Development and pilot testing of a mobile application for home-based exercise in children with cerebral palsy: A pilot pre-post study

การพัฒนาและการทดสอบนำร่องโมบายแอปพลิเคชันเพื่อการออกกำลังกายที่บ้านสำหรับเด็กที่มีภาวะสมองพิการ: การศึกษาแบบนำร่องก่อนและหลังการทดลอง

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ABSTRACT

Introduction: Cerebral palsy (CP) is a permanent neurological disorder characterized by motor impairments and secondary complications such as joint contractures. Physical therapy and regular home-based exercise are essential for improving functional outcomes. Mobile applications are increasingly utilized to support these interventions by offering accessible platforms for health information and facilitating independent practice.

Objective: This study aimed to develop a mobile application for home-based exercises and to conduct a preliminary evaluation of its feasibility and potential utility by comparing pre- and post-intervention Gross Motor Function Measure-66 (GMFM-66) scores in children with cerebral palsy.

Methods: A non-randomized quasi-experimental pre–post pilot study design was employed. Eleven children with cerebral palsy (Gross Motor Function Classification System; GMFCS levels I–V; aged 2–15 years) participated. Children and their caregivers received the Nooja mobile application and were instructed to complete the prescribed exercises daily for a continuous period of one month. The primary outcome, motor function, was assessed using GMFM-66.

Results: A paired sample t-test indicated a statistically significant increase in GMFM-66 scores after the intervention ($p=0.015$), with a mean increase of 2.34 points.

Conclusion: Mean GMFM-66 scores increased after one month of mobile application use, suggesting preliminary feasibility and potential utility as a supportive tool for gross motor practice in children with cerebral palsy. Larger randomized controlled trials are necessary to confirm effectiveness and inform future rehabilitation strategies. The findings should be interpreted with caution due to the pilot pre–post study design.

Keywords: cerebral palsy, mobile application, gross motor function, home exercise

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บทคัดย่อ

ที่มาและความสำคัญ: ภาวะสมองพิการเป็นความผิดปกติของระบบประสาทที่ไม่สามารถรักษาให้หายขาดได้ ส่งผลให้ผู้ป่วยมีความบกพร่องด้านการเคลื่อนไหวและมีความเสี่ยงต่อการเกิดภาวะแทรกซ้อนทางระบบกระดูกและกล้ามเนื้อ เช่น ภาวะข้อต่อยึดติด การดูแลรักษาด้วยกายภาพบำบัดร่วมกับการฝึกออกกำลังกายที่บ้านอย่างต่อเนื่องจึงมีบทบาทสำคัญในการส่งเสริมความสามารถในการทำหน้าที่ของร่างกาย ในปัจจุบัน การประยุกต์ใช้แอปพลิเคชันบนอุปกรณ์เคลื่อนที่ได้รับความสนใจเพิ่มมากขึ้นในฐานะเครื่องมือสนับสนุนการรักษา โดยช่วยอำนวยความสะดวกในการให้ข้อมูลด้านสุขภาพและส่งเสริมการฝึกออกกำลังกายด้วยตนเองอย่างสม่ำเสมอ

วัตถุประสงค์: เพื่อพัฒนาโมบายแอปพลิเคชันสำหรับการฝึกที่บ้าน และประเมินความเป็นไปได้เบื้องต้นและศักยภาพในการนำไปใช้ โดยเปรียบเทียบคะแนนความสามารถด้านการเคลื่อนไหวด้วยแบบประเมิน Gross Motor Function Measure-66 (GMFM-66) ก่อนและหลังการฝึกในเด็กที่มีภาวะสมองพิการ

