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Strength training with stretching in children with cerebral palsy to improve gross motor skills - A literature review

Bachelor's thesis in Human Movement Science
Supervisor: Karin Roeleveld
May 2022

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Abstract

Background: Cerebral palsy (CP) is the most common cause of motor disabilities in children. Living with CP can be challenging, as it will impact gross motor skills and children's ability to participate in daily activities. Therefore, it is crucial to find training methods that can improve functional abilities, such as walking. The aim of this review investigates if a combination of strength training and stretching in lower extremities improves gross motor skills in ambulant children with CP. **Method:** The studies were found through PubMed, SPORTDiscus and Medline. Participants included, were children with CP, GMFCS level I-III, age 4-18 years. Studies had to include a training program incorporating both strength training and stretching in the lower extremities. **Results:** Eight studies were included in this review. Six of these studies showed a significant improvement on gross motor skills. All studies investigating GMFM showed significant improvements, and 3 out of 7 studies investigating gait function, indicated a significant improvement of at least 1 of the gait variables. **Conclusion:** A combination of strength training and stretching seem to improve gross motor skills in ambulant children with CP based on improved GMFM, however, the effect on gait function is ambiguous.

Abstrakt

Bakgrunn: Cerebral parese (CP) er den vanligste årsaken til motorisk funksjonshemming hos barn. Å leve med CP kan være utfordrende, da det vil påvirke grovmotoriske ferdigheter, og barns mulighet til å delta i dagligdagse aktiviteter. Derfor er det viktig å finne treningsmetoder som kan forbedre funksjonelle evner, slik som gange. Problemstillingen i denne litteraturstudien undersøker om kombinasjon av styrketrening og tøying i underekstremiteter forbedrer grovmotoriske ferdigheter hos gående barn med CP. **Metode:** Studiene ble funnet gjennom databasene PubMed, SPORTDiscus og Medline. Deltakere inkludert var barn med CP, GMFCS level I-III, alder 4-18 år. Studiene måtte inkludere et treningsprogram som bestod av både styrke og tøying i underekstremitetene. **Resultat:** Åtte studier ble inkludert i denne litteraturstudien. Seks av studiene viste en signifikant forbedring på grovmotoriske ferdigheter. Alle studiene som undersøkte GMFM viste signifikant forbedring, og 3 av de 7 studiene som undersøkte gangfunksjon, indikerte en signifikant forbedring på minst en av gangvariablene. **Konklusjon:** Det virker som at en kombinasjon av styrketrening og tøying kan forbedre grovmotoriske ferdigheter hos gående barn med CP basert på forbedret GMFM, men effekten på gangfunksjon er usikker.

1. INTRODUCTION

Cerebral palsy (CP) is the most common cause of motor disabilities in children, and the prevalence in the western part of the world is approximately 2-3 per 1000 live births (1,2). CP is defined as a *permanent dysfunction of movement and motor functions that is caused by a non progressive damage of the immature brain*, and occurs prenatally, perinatally, postnatally or within 2 years of age (1, p.223). It is not a specific condition, but rather a group of neurological disorders with multiple causes (1). Individuals can be subcategorized into different categories of CP, where spastic CP is the most prominent type, and includes approximately 80% of all cases (1). To be included in this category, spasticity must be the dominant symptom affecting the individual. Additionally, muscle weakness and reduced joint range of motion (ROM) from hyper-resistant joints are typical symptoms (3,4). In addition to the different subtypes of CP, it is recommended to classify the children's gross motor function level by the Gross Motor Function Classification System (GMFCS) (1). The GMFCS consists of levels ranging from I-V, where level I refers to individuals that can walk without limitations, whereas level V refers to those who are dependent on wheelchair transport (1).

Children with CP often have reduced gross motor skills (1), which refers to the ability to coordinate body movements involving large muscle groups to perform basic movements, such as walking (5). A reduction in gross motor skills could lead to a lack of functional capacity, such as gait limitations, which are potential barriers in physical and social activities (6). Therefore, gross motor skills would be an important focus in treatment goals for rehabilitations in children with CP. Early interventions are proven to optimize neuroplasticity and functional outcomes (7), and it is crucial to begin an early rehabilitation program to improve mobility through functional independence, because this would directly influence participation (8). It is therefore important to gain knowledge on the effectiveness of training in children.

