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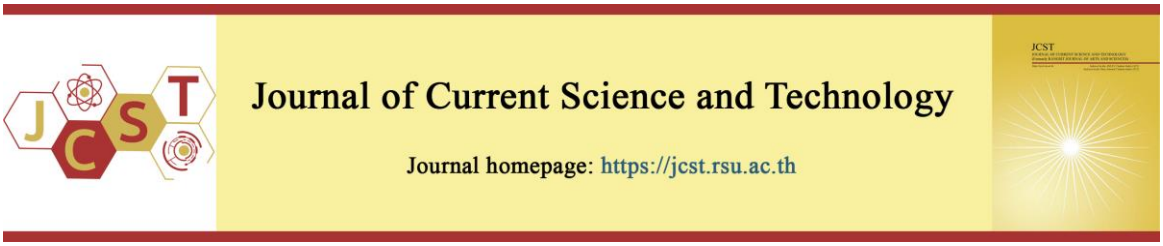

A Study of Opinion and Satisfaction of Physical Therapists About the Prototype Exercise Machine for Lower Limb Strengthening in Children with Cerebral Palsy

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Abstract

Children with spastic cerebral palsy commonly exhibit muscle spasticity, generalized weakness, and postural instability, with deficits in lower extremity strength markedly impairing their ability to perform functional activities such as standing and walking. In response to this clinical challenge, a prototype exercise machine was developed to enhance lower limb strength. However, the opinions and satisfaction of physical therapists regarding this machine constitute an important aspect that has not yet been systematically evaluated. Therefore, this study aimed to investigate their perspectives and satisfaction with the prototype. Thirty physical therapists were purposively recruited based on their clinical experience in pediatric physical therapy. Data were collected using a validated questionnaire, with an Index of Item-Objective Congruence (IOC) greater than 0.50 and a mean IOC of 0.98. Descriptive statistical analysis was conducted to examine participant demographics and satisfaction levels across various aspects. The mean satisfaction scores were as follows: design and structure (4.35 ± 0.63), safety (4.47 ± 0.57), usability (4.07 ± 0.79), and usefulness (4.27 ± 0.74). In conclusion, the equipment received high satisfaction ratings in all aspects. Further development is recommended in accordance with industry or medical device standards, along with additional studies involving a broader sample that includes both typically developing children and those with cerebral palsy.

Keywords: *satisfaction; children; exercise machine; lower limb strength*

1. Introduction

Cerebral palsy (CP) is a leading cause of motor and postural impairments in children, affecting approximately 2–3 per 1,000 live births (McIntyre et al., 2022; Paul et al., 2022). Among the different types, spastic CP accounts for around 80% of cases, with spastic diplegia being the most prevalent subtype (Rana et al., 2017). Children with spastic diplegia often experience decreased muscle tone, muscle weakness, and postural instability, which significantly impair their ability to perform fundamental activities such as standing and walking (Howard & Herzog, 2021).

Strengthening exercises, especially functional training such as sit-to-stand (STS) movements, play a critical role in rehabilitation programs for children with spastic diplegia CP. STS exercises target major muscle groups of the lower extremities and can improve basic motor functions, walking performance,

and balance (Liao et al., 2007; Morton et al., 2005). Moreover, in the design of progressive resistance exercise programs aimed at enhancing muscle strength in children with cerebral palsy, participants typically perform 3–4 sets of each exercise, with 5–10 repetitions per set at an intensity of 50–65% of their one-repetition maximum (1RM). Training sessions are generally conducted three times per week over a period ranging from 6 to 10 weeks (Özal et al., 2016). In addition, individuals with CP who exhibit motor impairments often face difficulties in performing these tasks due to poor postural control, compensatory movement patterns, muscle weakness, and challenges in following exercise programs (Pavão et al., 2013). To address these limitations, assistive devices are commonly implemented to support and guide exercise performance.

A Sliding Rehabilitation Machine (SRM) is a therapeutic exercise device specifically designed to support lower limb strengthening and functional movement training, particularly in individuals with motor impairments such as children with CP. The device allows for controlled and repetitive execution of weight-bearing and sliding movements within a partially gravity-reduced environment. Its primary component consists of an inclined sliding platform on which the child lies. This platform is mounted on rails or a track system and can move along the inclined plane through force applied by the feet to a footpad. This configuration enables the performance of closed kinetic chain exercises (CKC) involving the hip, knee, and ankle joints through repetitive, resisted flexion and extension of the lower extremities -movements which closely resemble sit-to-stand (STS) transitions. Studies have shown that SRM-based training can improve lower limb strength, gait parameters, and functional mobility in children with spastic CP (Lee et al., 2014; Park et al., 2014). Our earlier research also indicated that strength training with the SRM greatly improved the ability to stand up from a seated position and increased joint movement in children and teenagers with spastic diplegia (Borkam et al., 2020); nonetheless, a conventional SRM has limitations including being typically nonadjustable in inclination, having considerable weight, and lacking integrated resistance control. Additionally, adjusting the intensity often requires extra weights, such as a vest with sandbags based on one-repetition maximum (1RM) calculations, which can be challenging and time-consuming in clinical settings. A figure illustrating the SRM used in prior research is presented in Figure 1.