วิธีการวิจัย: การศึกษานี้ใช้รูปแบบการวิจัยนำร่องเชิงกึ่งทดลอง แบบกลุ่มเดียววัดผลก่อนและหลังการทดลอง โดยไม่มีการสุ่มตัวอย่าง อาสาสมัครเป็นเด็กที่มีภาวะสมองพิการ อายุระหว่าง 2-15 ปี จำนวน 11 คน มีระดับ Gross Motor Function Classification System (GMFCS) ระดับ 1-5 อาสาสมัครเด็กและผู้ปกครองจะได้รับโมบายแอปพลิเคชันชื่อหนูจ๋า และให้ฝึกปฏิบัติตามเนื้อหาทุกวันอย่างต่อเนื่องเป็นระยะเวลา 1 เดือน ประเมินผลความสามารถด้านการเคลื่อนไหวด้วยแบบประเมิน GMFM-66

ผลการวิจัย: เมื่อใช้สถิติ Paired sample t test พบว่ามีความแตกต่างอย่างมีนัยสำคัญทางสถิติก่อนและหลังการทดลอง (P=0.015) โดยมีค่าคะแนน GMFM-66 เฉลี่ย หลังจบการทดลอง เพิ่มขึ้น 2.34 คะแนน

สรุปผล: คะแนน GMFM-66 เฉลี่ยมีแนวโน้มเพิ่มขึ้นหลังการใช้โมบายแอปพลิเคชันเป็นระยะเวลา 1 เดือน สะท้อนถึงความเป็นไปได้ในการใช้งานและศักยภาพของแอปพลิเคชันเพื่อสนับสนุนการฝึกทักษะการเคลื่อนไหวของกล้ามเนื้อมัดใหญ่ในเด็กที่มีภาวะสมองพิการ ทั้งนี้ยังจำเป็นต้องมีการศึกษาวิจัยเพิ่มเติมในรูปแบบการทดลองแบบสุ่มและมีกลุ่มควบคุมในขนาดตัวอย่างที่ใหญ่ขึ้น เพื่อยืนยันประสิทธิผลและใช้เป็นแนวทางในการพัฒนาการฟื้นฟูในอนาคต ทั้งนี้ควรตีความผลด้วยความระมัดระวังเนื่องจากเป็นการศึกษาแบบนำร่องก่อนและหลังการทดลอง

คำสำคัญ: เด็กภาวะสมองพิการ, โมบายแอปพลิเคชัน, ความสามารถด้านการเคลื่อนไหว, การออกกำลังกายที่บ้าน

Introduction

Cerebral palsy (CP) refers to a group of permanent disorders that affect brain function in children, arising from disturbances during brain development in the prenatal, perinatal, or postnatal periods. While the underlying brain lesions are non-progressive, children with CP exhibit abnormal and delayed motor development, resulting in impairments in movement and posture. These impairments limit daily activities due to altered muscle tone, muscle weakness, impaired selective motor control, and abnormal joint function, which may lead to secondary complications such as joint contractures and skeletal deformities[1,2].

Physical therapy–based rehabilitation remains a primary approach in the conservative management of children with CP, aiming to improve gross motor function and functional mobility in daily life. Rehabilitation strategies typically focus on enhancing postural stability in functional positions such as sitting, standing, and walking, and underscore the importance of continued practice at

home. Consistent participation in home-based exercise programs has been shown to significantly improve motor outcomes in children with cerebral palsy (CP). For example, a two-month home exercise program employing a mirror neuron stimulation-based video significantly increased Gross Motor Function Measure-66 (GMFM-66) scores in children with CP aged 2 to 9 years[3].

Technological advancements have broadened access to health-related information and facilitated home-based self-care through mobile and digital health applications[4]. International research has increasingly examined the development and implementation of these tools across various patient populations. For example, ProFibro, a mobile application designed to provide patient care information and physical therapy content, has demonstrated improvements in daily living activities among individuals with fibromyalgia[5]. Similarly, the Cherry mobile application was developed for school-aged children and adolescents with cancer to improve their understanding of symptoms, treatment options, and support needs. Key features include symptom monitoring, appointment scheduling, and access to educational materials[6].