Both strength training and stretching are used in rehabilitation interventions for children with CP to improve gross motor skills (4,9). As children with CP are proven to be significantly weaker than children with no disabilities, it is important to implement strength training to promote muscle strength (10). Achieving high levels of muscular strength will prevent chances of developing functional limitations (10). A previous concern to strength training for children with CP, is that it would aggravate spasticity (10). However, more recent studies show that there is no change in spasticity during or after training (10). Multiple types of strength training are used in study interventions, including power training and functional resistance training, and there seems to be no consensus behind which is more superior for children with CP (2,3,11–16). A recent meta-analysis (9) looked at the effects of strength training programs in children and adolescents with CP to improve function, activity, and participation. The finding suggests that a strength training program had positive functional effects on muscle strength, balance, gait speed and/or gross motor functions (9). Children with CP often have shorter muscles due to reduced longitudinal muscle growth from spasticity (4,17). Stretching is therefore used as a common conventional method of treatment through increasing range of motion (ROM), and prevent worsening of muscle contractures, and thus possibly improve gross motor skills (4). Interestingly, stretching as an isolated treatment has shown to have little to no effect on function in children with CP (4). Still, stretching are commonly used in combination with strength training (18).

Living with spastic CP can be challenging and affects participation in functional daily activities (19), and can effect children´s walking abilities. Spasticity is defined as *an inappropriate involuntary muscle activity associated with upper motor neuron paralysis* (19, p.346). The gait cycle can be interrupted by inappropriate muscle activations from being rapidly lengthened, or from increased muscle stiffness, which affects the freedom of body segments to fluently move with each other, thus limiting the gait momentum and interrupts progressive locomotion (20). Walking is therefore an important focus in treatment goals for rehabilitations in children with CP (6).

Gait is considered a general motor status (21), and important aspects of gait function are gait speed, stride length, cadence and step length (20). These variables are often used to distinguish normal and abnormal walking. An ideal gait involves high gait speed, stride length and step length, and a low cadence (20). In addition to gait, the children's functional ability to perform everyday activities, such as standing, jumping and running are important gross motor skills to consider in social participation, and should therefore be included in rehabilitation (6). Gross motor skills can be evaluated by The Gross Motor Function Measure (GMFM) and gait. The GMFM evaluates multiple aspects including walking, standing, jumping and running, and is proven to be highly effective in assessing gross motor function in children with CP (22). Higher GMFM-score indicates better function. Additionally, gait is measured by walking analysis and specific walking tests such as 6-minute walking test (6MWT) and the 1-minute walking test (1MWT) (20).

An important aim of a combined treatment is to improve effectiveness of both stretching and strength training. Strength training has potential to increase the stretching stimulus by mechanical loading the muscle resulting in additional tendon stiffness (18). This is based on the assumptions that an increased tendon stiffness can result in that the in-series sarcomeres can detect more of the tensile stimulus from passive stretching and promote fascicle length (18). This phenomenon has been shown through a randomized control trial (RCT) (18), combining resistance training with passive stretching in children with CP, and thereby provide proof of the added effectiveness for combining stretching and strength training. Additionally, an increase in fiber length is believed to allow more muscle force capacity, through more ROM (4). Another study (23) looked at passive stretching and its effect on ROM, and found that an increase in ROM was achieved after a single bout of stretching, accompanied by a longer maximal fascicle length. An increased ROM could result in the muscle being able to generate more muscle force capacity from an increase in fiber length, and thus resulting in better outcome results from strength training interventions due to better performance (4). There is therefore reason to believe that stretching as an isolated treatment, despite proven non-effective on functionality, can be effective by implementing strength training, as both can benefit each other. Also, we know strength training can improve gross motor skills in children with CP (9), however, adding stretching might improve strength performance, resulting in better strength training outcomes thus further improving gross motor skills. Therefore, the aim of this literature review is to investigate if *strength training in combination with stretching in lower extremities, improves gross motor skills in ambulant children with cerebral palsy by the measure of GMFM and gait function.* A secondary aim was to investigate whether this combination will aggravate spasticity and thus affect gross motor skills.