To overcome these limitations, we developed a prototype exercise machine to improve lower limb strength in children with spastic CP, particularly those with moderate motor impairments who are able to participate in guided active training. The machine integrates an adjustable inclination system which modulates exercise resistance by changing the platform angle (0–90 degrees), thereby eliminating the need for external weights (Figure 2). It includes key components such as a linear actuator for smooth platform adjustment, an accelerometer for real-time angle monitoring, and a sensor to detect each child's body weight. The measure of a maximal voluntary isometric contraction (MVC), which refers to leg extension force, is utilized to estimate the one-repetition maximum (1RM) value and ascertain a suitable exercise intensity for children with cerebral palsy, such as a resistance force of 50% of the MVC. Embedded software utilizes these data inputs to calculate the optimal exercise load specific to each child. Unlike the SRM, the machine also features a user interface, electronic controls, a backup power supply, and four safety wheels for mobility.

Importantly, the prototype was designed for children with spastic cerebral palsy of mild to moderate severity (GMFCS levels I–III), who are most likely to benefit from structured resistance training with partial support. The effectiveness and usability of newly developed therapeutic equipment, however, largely depend on user feedback. Existing devices, such as the SRM or conventional tilt tables, have notable limitations, including large size, high cost, lack of automatic angle adjustment, and limited portability. These shortcomings often hinder their use in pediatric rehabilitation. Moreover, the satisfaction and acceptance of physical therapists are critical for successful clinical implementation, as therapists are the primary users responsible for ensuring both safety and therapeutic effectiveness. Thus, investigating their opinions and satisfaction with the prototype exercise machine is essential to guide further refinement and clinical adoption. In this context, input from physical therapists as the primary end-users is indispensable for optimizing device design, structural integrity, safety, usability, and overall clinical value, which have not yet been systematically evaluated. Therefore, to determine the clinical relevance of the machine and its alignment with therapist expectations, this study aimed to assess the opinions and satisfaction of physical therapists regarding the prototype exercise machine for improving lower limb strength in children with spastic cerebral palsy.

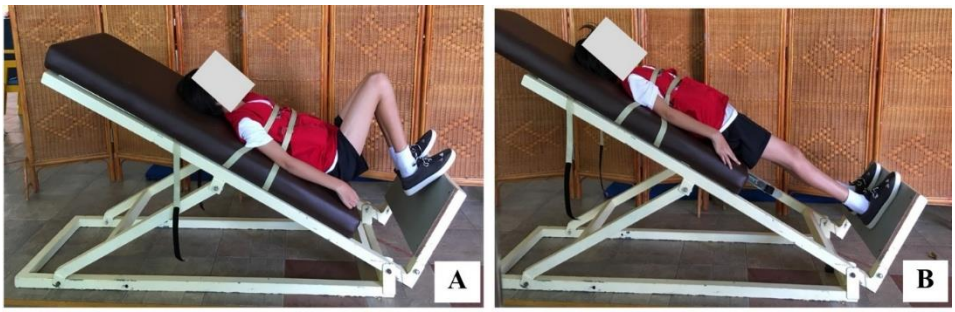

Figure 1 A conventional sliding rehabilitation machine (SRM): (A) starting position showing flexion of the knee and hip joints during exercises using the machine; (B) exercise position with the knee and hip joints extended, with resistance added by attaching sandbags to the vest

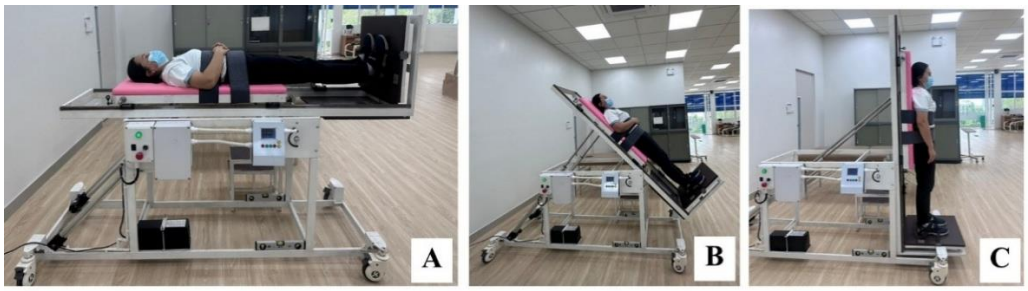

Figure 2 The prototype of an exercise machine for improving lower limb strength in children with spastic cerebral palsy at different platform inclinations: (A) 0 degrees; (B) 45 degrees; (C) 90 degrees

2. Objectives

The objectives of this study were to examine the opinions and satisfaction of physical therapists regarding the prototype of an exercise machine for improving lower limb strength in children with spastic CP.

