# Robotic-Assisted Gait Training in Improving Gait Ability in Patients with Cerebral Palsy: A Literature Review.

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***Abstract :*** Cerebral palsy is a complex disorder at the level of the central nervous system. Cerebral Palsy generally has symptoms that affect motor activity that has an impact on functional ability, especially in walking disorders. Cerebral palsy has disorders that are classified based on the location of the affected limb,namely monoplegia,hemiplegia, diplegia, and quadriplegia. One method of intervention that adapts to modern technology is the provision of RAGT (Roboric-Assisted Gait Training). Where robotic-based exercises as aids can improve the ability of motor function and walking ability of children with Cerebral Palsy. The purpose of this study was to determine the effectiveness of RAGT on these aspects in children with Cerebral Palsy.This study is a literature review study in the form of narrative, where six articles were found to be reviewed after research and selection on nine databases. The results of the review found that 153 children with a diagnosis of Cerebral Palsy aged 0-20 years with GMFM I-V were given RAGT intervention with Sessions 3-5 times per week, duration 20-30 minutes per session. After the intervention was given for 12 weeks and reevaluated after 3 months, the evaluation data analysis found a development in the ability of motor function, and the ability to walk. Based on the results of the review, it can be concluded that the provision of RAGT intervention provides neurological and physiological effects that are appropriate for the condition of children with CP, so that the provision of RAGT can be used as one of the intervention options to improve the ability of motor function and walking ability of children with Cerebral Palsy

***Keywords:*** Cerebral Palsy, RAGT (Robotic-Assisted Gait Training), GMFM, motor functionability, walking ability.

## 1. Introduction

Basically, humans will go through a growth and development phase. The growth and development phase is highly important for every individual. However, growth and development can lead to impairments, and one of the impairments that hinders the growth and development process is Cerebral Palsy. Cerebral Palsy (CP) is a neurological disorder that affects movement and coordination. According to the World Health Organization (WHO), Cerebral Palsy is a complex disorder at the central level of the nervous system. It is


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caused by irreversible brain lesions that occur during prenatal, natal, or postnatal periods [10]. Motor function impairment is the main issue in children with Cerebral Palsy [22].

Cerebral Palsy is a significant disorder that occurs frequently in child development. The results of a study in 2022 showed that the global prevalence of Cerebral Palsy is 1.6 per 1000 live births [14]. Several other studies have reported that 8.1 million (7.1-9.2) or 1.2% of children under the age of 5 suffer from Cerebral Palsy [18]. In Indonesia, the prevalence of children with Cerebral Palsy is estimated to be around 1-5 per 1,000 live births, with a higher prevalence among males compared to females [13]. Children with Cerebral Palsy generally exhibit symptoms such as motor control impairments that affect their functional activities [9]. One of the functional activities that poses difficulty for children with CP is walking. The type of CP, gross motor patterns (basic movement patterns), and the age at which this is achieved greatly determine the prognosis of walking ability [2].

CP types based on motor impairments are classified into spastic, dyskinetic, hypotonic, and ataxic. Mixed types of CP are not uncommon. Spastic CP is the most prevalent type, accounting for 85-91% of cases [24]. Spastic CP is further divided into diplegia, hemiplegia, and quadriplegia based on the affected limbs [23]. 35% A child with CP is classified as having spastic diplegia [19]. Children with CP, specifically diplegia type, generally have a good prognosis regarding their walking ability and ambulation [19]. CP with hemiplegia has a good prognosis in terms of walking ability and a high level of functional ability. On the other hand, children with CP quadriplegia have a poor prognosis regarding walking ability due to several common complications such as cognitive deficits, epilepsy, visual impairments, and other related disorders[19]. To prevent the prognosis getting worse, early intervention is crucial, particularly in terms of motor function. One of the interventions provided is physiotherapy..

Early physiotherapy intervention becomes highly important to optimize neuroplasticity, prevent complications, improve functional abilities, enhance participation, and enhance the quality of life for the child [21]. The long-term goal for children with CP is to improve walking ability [17]. Several interventions are carried out by physiotherapy, such as treadmill walking exercises and weight-bearing exercises [8]. In addition to conventional interventions, there is currently robotic technology available that can adjust functional abilities, particularly in walking, known as *Robotic Assisted Gait Training* (RAGT).

*Robotic Assisted Gait-Training (RAGT)* is a robotic technology that serves to improves walking ability [11]. *Robotic Assisted Gait-Training (RAGT)* is one of the technology-based interventions that can be combined with conventional interventions. This technology can provide several benefits for patients, particularly in improving the patient's walking capacity. It offers motor learning principles such as intensity, repetition, task specificity, and participation, with the aim of inducing neuroplastic changes and non-motor improvements in patients with central nervous system disorders related to walking impairments [3].

The benefits of Robotic Assisted Gait Training (RAGT) include facilitating the achievement of desired intensity levels within a standardized walking training environment. It also enables more objective assessment of walking abilities in the rehabilitation of children with CP [7]. The numerous benefits of RAGT make it an optimal modality for intervention in children with CP, especially in addressing walking impairments.

Based on the background discussed above, the author will be discussing a Final Project entitled "Effectiveness of Robotic-Assisted Gait Training in Improving Gait Ability in Cerebral Palsy Patients: A Literature Review." The aim of this study is to determine the effectiveness and dosage of RAGT (Robotic-Assisted Gait Training) and compare its effectiveness with other interventions.

The author hopes that this article will provide knowledge and understanding regarding the effectiveness, dosage of RAGT (Robotic-Assisted Gait Training), and a comparison between RAGT intervention and other interventions.