2. METHOD

The literature search was carried out using the databases PubMed, SPORTDiscus and Medline. The combination of keywords used were: “cerebral palsy” OR “CP” OR “child” OR “adolescent” AND “strength training” OR “stretching” OR “lower extremities” OR “power training” AND “gait” OR “GMFM”. Inclusion criteria for the chosen studies were that they were conducted on children with cerebral palsy, GMFCS level I-III and written in English. In this review, children are defined as under 18 years old. The studies needed to include a training program including both strength training and stretching in lower extremities. Since there were few studies only investigating GMFM, we chose to include studies with gait variables. The outcome measures were therefore GMFM or gait function. The gait variables were gait speed, stride length, cadence, step length and walking distance. The exclusion criteria were: 1) training programs that included aerobic exercises and 2) studies where the participants had medical treatments, such as surgery or botulinum injections 6 months before the training program.

3. RESULTS

Eight articles (2,3,11–16) concerning strength training in combination with stretching in ambulant children with CP were included in this review. See flowchart (Figure 1) for the inclusion process.

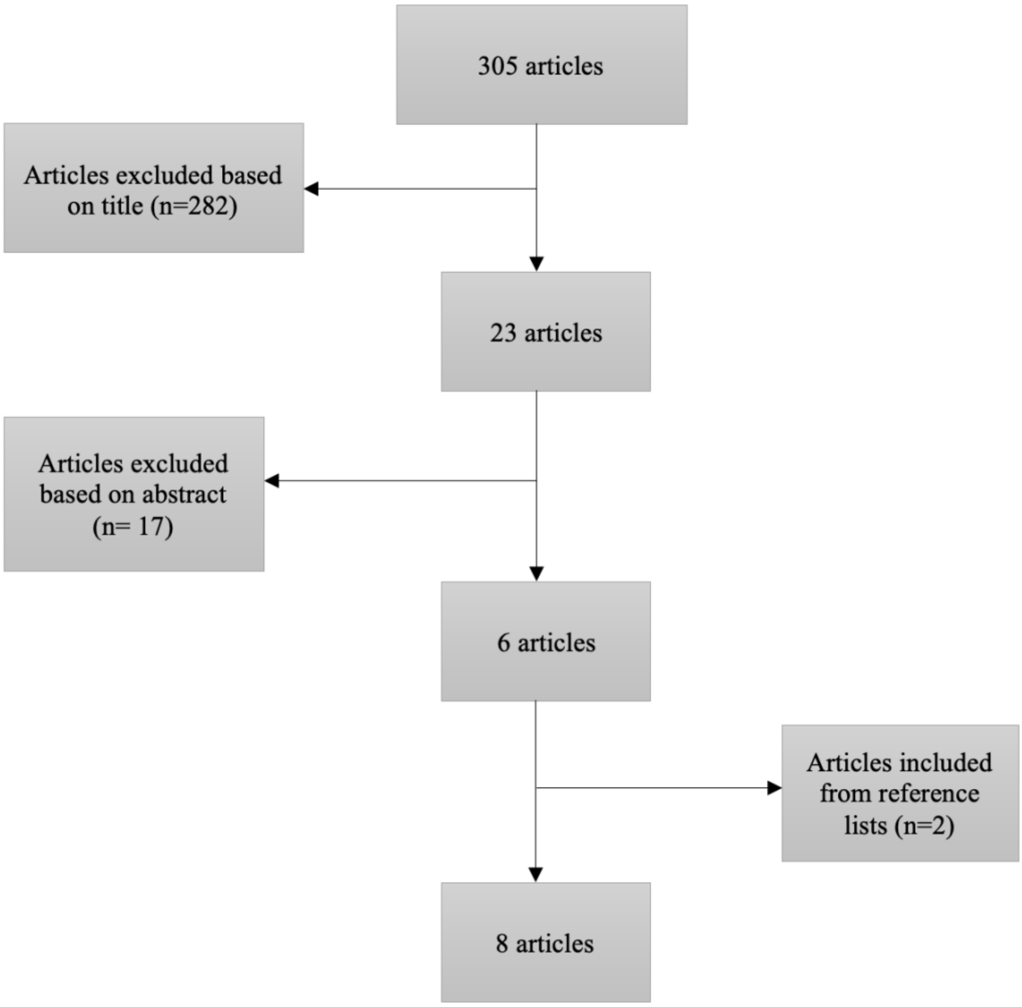

Figure 1: Flowchart of the inclusion process.

