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A comparison of strength training to standard care at Khayelitsha Special School in improving motor function and strength in ambulatory children with cerebral palsy

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Title: A comparison of strength training to standard care at Khayelitsha Special School in improving motor function and strength in ambulatory children with cerebral palsy

Clinical scenario: I am a DPT student who is doing a clinical internship at Khayelitsha Special School, a school in a South African township for children with learning disabilities. There are many ambulatory children with cerebral palsy (CP) at the school who are either receiving no physical therapy interventions or are only given stretching and range of motion exercises for treatment. I would like to know if these children could make strength gains and improve motor function if their treatment included a lower extremity strengthening program.

Clinical question: Can lower extremity strengthening exercises increase strength and improve motor function, particularly gait, in ambulatory children with CP?

Clinical PICO:
P: South African children ages 7 - 18 with CP
I: Lower extremity strengthening exercise
C: Stretching or no intervention
O: Gross Motor Function Measure (GMFM), various strength measurements

Overall Clinical Bottom Line: Based on the studies done by Dodd et al. and Lee et al., there are mixed results as to whether exercise programs focused on lower extremity strengthening significantly improve strength and motor function in children with cerebral palsy. Dodd et al. found no effect of a home-based strengthening exercise program on subjects' GMFM scores or the strength of ankle plantarflexors, knee extensors, hip extensors and total extensors. The authors did find a significant increase in combined ankle plantarflexor and knee extensor strength. Lee et al. found that a strengthening physical therapy program resulted in increased GMFM D and E scores, increased hip extensor strength, increased gait speed, increased stride length and decreased double support in ambulation. By contrast, no effect on total GMFM score, strength of other lower extremity muscles, or cadence and single support in ambulation was found. The fair internal validity of the studies, use of subjects from areas other than South African townships, and use of subjects without learning disabilities limited the generalizability of these results to my patient population. More research needs to be done to determine the effectiveness of strengthening exercise in increasing strength and improving motor function in ambulatory school-age children with cerebral palsy. Future research should include larger study populations for adequate power, exercise programs that can be implemented in a school setting, a focus on determining if there is a difference in effectiveness between individual therapy, group therapy, or home exercise, as well as exploring exercise protocols that can be done with children with intellectual disabilities.

Search terms: cerebral palsy, gait, strength training, strengthening

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Rationale for chosen articles: Articles chosen for this CAT were found by searching the PEDro and CINAHL databases with terms listed above. I selected the following se three articles based on their similarities to my own PICO and clinical question. I also took into account the quality of research based on PEDro scores that I calculated for each article. The subjects of each article were ambulatory children with CP who fall within the age range of the patient population I work with at my clinical setting. All three chosen articles utilized a strength training intervention. Different outcome measures were used, but each study included at least one measurement of strength. Only the studies by Dodd et al. and Lee et al. include the GMFM as an outcome measurement, whereas the study by Damiano et al. used gait analysis parameters as the primary outcome measure.

I calculated the PEDro scores for each study. The studies by Dodd et al. and Lee et al. scored 8/10 and 7/10 respectively and both were randomized control trials. The study by Damiano et al. only scored 3/10. The primary limitation to this study was the lack of a control group. With no control group the study was unable to include random allocation, blinding, or a between-group comparison. Another limitation to the Damiano et al. study was the small number of subjects. There were only eight subjects in the Damiano et al. study, while there were 22 subjects in the Dodd et al. study and 17 subjects in the study by Lee et al.

Damiano DL, Arnold AS, Steel KM and Delp SL. Can strength training predictably improve gait kinematics? A pilot study on the effects of hip and knee extensor strengthening on lower-extremity alignment in cerebral palsy. *Physical Therapy* 2010; 90(2):269 – 279.

> PEDro score: 3/10
>
> P: Children with spastic diplegic cerebral palsy (CP), ages 5.5 to 13.4 years, levels I to III on the Gross Motor Functional Classification System (GMFCS)
> I: 8-week community-based progressive resistance exercise program led by a physical therapist 1 hour three times per week
> C: None
> O: 3 dimensional gait analysis, isokinetic testing, passive range of motion (PROM), Ashworth Scale, and the Peds QL CP module.