In pediatric rehabilitation, the use of mobile and digital health applications to support children with CP has grown over the past decade. Mobile applications focused on daily living activities have significantly improved parental knowledge about caring for children with CP[7]. Recent digital interventions have focused on motor-related outcomes. For example, the web-based multimodal training program 'Move it to improve it' (Mitii™) has significantly improved occupational performance and functional outcomes in children with unilateral cerebral palsy[8]. More recently, a structured telerehabilitation-based home program was reported to significantly improve GMFM-66 scores in children with CP[9]. However, a systematic review highlighted that although numerous CP-related mobile applications exist, the overall methodological quality and evidence of clinical effectiveness remain limited, particularly for structured gross motor training in home-based contexts[10].

In Thailand, the development and widespread adoption of mobile applications to support physical exercise and motor training for children with CP remain limited. Barriers to ongoing physical therapy services include workforce shortages, travel distances, and caregiver time constraints, which frequently impede structured and consistent home-based training. While mobile applications in Thailand have primarily been developed to support communication abilities, such as AAC-based tools that enhance usability and user satisfaction among children with CP who have communication difficulties[11], few interventions have specifically targeted structured gross motor training or individualized home-based physical exercise programs aimed at supporting motor rehabilitation in children with cerebral palsy.

These gaps highlight the need for a mobile application that delivers structured and accessible home-based exercise content to promote active motor practice in children with CP. Accordingly, the present study aimed to develop a home-based exercise mobile application guided by a

conceptual framework informed by motor learning principles and a caregiver-supported practice approach. The application presents exercise content in text and animation, allowing caregivers to select appropriate exercises and adjust the difficulty level for each child during home practice. This study aimed to evaluate the preliminary feasibility and potential effects of a mobile application on the gross motor function of children with cerebral palsy. The hypothesis was that GMFM-66[12,13] scores would improve following participation in the mobile application.

Methods

Study design

The Thammasat University Human Research Ethics Committee, Cluster 3 (Science), approved this research (approval number 076/2562). The study adhered to the Declaration of Helsinki. All participants and their legal guardians received information regarding the study's objectives and procedures, and written informed consent was obtained before participation. The research was conducted in two phases from 2020 to 2022 during the COVID-19 pandemic.

Phase 1 (Mobile application development):

The first phase involved the creation and development of the Nooja mobile application. (Figure 1). The primary objective of this application is to deliver evidence-based physical therapy knowledge to support children with cerebral palsy aged 2 to 15 years at Gross Motor Function Classification System (GMFCS) levels I through V[14-16]. The application features sitting exercises, self-care routines for daily activities, recommended best practices, and relevant precautions.



Figure 1 The Nooja mobile application icon

The initial stage consisted of drafting the content and defining the objectives of the mobile application. Subsequently, a comprehensive literature review was conducted to gather information on children with cerebral palsy, optimal sitting posture, and exercises designed to improve sitting balance. Additional content addressed stretching exercises, parachute reaction training to reduce fall risk, and the use of age-appropriate toys to facilitate skill development in a seated position[17-19].

An initial content outline was developed based on established physical therapy principles and reviewed by four expert physical therapists, each with over five years of experience in pediatric cerebral palsy rehabilitation, utilizing a qualitative expert review process. Content validity was ensured through expert consultation rather than quantitative measures. The content was revised in accordance with expert recommendations before collaborating with a professional mobile application development team, resulting in a prototype version of the mobile application. The prototype was subsequently evaluated by the experts, as well as by children with cerebral palsy and their parents, to gather additional feedback for further refinement. At the time of the study, the mobile application was

fully functional and available on the Android operating system.