## 2. Research Methods

The compilation of this article was conducted by the author through a literature review, gathering articles from the internet that are relevant to the topic being addressed. Evidence was sought from various online accessible databases. A literature search was performed to answer the research questions using search engines such as ClinicalKey, EBSChost, ProQuest, Emerald Insight, Sage Journals, Oxford Academic, ScienceDirect, Google Scholar, Scopus, and Taylor & Francis. The keywords used, based on the PICO (population, intervention, comparison, outcome) framework, were "Cerebral Palsy" AND "Robotic Assisted Gait Training" OR "Robotic Assisted" OR "Robotic Gait." *Training*" OR "*Robotic Rehabilitation*" OR "*Robotic Assisted "Therapy" AND "Conventional Therapy" OR "Conventional Physical Therapy" AND "Gait Ability" OR "Walking ability" OR "Ambulatory Ability".* The appraisal instrument used is the *JBI Critical Appraisal Tools*, which is a critical assessment tool used to evaluate the methodological quality of a research study. Its purpose is to determine the extent of bias in the article being studied, particularly in terms of design, management, and data analysis. This method is performed by two individuals. The instrument used for data extraction and synthesis is the *JBI Extraction Tools*. Data synthesis is conducted using a Simplified Approach to summarize articles and address the research literature review. A total of 4,535 articles were found that matched the keywords. The research articles were then re-screened based on their titles and abstracts, resulting in 25 articles. The authors then conducted a full-text analysis and excluded texts that did not meet the inclusion criteria, leaving 8 articles. Out of these 8 articles, a critical appraisal analysis was performed based on the article type, resulting in the exclusion of 2 articles that did not meet the inclusion criteria. Therefore, a total of 6 articles were synthesized.

# 3. Results

This literature review study resulted in 6 articles that underwent data synthesis and met the inclusion criteria as described in the research method. The results of each study are presented in Table 1.

**Table 1. Results of Analysis of 6 Articles**

| Study | Sample | Age | Diagnosis | Intervention | | Dosage | | Outcome | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Study | control | RAGT | Other intervention | Outcome measure | Other outcome |
| Mohammed Serag, et al.(Mahgoub 2020 | T : 30<br>C : 15<br>I: 15 | 7-14 | Spastic Hemiplegia | The intervention provided is Lokomat gait training combined with exercise therapy. | The intervention provided is conventiona l exercise therapy such as *stretching exercise, bobath approach, balance exercise,* and *gait training* | RAGT-Lokomat is performed 3 times per week. Each training session lasts for 1 hour, including a 30-minute setup time. The intervention is conducted for a duration of 12 weeks. | The exercise is conducted 3 times per week, with each training session lasting for 1 hour. | *Modified Ashworth Scale* (MAS) | The pro-reflex system (gait parameter) |
| Elena Baretta,et al.(Beretta et al., 2020) 2020 | T: 182<br>ABI: 110<br>CP: 72 | 4-18 | Spastic Diplegia | The RAGT-Lokomat intervention is combined with another intervention. | | RAGT-Lokomat is conducted for 20 sessions, each lasting 45 minutes. The Body Weight Support is initially set at 50% and gradually increased based on the patient's tolerance. | The conventional therapy exercises include strengthening exercises, stretching exercises, dynamic balance training, and functional ability exercises. | *Gross Motor Function Measure* (GMFM), 6-*Minute Walking Test*. | Wechsler Intelligence Scales, Wechsler Preschooldan Primary Scale of Intelligence |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Meltem Yazici, et al.(Yaz et al., 2019) 2019 | T : 24<br>C : 12<br>I : 12 | 5-12 | Spastic Hemiplegia | *Robotic Gait Training* (RGT) *The innowalk Pro* | The intervention provided is conventional exercise therapy such as *strengthening active functional, Stretching exercise, functional reaching, balance training,* | The intervention are conducted 3 times per week, with each session lasting for 30 minutes. The intervention is carried out for a duration of 12 weeks. | The intervention are conducted 3 times per week, with each session lasting for 30 minutes. The intervention is carried out for a duration of 12 weeks. | GMFM-88, *Pediatric Berg Balance Scale* (PBS), 10-MWT, 6-MWT | The Gillette Functional Assessment Questionnaire Walking Scale (FAQ-WL), NIRS, *Regional muscle oxygenation* (rSO2). |
| Yoo Myungeun, et al.(Cerebral et al., 2021) 2021 | *Case* 1 : 1<br>*Case* 2 : 1 | 11-12 | Ataxia | Using Overground-RAGT *Angel legs* M20, *torque-assisting exoskeleton robot,* | | The intervention is conducted for a total of 20 sessions, with each session lasting for 30 minutes. These sessions are performed with a frequency of 5 sessions per week and are applied to 2 children with CP ataxia. | | GMFM, *Pediatric Berg Balance Scale* (PBS), *Pediatric Reach Test* (PRT), 1-MWT | *Time Up and Go* (TUG) |
| Fabian Moll, etal.(Moll et al., 2022) 2022 | T : 30<br>C : 15<br>I : 15 | 8-18 | Spastic Cerebral Palsy | The intervention provided is RAGT with HAL (*Hybrid Assistive Limb*) | Inpatient therapy is provided, including walking exercises, pain management, and functional training. | The intervention is conducted for 6 sessions, with each session lasting for 90 minutes, including the actual walking time on the Hybrid Assistive Limb (HAL) device for 20 minutes. | There are 10 sessions of physiotherapy, massage therapy, and medical exercise training, as well as 8 sessions of manual treatment, with each session lasting for 30 minutes. | 10-MWT (*Self selected walking*) | 10-MWT (MAX), 6-MWT, GMFM-88, pROM, Pedoscan |
| Shogo Nakagawa, et al.(Nakagawa et al., 2020) | T : 19<br>$I_1$ : 19<br>$I_2$ : 19 | 3-14 | Spastic Cerebral Palsy | RAGT (Robotic-Assisted Gait Training) with HAL | | The intervention is conducted in one session, and each session lasts for 20 minutes. | | Data collection is conducted | 10-MWT, pROM |

