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Perspective of robotic-assisted treadmill training effect in children with cerebral palsy on motor functions and gait

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Разматрање утицаја роботски потпомогнутог тренинга хода на покретној траци на моторичке функције и ход код деце са церебралном парализом

SUMMARY
Robotic-assisted treadmill training has been applied in the last two decades for children with cerebral palsy. The high technology of robotic devices enables an individualized approach, physiological gait pattern, intensive training through a large number of repetitions, while enhancing motivation with active attention that influence motor learning and neuro plasticity. The results of clinical studies are controversial regarding the effectiveness of robotic-assisted gait training on speed and endurance in walking, gross motor functions, postural control, and balance in children with cerebral palsy who are at different levels of motor functioning. Scientific evidence does not highlight the superiority of robotic gait rehabilitation over conventional therapies. The intensity, frequency, duration of therapy, and sustainability of effects are current research questions. Future studies should involve a larger number of participants, higher methodological quality, standardization of reporting robotic parameters, and the impact on the activity, participation, and quality of life of children with cerebral palsy.
Keywords: cerebral palsy; robotic-assissted gait traning; motor functions; gait; children

САЖЕТАК
Роботски потпомогнути тренинг хода на покретној траци се примењује у задње две деценије код деце са церебралном парализом. Висока технологија роботског уређаја омогућава индивидуални приступ, физиолошки образац хода, интезиван тренинг кроз велики број понављања уз поспешивање мотивације и активне пажње које утичу на моторичко учење и пластицитет мозга. Резултати клиничких студија су контроверзни у погледу ефикасности роботски потпомогнутог тренинга хода на брзину и издржљивост у ходу, грубе моторичке функције, постуралну контролу и баланс код деце са церебралном парализом која су на различитом нивоу моторичког функционисања. Научни докази не истичу супериорност роботске рехабилитације хода у односу на конвенционалну терапију. Интензитет, учесталост, трајање терапије и одрживост ефеката су актуелна истраживачка питања. Будуће студије треба да обухвате већи број испитаника, виши методолошки квалитет, стандардизацију извештавања роботских параметара и утицај роботски потпомогнутог тренинга хода на активност, партиципацију и квалитет живота деце са церебралном парализом.
Кључне речи: церебрална парализа; роботски потпомогнути тренинг хода; моторичке функције; ход; деца

INTRODUCTION

Cerebral palsy (CP) is a non-progressive neurodevelopmental disorder affecting a child's motor and sensory system due to brain lesion, and consequently movement, posture, and walking [1].

Gross motor function classification system (GMFCS) is an evidence-based tool that measures the severity of motor functioning in CP. The functional mobility of CP children is classified into different levels as independent walking (Level I-II), walking with handheld aids (Level III), and wheelchair mobility (Level IV-V) [2].

Children with CP have impaired gait function due to motor impairments such as spasticity, muscle weakness, lack of selective motor control, reduced range of motion and joint contractures. Common gait deviations seen in CP children as equines or crouch gait include reduced speed and endurance, decreased step and stride length, decreased toe clearance, decreased balance, fatigue and pain [3, 4, 5]. As the children mature, they tend to have decreased balance and gait stability due to growing related musculoskeletal impairments which have negative implications on the activity, participation, and quality of life especially for children at level III and IV on GMFCS, who are the most at risk for losing locomotor abilities [6]. Hence, there is high emphasis on gait training in children with CP for maintaining their gait pattern for a long period of time [7].