Phase 2 (Pilot study / Feasibility evaluation):

Following completion of phase 1, a non-randomized, quasi-experimental pre–post pilot design was conducted to evaluate the feasibility and preliminary outcomes of the mobile application. This phase utilized a quasi-experimental design to assess the prototype mobile application in 11 children with cerebral palsy, a sample size deemed suitable for pilot studies[20]. Gross motor function was measured at baseline and after a one-month intervention using GMFM-66, which is composed of items scored on a 4-point ordinal scale; higher scores reflect better performance. Total scores were calculated using the Gross Motor Ability Estimator (GMAE) software[12,13]. The study was single-blind and conducted in a laboratory environment. All study personnel were members of the research team and were familiar with the procedures. A pediatric physical therapist provided mobile application instructions to parents or caregivers and conducted the baseline GMFM-66 assessment. The same researcher monitored participant compliance and documented co-interventions during the intervention period. To maintain objectivity, a different pediatric physical therapist, who was not involved in intervention delivery and was blinded to baseline GMFM-66 scores, performed the post-intervention GMFM-66 assessments. The GMFCS and GMFM-66 assessments were administered by separate assessors. The reliability of the five assessors was established prior to the study through video-based evaluations of ten children not included in the study sample, demonstrating excellent inter-rater and intra-rater reliability, with intraclass correlation coefficient (ICC) values ranging from 0.97 to 1.00.

Participants

Eligible participants were children with cerebral palsy aged 2–15 years and classified as GMFCS levels I–V, a five-level system describing gross motor function and mobility, where higher levels indicate greater functional limitations[14-16]. Participants were required to be able to understand and communicate with the researcher. Exclusion criteria included recent botulinum toxin injections or surgery within the past six months, severe uncontrolled seizures, significant medical complications precluding participation, or severe visual, auditory, or musculoskeletal abnormalities. Recruitment was conducted at the Physical and Hydrotherapy Unit, Faculty of Allied Health Sciences, Thammasat University, and Thammasat University Hospital.

Procedures

After eligibility screening, the researcher explained the study to children and their parents and obtained informed consent. Participants received the Nooja mobile application and were instructed to practice daily for one month. Sessions were to take place in a comfortable setting chosen by participants to reduce stress and support a natural environment. All participants accessed identical standardized educational content through the mobile application. The program did not adhere to a fixed exercise routine; rather, exercises were selected flexibly to accommodate each child's

physical abilities and functional objectives. Parents or caregivers were encouraged to select the most suitable activities for their child's specific needs, with guidance from a physical therapist.

Interventions

Participants were instructed to use the mobile application daily over a one-month period. A day of application use was defined as the completion of at least one training session. Each session comprised multiple sitting-based exercises targeting trunk control and postural stability, with repetitions adjusted based on the child's tolerance and cooperation. Progression was implemented by incrementally increasing task difficulty, such as extending postural holding duration, incorporating trunk movements, or decreasing external support. The mobile application was intended for use with family assistance and encouragement, facilitating individualized practice within a home-based training context. Each home-based exercise session lasted 45 to 60 minutes and followed a structured protocol delivered through the mobile application. Sessions included a 10 to 15-minute warm-up with therapeutic stretching, 25 to 35 minutes of core functional training focused on sitting balance and trunk control, and a 5 to 10-minute cool-down. Training was individualized, with caregivers selecting 3 to 5 exercises from the application's 20-item library to match each child's motor ability and GMFCS level. Detailed components of the mobile application intervention are presented in Table 1.

Table 1 Functional features of the Nooja Mobile Application

Component	Description
Main Modules	A sitting-based rehabilitation program including (1) therapeutic stretching, (2) muscle strengthening, and (3) functional balance training
Training focus	**Upper/Lower Limbs & Trunk:** Stretching of major muscle groups. **Core Stability:** Strengthening of trunk muscles, hip extensors, and knee extensors. **Function:** Sitting balance and postural control.
Educational content	CP-related education: Clinical overview, ergonomic sitting postures (Correct vs. Inappropriate), and ADL integration strategies.
Exercise Library	Total of 20 categorized exercises (Animated visuals with synchronized text descriptions).
Prescription & Dosage	**Frequency:** Minimum once daily (Based on child's tolerance). **Duration:** 45–60 minutes per session.
Individualization	**Adaptive Programming:** Exercises are selected based on the child's physical functional level (aligned with GMFCS) and individual rehabilitation goals, guided by caregivers.
Safety Guidelines	**Supervised Training:** Mandatory caregiver supervision. **Red Flags:** Immediate discontinuation if pain, excessive fatigue, or postural instability occurs.