3.1 Characteristics and primary outcome measures of included studies

Children included in this review were between the age of 4-17 years. The number of children participating in each study varied from 8 to 40, with a total of 209 children. The studies were conducted in different countries: Norway, Taiwan, Sweden, Myanmar, Saudi Arabia, Turkey, and the United States of America. All the studies included both strength training and stretching of lower extremities. Six (2,3,12,14–16) looked at traditional strength training, while 2 examined power/plyometric and strength training (11,13). The duration of the interventions varied from 6-16 weeks, with 2-3 sessions per week. The stretching duration varied from 5-30 minutes, and was most common to implement in the warm-up and the cool-down. Table 1 gives an overview of the interventions in the included studies. The main outcome variables were GMFM dimensions D (standing) and E (walking, jumping, running), gait speed, stride length, cadence, step length and walking distance. The results from the studies included are presented in table 2.

Table 1: Description of the interventions from studies included in the review.

Author, (reference number), study design	**Population**	**Age (years)**	**Intervention**	**Measurement tools**	**Outcome measure**
Fosdahl, 2019 (3), RCT	Intervention group (*n*) = 17 Comparison group (*n*) = 20	7-15	Intervention: 16-week combined exercise program, 3 sessions per week. 16-week follow-up • Strength: 4 PRE exercises (multi joint with weight): squats, heel rise, step-up on chair and max. knee extension (single-joint) • Stretching: Active and passive stretching sessions on hamstrings musculature Control: Care as usual, no new treatment modalities	6MWT Step length (cm), gait speed (m/s)	Walking distance (m) Step length (cm), gait speed (m/s)
Elnaggar, 2019 (11), RCT	Intervention group (n) = 19 Control group (n) = 20	8-12	Intervention (PLYO): 16 sessions with traditional physical therapy in 8 weeks, lasted 1 hour (2 times a week). 30 min plyometric training in addition. • Plyometric training focuses on lower extremity strength training. Horizontal training paradigm: Bounding, Forward jump, counter jump, lateral leaping. Vertical training paradigm: Stride, squat, tuck, step jumping • Static and dynamic stretching 5 min warm-up. Cool-down stretch for 5 min Control (Non-PLYO): 16 sessions with traditional physical therapy in 8 weeks, lasted 1 hour (2 times a week).	3D gait analysis (motion capture system)	Gait speed (m/s), stride length (m),
Liao, 2007 (12), RCT	Intervention group (n) = 12 Control group (n) = 12	5-12	Intervention group: 6 weeks STS exercise (3 times a week, 3 sets per day) and physical therapy training. • STS exercise with weight and physiotherapy (balance, functional training, passive ROM exercises) • Warm-up stretching for 5-10 min on lower extremity muscles: hip adductors, ankle PF, hamstrings muscles and lumbar extensors. Control group: Only physical therapy training	GMFM-88 10m walk	GMFM-D and E Gait speed (m/min)
Kaya Kara, 2019 (13), RCT	Intervention group (n) = 17 Control group (n) = 16	7-16	Intervention: Functional strength training, 3 times a week for 90 minutes. 12 weeks. 36 sessions in total. • Functional progressive strength and power training program. Computer-aided horizontal leg press machine, including concentric, eccentric, and isometric muscle contractions. Muscle groups: quadriceps femoris, hamstrings, tibialis anterior and	GMFM-88 1MWT	GMFM–E Walking distance (m)