3. Materials and Methods

3.1 Study Design and Prototype Development

This exploratory study aimed to evaluate the opinions and satisfaction of physical therapists regarding a prototype exercise machine designed to enhance lower limb muscle strength in children with spastic cerebral palsy. The study was conducted in Khon Kaen Province, Thailand. The prototype was developed based on the closed kinetic chain (CKC) exercise principle, allowing simultaneous flexion and extension of the hip and knee joints in both legs (Figure 3). The design emphasized both safety and usability. The machine included trunk and ankle support and was structurally designed using SolidWorks software (Education/Student version 2015). The engineering framework comprised of three main components: the base frame, the bed structure, and the sliding pad.

The linear actuator employed in this study was a 24V DC heavy-duty model, with a stroke length of 1,000 mm, a maximum load capacity of 6,000 N (600 kg), a movement speed of 5 mm/s, and an IP54 protection rating. The system utilized a linear actuator, which produces straight-line motion and is often employed as an alternative to hydraulic or pneumatic systems. Furthermore, an Arduino Mega 2560 microcontroller board was selected for its ample input/output ports allowing integration with various subsystems, including the control of a liquid crystal display (LCD), stepper motor drivers, and manual switches. A gyroscope module was mounted near the tilting bed to monitor and report changes in the bed's angle of inclination over time. Calibration and testing of the gyroscope module were conducted by the Center of Industrial Instrument Calibration, Faculty of Engineering and Architecture, Rajamangala University of Technology Isan, Thailand. The results confirmed that the module's accuracy was within acceptable limits, with a maximum deviation not exceeding 5 degrees (Certificate No. ML-026-22).

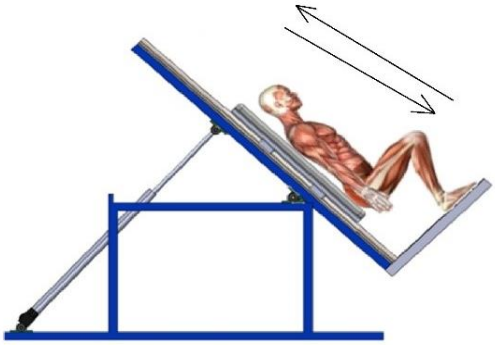

Figure 3 A basic design concept of the prototype of an exercise machine for improving lower limb strength

3.2 Instrument Development and Validation

With regards to the opinions and satisfaction of physical therapists concerning the prototype exercise machine designed to enhance lower limb muscle strength, key steps in this process included the development of a user manual and a video demonstration illustrating the device's operation. Additionally, an assessment questionnaire was developed to gather structured feedback from physical therapists regarding the prototype. This questionnaire served as the primary research instrument in the present study, providing a systematic means to evaluate therapists' opinions and satisfaction. The Index of Item–Objective Congruence (IOC) refers to a content validity index that quantifies the extent to which each questionnaire item is consistent with its intended objective, as judged by subject-matter experts. To evaluate the content validity of the assessment tool, five experts in pediatric physical therapy and rehabilitation reviewed all questionnaire items. Each item was rated using a three-point scale: +1 = strongly agree (the item is clearly congruent with the objective), 0 = uncertain (the item is ambiguous or only partially congruent), and –1 = strongly disagree (the item does not reflect the objective). The IOC value for each item was calculated using the following formula:

$$\text{IOC} = \frac{\sum R}{N}$$

where:

IOC represents the Index of Item-Objective Congruence, indicating the consistency of each question item.

$\sum R$ represents the total score of experts' evaluations for all items.

N represents the total number of experts.

According to established criteria, an IOC value of 0.50 or higher was considered acceptable for content validity (Phonphotthanamat, 2022). The results showed that all items exceeded the minimum threshold, with an overall average IOC of 0.90**,** indicating strong agreement among experts and confirming that the questionnaire was suitable for data collection

3.3 Participants and Recruitment

A purposive sampling method was employed to recruit participants who possessed qualifications and expertise directly aligned with the study objectives. In total, 30 licensed physical therapists were included. All participants had a minimum of three years of professional experience and prior clinical practice in the management of children with cerebral palsy.