Outcome measures

Gross motor function will be assessed with the GMFM-66 at baseline and after the intervention. A logbook was provided to record practice frequency and any additional treatments. Data were collected using a Google Form and supplemented by weekly phone calls to parents throughout the month. Cooperation was evaluated using a caregiver-reported 5-point ordinal scale for each training session, with scores ranging from 1 (very low cooperation) to 5 (very high cooperation), reflecting the child's willingness to participate and follow instructions. The mean cooperation score for each participant was calculated by averaging scores across all completed sessions.

Data analysis

For data collection and statistical analysis, the Shapiro-Wilk test was applied to assess data normality, confirming a normal distribution. Descriptive statistics were used to present participant demographic data. Mean GMFM-66 scores before and after mobile application use were compared using a paired sample t-test. The significance level was 0.05. All analyses were performed using IBM SPSS Statistics for Windows, Version 25.0 (IBM Corp., Armonk, NY, USA).

Results

During the initial phase of mobile application development, expert feedback from four reviewers informed several content refinements. Language was simplified to enhance accessibility and appropriateness for participants' age and ability levels. Nonessential content, including information on orthotic devices, was removed to better align with study objectives. Images were revised to correspond more closely with the accompanying text, and instructions for caregiver or parent positioning during exercises were incorporated to improve participant safety. The Nooja mobile application did not feature an automated usage logging system; therefore, adherence and application usage were monitored through self-reported methods. Parents or caregivers recorded application use in a logbook, and usage data were collected via Google Forms. This approach was chosen to support feasibility in a pilot study and to minimize technological burden on families. Eleven children with cerebral palsy participated in and completed the study, with no dropouts or missing data.

Table 1 presents components of the mobile application, including exercise modules, instructional formats, and safety protocols implemented in the study. Table 2 summarizes participant characteristics; five participants (45.45%) received concurrent physical therapy or other treatments during the study period. The median number of concurrent treatment sessions over the 1-month study period was 0 (Q1–Q3: 0–4). Table 3 presents individual and group-level changes in GMFM-66 scores, effect size, and participant acceptability following the one-month mobile application intervention. A statistically significant improvement in GMFM-66 scores was observed, with a mean change of 2.34 ± 2.67 points (from 44.84 ± 15.99 to 47.19 ± 17.17; $p = 0.015$), with a large effect size (Cohen's $d = 0.88$). Participant acceptability was moderate, as indicated by a mean cooperation score of 3.03 and consistent application use (mean 15.64 days and 18.27 hours) during the intervention period. Table 4

details changes in GMFM-66 scores stratified by GMFCS level, with greater mean improvements observed in participants classified as GMFCS level III compared to other functional levels. During the study period, some participants received a range of concurrent interventions, including conventional pediatric physical therapy, caregiver-assisted home exercises, and adjunctive therapies such as thermal or electrical stimulation.

Table 2 Demographic and clinical characteristics of the study participants (n = 11)

Characteristic	Value
1. Age (years), mean ± SD	11.82 ± 6.37
2. Gender (n, %)	
Male	4 (36.36 %)
Female	7 (63.64 %)
3. Type of Cerebral Palsy (n, %)	
Hypotonia	2 (18.18 %)
Monoplegia	1 (9.09 %)
Diplegia	3 (27.27 %)
Quadriplegia	3 (27.27 %)
Athetoid	1 (9.09 %)
Ataxia	1 (9.09%)
4. GMFCS level (n, %)	
Level I	1 (9.09 %)
Level II	0 (0 %)
Level III	4 (36.36 %)
Level IV	5 (45.45 %)
Level V	1 (9.09 %)
5. Number of participants who received physical therapy or other concurrent treatments from external healthcare facilities during the 1-month study period, n (%)	5 (45.45 %)
6. Number of concurrent treatment sessions from external facilities during the 1-month study period, median (Q1–Q3)	0 (0-4)

Note: GMFCS = Gross Motor Function Classification System.