			gastrocsoleus. Plyometric exercises (power) included jumping exercises. Balance training: 1-legged standing and BOSU-ball standing. • Intervention group: dynamic stretching cool-down for 5-10 min. Control: Therapy without progressive strength training, 3 times a week for 60 min. 12 weeks		
Engsberg, 2006 (14), Pilot RCT	Intervention group (n) = 9 Control group (n) = 3	6-13	Intervention: 12-weeks strength program using an isokinetic dynamometer, 3 sessions per week. • 3 strength training programs: DF, PF and DF/PF group. Concentric and eccentric training with both slow and fast speed. • Passive stretching of ankle PF, in spasticity tests in KinCom dynamometer Control: no strength training program	GMFM-88 Surface markers, then upload to KinTrack software	GMFM-E Gait speed, cadence, stride length
Aye, 2016 (15) Intervention study	Intervention group (n) = 40 No control group	4-12	Strength training 3 times per week for 6 weeks. 1 session per training day. • Strength: Hip and knee extensors exercises with cuffs Passive stretching of hip flexors, adductors, hamstrings, triceps surae, 15 minutes in warm-up and 15 minutes in cooldown	GMFM-88	GMFM- E
Damiano, 2010 (2) Pilot prospective clinical trial	Intervention group (n) = 8 No control group	5-17	8 weeks physical therapy PRE, 3 times a week. • Therapy guided strength sessions. PRE-program using free weight or weight machine, targeting gluteus maximus and quadriceps musculature. Resisted leg press and knee extension. • Passive stretching exercises at the hip and knee for warm-up and cool-down.	3D gait analysis	Gait speed, cadence, stride length
Eek, 2008 (16) Clinical trial	Intervention group (n) = 16 No control group	10-15	Strength training for 8 weeks, 3 times a week, 1.5 hour. Stretching as part of the training session. • Strength: 3 sets and 10 reps of each lower extremity muscle group with weight, rubber bands and body weight • Stretching of muscles after training session: hamstrings, rectus femoris, PF.	GMFM-66 3D gait analysis (motion capture system)	GMFM-D and E Gait speed (m/s), stride length (m), cadence (steps/min).

Abbreviations: RCT= Randomized Control Trial, PRE= Progressive Resistance Exercises, 6MWT= Six-Minute Walking Test, PLYO = Plyometric, GMFM = Gross Motor Function Measures, 1MWT = One-Minute Walking Test, STS = Sit To Stand, ROM = Range Of Motion, DF = Dorsiflexor, PF = Plantar Flexor, DF/PF = Dorsi- and Plantar Flexor.

Table 2: Results from the studies included in this review.

Author (reference number), Study design	Outcome measure	Change within groups				Difference between groups
Fosdahl, 2019 (3), RCT		Results presented as Mean ± Standard deviation				Presented as mean difference (95% Cl) Negative prefix = best effect for intervention group. Positive prefix = best effect for control group
		Intervention		*Control*		
		Pre	Post	Pre	Post	
	Gait speed (m/s)	1.05 ± 0.2	1.1 ± 0.2	1.02 ± 0.2	0.97 ± 0.3	-0.1 (-0.2 to 0.05)
	Step length (cm)	52.7 ± 8.2	54.0 ± 9.8	51.6 ± 9.5	51.2 ± 9.8	-1.5 (-5.3 to 2.2)
	Walking distance (m)	390.5 ± 106.9	436.2 ± 114.8*	349.9 ±112.7	405.2 ±123.5*	10.6 (-29.3 to 50.6)
Elnaggar, 2019 (11), RCT		Results presented as Mean ± Standard deviation				
		PLYO		*Non-PLYO*		
		Pre	Post	Pre	Post	
	Gait speed(m/s)	1.18 ± 0.08	1.29 ± 0.06*	1.21 ± 0.09	1.25 ± 0.05*	Statistically significant difference*
	Stride length (m)	1.24 ± 0.05	1.30 ± 0.05*	1.18 ± 0.06	1.21 ± 0.06*	Statistically significant difference*
Liao, 2007 (12), RCT		Results presented as Mean				
		Intervention		*Control*		
		Pre	Post	Pre	Post	
	GMFM goal dimension score (%)	76.6	82.7	83.1	80.6	Statistically significant difference*

