacy, normality, uniformity, and percentile analyses before the final dimensions of the chair and table were determined.

Anthropometric Data Processing and Product Dimension Determination

The anthropometric measurements obtained during the data collection stage were processed statistically to determine their adequacy, normality, and uniformity before being applied to product dimension determination. This procedure was necessary because the chair and table dimensions had to be derived from empirical measurements that adequately represented the physical characteristics of the intended users. The adequacy test was conducted first to verify whether the number of observations collected was sufficient for each anthropometric variable. A sufficient number of observations provides a stronger basis for estimating body-dimension variability and reduces the possibility of deriving product dimensions from an inadequate dataset. The processing sequence also follows the principle of anthropometric-based ergonomic design, in which measured body dimensions are statistically evaluated before being translated into technical product specifications (Andriani et al., 2026). The results of the adequacy analysis are presented in Table 3.

Table 3. Recapitulation of Data Adequacy Test

Anthropometry	N	N'	Description
Sitting Elbow Height	30	29,59	Sufficient
Popliteal Height	30	12,25	Sufficient
Shoulder Width	30	12,25	Sufficient
Forward Hand Reach	30	11,50	Sufficient
Normal Sitting Height	30	4,97	Sufficient
Popliteal Length	30	3,83	Sufficient

The results in Table 3 show that the required observations (N') for all six anthropometric dimensions were lower than the available observations of 30 respondents, indicating that the dataset was sufficient for further analysis. The sitting elbow height produced the highest N' value of 29.59, which remained below the available sample of 30 observations and therefore fulfilled the adequacy requirement. The other variables showed considerably lower required sample sizes, ranging from 3.83 for popliteal length to 12.25 for popliteal height and shoulder breadth. This condition indicates that the collected measurements provided an adequate empirical basis for representing the anthropometric variation of the intended users. Adequate sample size is important because insufficient observations may reduce the reliability of statistical estimates and affect the resulting percentile-based product dimensions. After the adequacy criterion was fulfilled, the anthropometric variables were subjected to a normality test to evaluate their statistical distribution (Fitrianto et al., 2025). The normality-test results are presented in Table 4.

Table 4. Recapitulation of Data Normality Test

Anthropometry	α	Asymp. Sig.	Description
Sitting Elbow Height	0,05	0,103	Normal
Popliteal Height	0,05	0,200	Normal
Shoulder Width	0,05	0,200	Normal
Forward Hand Reach	0,05	0,153	Normal
Normal Sitting Height	0,05	0,200	Normal
Popliteal Length	0,05	0,079	Normal

Table 4 indicates that all anthropometric variables had Asymp. Sig. values greater than the significance level of 0.05, confirming that the data followed a normal distribution. The lowest significance value was 0.079 for popliteal length, while the highest values of 0.200 were obtained for popliteal height, shoulder breadth, and normal sitting height. The normality condition allows the observed body dimensions to be analyzed using statistical measures that support percentile determination without requiring transformation of the original data. This result is relevant because the chair and table must accommodate variation in user dimensions while maintaining an appropriate physical relationship between the seated body, elbow, and therapy surface. Anthropometric compatibility is a fundamental consideration in ergonomic furniture design because discrepancies between body dimensions and furniture dimensions can influence posture, comfort, and physical interaction with the workstation (Fitrianto et al., 2025). The next stage examined the uniformity of the anthropometric observations to ensure that the variation within each measurement remained statistically controlled.