Table 3 Comparison of pre- and post-intervention GMFM-66 scores, effect sizes, and participant acceptability of the mobile application

Participant ID	GMFCS level	GMFM-66 (score)		Change (Δ) (score)	Days of application usage (days/month)	Total application usage time (hours/month)	Cooperation score (0-5)
		Baseline (score)	After intervention (score)				
1	5	24.01	24.01	0.00	12	12	2.6
2	3	60.09	65.33	+5.24	12	13	4.5
3	1	70.04	72.16	+2.12	17	17	3
4	4	35.67	35.67	0.00	24	44	3.25
5	4	44.38	46.32	+1.94	22	22	2
6	4	45.91	46.09	+0.18	24	24	3
7	4	21.25	25.31	+4.06	19	19	3
8	3	52.85	56.15	+3.30	12	12	3
9	3	55.39	63.63	+8.24	4	4	2
10	4	27.31	27.31	0.00	13	13	4
11	3	56.39	57.09	+0.70	13	21	3
Mean (SD)		44.84 (15.99)	47.19 (17.17)	2.34 (2.67)	15.64 (6.56)	18.27 (10.28)	3.03 (0.74)
95% CI				(0.55 - 4.13)			
t-test (df)				t(10)=2.92			
p-value				0.015*			
Effect size (Cohen's d)				d=0.88			

Note: GMFCS = Gross Motor Function Classification System; GMFM-66 = Gross Motor Function Measure-66.

* Significant difference (p<0.05) between baseline and after intervention using paired t-test

Table 4 Changes in GMFM-66 scores following mobile application intervention by GMFCS Level

GMFCS level (n)	Baseline GMFM-66 (Mean ± SD)	Post-intervention GMFM-66 (Mean ± SD)	Mean change (Range)
I-II (1)	70.04	72.16	2.12 (2.12 - 2.12)
III (4)	56.18 ± 3.00	60.55 ± 4.61	4.37 (0.70 – 8.24)
IV-V (6)	33.08 ± 10.53	34.11 ± 10.20	1.03 (0.00 – 4.06)
Overall (11)	44.84 ± 15.99	47.19 ± 17.17	2.34 (0.00 – 8.24)

Discussion

The observed improvement in GMFM-66 scores in this study is likely attributable to increased opportunities for motor practice enabled by mobile application within the home environment. The application facilitated repeated practice and sustained engagement with motor activities, which may foster motor learning and functional improvement. These findings are consistent with prior research that has shown significant improvements in activity performance and satisfaction after an eight-week home-based exercise program delivered through the Physitrack mobile health application for children with cerebral palsy and other neurodevelopmental disabilities[21].

The short-term improvement in GMFM-66 scores observed in this pilot study is more likely due to motor learning processes and experience-dependent neural adaptation than to structural muscular changes. Repeated motor practice may facilitate motor improvement through experience-dependent neural plasticity mechanisms[22]. Increased frequency and consistency of home-based practice, supported by caregiver involvement, may further facilitate functional gains. This finding aligns with previous evidence highlighting the effectiveness of goal-directed home programs for children with cerebral palsy[23].

These findings are consistent with previous telerehabilitation studies, which reported significant improvements in GMFM-66 scores following caregiver-assisted home-based telerehabilitation during the COVID-19 lockdown, particularly for children classified as GMFCS levels I and II[24]. In the present study, increases in GMFM-66 scores were also associated with home-based training supported by the mobile application. Concurrent therapies received by some participants may have contributed to these improvements. Furthermore, greater improvements were correlated with higher training frequency, increased total practice time, and greater participant cooperation, as recorded by parents.