3.4 Data Collection

This study was approved by the Ethics Committee for Human Research, Khon Kaen University under the project identification number HE664018. Following ethical approval, the researcher initiated project promotion and invited eligible participants to take part in the evaluation of the questionnaire assessing the opinions and satisfaction of physical therapists regarding the prototype exercise machine designed to enhance lower limb muscle strength. Participants meeting the selection criteria were provided with a user manual, an instructional video demonstrating use of the equipment, and the questionnaire to evaluate their opinions and satisfaction. The researcher then collected the completed questionnaires and performed data analysis accordingly.

3.5 Statistical Analysis

The data were analyzed using SPSS Statistics version 29 (IBM Corporation, USA). Descriptive statistics, including percentages, mean, standard deviation, minimum, and maximum values, were used for the analysis.

The questionnaire assessing the opinions and satisfaction of physical therapists regarding the prototype exercise machine for improving lower limb muscle strength consisted of three sections:

Section 1: General information — this section includes details such as gender, age, and years of experience in physical therapy.

Section 2: Satisfaction with the prototype exercise machine — this section covered four aspects: design and structure, safety, usability, and usefulness. The interpretation of the satisfaction scores was based on the following scale:

Mean score 1.00 – 1.50: Very low satisfaction
Mean score 1.51 – 2.50: Low satisfaction
Mean score 2.51 – 3.50: Moderate satisfaction
Mean score 3.51 – 4.50: Good satisfaction
Mean score 4.51 – 5.00: Very good satisfaction

Section 3: Open-ended questions — this section allowed respondents to provide additional comments and suggestions. The exact wording of the open-ended item was: "Please provide any comments or suggestions regarding the strengths, limitations, and potential improvements of the prototype of an exercise machine for improving lower limb strength in children with spastic cerebral palsy".

Mean scores and standard deviations were computed for each Likert-scale domain to summarize satisfaction levels and variability. For the open-ended responses, a descriptive review was performed, and recurring comments (e.g., safety and machine size) were summarized.

4. Results

4.1 The Characteristics of the Prototype of an Exercise Machine

The prototype exercise device was constructed with a rectangular frame measuring 214 cm in length and 60 cm in width. The adjustable platform could be positioned vertically, reaching a maximum height of 221 cm, or horizontally at a height of 150 cm (Figure 4). This design was developed to facilitate therapeutic exercises based on the CKC principle, which allows simultaneous flexion and extension of the hip and knee joints in both lower limbs under weight-bearing conditions. By enabling controlled and repetitive movements within a stable framework, the device provides an opportunity to promote muscle strengthening, joint stability, and functional motor training in children with spastic cerebral palsy, while ensuring safety and therapist supervision (Figure 5).

4.2 Characteristics of Subjects

A total of 30 physical therapists participated in the study. Table 1 summarizes the general characteristics of the respondents. The majority were female (n = 18, 60%), whereas male respondents accounted for 40% (n = 12). The mean age was 30.43 ± 3.46 years, with a range of 26–42 years. The mean duration of professional experience in physical therapy was 7.47 ± 3.48 years. Subgroup analysis based on years of experience revealed that 28 respondents had 2–10 years of experience, with a mean of 6.75 ± 2.14 years; among them, 17 (60.71%) were female and 11 (39.29%) were male. Two respondents reported 11–20 years of experience, with a mean of 17.5 ± 3.54 years, comprising of one male and one female.

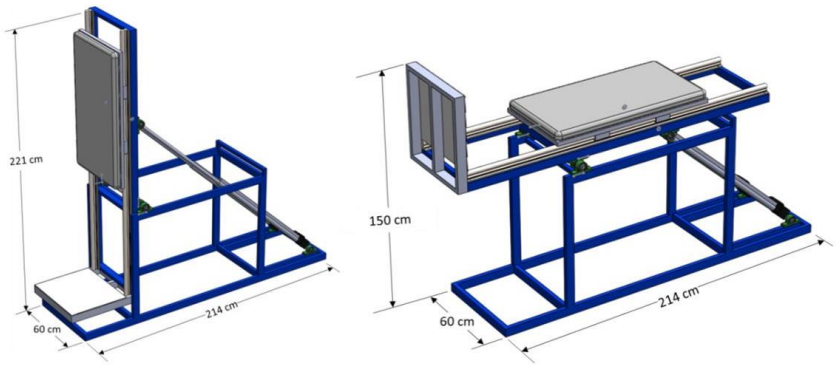

Figure 4 Design of the width, length and height of an innovative exercise machine for improving lower limb strength