	Gait speed (m/min)	56.9	61.3	63.8	59.0	No statistically significant difference
Kaya Kara, 2019 (13), RCT		Results presented as Median (minimum-maximum)				Positive prefix = best effect for intervention group
		Intervention		*Control*		
		Pre	Post	Pre	Post	
	GMFM-E	94.44 (88.88-100)	97.22 (91.66-100)*	95.83 (93.05-100)	95.83 (88.88-100)	2.68*
	Walking distance – (m)	94 (80-116)	102.5 (89-118.5)*	92 (79-103)	90 (80-110)	7.23*
Engsberg, 2006 (14), Pilot RCT		Results reported as Mean ± Standard deviation				
		Intervention		*Control*		
		Pre	Post	Pre	Post	
	GMFM-WRJ (%)	65.8 ± 30.8	69.1 ± 28.4*			No data reported, but data presented as intervention study
	Gait speed (cm/s)	85.9 ± 31.1	91.0 ± 34.6	80.1 ± 23.4	78.6 ± 31.3	
	Stride length (cm)	82.6 ± 21.0	84.8 ± 21.4	80.6 ± 14.8	77.7 ± 25.8	
	Cadence (steps/min)	120.3± 36.3	124.4 ± 37.2	121.7 ± 17.9	123.1 ± 12.9	
Aye, 2016 (15), Intervention study		Results presented as Mean ± Standard deviation				
		Intervention		No control group		
		Pre	Post			
	GMFM-E	42.4 ± 19.3	54.9 ± 22.5*			

Damiano, 2010 (2), Pilot prospective		*Intervention*		No control group	No significant changes
		Pre	Post		
	Gait speed	No numbers reported			
	Stride length	No numbers reported			
	Cadence	No numbers reported			
Eek, 2008 (16), Clinical trial		Results presented as Median (range)			
		Intervention		No control group	
		Pre	Post		
	GMFM (D and E)	84.8 (66.7-100)	90.0 (67.4-100)*		
	Gait speed (m/s)	1.2 (1-1.5)	1.25 (0.9-1.6)		
	Stride length (m)	1.1 (0.9-1.4)	1.15 (0.9-1.5)		
	Cadence (steps/min)	132 (108-151)	130.5 (104-149)*		

Abbreviations: GMFM = Gross Motor Function Measure. WRJ = Walking, Running and Jumping. RCT = Randomized controlled trial.

GMFM goal dimension score (%): derived by averaging the percentage scores for dimension D and E. GMFM-WRJ(%): same as GMFM dimension E.

** = p<0.05: Statistically Significant.*

3.1.1 GMFM

All 5 studies (12–16) investigating GMFM dimension E (and in some cases dimension D) found significant improvements. The RCTs (12,13) found a significant difference between groups for GMFM, where the intervention groups had the best score, indicating improvement. Additionally, Kaya Kara et al. (13) found a positive significant change in GMFM after the intervention, whereas the control group had no significant changes. Engsberg et al. (14) found a significant increase after the intervention concerning GMFM-E. The clinical trial (16) and the intervention study (15) also found significant changes between the pre and post intervention training. Aye et al. (15) found the largest increase from 42.4 to 54.9 of the maximal score of 72 for GMFM-E, while Eek et al. (16) had an increase from 84.8 to 90.0 of the maximal score of 111 for both GMFM-D and E.

3.1.2 Gait function

Gait function was measured in several different ways: gait speed, stride length, cadence, step length and walking distance. The majority of results showed no significant improvement on gait function.

Five out of 6 studies (2,3,12,14,16) measuring gait function by using *gait speed*, found no significant differences between groups or improvement after the interventions in the non-RCTs. Only 1 study (11) found a significant difference between the intervention and the control group. Elnaggar et al. (11) found a significant change in gait speed after the intervention within both the intervention and the control group, where the intervention group had the largest improvement. The remaining 5 studies found no significant improvement within the groups for gait speed before and after the intervention. Four studies (2,11,14,16) investigating *stride length*, where 3 of the studies (2,14,16) found no significant improvements after the interventions or improvement after the interventions in the non-RCTs. Elnaggar et al. (11) was the only study that found a significant difference between the intervention and the control group. There was also a significant change in stride length after the intervention within both the intervention- and the control group, where the intervention group had a slightly larger increase than the control group. The 3 other studies found no significant improvement within the groups for stride length before and after the intervention. Two studies (14,16) investigated *cadence*, and Eek et al. (16) was the only study that found a significant reduction in cadence after the intervention. The other study, Engsberg et al. (14) found no significant changes for cadence. Fosdahl et al. (3) was the only study investigating *step length*, and found no significant difference between groups, nor a significant change in step length after the intervention within the intervention and control group.

To measure *walking distance*, Fosdahl et al. (3) used the 6MWT, whereas Kaya Kara et al. (13) used the 1MWT. Kaya Kara et al. (13) found a significant difference between the intervention and the control group, while Fosdahl et al. (3) did not. Furthermore, Fosdahl et al. (3) found a significant increase in walking distance after the intervention, within both the intervention and the control group. While Kaya Kara et al. (13) only found a significant increase within the intervention group, and not in the control group.