The feasibility and preliminary outcomes of mobile-based home exercise program are determined by training intensity, caregiver involvement, and participant cooperation. More than 90% of participants in this study completed

over 1.5 hours of home exercise per week, and increased training duration was associated with positive changes in GMFM-66 scores. These findings align with previous research highlighting that parental education and active caregiver involvement are crucial for the successful implementation of home programs[25]. Additionally, the data show that participant cooperation is a significant factor, as moderate to high engagement levels correlated with enhanced motor outcomes, supporting previous conclusions regarding the impact of a child's interest on intervention effectiveness. Importantly, individual variability, such as the progress observed in a participant with GMFCS level III despite limited practice, suggests that unreported concurrent therapies may have contributed to the outcomes[26].

GMFM-66 scores were calculated using the Gross Motor Ability Estimator (GMAE), which provides only overall total scores. As a result, formal statistical analysis of individual sub-components or specific dimensions was not possible. However, descriptive clinical observations suggest that overall improvements were mainly due to gains in sitting-related abilities. Qualitative improvements were noted in trunk control and sitting balance, including unsupported sitting, reaching for objects while seated, and trunk rotation. These non-statistical observations are consistent with the training program's focus, while higher-level locomotor items showed less improvement. Descriptive gains were more apparent in participants at GMFCS levels I–III than in those at levels IV–V. Because these sub-component observations are descriptive and lack independent statistical validation, they should be interpreted with caution and considered preliminary until confirmed by dimension-specific analyses in future studies.

While the post-intervention increase in GMFM-66 scores was statistically significant, these results must be interpreted in the context of established clinical benchmarks. The Minimal Clinically Important Difference (MCID) for the GMFM-66 in ambulatory children with cerebral palsy ranges from 3.5 to 5.4 points[27]. The observed mean increase of 2.34 points falls below this threshold. Given the pilot nature of this study and the small sample size of 11 participants, the observed mean change may not fully reflect the intervention's potential. An improvement of 2 to 3 points over one month should be viewed with caution. The effects of the mobile application cannot be separated from confounding factors such as natural development, age-related maturation, and concurrent physical therapy, which nearly half of the participants received. Information on the content and intensity of these therapies was limited. The small sample size, participant heterogeneity, and pilot design also limited the ability to conduct detailed sensitivity or subgroup analyses. Therefore, definitive causality cannot be attributed solely to the mobile application.

The mobile application is most appropriate for children classified at Gross Motor Function Classification System (GMFCS) levels I to III, as these individuals typically possess the voluntary motor control required for home-based motor practice. For children at GMFCS levels IV and V, the application is more effective as a

supportive tool when used with caregiver assistance, rather than as an independent intervention. This approach aligns with existing evidence indicating that children with severe motor impairments generally achieve more limited functional gains compared to those at higher functional levels[28]. Training exposure and cooperation in this study relied on parent-reported records, which may introduce recall or reporting bias. While greater training exposure and higher cooperation appeared linked to improved GMFM-66 scores, the small sample size and pilot design limited further analysis.

To address these limitations, future research should use randomized controlled trials with larger, more homogeneous samples across all GMFCS levels. It is recommended to incorporate automated usage tracking in the application and to standardize monitoring of co-interventions, specifying the type, frequency, and intensity of concurrent therapies. This will help isolate the therapeutic impact of the mobile application. The application is designed to supplement, not replace, standard physical therapy, especially for home-based practice. Initial guidance from a physical therapist is essential for appropriate task selection, patient safety, and long-term adherence.

Conclusion

A mobile application was developed to support home-based exercise for children with cerebral palsy, and its feasibility and preliminary outcomes were evaluated. After one month, statistically significant improvements in GMFM-66 scores were observed. However, as this was a pilot study, these results should be interpreted with caution. When used alongside standard physical therapy, the application shows strong feasibility and acceptability for home-based motor practice, especially in children with mild to moderate motor impairments. Due to the small sample size and varied concurrent interventions, definitive causality cannot be attributed solely to the application. Larger randomized trials are needed to confirm its independent therapeutic efficacy.

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