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Table 5. Recapitulation of Data Uniformity Test

Anthropometry	$\bar{x}$	σ	UCL	LCL	Max	Min	Remark
Sitting Elbow Height	24,0	3,81	31.96	16,24	30	17	In Control
Popliteal Height	45,2	4,01	53.22	37,18	53	39	In Control
Shoulder Breadth	44,6	3,84	53.54	35,36	51	38	In Control
Forward Grip Reach	71,7	4,99	81.68	61,72	81	63	In Control
Normal Sitting Height	85,6	4,84	95.28	75,92	95	77	In Control
Popliteal Length	55,6	5,41	66.42	41,78	63	42	In Control

The uniformity results in Table 5 demonstrate that all anthropometric observations were within their respective upper and lower control limits. The maximum and minimum observations for sitting elbow height, popliteal height, shoulder breadth, forward grip reach, normal sitting height, and popliteal length remained between the calculated UCL and LCL values, resulting in an “In Control” classification for all variables. For example, sitting elbow height had a maximum value of 30 cm and a minimum value of 17 cm, while its control limits were 31.96 cm and 16.24 cm. Similar patterns were observed for the other dimensions, indicating that no measurement represented an uncontrolled extreme that needed to be removed from the dataset. Maintaining these observations is important because anthropometric variation itself constitutes relevant information for designing products that accommodate differences among users. The use of controlled anthropometric data supports more reliable dimensional decisions in ergonomic workstation development (Hidayatullah et al., 2024). The adequate, normally distributed, and uniform dataset could therefore be used to determine the product dimensions through an appropriate percentile strategy.

Percentile determination was performed by relating each anthropometric variable to the functional requirements of the chair and table rather than applying a single percentile to every component. Sitting elbow height and popliteal height were combined to establish the vertical relationship between the seated user and the therapy surface, producing lower and upper table-height values of 60.33 cm and 86.07 cm after a 4 cm allowance was incorporated. Shoulder breadth was used to determine the table length, with a measured value of 44.6 cm and an additional 1 cm allowance resulting in a final dimension of 45.6 cm. Forward grip reach was used to determine the table width, where the selected value of 78.1 cm combined with a 2 cm allowance produced a final width of 80.1 cm. Normal sitting height resulted in a backrest height of 87.6 cm after adding a 2 cm allowance to the 85.6 cm measurement, while popliteal length produced a seat length of 66.5 cm from a 64.5 cm measurement and a 2 cm allowance. The dimensional calculations are summarized in Table 6 and provide the quantitative basis for translating anthropometric characteristics into physical product specifications.

Table 6. Determination of Product Dimensions Based on Anthropometric Percentiles

No.	Element	Anthropometry	Dimension	Allowance	Result
1.	Table Surface Height	Sitting Elbow Height + Popliteal Height	(P_5) 17.73 + 38.60 (P_{95}) 30.27 + 51.80	4 cm	(P_5) 60.33 cm (P_{95}) 86.07 cm
2.	Table Length	Shoulder Breadth	(P_{50}) 44.6 cm	1 cm	45.6 cm
3.	Table Width	Forward Grip Reach	(P_{90}) 78.1 cm	2 cm	80.1 cm
4.	Chair Backrest Height	Normal Sitting Height	(P_{50}) 85.6 cm	2 cm	87.6 cm
5.	Chair Seat Length	Popliteal Length	(P_{90}) 64.5 cm	2 cm	66.5 cm

The results in Table 6 demonstrate that the anthropometric analysis generated specific dimensional requirements for the Telbowmes supporting system rather than relying on generalized furniture dimensions. The adjustable table surface height of 60.33–86.07 cm provides a vertical range intended to accommodate variation in the combined relationship between popliteal height and sitting elbow height. The table length of 45.6 cm and width of 80.1 cm establish the horizontal working area required for interaction with the therapy device while incorporating allowances for practical use. The chair backrest height of 87.6 cm provides additional vertical support for the user's seated posture, while the 66.5 cm seat length is intended to provide adequate thigh support without excessive pressure at the popliteal region. Anthropometric furniture development similarly emphasizes the conversion of measured body dimensions into specific product dimensions to improve compatibility between users and physical equipment (Fitrianto et al., 2025). In rehabilitation-device applications, appropriate human–device interaction is also important because physical compatibility can influence usability, comfort, and the user's experience during therapeutic activities (Yeh & Chou, 2023). These dimensional results establish the empirical foundation for the subsequent design concept, product configuration, material selection, and manufacturing analysis of the Telbowmes chair and table.