## 4. Discussion

### The effectiveness of RAGT (Robotic Assisted Gait Training) on gait ability.

Among the six reviewed articles, there are three studies conducted by Mohamed Serag, Elena Beretta, and Fabian Moll, including both RCTs and cohort studies, which demonstrate a positive effect of RAGT in improving gait ability in patients with cerebral palsy. In the study conducted by Mohamed Serag et al [12] there was an improvement in the gait pattern of children with spastic hemiplegic cerebral palsy. The results were measured using the Q-trac software from the Pro-Reflex system to evaluate gait parameters such as ankle joint angle at initial contact, stride length, cadence, and speed. From the intervention provided by Mohamed Serag et al [12]. showed an increase in the mean values of the treatment group across all measured variables. Mohamed Serag et al [12]. also demonstrated that training using RAGT can improve locomotor abilities in patients with cerebral palsy. Additionally, Mohamed Serag et al [12]. also assumed that the central pattern generator activation and automatic feedback mechanism play a crucial role in stimulating walking through limb movement. Mohamed Serag et al [12]. They also aligned their research with other studies and obtained evidence that RAGT provides an opportunity to improve walking ability with the mechanical assistance of robotic devices, where children may not be able to generate sufficient or correct movements with an adequate repetition when receiving intervention without robotics [12]. This improvement is attributed to the fact that RAGT technology provides repetitive movements that can enhance motor function of the affected limbs. It is based on the neuroplasticity of the central nervous system at various levels, resulting in compensation for the loss of brain or spinal cord lesions.

In the study conducted by Elena Beretta et al [1] , which evaluated the effectiveness of combining RAGT with other interventions in 182 children from different populations, it was demonstrated that there was a significant improvement in the overall group as well as in two subgroups (ABI and CP) in the 6-Minute Walk Test (6-MWT). Improvement was also observed in gross motor capacity. The total score of the Gross Motor Function Measure (GMFM) significantly increased in the entire group of patients with ABI, but not in the CP group. Elena Beretta et al [1] aligned their findings with previous research and found that there was a higher improvement in GMFM Dimension D compared to GMFM Dimension E in patients with CP compared to those with ABI. They also showed that after RAGT combined with other interventions, children affected by ABI achieved significant improvements in all GMFM dimensions, while children with CP only benefitted from robotic rehabilitation in the GMFM Level III. Elena Beretta et al [1] suggested that for patients with CP, the best outcomes were obtained when children walked using assistive mobility devices or engaged in functional exercises such as climbing stairs with therapist assistance. Their hypothesis was that the ceiling effect in patients with CP and functional levels GMFM I and GMFM II did not show significant improvements from the interventions, as CP patients with GMFM I and GMFM II already achieved good results in their walking performance. The study conducted by Elena Beretta et al [1] highlighted the role of injury timing as a covariate explaining the difference in improvements between patients with ABI and CP. In their study, patients with ABI were treated immediately after the acute event, while the CP group received intervention after their walking pattern had stabilized. The results indicated that the difference in response may be due to the timing of injury occurrence, as CP patients tended to be in the chronic phase compared to ABI patients. Elena Beretta et al [1] stated that the earlier the intervention is initiated, the greater the likelihood of its effectiveness.

The study conducted by Meltem Yazici et al [25] resulted in improvements in balance, gait speed, and functional abilities with RAGT in addition to other interventions in children with hemiparetic cerebral palsy. The study by Meltem Yazici et al [25] showed that children who underwent RGT experienced a decrease in time in the 10-Meter Walk Test (10-MWT) at their self-selected speed and felt more comfortable at higher speeds. Meltem Yazici et al [25] suggested that children's perception of speed should be altered through high-repetition walking training, and high-repetition at higher speeds also had a perceived effect on the children. Regarding the integration of sensory-perceptual-motor aspects, Meltem Yazici et al [25] aligned with previous research that walking parameters in children with hemiparetic cerebral palsy can vary depending on the level of sensory stimulation.

The study by Meltem Yazici et al [25] demonstrated an increase in distance measured by the 6-Minute Walk Test (6-MWT) in both the intervention and control groups. The improvement in the intervention group was three times higher than the control group (mean distance in the intervention group: 66 m, in the control group: 22 m), indicating that performance improvement in children with CP is achieved gradually and with difficulty. In the intervention group, the improvement in balance after the intervention showed a positive effect of RGT. During RGT intervention, more load can be transferred to the paretic extremities due to reduced connective tissue and dependence on walking speed. In the study by Meltem Yazici et al [25], children with hemiparetic CP exhibited walking patterns similar to those of healthy children and consecutive weight shifting during walking. This effect was considered to result in increased weight-bearing time on both extremities of children in the intervention group. The improvements provided by RGT in all functional parameters in the intervention group were higher compared to the control group. Additionally, 30 minutes of walking exercise with Innowalk Pro also improved endurance. Substantial endurance training contributes to increased functional capacity and motor performance. Improvements were also observed in GMFM-D in both groups, but an increase in GMFM-E was only observed in the intervention group. Evaluation of functional muscle strength in the lower extremities revealed significant improvements in all parameters except for lateral step-up by the paretic extremities in the intervention group. The influence of the RGT program combined with other interventions on walking ability can yield different outcomes. Most children at GMFCS level I had spasticity in knee flexors and extensor muscles with a MAS scale score of 0-1, and it was found that children at GMFCS level II had higher levels of spasticity compared to GMFCS level I. In hemiparetic CP, walking impairment is more related to the loss of strength in the lower extremities, but walking ability can be improved through strength and balance training. Improvement in walking speed has an effect on enhancing functional ability. Therefore, according to Meltem Yazici et al [25] a combination of RGT and other interventions is needed to maximize walking ability in children.