ROBOTIC-ASSISTED GAIT TREADMILL TRAINING (RAGTT)

There are different ways of providing gait training on ground with and without body weight support (BWS) and one of the advantages of robotic gait training is that it allow children on level III and IV to walk while maintaining the same quality for longer period. RAGTT is a high- technology intervention with increasing popularity in rehabilitation centers [8]. Lokomat® (Hocoma AG, Volketswil, Switzerland) is one of the most popular RAGTT that supports patient on a treadmill with adjustable robotic orthoses (exoskeletons) for each leg, suspension system controlling body weight, treadmill, and feedback screen [9]. The system offers varying levels of BWS, to enable stepping practice for both ambulatory and non-ambulatory patients. Robotic orthosis movements synchronize with the treadmill speed through a computer algorithm for hip and knee joint motion, providing a near physiological gait phases [10]. The multimodal Lokomat control has adjustable settings for muscle assist ranging from passive to active resistance, allowing muscle activity and incrementally reducing dependence on robotic support by progressively decreasing BWS and guidance while increasing the treadmill speed [6]. The computer algorithm for treadmill walking is connected to a video game that sets target, provides feedback on the screen and constantly engaging active cognitive and motor participation of the children during the training.

RAGTT has shown positive possibilities for increasing gait speed, stride length, lower limb strength, muscle endurance, balance spatiotemporal gait parameters in children and adolescents with CP due to its high repetition, intensive practice [6, 11]. It additionally is known to enhance cardiovascular endurance, improve muscle strength, balance, motor planning and other physiological functions [10, 12, 13]. The hip and knee extension can be adjusted to allow standing even in severely affected CP children, which could have impact on muscles flexibility, ROM, spasticity, balance, gait, and postural control [14].

RAGTT is a stationary type of robot and has a few limitations – costly device, takes up large space, therapists require training and ongoing maintenance of the equipment. It allows only forward walking without any opportunities to change direction, practice backward walking, or walking on uneven terrain.

MOTOR LEARNING AND NEUROPLASTICITY ASSOCIATED TO RAGTT

RAGTT provides intensive, repetitive, task-oriented motor activities by increasing motivation, attention, and active participation which influenced motor learning and neuroplasticity [12]. RAGTT produces bilateral changes in cortical areas, which are involved in motor coordination and complex movements, proprioceptive control, spatial memory and in attention, self-control and working memory [12].

A neuroimaging study using functional near-infrared spectroscopy (fNIRS) in children with CP after 12 RAGTT sessions as an adjunct to conventional therapy showed significant differences in the activation of sensorimotor cortex. The increase in prefrontal activity was found to be positively related to concentration, attention, and engagement with therapy [15].

EFFECTIVES OF RAGTT ON GROSS MOTOR FUNCTIONS, GAIT SPEED, GAIT ENDURANCE ACCORDING TO THE LEVEL ON GMFCS AND AGE

Level of motor functioning, comorbidities, and age are important factors influencing effectiveness of any CP interventions [16].

Most of the randomized control trials (RCT) in their RAGTT studies for children with bilateral spastic CP use functional tests such as GMFM (D- standing dimension & E- walking, running, and jumping dimension), 6 min walk test for gait endurance, 10-meter walk test for gait speed. The studies on the effectiveness of RAGTT have mixed results with most studies showing improvements in gait speed and endurance. A systematic review with meta-analyses done by Cortes- Perez that included 15 articles with 413 CP children, a mean age of 10.33+_ 4.1 years concluded that RAGTT is more effective than conventional therapy on gait speed, walking distance and dynamic balance associated with locomotion (improvement in dimension E on

GMFM) [12]. Similarly, a systematic review by Volpini et al. synthesizing 7 studies with a total of 77 participants showed improvements in gait endurance [17].

A study done by Cherni et al. (2020) showed improvements in gait speed, endurance, and step length, regardless of the severity level on GMFCS [4]. A study done by Jin (2020) showed more improvement in the GMFM (D and E score) in ambulatory compared with non-ambulatory children indicating that children with mild and moderate impairments benefit more from RAGTT [16].

On the contrary, systematic reviews done by Olmos-Gomez (2021), Corner (2022), with 8 and 8 papers respectively found a weaker and inconsistent evidence on the use of RAGTT for gait and motor function on children, adolescents, and young adults with CP [18, 19]. Vezer et al (2024) in the meta-analysis that included 7 papers on CP did not show difference between RAGTT and conventional physiotherapy [5]. This raises an important question about the high cost involved with RAGTT and it may not always be justifiable [19].