Product Design and Manufacturing Analysis

The product design stage translated the anthropometric requirements and functional specifications into an integrated chair-and-table configuration for the Telbowmes elbow therapy device. The design emphasized ergonomic compatibility between the seated user, therapy surface, and elbow movement while maintaining structural strength, adjustability, safety, and ease of maintenance. The principal design requirements and their technical solutions are presented in Table 7, including the use of sitting elbow height, popliteal height, shoulder breadth, and forward hand reach with a P5–P95 approach to accommodate variation in user body dimensions. The combination of sitting elbow height and popliteal height established the vertical relationship between the seated user and therapy surface, while shoulder breadth and forward hand reach informed the horizontal dimensions. Hollow-iron framing, protective finishing, and a simple construction configuration were selected to support structural stability and maintenance requirements. This human-centered design approach is consistent with ergonomic assistive-device development that integrates anthropometric characteristics into technical product specifications (Andriani et al., 2026).

Table 7. Design Concept

No.	Requirement	Solution
1	Ergonomic therapy equipment suitable for user body dimensions	Anthropometric-based design using sitting elbow height, popliteal height, shoulder breadth, and forward hand reach with P5–P95 approach
2	Comfortable and safe therapy position for a certain duration	Table-surface height determined from sitting elbow height and popliteal height with an allowance
3	Strong and stable structure during use	Hollow-iron frame with symmetrical construction and supporting legs
4	Ease of use for users with different body dimensions	Table length and width determined from P50 shoulder breadth and P90 forward hand reach
5	Safety, durability, and ease of maintenance	Strong frame material, protective finishing, and simple easy-to-clean construction

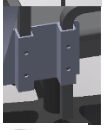
The design concept was converted into a physical configuration consisting of a chair and supporting table that function as an integrated system with the Telbowmes device. The chair includes a frame, seat, backrest, headrest, armrest, gas-lift mechanism, tilt mechanism, star base, and casters, while the table comprises a support frame, therapy tabletop, and adjustable mechanism. The spatial arrangement of these components was determined according to their functional contribution to user support, device accessibility, and compatibility with the anthropometric dimensions established previously. The calculated table-height range of 60.33–86.07 cm requires an adjustable mechanism capable of accommodating variation in seated elbow position. The overall configuration is presented in Figure 2, showing the relationship between the chair, therapy table, and Telbowmes device. Such integration is relevant to rehabilitation equipment because human–device interaction can influence usability and user experience during therapeutic activities (Yeh & Chou, 2023).

Figure 2. Design of the Telbowmes Elbow Therapy Supporting Chair and Table

The components shown in Table 8 consist of customized structural elements and standardized mechanical components selected according to their functional requirements. The chair frame, table support frame, and therapy tabletop require dimensional control because their geometry is directly related to the anthropometric design, whereas the gas lift, tilt mechanism, star base, casters, and fastening components can be obtained commercially. The combination of fabricated and purchased components reduces unnecessary manufacturing complexity while preserving control over critical product dimensions. The adjustable mechanisms provide flexibility for different user body dimensions, while the seat, backrest, headrest, and armrest provide physical support during therapy. This configuration reflects a product-development strategy in which customized structural components are integrated with established mechanical components to achieve functional flexibility and manufacturing practicality (Demirsoy et al., 2024). The resulting component structure forms the basis for the make-or-buy analysis.