3.2 Secondary outcomes measures

3.2.1 Spasticity

Three studies (2,14,16) performed a spasticity test before and after their interventions. They all indicated that spasticity did not increase after their interventions.

4. DISCUSSION

Six (11-16) of 8 studies showed a significant improvement on gross motor skills by increased GMFM-score and/or increased gait function from the combination of strength training and stretching in lower extremities. Increased gait function was shown by an increase in gait speed, stride length, step length, walking distance and a reduced cadence. All 5 studies (12-16) that investigated GMFM found a significant improvement between groups (RCT) or before and after the intervention. Three (11,13,16) out of the 7 studies that investigated gait function, indicated a significant improvement of at least 1 of the gait variables. The remaining four (2,3,12,14,) found no significant improvement between groups or before and after the intervention. Although Fosdahl et al. (3) found a significant improvement within groups, the intervention and control group showed somewhat similar improvement, indicating that the intervention itself was not the determining factor for the improvement.

It should be noted that Damiano et al. (2) had no control group, which means we do not know which factors solely contribute to changes due to the intervention. Furthermore, it is important to consider that gait function can be measured by multiple variables, and varied in our study selection, making it difficult to compare the results directly.

4.1. GMFM and gait function

A recurring problem is that the majority of our studies have a shorter duration of stretching compared to strength training. Therefore, it is reasonable to assume that the strength training may have a bigger impact on the results. Due to this assumption, it is important to highlight the studies with the longest stretching sessions incorporated in their interventions, in order to make an accurate assessment of the effect from the combination as equal components.

A key finding in our review is that all the studies investigating GMFM showed a significant improvement. Due to the GMFM variable considering multiple aspects of functional domains like standing, walking, running and jumping, the increase in GMFM-scores would indicate that the children achieved a greater general functional ability, and is therefore an important variable to consider for social participation. Out of the 5 studies (12-16), Aye et al. (15) found the largest increase in GMFM-score, and had the longest stretching duration in the intervention. However, as an intervention study, they had no control group to ensure the increase was from the training intervention, and due to a lack of attendance for the follow-up assessments, it is unsure if the combination of strength training and stretching can have a long-term effect on the GMFM. Nevertheless, the overall results showing significantly increased GMFM-score, may apply that this combination in training can have an effect on the children's general functionality in gross motor skills.

All studies, except Aye et. al. (15) looked at one or more gait variables. In contrast to the GMFM variable, gait function takes multiple variables into consideration, in order to make a more complex analysis on the children’s walking ability. Only 1 (11) out of 6 found a significant increase in gait speed, 1 (11) out of 4 found an increase in stride length, 1 (16) out of 2 found a reduction in cadence and 1 (13) out of 2 found an increase in walking distance. These findings show an inconsistent tendency which makes it difficult to make a general assumption of the effect on gait function from a combination of strength training and stretching program.

Both strength training and stretching may have different effects on the gait variables. Kaya Kara et al. (13) was the only study measuring the 1MWT, where they found a significant improvement. As Merino-Andrés et al. (9) has shown that strength training can increase gait speed, this finding is not surprising, considering that participants had to walk as fast as possible within a given distance. This could indicate that an increase in muscle strength could increase both gait speed and 1MWT. Stretching could have the biggest impact on stride and step length due to the potential to increase ROM (4). It is important to notice that the studies investigating stride length either failed to specify duration, or had a maximum of 10 minutes of stretching. There is reason to believe that a longer stretching session could further improve this variable through increased ROM, due to the importance of adequate stretching to increase fiber length (4). However, Fosdahl et al. (3) had a sufficient stretching session, but the stretching only included hamstring musculature. Since gait is a complex movement involving the coordination of large muscle groups, a longer stretching duration, including multiple relevant muscle groups, could potentially lead to better outcome measures. Furthermore, it is interesting to investigate if stretching as an integrated component to strength training will further increase efficiency, through comparing the outcome results from isolated interventions. Merino-Andrés et al. (9) focused on strength training and found similar results to our findings for the GMFM-score, and thus it may seem like integrating stretching would not further improve gross motor skills. However, Merino-Andrés et al. (9) did not exclude stretching in their interventions, making it difficult to draw conclusions.