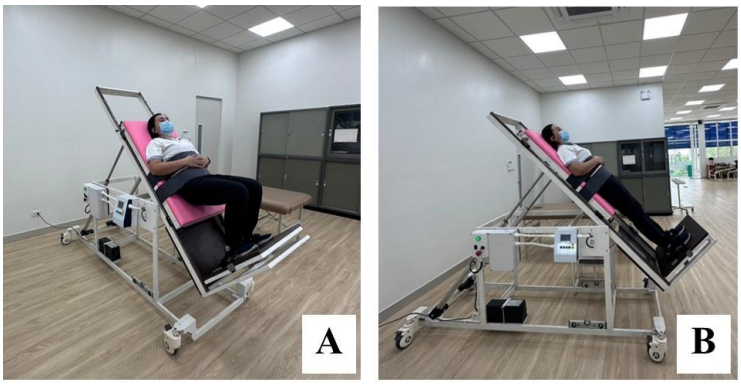

Figure 5 The prototype of an innovative exercise machine for improving lower limb strength: (A) the starting position for exercises using the machine involves flexion of the knee and hip joints; (B) exercises using the machine in knee and hip extension positions are designed to enhance leg muscle function

Table 1 Characteristics of subjects (n=30)

Characteristics	**Mean ± SD**	**Min – Max**
Sex: Male (Percent)/ Female (Percent)	12 (40) / 18 (60)	–
Age (year)	30.43 ± 3.46	26 – 42
Experience as a physical therapist (years)	7.47 ± 3.48	3 – 20
Preliminary information is divided by work experience period.		
2-10 years (years)	6.75 ± 2.14	3 – 10
Sex: Male (Percent)/ Female (Percent)	11 (39.29) / 17 (60.71)	-
11-20 years (years)	17.50 ± 3.54	15 – 20
Sex: Male (Percent)/ Female (Percent)	1 (50) / 1 (50)	-

Abbreviation: SD = standard deviation

4.3 Satisfaction of Physical Therapists Regarding the Prototype of an Exercise Machine for Improving Lower Limb Strength

Table 2 presents the overall satisfaction levels of physical therapists regarding the exercise machine for improving lower limb strength. The study results indicated that physical therapists reported a good level of satisfaction with the prototype exercise machine across four domains. Design and structure, the overall mean satisfaction score was 4.35 ± 0.63, reflecting a good level of satisfaction. Specifically, the appropriateness of the equipment size received a mean score of 4.30 ± 0.60, whereas the creative design aspect scored 4.40 ± 0.67. For safety, the overall mean satisfaction score was 4.47 ± 0.57, indicating a good level of satisfaction. The structural strength of the equipment scored 4.50 ± 0.50, while the overall safety of the equipment received a score of 4.43 ± 0.63. For usability, the overall mean satisfaction score was 4.07 ± 0.79, reflecting a good level of satisfaction. Convenience of use scored 4.00 ± 0.74, ease of moving the equipment scored 3.83 ± 0.79, and the effectiveness of the equipment in strengthening lower limb muscles scored 4.37 ± 0.76. For usefulness, the overall mean satisfaction score was 4.27 ± 0.74, indicating a good level of satisfaction. The effectiveness in promoting exercise for children with spastic cerebral palsy scored 4.27 ± 0.69, the equipment's contribution to facilitating rehabilitation for children with spastic cerebral palsy scored 4.23 ± 0.70, and the practicality of the equipment received a score of 4.30 ± 0.84.

Table 3 presents an analysis of physical therapists' satisfaction regarding the prototype exercise machine among respondents with 2–10 years of work experience. Respondents in this subgroup demonstrated an overall satisfaction level rated as good across all domains. The mean score for design and structure was 4.32 ± 0.64, for safety was 4.45 ± 0.57, for usability was 4.01 ± 0.78, and for perceived usefulness was 4.23 ± 0.74. In addition, respondents with 11–20 years of experience rated the prototype highly, with all domains receiving a mean satisfaction score of very good. Design and structure averaged 4.75 ± 0.50, safety 4.75 ± 0.50, usability 4.83 ± 0.41, and practical benefits 5.00 ± 0.00 (Table 4).

Table 2 Satisfaction of physical therapists concerning the prototype of an exercise machine (n=30)

Satisfaction assessment topics	Mean ± SD	Satisfaction level
Design and structure		
The size of the machine is appropriate.	4.30 ± 0.60	Good
The machine reflects a creative design idea.	4.40 ± 0.67	Good
Average	**4.35 ± 0.63**	**Good**
In terms of safety		
The machine has a stable and solid structure.	4.50 ± 0.50	Good
The machine can be used safely.	4.43 ± 0.63	Good
Average	**4.47 ± 0.57**	**Good**
In terms of usability		
The machine is appropriate to use.	4.00 ± 0.74	Good
The machine is easy to move.	3.83 ± 0.79	Good
The machine is effective for improving lower limb strength.	4.37 ± 0.76	Good
Average	**4.07 ± 0.79**	**Good**
In terms of usefulness		
The machine is useful for facilitating exercise of children with spastic cerebral palsy.	4.27 ± 0.69	Good
The machine facilitates rehabilitation of children with spastic cerebral palsy.	4.23 ± 0.70	Good
The machine is practical.	4.30 ± 0.84	Good
Average	**4.27 ± 0.74**	**Good**