Table 8. Product Design Components

Component	Desain
Chair Frame	
Seat	
Backrest	
Headrest	
Armrest	
Gas Lift	
Tilt Mechanism	
Star Base	
Caster	

Table Support Frame	
Therapy Tabletop	
Adjustable Table Mechanism	
Bolts and Nuts	
Finishing	

The make-or-buy analysis determines the allocation of components between internal fabrication and external procurement based on dimensional specificity, availability, and functional requirements. The chair frame, seat cushion, backrest, headrest, gas lift, star base, caster wheels, table support frame, therapy table board, adjustable mechanism, fastening components, and finishing materials were evaluated according to their respective specifications and estimated costs. Components requiring direct dimensional adaptation to the anthropometric design, particularly the table support frame and therapy table board, were classified as make items, while standardized mechanical components were primarily classified as buy items. This allocation can reduce fabrication complexity and facilitate future replacement of standardized parts without modifying the primary structure. The detailed allocation, quantities, specifications, and estimated costs are presented in Table 9. Such component-selection strategies are relevant to iterative rehabilitation-device development because mechanical availability and structural compatibility influence the feasibility of prototype refinement (Ceccarelli et al., 2024).

Table 9. Make-or-Buy Analysis

No	Component	Dimensions / Specification	Quantity	Estimated Cost (IDR)	Make / Buy
A. Chair Components					
1	Chair Frame	Hollow 40x40 mm	1 set	500,000	Buy
2	Seat Cushion	Multiplex 18 mm + foam	1	250,000	Buy
3	Backrest	Multiplex + foam	1	200,000	Buy
4	Headrest	Adjustable	1	150,000	Buy
5	Gas Lift	Class 3	1	180,000	Buy
6	Star Base	Ø 60 cm	1	300,000	Buy
7	Caster Wheels	2 inch	5	150,000	Buy
B. Therapy Table Components					
8	Table Support Frame	Hollow 30x30 mm	1	300,000	Make
9	Therapy Table Board	40 x 30 cm	1	200,000	Make
10	Table Adjustable Mechanism	Hinge + lock	1	200,000	Buy
11	Bolts & Nuts	M8 & M10	1 set	70,000	Buy
12	Finishing (Paint)	Powder coating	1	200,000	Buy

The economic allocation was used to establish the production cost and estimated selling price of the developed supporting system. The component expenditure was Rp2,700,000, while labor was calculated from two workers at Rp300,000 per person, resulting in a labor allocation of Rp600,000. The total production cost was therefore Rp3,300,000 per unit, representing the expenditure required to fabricate one unit of the product. A profit margin of 20% generated Rp660,000, resulting in an estimated selling price of Rp3,960,000 per unit. This economic calculation provides an initial basis for assessing the feasibility of producing the supporting system while maintaining the required ergonomic and structural specifications. Engineering economic analysis is relevant to product development because technical performance must be considered alongside production expenditure and potential commercialization.

The manufacturing documentation establishes the relationship between the finalized design and the physical fabrication process through material identification, processing, inspection, movement, and assembly activities. The Bill of Material (BOM) identifies the hierarchical composition of the chair-and-table system and specifies the components required to produce the finished product, as presented in Figure 3. The BOM provides a material-planning reference by linking the main product with its structural frames, seating components, therapy surface, adjustment mechanisms, and fastening elements. Clear identification of components is important in R&D because prototype fabrication requires traceability between design requirements and physical construction (Sasono et al., 2022).