4.2 Secondary outcome

4.2.1 Spasticity

Three out of 8 studies performed spasticity tests and showed that the intervention programs did not aggravate spasticity. This finding implies that the gait cycle will not get further limited by spasticity. Additionally, as mentioned earlier spastic muscles has a negative effect on progressive locomotion due to the restricted gait momentum (20). Therefore, these non-changes indicate that gross motor skills will not be affected by spasticity in our studies. This finding is supported by previous research showing that strength training will not affect spasticity (9,10).

4.3 Methodological consideration

4.3.1 Generalizability

The studies were conducted in different parts of the world, with participants from a large age-range, making the results more generalizable. However, our study population was limited to children with CP, GMFCS level I-III, and will not be transferable for the remaining GMFCS levels. In addition, children with CP are a heterogeneous group, making it difficult to know if there are certain individuals that respond better to interventions than others. Another strength of this review is that gross motor skills were measured by valid objective measurements like

GMFM and walking analysis (20,22). Furthermore, the type of strength training varied among the studies. This makes it difficult to give specific training guidelines, as there seems to be no consensus among what type of strength training has the best effect on ambulant children with CP.

4.3.2 Training-dose relationship

An important factor to consider is the training-dose relationship among our studies. For the studies in our review the interventions varied from 6-16 weeks, 2-3 sessions per week with stretching sessions variating from 5-30 minutes. A key factor to consider is the duration of the components in the intervention in order to have an effect on the training outcome. According to a review (4), an essential part of stretching interventions is that the muscle fibers receive an adequate stretching stimulus. As mentioned earlier, a recurring problem in our studies is that several have short stretching durations in their intervention, making it difficult to know if the stretching in itself was above the minimal doses to achieve an effect combined with strength training on the outcome variables. Fosdahl et. al. (3) was the only study investigating the combination of strength training and stretching as equally important components. However, the result shows no significant differences between groups, indicating that it does not have an effect on gait function. Additionally, Aye et. al. (15) reported the longest duration of the stretching intervention, lasting for a total of 30 minutes and found a positive effect on gross motor skills by the measure GMFM-E. As there is little research on the combination of strength training and stretching, it is difficult to know the adequate training dose for optimal effects.

4.3.3 Limitations

A difficulty in the investigation of an intervention in children is the change in growth. The physiological changes are at its peak within this age range (4-17 years), and could be a possible confounder, in which it could impact their strength and coordination. No studies have adjusted for this. This highlights the importance of a control group, which makes RCTs a more fitting study design for this population group. Only 1 (2) out of 3 non-RCTs seem to consider growth as a precipitating factor, although all 3 studies are prone to this factor impacting their results. Another impacting factor is the additional training. Kaya Kara et al. (13) had an intervention that consisted of balance in addition to the combination of strength training and stretching, and this may alter the results. Additionally, our study selection was limited by little research incorporating the combination of strength training and stretching, and this could problematize finding studies with large sample sizes. The studies with large sample sizes (11,15) both found significant changes in the variable measured, and their findings are therefore important to highlight. Lastly, we only included articles published in English, and therefore articles written in other languages might have gone unnoticed.

4.3.4 Future research

More research combining strength training and stretching as equal components in large muscle groups, is needed to evaluate its effect on gross motor skills. Studies should aim to include large sample sizes, investigating comparable variables that we know are effective in assessing gross motor skills, such as common gait variables and GMFM, in the form of RCTs. Researchers should consider potential confounders, like additional training and children's growth spurts. More research at sarcomere-level is needed to see if this combination could alter muscle architecture for children with CP (4). Furthermore, future research should assess the impact and doses of each component when combining strength training and stretching in children with CP.

5. CONCLUSION

In conclusion, a combination of strength training and stretching in lower extremities seem to improve gross motor skills in ambulant children with CP, without aggravating spasticity. This is based on a significant improvement in the GMFM-score, and non-changes in spasticity measurements. However, due to inconsistent results from the gait analysis, the effect on gait function specifically is ambiguous. Although the combined strength training and stretching seems effective on improvement in GMFM, this review cannot conclude on its effect on gait function.

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