The study conducted by Yoo Myungeun et al [4] demonstrated improvements in walking ability, gross motor function, and balance in CP with ataxia type. Yoo Myungeun et al [4] combined untethered RGT using an exoskeleton device with task-specific over-ground training. Untethered RGT using an exoskeleton device utilizes more realistic walking capabilities, and this robotic system enhances postural balance and walking capacity.

Fabian Moll et al [15] in their study using HAL, found no significant difference in the 10-Meter Walk Test (self-selected walking speed, SSW). The average time in the 10MWT (SSW) decreased by 5.5 seconds in the intervention group, while subjects in the control group took 1.8 seconds longer compared to T1 and T2. Changes in the 10MWT (maximum speed) could be hypothesized to show significant differences between the groups with a larger sample size. In secondary outcome measures, there was an absolute change of 7% in total GMFM in the intervention group. This is attributed to the use of modern technology creating motivational and supportive aspects for children. The use of Overground-RAGT with HAL enhances the focus on learning individual movements and functions, which are then integrated into walking patterns. Therefore, Fabian Moll et al [15] suggest the need for improvement in individual function before implementing it into more complex walking patterns.

Shogo Nakagawa et al [16] demonstrated that Overground-RAGT with an exoskeleton is proven to be safe for children with cerebral palsy. Furthermore, they found an improvement in walking ability. The improvement in walking ability and changes in walking patterns are attributed to changes in muscle activity. Shogo Nakagawa et al [16] manipulated muscle activity in an 11-year-old child with CP at GMFCS level III. After the HAL 2S intervention, they stated that the normalization of muscle balance allows the patient to move their legs forward more easily. In the study by Shogo Nakagawa et al [16] improvements in the free distance during the swing phase and increased hip extension range of motion, likely due to increased activity in the semitendinosus and gluteus medius muscles during the terminal stance phase, were largely associated with an increase in step length, although there were significant differences in muscle activity among participants. These participants underwent electromyogram (EMG) and exhibited different walking styles, with one showing apparent equinus (AE) and the other exhibiting a squat walking posture, and different walking aids were used as well. Muscle activity during walking varies in children depending on their age. The specific pattern of muscle activity required for improving walking gait significantly differs between participants [16].

From the six articles that have been reviewed, the authors conclude that the provision of RAGT intervention is effective to improve the ability to walk (gait ability). There was a significant improvement in gait parameters and also GMFM after the child was given RAGT intervention. In addition, the use of RAGT is also very effective for increasing walking endurance [5]. RAGT also has multisensory and task-oriented rehabilitation and

RAGT can be done in a safe and pleasant environment, thus maintaining a higher level of motivation and compliance with the intervention [6].

**Dosage of Robotic Assisted Gait Training (RAGT) Intervention.**

From the six reviewed articles, three studies conducted by Mohamed Serag et al, Elena Beretta et al, and Fabian Moll et al, both RCTs and Cohort studies, demonstrate the positive effects of RAGT on improving gait ability in patients with cerebral palsy. In Mohamed Serag et al's study, RAGT-Lokomat was conducted three days per week. Each training session lasted for one hour, including setup time, with 30 minutes of actual training per session. The treadmill speed started at 0.5 km/h and increased up to 1 km/h based on the child's tolerance. The intervention was provided for 12 weeks, and participants were evaluated before and after the intervention.

The cohort study conducted by Elena Beretta et al. implemented a rehabilitation program consisting of 20 RAGT sessions and 20 sessions of other interventions. The interventions were provided from Monday to Friday for four weeks. Each RAGT session and other intervention session lasted for 45 minutes. The RAGT sessions utilized the Lokomat, providing active lower limb exoskeleton assistance at the hip and knee joints. For all patients, the same training group was given the same duration, preset initial speed, and difficulty level. The initial body support was set at 50% and gradually reduced based on the child's response to the intervention and their functional capacity.

In Meltem Yazici et al.'s study, the Innowalk Pro was used with customized device sizes based on the child's height. The medium size was suitable for children with a height range of 100-140 cm, while the large size was used for children taller than 140 cm. Innowalk Pro was utilized for aerobic training, where the low-dose aerobic exercise program consisted of a 5-minute warm-up and cooldown at 30-40% of maximum heart rate (HR). Fast walking was performed for 20 minutes at 55-75% of maximum HR. The walking exercise consisted of active walking for 30 minutes.

According to the study conducted by Yoo Myungeun et al., the dosage of Overground-RAGT using the Angel Legs M20 was 20 sessions, with each session lasting for 30 minutes. Five sessions were conducted per week for two children with CP ataxia. Yoo Myungeun et al. also included other interventions, such as occupational therapy, in a regular dosage alongside the Overground-RAGT intervention.