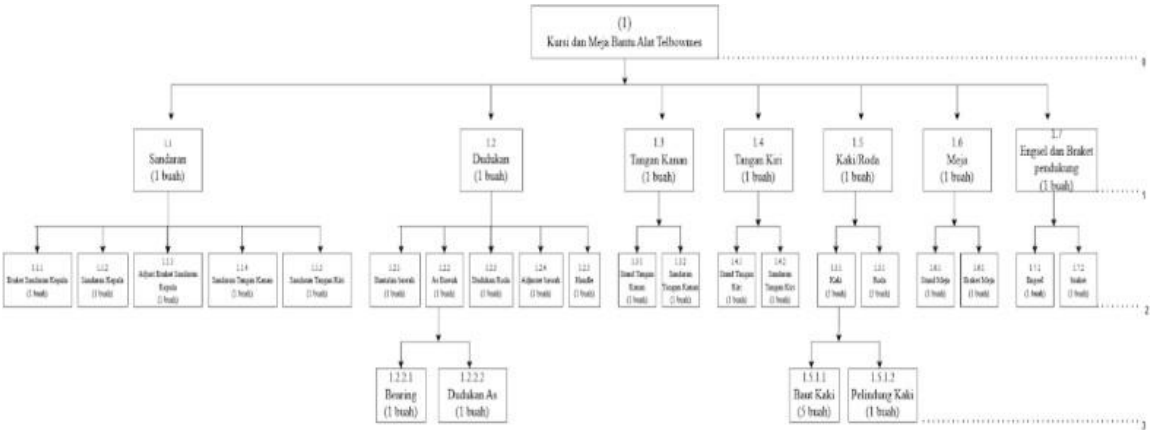


Figure 3. Bill of Material Structure

Figure 3 illustrates the hierarchical composition of the Telbowmes supporting system, beginning with the finished product and extending to the chair, table, structural elements, supporting surfaces, adjustment mechanisms, and fastening components. The structure clarifies the relationship between major assemblies and their constituent components. It also facilitates material preparation, procurement, assembly, and subsequent maintenance because each component can be identified according to its position within the product. The BOM provides a systematic reference for ensuring that the materials required during fabrication correspond to the established design. This traceability supports iterative product development when modifications are required after prototype testing (Sasono et al., 2022).

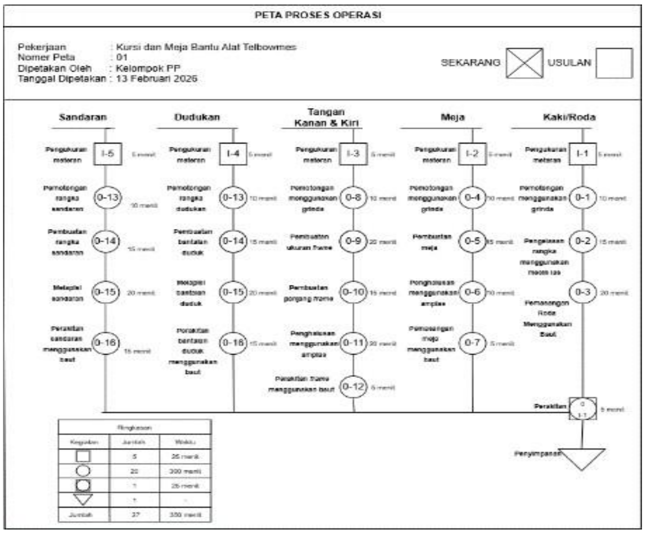


Figure 4. Operation Process Chart (OPC)

Figure 4 presents the principal sequence of manufacturing activities required to transform the identified materials into functional components of the Telbowmes supporting system. The process includes material preparation, fabrication of structural elements, preparation of supporting surfaces, assembly-related operations, finishing, and inspection. The sequence provides a controlled representation of the transformation from raw materials into components that satisfy the dimensional and structural requirements of the design. Inspection activities are important because dimensional deviations during fabrication can alter the anthropometric relationships established during product development. A structured operational sequence also facilitates identification of defects before final integration with the therapy device (Ceccarelli et al., 2024).