A study done by Aman Reiffer (2020) reported no significant changes in motor function and walking with 15 sessions of RAGTT for children between 6 to18 years of age with level II-IV on GMFCS. This is because the participants included in this study had reached their maximal motor capabilities with early intervention programs, intensive rehabilitation and prior RAGTT [9].

Most of the studies included only children and adolescents, with a few older than 21 years [19, 20]. In a study done by Klobucka at al., for adolescents and adults with bilateral spastic CP, levels II-IV on GMFCS found statistical improvement on GMFM in RAGTT group in comparison to conventional therapy [20].

INTENSITY, FREQUENCY, DURATION AND FOLLOW UP OF RAGTT

The optimal training intensity, duration, and frequency of RAGTT sessions is an ongoing discussion among researchers and clinicians [10]. As the cost of RAGTT is very high it is important to have evidence of the optimal number of sessions required for RAGTT.

The number of sessions utilized in the current literature on RAGTT range from 12 - 40, for 3–12 weeks, with a frequency of 1–5 times per week, and session duration lasing between 20–45 minutes. The studies that have shown positive changes on gait and motor function have an average of 20 Lokomat sessions with short intervention duration of 4 weeks and high frequencies, 5 sessions per week [4, 20]. The effectiveness of therapy if repeated more than once block is still not very well understood.

Recent study by Choi at al. (2024) examined different intensities of speed and BWS on RAGTT for children on level II-III on GMFCS. With 18 sessions better results were seen on GMFM with in high-intensity (fastest walking speed and lowest BWS) and comfortable intensity (intermediate speed and intermediate BWS) when compared to low intensity group [21].

Several studies have 3–6 months follow up assessments after the RAGTT. In adolescents and adults, scores on all dimensions of GMFM were maintained 3–4 months after RAGTT [20]. Six months of sustained effects were seen in a study done by Cherni after 24 sessions of RAGTT [4].

FURTHER STUDIES

It is well known that RAGTT is considered as an adjunct therapy rather than the substitute for conventional physiotherapy [3, 21, 22]. To get precise information about the effectiveness of RAGTT, high-quality randomized studies are needed, involving larger number of participants, homogenized patient groups, research standardization, and monitoring sustainability of the effects [3, 5, 6, 18].

As there is no standardized protocol for RAGTT, determining the parameters of robotic training is an individual decision of the physiotherapist. To optimize RAGTT, guidelines for selection of parameters are essential [6] and emphasis must be placed on walking speed, body-weight support, and guidance force, that contribute to a better understanding of the effects of RAGTT and correlate the results with clinical practice [23].

Furthermore, assessments on the influence of RAGTT on functional activities, participation and quality of life need to include patient or parent-reported outcomes [5]. To what extent children improve fitness level, reduce tiredness in physical activities and decrease assistance in daily life after RAGTT is to be explored.

CONCLUSION

RAGTT is an enjoyable and safe intervention for CP children, with simultaneous motor and cognitive engagement with positive effect on motor learning and neuroplasticity.

The main goal of this paper was to synthesize and reflect on the research findings about efficiency of RAGTT on motor functions, gait speed, endurance and intensity of the sessions and sustainability of RAGTT effects.

Studies have shown that children with mild and moderate impairments improve dynamic skills such as locomotor skills, walking distance and speed. However, for those with severe impairment, improvements are seen only in rolling and sitting which might be due to better postural control.

Most of the studies used intensive training of 20 sessions as an adjunct to conventional therapy with pre, post and follow up at 3 & 6 months, demonstrating the sustained functional effects of RAGTT.

The future studies need to consider larger sample size, longer follow up and influence on participation restriction and quality of life.

Ethics: This article was written in accordance with the ethical standards of the institutions and the journal.

Conflict of interest: None declared.

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