In Fabian Moll et al.'s study, the HAL intervention was administered for six sessions, with each session lasting for 90 minutes, including actual walking time in HAL (20 minutes), time for HAL installation and removal, rest periods, and patient skin and health evaluations before and after the intervention. The study conducted by Shogo Nakagawa et al. utilized Overground-RAGT with the HAL device, targeting children with a height of

100-150 cm and a weight of 15-40 kg. The Overground-RAGT intervention with HAL lasted for 20 minutes, including rest time. The walking speed was adjusted based on the participant's tolerance.

Based on the six reviewed articles, the author concludes that the dosage of RAGT varies depending on the type of device used. For RAGT-Lokomat, the effective dosage per session is 30 minutes, three times per week. The initial body support in RAGT-Lokomat is provided based on the patient's tolerance but starting at the lowest level, such as 50% of the initial body support. In other studies, giving body weight support did not exceed 50%, and did not reduce body weight support below 50%.(Petrarca et al., 2021) For RAGT-Overground, the effective dosage per session is 20 minutes, five sessions per week. This dosage aligns with the findings from Mohamed Serag et al.'s study, suggesting that RAGT provides a repetitive effect that can enhance neuroplasticity, aiding children in improving motor function, specifically in walking ability. The author also aligns with the findings of Yoo Myungeun et al. that RAGT has a realistic effect on children's walking ability. Fabian Moll et al. also mentioned that RAGT improves children's motivation during training. Shogo Nakagawa et al. stated that normalizing muscle balance enables patients to move their legs more easily. The author concludes that regular RAGT interventions can provide a realistic effect that motivates children to engage in training, leading to the normalization and activation of lower limb muscles and the creation of neuroplasticity effects that facilitate walking ability in children with cerebral palsy.

**Comparison of RAGT Interventions with Other Intervention**

From the six reviewed articles, varied results were obtained regarding gait ability in patients with Cerebral Palsy. In the study conducted by Mohammed Serag et al. with 15 participants in the intervention group and 15 participants in the control group, it showed a positive effect of using RAGT Lokomat combined with exercise therapy on improving gait patterns in children with spastic hemiplegic Cerebral Palsy compared to receiving only conventional exercise therapy. The researchers evaluated the participants after 3 months of intervention. There was an improvement in gait parameter scores in the intervention group compared to the control group, measured using The pro-reflex system (P = <0.01). The values of gait parameters before and after the intervention in the intervention group and control group can be seen in Table 2.

**Table 2.** Comparison of gait parameter values measured using the pro-reflex system

| Outcome | Intervention Group (n=15) | Control Group (n=15) | Difference Average | 99% Confidence interval | P-value |
|---|---|---|---|---|---|
| Speed pre | 0.4733 ± 0.0798 | 0.4467 ± 0.0915 | 0.027 | (-0.060, 0.113) | 0.403 |
| Speed Post | 0.5867 ± 0.0915 | 0.7200 ± 0.1146 | -0.133 | (-0.238, -0.029) | 0.001 |
| P-value | 0.0001 | 0.0001 | | | |
| Cadence pre | 130.00 ± 3.964 | 130.73 ± 5.560 | -0.733 | (-5.606, 4.139) | 0.681 |
| Cadence Post | 125.00 ± 4.225 | 119.93 ± 5.105 | 5.067 | (0.338, 9.795) | 0.006 |
| P-value | 0.0001 | 0.0001 | | | |
| Stride Length pre | 0.3800 ± 0.0774 | 0.4000 ± 0.0845 | -0.020 | (-0.102, 0.062) | 0.505 |
| Stride Length post | 0.5067 ± 0.0703 | 0.7400 ± 0.0985 | -0.233 | (-0.320, -0.147) | 0.0001 |
| P-value | 0.0001 | 0.0001 | | | |
| Ankle angle pre | -2.7267 ± 1.081 | -2.7173 ± 0.9047 | -0.009 | (-1.016, 0.997) | 0.980 |
| Ankle angle post | -1.3600 ± 0.6467 | 1.5560 ± 2.293 | -2.916 | (-4.616, -1.216) | 0.0001 |
| P-value | 0.012 | 0.0001 | | | |

In the study conducted by Elena Beretta et al., involving 110 children with Acquired Brain Injury (ABI) and 72 children with Cerebral Palsy (CP), the use of RAGT intervention with Lokomat and combined with other therapy showed positive changes in gait performance in children with CP and ABI. The evaluations were conducted before (T0) and after (T1) undergoing 20 sessions of RAGT-Lokomat training and 20 sessions of conventional therapy, using the Gross Motor Function Measure (GMFM) and 6-Minute Walk Test (6-MWT).50 Statistical analysis revealed a significant effect of intervention and interaction between intervention and etiology for the response variables. There were also significant differences in values between before intervention (T0) and after intervention (T1) in the post hoc test, with significant differences observed in each response variable between etiologies within each GMFM level, adjusting for the least significant difference, where adjustments were identified with a P-value of .05 (P = <.05).50 The differences in intervention and interaction between intervention and etiology for response variables, as well as the differences in each response variable between etiologies within each GMFM level, can be seen in Table 3 and Table 4.