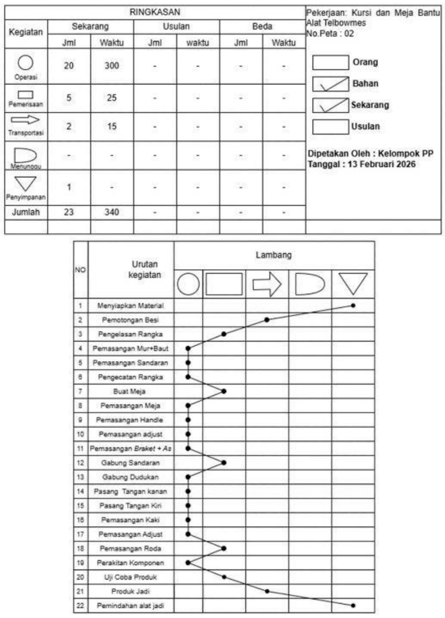


Figure 5. Assembly Process Chart

Figure 5 presents the flow of production activities by distinguishing operations, inspections, transportation, waiting, and storage during fabrication of the chair and table. This representation provides more detailed process information than the OPC because it includes activities that do not directly modify the physical characteristics of the product. Operations represent direct production activities, whereas inspections verify material, dimensional, and construction conformity. Transportation, waiting, and storage indicate stages that may consume time and resources without directly increasing product value. Identifying these activities provides a basis for reducing unnecessary movement and handling while preserving the dimensional accuracy required for ergonomic performance. Such process evaluation is relevant to ergonomic product development because production efficiency must remain compatible with product quality and functional requirements (Hidayatullah et al., 2024).

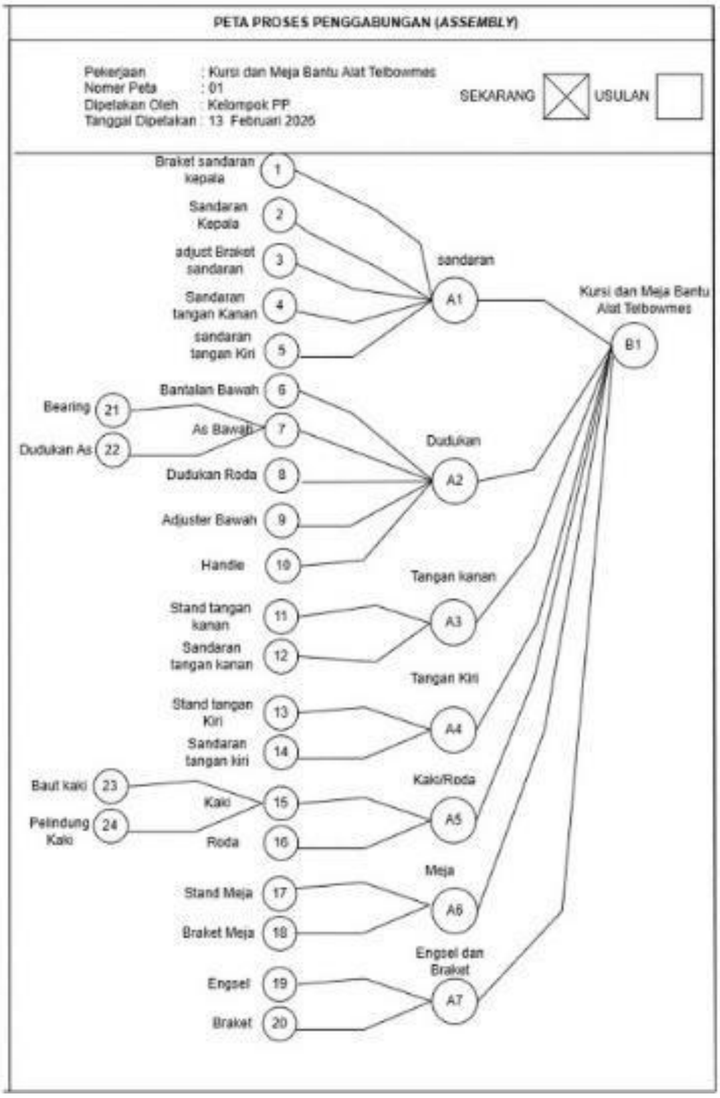


Figure 6. Assembly Process Chart

Figure 6 illustrates the sequence and relationship among individual components during the final integration of the chair and table supporting system. The assembly begins with the primary structural components and proceeds through installation of the seating, back-support, adjustment mechanisms, therapy surface, and connecting elements. The sequence is arranged to form a stable structure capable of supporting the intended user load and the Telbowmes therapy device. The use of bolts and nuts provides practical advantages because selected components can be removed for inspection, maintenance, or replacement without permanently modifying the primary frame. Assembly accuracy remains important because component-position deviations can affect seat geometry, table height, therapy-device accessibility, and elbow positioning during use (Yeh & Chou, 2023). The completed assembly represents the integration of the manufactured components into the final rehabilitation-support system.