Note: SD = standard deviation

Table 3 Satisfaction of physical therapists concerning the prototype of an exercise machine among respondents with 2–10 years of work experience (n=28)

Satisfaction assessment topics	Mean ± SD	Satisfaction level
Design and structure		
The size of the machine is appropriate.	4.25 ± 0.59	Good
The machine is a creative design idea.	4.39 ± 0.69	Good
Average	**4.32 ± 0.64**	**Good**
In terms of safety		
The machine has a stable and solid structure.	4.46 ± 0.51	Good
The machine can be used safely.	4.43 ± 0.63	Good
Average	**4.45 ± 0.57**	**Good**
In terms of usability		
The machine is appropriate to use.	3.96 ± 0.74	Good
The machine is appropriate to move.	3.75 ± 0.75	Good
The machine is effective for improving lower limb strength.	4.32 ± 0.77	Good
Average	**4.01 ± 0.78**	**Good**
In terms of usefulness		
The machine is useful to facilitate the exercise of children with spastic cerebral palsy.	4.21 ± 0.69	Good
The machine facilitates the rehabilitation of children with spastic cerebral palsy.	4.25 ± 0.70	Good
The machine is practical.	4.25 ± 0.84	Good
Average	**4.23 ± 0.74**	**Good**

Note: SD = standard deviation

Table 4 Analysis of satisfaction of physical therapists concerning the prototype of an exercise machine among respondents with 11–20 years of work experience (n = 2)

Satisfaction assessment topics	Mean ± SD	Satisfaction level
Design and structure		
5.00 ± 0.00	5.00 ± 0.00	Very Good
4.50 ± 0.71	4.50 ± 0.71	Good
Average	**4.75 ± 0.50**	**Very Good**
In terms of safety		
5.00 ± 0.00	5.00 ± 0.00	Good
4.50 ± 0.71	4.50 ± 0.71	Good
Average	**4.75 ± 0.50**	**Very Good**
In terms of usability		
The machine is appropriate to use.	4.50 ± 0.71	Good
The machine is appropriate to move.	5.00 ± 0.00	Very Good
5.00 ± 0.00	5.00 ± 0.00	Very Good
Average	**4.83 ± 0.41**	**Very Good**
In terms of usefulness		
The machine is useful to facilitate the exercise of children with spastic cerebral palsy.	5.00 ± 0.00	Very Good
The machine facilitates the rehabilitation of children with spastic cerebral palsy.	5.00 ± 0.00	Very Good
The machine is practical.	5.00 ± 0.00	Very Good
Average	**5.00 ± 0.00**	**Very Good**

Note: SD = standard deviation

4.4 Additional Opinions from Open-ended Questions

Additional opinions provided by the physical therapists regarding the prototype highlighted several concerns and suggestions. In terms of safety, two participants noted that the machine is relatively tall, which may pose risks for children with cerebral palsy (n = 2). Regarding size and portability, two participants commented that the device is large and may be difficult to move (n = 2). With respect to functional adjustments, one participant suggested that the angle adjustment mechanism should be rotatable for emergency use in case of a control malfunction (n = 1), whereas another recommended that the foot positioning angle should be adjustable (n = 1). Additionally, one participant proposed the inclusion of a knee support pad to prevent hyperextension during exercise (n = 1).

5. Discussion

The present study examined the opinions and satisfaction of physical therapists regarding a prototype exercise machine designed to improve lower limb strength in children with spastic cerebral palsy. Overall satisfaction scores across the design and structure, safety, usability, and usefulness domains were consistently rated as good. However, it is important to interpret these findings beyond mean scores. The standard deviations (range: 0.57–0.79) suggest notable variability in responses, indicating that while the majority of therapists expressed positive views, a minority held more cautious or divergent opinions. For example, although usability received a mean score of 4.07, the higher variability in this domain (SD = 0.79) implies that some therapists perceived difficulties in handling or transporting the device. Such variations underscore the necessity of iterative refinements to address differing user experiences.

In addition to quantitative ratings, open-ended responses provided further insights into the perceptions of physical therapists. Concerns were raised about the overall height of the prototype, which may compromise safety for children with cerebral palsy, as well as its large size and limited portability, which could hinder use in smaller clinical settings. Suggestions included adding a rotatable emergency adjustment mechanism in case of a control malfunction, making the foot positioning angle adjustable, and incorporating a knee support pad to prevent hyperextension during exercise. These issues mirror practical challenges frequently reported in prior evaluations of pediatric rehabilitation devices, particularly regarding safety and portability (Money et al., 2011; Woudstra et al., 2023). The alignment of these qualitative comments with recurring themes in previous literature highlights both the strengths of the

prototype in terms of safety and structure, as well as areas requiring design refinements for clinical feasibility.