**Table 3.** the difference in intervention and interaction effects, as well as the differences in each response variable between etiologies within each GMFM level

| Source of Variation | df | 6 MWT | | GMFM Total | |
|---|---|---|---|---|---|
| | | F | P-value | F | P-value |
| Within=subject | | | | | |
| Intervention | 1 | 71.99 | <.001 | 62.60 | <0.001 |
| Intervention x GMFCS | 2 | 0.37 | .688 | 0.06 | .941 |

| | | | | | |
|---|---|---|---|---|---|
| Intervention x etiology | 1 | 12.20 | .001 | 33.19 | <.001 |
| Intervention x GMFCS x Etiology | 2 | 1.00 | .372 | 0.34 | .713 |

**Table 4.** The Differences in each response variable between etiologies with each level of GMFM

| Score | 6 MWT | | GMFM Total | |
|---|---|---|---|---|
| | T0 | T1 | T0 | T1 |
| ABI | | | | |
| GMFCS I-II | 308 ± 132 | 385 ± 112 | 202 ± 47 | 221 ± 40 |
| GMFCS III | 192 ± 115 | 265 ± 107 | 177 ± 59 | 194 ± 53 |
| GMFCS IV | 142 ± 251 | 188 ± 183 | 111 ± 73 | 129 ± 78 |
| GMFCS total | 233 ± 143 | 304 ± 144 | 168 ± 69 | 187 ± 68 |
| CP | | | | |
| GMFCS I-II | 319 ± 127 | 342 ± 134 | 172 ± 71 | 174 ± 70 |
| GMFCS III | 193 ± 79 | 219 ± 89 | 150 ± 54 | 155 ± 54 |
| GMFCS IV | 148 ± 73 | 179 ± 78 | 127 ± 43 | 129 ± 44 |
| GMFCS total | 222 ± 117 | 248 ± 120 | 151 ± 59 | 155 ± 59 |
| All Sample | 228 ± 131 | 277 ± 136 | 162 ± 66 | 174 ± 66 |

The study conducted by Meltem Yazici et al. on 24 children, with 12 children in the study group receiving Innowalk Pro Lokomat-RAGT intervention and 12 children in the control group receiving other exercise interventions without RAGT. Evaluations were performed at pre-treatment, followed by a follow-up assessment after 12 weeks of training, and another evaluation after 3 months of intervention for both the study and control groups. At the pre-treatment stage, there were no significant differences observed between the two groups in terms of walking speed, endurance, balance, and functional abilitiesIn the study group, the comparison of pre- and post-intervention results revealed a decrease in time for the 10-Meter Walk Test (10-MWT) at the selected speed by the children, but an increase in distance for the 6-Minute Walk Test (6-MWT). In the control group, there was an increase in distance for the 6-MWT. Improvement was also observed in the standing position on the paretic side and Pediatric Balance Scale (PBS) scores in the study group, while no differences were observed in the control group.

Significant differences were observed in the scores of GMFM-88, GMFM-D, and GMFM-E in the study group, with an increase in GMFM-88 and GMFM-D scores in the control group. All functional muscle groups showed improvement in the study group, while in the control group, all functional muscle parameters, except for half-kneel on the paretic side, showed improvement. In the study group, there was a static increase post-intervention that persisted until the evaluation after 3 months of intervention. This improvement was observed in the Pediatric Balance Scale (PBS), GMFM-88, GMFM-D, and Sit-to-stand test..

Improvements in these parameters continued to increase at the 3-month evaluation following the intervention, especially in the standing on the paretic leg and lateral step-up movements performed by both the paretic and non-paretic extremities. In the control group, there was only an improvement observed after the intervention in the 10-Meter Walk Test (10-MWT) with the child's selected speed, and the number of lateral steps taken by the non-paretic leg was maintained. The results of the evaluation of gait and functional performance before the intervention, after the 12-week intervention, and 3 months after the intervention can be seen in Table 5.

**Table 5.** The result of the evaluation of gait and functional performance before the intervention, after the 12-week intervention, and 3 months after the intervention