Safety, Final Dimension, and Body of Knowledge Analysis

Safety evaluation was conducted to ensure that the developed chair and table could support therapeutic activities without introducing avoidable mechanical or ergonomic hazards. The safety requirements were incorporated directly into the product configuration through a stable frame, protected edges, secure connections, appropriate surface finishing, and mechanisms that prevent unintended movement during use. Structural stability is particularly important because the supporting system must accommodate the user's body load and the mechanical interaction generated during elbow rehabilitation. The use of appropriate safety features is consistent with rehabilitation-device development, in which mechanical reliability and user interaction need to be considered together during prototype optimization (Ceccarelli et al., 2024). The gas-lift mechanism and caster configuration were also considered from a safety perspective because adjustable and mobile components can introduce instability if they are not properly controlled. These considerations establish safety as an integrated design requirement rather than an independent inspection performed only after fabrication.

The anthropometric analysis was further evaluated to determine whether the selected percentiles were appropriate for each product dimension and functional requirement. The table height employed P5 and P95 because the adjustable mechanism needed to accommodate users at both lower and higher dimensional ranges. The table length used P50 based on shoulder breadth to obtain a representative dimension, whereas P90 forward hand reach was selected for table width to provide adequate access to the therapy area. The chair backrest height was derived from normal sitting height, while P90 popliteal length was applied to the seat dimension to provide adequate thigh support without excessive pressure at the posterior knee region. This differentiated percentile strategy reflects the principle that anthropometric dimensions should be selected according to the functional purpose of each product element rather than applying a single percentile to all dimensions (Fitrianto et al., 2025). The final product dimensions are presented in Table 11.

Table 11. Final Product Dimensions Table

No.	Element	Dimensions
1.	Table Surface Height	60.33 - 86.07 cm
2.	Table Length	45.6 cm
3.	Table Width	80.1 cm
4.	Chair Backrest Height	87.6 cm
5.	Chair Seat Height	66.5 cm

Table 11 shows that the developed supporting system has an adjustable table-surface height of 60.33–86.07 cm, a table length of 45.6 cm, and a table width of 80.1 cm. The chair backrest height was established at 87.6 cm, while the seat dimension was determined at 66.5 cm based on the selected anthropometric criterion. These dimensions represent the conversion of anthropometric measurements into functional engineering specifications for the Telbowmes therapeutic workstation. The adjustable table-height range is particularly important because it permits the therapy surface to be positioned according to differences in seated elbow and popliteal dimensions. The table dimensions provide a defined working area for upper-limb interaction while maintaining the intended relationship between the user and the Telbowmes device. Anthropometric-based furniture design similarly emphasizes the importance of matching product dimensions with user body characteristics to improve ergonomic compatibility and physical comfort (Hidayatullah et al., 2024).

The final configuration provides an integrated relationship among the chair, table, and Telbowmes therapy device. The seat, backrest, armrest, adjustable table mechanism, and therapy surface are arranged to support a stable seated posture while allowing the user to perform the intended elbow movement. The adjustable components provide flexibility for differences in body dimensions, while the structural arrangement prevents the therapy surface from functioning as an isolated workstation element. This relationship is relevant to rehabilitation technology because effective interaction depends on compatibility among the human body, supporting furniture, and therapeutic mechanism. Studies of upper-limb rehabilitation devices have emphasized that user experience and physical interaction should be considered during design optimization rather than focusing exclusively on the mechanical operation of the rehabilitation mechanism (Yeh & Chou, 2023). The resulting configuration therefore represents an integrated human–product–device system.