Our findings of high satisfaction among physical therapists, particularly regarding safety and structural design, are consistent with previous reports on pediatric rehabilitation technologies. Chrif et al. (2022) observed positive usability perceptions of a training robot for interactive leg press exercises among both patients and therapists. Whereas our respondents emphasized practical concerns such as device height, portability, and emergency adjustments, their study highlighted challenges related to seat access, calibration, and motivational engagement through exergames. Collectively, these findings highlight the need for iterative design refinement that addresses both clinical usability and patient engagement. Similarly, our findings parallel those of Raigoso et al. (2021), who reported overall positive perceptions of robotic integration
in gait rehabilitation. However, their study revealed differences between clinicians and patients, particularly regarding entertainment and performance expectations, whereas our study primarily emphasized therapists' practical concerns, including ergonomic and safety-related features. This contrast suggests that although new rehabilitation technologies are broadly acceptable, their long-term success requires balancing therapist-centered usability with patient-centered motivational factors. Our results also align with Cumplido-Trasmonte et al. (2024), who demonstrated that the ATLAS 2030 pediatric robotic exoskeleton was safe and generally well accepted in clinical practice. In comparison, our respondents stressed ergonomic concerns such as device height and portability, while their study emphasized operational barriers including donning and doffing procedures, fitting challenges for younger children, and increased therapist workload. These complementary findings highlight that the broader adoption of pediatric rehabilitation devices depends not only on safety and structural design but also on minimizing workflow barriers to optimize clinical integration. Taken together, these studies support the view that although safety and usability are fundamental prerequisites for acceptance among therapists, clinical translation requires a dual focus that ensures ergonomic feasibility for clinical practice and fosters engaging, motivational experiences for patients.

The findings align with prior studies that emphasize the benefits of closed kinetic chain (CKC) exercises in enhancing lower limb strength and functional mobility in children with cerebral palsy (Baruah et al., 2016; Lee et al., 2014). The ability of the prototype to enable resisted flexion and extension of the hip and knee joints under weight-bearing condition highlights its conceptual similarity to previously studied sliding rehabilitation machines (SRM). Nevertheless, unlike conventional SRMs, which often require external weights or lack adjustable inclination, this prototype integrates an automated angle adjustment system and safety features. Such design innovations may explain the high ratings for safety and structure in this study. Finally, compared with user satisfaction studies of similar rehabilitation devices, the positive perception of safety and structural stability reported here is consistent with previous findings, while concerns regarding size and portability mirror common challenges identified in prior device trials (Money et al., 2011; Woudstra et al., 2023). This pattern suggests that although safety and functionality represent clear strengths, practicality in terms of portability and clinical deployment remains an important area for future development.

On the basis of these insights, four complementary pathways for clinical adoption are proposed. The prototype may be integrated into pediatric rehabilitation as an objective platform to assess lower-limb strength before and after structured exercise or therapy blocks, using standardized, repeatable protocols appropriate for children with spastic cerebral palsy (GMFCS levels I–III). Its sensor-guided, adjustable resistance enables longitudinal monitoring of training progression, including changes in prescribed intensity, session volume, and tolerance, allowing therapists to document and titrate programs over time. The provision of progressive, closed kinetic chain strengthening under partial support allows the device to function as an efficiency-enhancing exercise aid that facilitates individualized dosing and may broaden access to appropriately prescribed lower-limb exercise. In addition, the adjustable inclination and supportive features permit standing practice and graded weight-bearing to stimulate lower-limb muscle activation. Sessions can be supervised for safety by physical therapists or trained personnel without the need for continuous manual assistance. Collectively, these use cases align with the device's design intent and observed acceptability and outline a practical pathway for early clinical deployment.

Another consideration is the suitability of the device for children with varying levels of cerebral palsy severity. The prototype was primarily designed