| Test | Study Group | | | | Control Group | | | |
|---|---|---|---|---|---|---|---|---|
| | Pre-T | Post-T | Post-T Third Month | $p^*$ | Pre-T | Post-T | Post-T Third Month | $p^*$ |
| 10 m walking at selected velocity, s | 5.80 (0.56)$^a$ | 5.11 (0.92)$^b$ | 5.36 (0.96)$^{a,b}$ | 0,017 | 5.18 (1.13)$^a$ | 4.86 (0.67)$^a$ | 5.90 (0.90)$^b$ | 0.050$^{**}$ |
| 10 m walking at fast velocity, s | 3.84 (0.71)$^{a,b}$ | 3.41 (0.37)$^a$ | 3.66 (0.51)$^b$ | 0,039 | 3.85 (0.65)$^a$ | 3.78 (0.59)$^a$ | 3.94 (0.45)$^a$ | 0,104 |
| Six min walking:, m | 409.58 (49.1)$^a$ | 475.17 (47.7)$^b$ | 438.17 (47.3)$^a$ | 0,002 | 437.0 (55.0$^{a,c}$ | 459.17 (53.75)$^b$ | 443.43 (43.91)$^{b,c}$ | 0,066 |
| Standing on the P leg, s | 4.38 (3.84)a | 9.90 (14.81)$^b$ | 31.80 (74.91)$^b$ | 0.046$^{**}$ | 5.80 (5.81)$^a$ | 13.87 (19.46)$^a$ | 8.09 (7.02)$^a$ | 0,180 |
| Standing on the NP leg, s | 42.95 (76.17)$^a$ | 58.81 (69.96)$^a$ | 61.54 (74.37)$^a$ | 0,076 | 74.74 (117.2)$^a$ | 105.11 (173.6)$^a$ | 112.77 (196.0)$^a$ | 0,867 |
| Berg balance score | 50.08 (2.43)$^a$ | 52.08 (2.68)$^b$ | 52.00 (3.08)$^b$ | 0.000$^{**}$ | 50.25 (2.93)a | 51.00 (3.30)$^a$ | 51.71 (3.82)$^a$ | 0,066 |
| GMFM-88 | 253.00 (8.81)$^a$ | 256.17 (8.23)$^b$ | 256.17 (8.24)$^b$ | 0.000$^{**}$ | 253.67 (7.70)$^{a,c}$ | 255.25 (7.94)$^b$ | 254.25 (9.00)$^{b,c}$ | 0,163 |
| GMFM-0 | 36.08 (2.27)$^a$ | 36.92 (1.73)$^b$ | 36.92 (1.88)$^b$ | 0.003$^{**}$ | 36.75 (2.22)$^{a,c}$ | 37.42 (1.98)$^b$ | 37.63 (2.00)$^{b,c}$ | 0,115 |
| GMFM-E | 64.00 (6.90)$^a$ | 66.25 (6.78)$^b$ | 65.50 (6.69)$^b$ | 0,000 | 64.08 (6.43)$^a$ | 64.92 (6.72)$^a$ | 63.87 (7.92)$^a$ | 0,305 |
| P lateral step | 19.50 (4.28)$^a$ | 23.00 (4.13)$^{a,c}$ | 24.83 (5.80)$^{b,c}$ | 0.005$^{**}$ | 20.08 (3.68)$^{a,c}$ | 22.83 (4.51)$^b$ | 21.71 (4.92) $^b$ | 0,317 |
| NP lateral step | 19.67 (4.40)$^a$ | 24.25 (4.73)$^b$ | 26.33 (5.76)$^b$ | 0.002$^{**}$ | 21.08 (3.45)$^a$ | 24.75 (3.86)$^b$ | 22.29 (3.95)$^b$ | 0.015$^{**}$ |
| Sit-to-stand | 15.08 (3.09)$^a$ | 18.50 (2.24)$^b$ | 17.17 (2.37)$^c$ | 0.000$^{**}$ | 15.50 (3.66)$^a$ | 16.92 (3.94)$^b$ | 14.71 (2.75)$^b$ | 0,141 |
| Standing from half kneeling on the P leg | 14.00 (4.73)$^a$ | 18.92 (5.58)$^b$ | 16.17 (3.46)$^a$ | 0,001 | 15.50 (3.43)$^a$ | 16.42 (4.91)$^a$ | 15.14 (2.91)$^a$ | 0,738 |
| Standing from half kneeling on the NP leg | 15.92 (2.39)$^{a,c}$ | 20.50 (5.90)$^b$ | 18.83 (4.17)$^{b,c}$ | 0,017 | 18.33 (3.60)$^{a,c}$ | 19.17 (5.56)$^b$ | 17.00 (5.16)$^{b,c}$ | 0,764 |
| FAQ-WL | 91(7.14)$^{a,c}$ | 93.92 (8.96)$^b$ | 93.00 (10.11)$^{b,c}$ | 0,025 | 92 (9.27)$^a$ | 94.00 (8.36)$^a$ | 92.71 (8.88)$^a$ | 0,091 |
| $\Delta rSO_2$ for P leg | 4.89$^a$ | 2.63$^a$ | 2.14$^a$ | 0,280 | 3.04$^a$ | 3.07$^a$ | 3.05$^a$ | 0,314 |
| $\Delta rSO_2$ for NP leg | 2.98$^a$ | 1.47$^a$ | 1.44$^a$ | 0,636 | 3.18$^a$ | 2.07$^a$ | 2.09$^a$ | 0,231 |

Data are presented as mean (standard deviation) or median, where appropriate. Pre-T, pre-treatment; Post-T, post-treatment; P, paretic; NP, non-paretic; GMFM, Gross Motor Function Measurement; FAQ-WL; Functional Assessment Questionnaire Walking Scale; rSO2, regional oxygenation of the muscle; SD, standard deviation. a, b, and c stands for indicating significant difference between the means defined by different letters in the same line ($p < 0.05$). $\Delta rsO_2 = rSO_2$ at rest – $rSO_2$ at maximum exercise.

Bold values signifies $p < 0.05$.

* Friedman test.

** Indicates preserved or continuing improvement.

In the study conducted by Yoo Myungeun et al., two cases of children with CP ataxia were examined. The sample selection was carried out in accordance with the patients' informed consent. In case 1, an 11-year-old child showed overall hypotonia and developmental delay. The child was unable to walk independently and had a slow gait with special protection. In case 2, a 12-year-old child exhibited hypotonia throughout the body and was unable to walk or stand independently. The intervention provided was Overground-RAGT with an exoskeleton, and evaluation was conducted after 4 weeks of intervention. The results showed differences before and after the intervention in GMFM, PBS, PRT, and 1-MWT. The evaluation results for functional walking abilities before and after the intervention can be seen in Table 6, Table 7, and Table 8.

**Table 6.** The evaluation result for GMFM after RAGT intervention

| | | **GMFM-88 (%)** | | | | | |
|---|---|---|---|---|---|---|---|
| | | **A** | **B** | **C** | **D** | **E** | **Total** |
| Case 1 | Pre | 100 | 100 | 100 | 79.49 | 77.78 | 91.45 |
| | Post | 100 | 100 | 100 | 92.31 | 80.56 | 94.57 |
| Case 2 | Pre | 100 | 100 | 97.62 | 87.18 | 51.39 | 87.24 |
| | Post | 100 | 100 | 100 | 89.74 | 54.17 | 88.78 |