The Body of Knowledge (BoK) analysis was used to organize the engineering knowledge underlying the development of the Telbowmes supporting system. Four principal knowledge domains were identified: Product Design and Development, Ergonomics and Human Factors, Safety, and Engineering Economic Analysis. Product Design and Development provides the framework for translating user requirements into specifications, concepts, prototypes, and design refinement, consistent with the R&D orientation adopted in this study (Sasono et al., 2022). Ergonomics and Human Factors provides the basis for applying anthropometric measurements, percentile selection, adjustable dimensions, and user–device interaction to the product configuration. Safety addresses structural stability, edge protection, secure mechanisms, and risk reduction during therapeutic use, while Engineering Economic Analysis evaluates production expenditure and potential financial feasibility. The relationship among these domains establishes a multidisciplinary foundation for the developed product.

Table 12. Product Price Range Table

Product	Price
	IDR 3,500,000 – 3,960,000

The economic assessment indicates that the developed supporting system requires a production expenditure of Rp3,300,000 per unit, consisting of Rp2,700,000 for components and Rp600,000 for labor. With a 20% profit allocation of Rp660,000, the estimated selling price becomes Rp3,960,000 per unit. The price range presented in Table 12 provides an initial reference for the potential economic positioning of the developed product, while the calculated selling price represents the estimated price based on the production-cost structure. This economic consideration is important because a technically effective rehabilitation-support product also needs to remain reasonably producible and accessible. The combination of ergonomic functionality and controlled production expenditure provides a basis for further assessment of commercialization potential. The economic dimension complements the BoK framework by connecting engineering design decisions with resource requirements and prospective implementation. Overall, the final design integrates anthropometric suitability, safety, functional interaction, manufacturing considerations, and economic feasibility into a unified supporting system for the Telbowmes elbow rehabilitation device.

CONCLUSION

The design and assembly of the chair and table supporting the Telbowmes therapy device successfully produced an integrated support system for elbow and arm rehabilitation activities, particularly for stroke patients. The development process involved identifying product requirements, collecting anthropometric data, conducting data adequacy, normality, and uniformity tests, determining appropriate percentiles, and translating the analytical results into product dimensions. The anthropometric analysis resulted in a table-surface height adjustment range of 60.33–86.07 cm, a table length of 45.6 cm, a table width of 80.1 cm, a chair backrest height of 87.6 cm, and a seat dimension of 66.5 cm. The application of anthropometric principles and differentiated percentile selection for each component enables the product to accommodate variations in user body dimensions while maintaining an appropriate relationship among the seated position, elbow, arm, and therapy surface. Functionally, the chair and table were designed as an integrated system equipped with supporting components such as a gas lift, tilt mechanism, backrest, casters, structural frames, and adjustable table mechanisms to provide flexibility during therapy. Safety considerations were incorporated through a stable frame, secure connections, protected surfaces, and mechanisms designed to maintain user stability during rehabilitation activities. Based on the make-or-buy analysis and economic calculation, the estimated production cost was IDR 3,300,000 per unit with an estimated selling price of IDR 3,960,000, providing an economic basis for further product development.

This study demonstrates that the development of supporting facilities for rehabilitation devices requires the integration of ergonomics, anthropometry, product design, safety, manufacturing processes, and economic considerations within a unified development framework. The preparation of the Bill of Material (BOM), Operation Process Chart (OPC), Flow Process Chart, and Assembly Process Chart provided a systematic basis for connecting the product design with its manufacturing and assembly processes. Although the resulting design provides dimensions and configurations consistent with the established requirements, further development is still necessary to improve product flexibility for a wider range of patient conditions and postures. The table-adjustment mechanism and supporting components can be further developed using more flexible systems, including multi-axis or hydraulic mechanisms, to optimize therapeutic positioning. Direct testing with patients and physiotherapists is also recommended to obtain empirical evidence regarding comfort, stability, usability, and product suitability during therapeutic activities. Structural strength analysis through stress and load simulations, combined with physical testing, can further verify frame durability and improve the safety factor for long-term use. In addition, optimization of material selection, manufacturing processes, and additional features such as automatic caster locks, folding or storage mechanisms, and supplementary therapeutic equipment may improve cost efficiency, safety, multifunctionality, and the potential application of the developed product.

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