for children with mild to moderate impairments (GMFCS levels I–III). Future research should explicitly evaluate which subgroups derive the most benefit, as children with severe motor impairments may require additional modifications or supportive components. In addition, the potential cost-effectiveness of the prototype warrants discussion. The estimated production cost of the current prototype is approximately 100,000 THB, which is substantially lower than the market price of standard electrical tilt tables used for standing training (200,000–250,000 THB). Importantly, although tilt tables primarily facilitate standing, they do not allow for active strengthening of the lower limbs, which is a key feature of the present prototype. This suggests that the device not only provides added functional benefits but also represents a more economical option. With further refinement and scaled production, the unit cost could be reduced even further, thereby enhancing accessibility for rehabilitation centers and potentially for home-based use. If the machine can also reduce therapist workload and standardize resistance training, it may generate both clinical and long-term economic advantages. Therefore, incorporating economic evaluation into future research will be critical to confirm the prototype's value relative to existing rehabilitation technologies. Future research should incorporate formal cost-effectiveness analyses as a foundational element of new device development. By systematically relating capital and maintenance expenditures, implementation resources, and therapist time to clinically meaningful outcomes such as functional gains and health-related quality of life, these analyses will quantify the prototype's long-term value and reduce decision uncertainty for stakeholders. The resulting evidence is essential for optimizing design, prioritizing resource allocation, planning scale-up and manufacturing, and supporting procurement and reimbursement decisions. Consistent with this rationale, evidence from previous evaluations of rehabilitation devices, such as robotic gait trainers (Klobucká et al., 2023) and a novel stander that enables dynamic standing through walking movements in children with CP (Lauruschkus et al., 2022), has demonstrated that while these technologies may involve higher upfront costs, their ability to reduce therapist workload and improve functional outcomes can influence their overall economic value.

This study has several limitations. First, satisfaction was assessed using videos and manuals rather than hands-on clinical trials, which may introduce bias into participants' evaluations. Future studies should therefore incorporate direct clinical trials with actual device use to capture more accurate and ecologically valid feedback. Second, response bias cannot be ruled out, as physical therapists may have provided socially desirable responses given their role as expert evaluators. To minimize this limitation, future work could include anonymous surveys or triangulate therapist feedback with patient and caregiver perspectives. Third, all participants were recruited from a single geographical region, potentially limiting the generalizability of the findings. Expanding recruitment across multiple regions and diverse clinical settings would improve external validity. Fourth, the subgroup of therapists with more than 10 years of experience included only two respondents (n = 2), which limits the ability to draw firm conclusions for this group. Although the satisfaction scores within this subgroup were relatively high, the small number of participants precludes any definitive interpretation of these results. This represents a methodological limitation, as no predetermined minimum sample size was established for each subgroup to ensure the validity of conclusions (Table 4). Future studies should include a greater number of experienced therapists to enable more meaningful subgroup comparisons and improve the robustness of statistical analyses. Fifth, the relatively small sample size further constrains the strength of the conclusions and limits the ability to conduct subgroup analyses with adequate statistical power. Larger-scale studies with sufficient sample sizes are needed to confirm these preliminary findings. Finally, the study did not assess whether participants had prior experience with similar technologies, which could have influenced their perceptions of usability. Future research should account for prior exposure to rehabilitation technologies to better understand its influence on user satisfaction and acceptance.

Future work should be strategically divided into short- and long-term goals. In the short term, prototype modifications should address identified concerns, such as machine size, portability, and emergency adjustment mechanisms, followed by usability testing with therapists and typically developing children. In the long term, rigorous clinical trials, including randomized controlled trials (RCTs), should be conducted to establish the efficacy and safety of the machine in children with cerebral palsy. Furthermore, regulatory approval processes and cost-effectiveness analyses will be critical for eventual implementation in rehabilitation centers. By following this roadmap, the device can

evolve from a promising prototype into a clinically validated and widely applicable rehabilitation tool.

6. Conclusion

The satisfaction of physical therapists with this machine was found to be at a satisfactory level. With further improvements and development, it holds the potential to become a valuable tool amid pediatric rehabilitation. Moreover, the development and production of future models should adhere to established medical equipment manufacturing standards, taking into account factors such as production costs and practical usability. Furthermore, training programs for users should be developed to enhance accessibility and optimize the utilization of the technology by both individuals with disabilities and physical therapists. Future research should also include both short - and long-term studies involving typically developing children as well as children with CP.

7. Abbreviations

Abbreviation	Full Term
1RM	One-Repetition Maximum
CKC	Closed Kinetic Chain
CP	Cerebral Palsy
DC	Direct Current
GMFCS	Gross Motor Function Classification System
IOC	Index of Item–Objective Congruence
LCD	Liquid Crystal Display
MVC	Maximal Voluntary Isometric Contraction
NRCT	National Research Council of Thailand
RCTs	Randomized Controlled Trials
SD	Standard Deviation
SPSS	Statistical Package for the Social Sciences
SRM	Sliding Rehabilitation Machine
STS	Sit-to-Stand
THB	Thai Baht

8. CRediT Statement

Ratchadaporn Borkam: Conceptualization, Methodology, Investigation, Data Curation, Formal Analysis, Visualization, Writing – Original Draft, Funding Acquisition.
Wanida Donpunha: Methodology, Supervision, Project Administration, Writing – Review & Editing.
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