**Table 7.** The evaluation for PBS and PRT before and after RAGT intervention

| | | **Case 1** | **Case 2** |
|---|---|---|---|
| PBS | Pre | 35 | 35 |
| | Post | 45 | 42 |
| PRT in Standing | | | |
| Forward Reach (cm) | Pre | 21 | 13 |
| | Post | 35 | 25 |
| Right Reach (cm) | Pre | 8 | 8 |
| | Post | 24 | 15 |
| Left Reach (cm) | Pre | 10 | 12 |
| | Post | 26 | 14 |
| PRT in sitting | | | |
| Forward Reach (cm) | Pre | 36 | 21 |
| | Post | 42 | 34 |
| Right Reach (cm) | Pre | 16 | 13 |
| | Post | 32 | 20 |
| Left Reach (cm) | Pre | 21 | 17 |
| | Post | 35 | 20 |
| PRT Total (cm) | Pre | 112 | 84 |
| | Post | 194 | 128 |

**Table 8.** The evaluation result for 1-MWT and TUG Test after RAGT intervention

| | | Case 1 | Case 2 |
|---|---|---|---|
| 1MWT (meter) | Pre | 46.16 | 10.10 |
| | Post | 61.06 | 21.30 |
| TUG test (s) | Pre | 25.42 | 39.95 |
| | Post | 19.58 | 24.51 |

In a study conducted by Fabian Moll et al, which involved 30 children in hospitalization were divided into two groups, 15 children in the intervention group and 15 children with the control group. Sample randomization is done by 1:1 ratio division without limitation or stratification using Microsoft Excel for random sample list. Both groups are selected by staff to select eligible children and manage patients (e.g., answer questions about interventions). The participants were recruited from the clinic's patient population. All examination results are collected at the beginning (1st day = T1) and at the end (11th day = T2) of hospitalization. Providing intervention in the intervention group in the form of HAL (hybrid assistive limb) combined with exercise therapy. In the control group, only exercise therapy was routinely performed in inpatient settings. There was a difference in time at 10 MWT (self-selected walking) from 41.4±64.3 seconds (MW±SD) (T1) to 35.9 ±46.8 seconds (T2) in the intervention group and from 28.3 ±21.8 seconds (T1) to 30.1 ±30.2 seconds (T2) in the control group ($p < 0.05$).52 There was no significant change (F [1.18] = 0.851; p = 0.368) between T1 and T2. Meanwhile, at 10-MWT (Max) it changed from 28.2 ± 39.4 seconds (T1) to 25.6 ±34.9 seconds (T2) in the intervention group and from 21.7 ±17.1 seconds (T1) to 23.0 ±26.1 seconds (T2) in the control group. No significant change (F [1.18] = 2.62; p = 0.123) between T1 and T2.52 the distance at 6-MWT increased from 156.4 ±83.8 m (T1) to 168.2 ±85.3 m (T2) in the intervention group and from 142.6±111.4 m (T1) to 157.3 ±116.7 m (T2) in the control group. There was no significant change (F [1.18] = 0.07; p = 0.800) between T1 and T2. 52 In GMFM, there was an increase in the score from 68.5±10.8% (T1) to 75.5 ±10.1% (T2) in the intervention group and from 64.9±17.7% (T1) to 67.3±18.4% (T2) in the control group. There was a significant change (F [1,18] = 13,12; p = 0,002) between T1 and T2.52 the GMFM score (Dimension D + E) increased from 40.2±18.8% (T1) to 51.9±18.3% (T2) in the intervention group and from 44.3± 23.5% (T1) to 49.4±26.4% (T2) in the control group. There was a significant change (F [1.18] = 4.59; p = 0.046) between T1 and T2. 52

Research conducted by Shogo Nakagawa, et al. examining the comfort and feasibility of Overground-RAGT on gait training in children with CP. Tools used in the form of things. To examine the comfort and feasibility of Overground-RAGT, Nakagawa, et al asked patients what they felt after being given the intervention and performed a head-to-toe examination to see if any damage to the skin was possible. In addition Nakagawa, et al also examined the direct effect on overground-RAGT administration with P. To evaluate this Nakagawa, et al used 10-MWT. Nakagawa, et al also conducted a study on gait parameters when performing 10-MWT. The evaluation is carried out only 1 day after the intervention is given. The results showed a significant improvement after the intervention. Especially gait speed and stride length. Comparison of gait parameters before and after intervention can be seen in Table 9.

**Table 9.** Different result *gait parameter* before and after intervention

| Outcome Measure | Sebelum | Sesudah | P-value |
|---|---|---|---|
| Gait Speed (SD) (step/min) | 47.1 (18.4) | 54.7 (22.2) | |
| Step Length (SD) (step/min) | 39.9 (10.1) | 43.5 (9.8) | |
| Cadence (SD) (step/min) | 115.6 (30.3) | 122.1 (31.2) | |

## 5. Conclusion

From 6 articles that have been reviewed, it can be concluded that the administration of RAGT proved effective in improving the ability to walk in patients with cerebral palsy. This was evidenced by several positive effects measured using parameters GMFM, 1-MWT,6 - MWT,10-MWT,PBS,PRT. RAGT be one of the interventions that are quite effective and create a pleasant environment with a level of difficulty that adjusts to the ability of the child objectively. In addition, RAGT gives supportive effect of children so that children are more motivated in carrying out the exercise.

RAGT can also be used as a modality to be combined with other therapies. It was proved that there is a more optimal increase in the ability of motor functions that affect the ability to walk in children with cerebral palsy. Things that must be considered in the provision of RAGT is to adjust the initial body weight support, the level of difficulty and duration of the intervention. The dose of exercise that can be given is about 20 to 30 minutes for one training session. The speed and ability of the patient, and age become one of the important factors in the success of the intervention provided.

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