☐ Dodd KJ, Taylor NF, Graham HK. A randomized clinical trial of strength training in young people with cerebral palsy. *Developmental Medicine & Child Neurology* 2003; 45: 652 – 657.

PEDro score: 8/10

P: Children with spastic diplegia, 8 to 18 years, Levels I to III on the GMFCS
I: Home-based strength training program performed three times per week for six weeks, including three physiotherapy visits.
C: Usual care including typical physiotherapy program excluding progressive resistance strength training.
O: Hand-held dynamometer strength test, dimensions D and E of the GMFM, timed stair test, and self-selected walking speed.

☐ Lee JH, Sung IY, Yoo JY. Therapeutic effects of strengthening exercise on gait function of cerebral palsy. *Disability and Rehabilitation* 2008; 30(19):1439-1444.

PEDro score: 7/10

P: Children with spastic diplegic or hemiplegic CP, ages 4 to 12 years, level II or III on the GMFCS
I: Five week strengthening program including one hour sessions three times per week.
C: Five weeks of conventional physical therapy including Neurodevelopmental Therapy (NDT), range of motion (ROM), not indicated by authors whether passive or active, and gait training.
O: Modified Ashworth Scale (MAS), Manual Muscle Test (MMT), GMFM, timed lateral step ups and squat to stand, three dimensional gait analysis

Comparison of PEDro scores:

	Damiano et al.	Dodd et al.	Lee et al.
Random Allocation	0	1	1
Concealed Allocation	0	1	1
Baseline Similarity	1	1	1
Subject Blinding	0	0	0
Therapist Blinding	0	0	0
Assessor Blinding	0	1	0
Outcomes from 85% of subjects	1	1	1
Intention to treat	1	1	1
Between-Group Comparison	0	1	1
Point Measure and Measure of Variability	1	1	1
Total Points	3/10	8/10	7/10

Article 1: Dodd KJ, Taylor NF, Graham HK. A randomized clinical trial of strength training in young people with cerebral palsy. *Developmental Medicine & Child Neurology* 2003; 45: 652 – 657.

Clinical Bottom Line: Based on the results of this study, there is fair evidence to suggest that for school-age children with spastic diplegic CP an intervention of a home-based lower extremity strength training program can increase combined plantarflexor and knee extension strength. The exercise sessions for the intervention group consisted of three sets of ten heel raises, half squats and step ups, three times per week for six weeks. The results showed no statistical difference between groups in GMFM scores, plantarflexor strength, knee extension strength, hip extension strength or total extension strength. The exercise group did have a significant increase in comparison to the control group for combined knee extensor and plantar flexor strength from baseline to 6 weeks (p = 0.046) to 18 weeks (p=0.041). Threats to internal validity included small sample size, lack of subject or therapist blinding, and lack of control for physical activity and physiotherapy outside of the intervention. This would be a feasible treatment option if the cost of equipment was covered and parents would insure their child's adherence to the home program. The primary differences between subjects in the study and our clinical patient population are cultural and socioeconomical. To be more confident applying this intervention to our patient population I would like to see further studies using a larger sample size and a patient population located in a South African township.

Article PICO:

P: Children (n=21) with spastic diplegia, 8 to 18 years, who can walk independently with or without an assistive device (GMFCS Levels I to III)

I: Home-based strength training program performed three times per week for six weeks, including three physiotherapy visits.

C: Usual care including normal physiotherapy program excluding progressive resistance strength training.

O: Hand-held dynamometer strength test, dimension D and E of the GMFM, timed stair test, and self-selected walking speed.

Blinding: The assessor was blinded in this study. There was no blinding of subjects or therapist. The blinding of therapist is not possible as they were providing the intervention program to the subjects. Lack of subject blinding is not a serious threat due to the fact that cerebral palsy is a non-progressive neurodevelopmental condition, in which impairment level changes do not occur in such a short time duration. I do not consider the lack of therapist and subject blinding a serious threat to internal validity.

Controls: The control group received no specific intervention as part of the study. Both the control and intervention group were allowed to continue with normal sports activities and physical therapy program as long as it did not include progressive resistance exercises. Though the authors assumed the amount of sports and physiotherapy typically received by the subjects would not lead to strength gains, this poses a potential threat to confound the results of the study, especially if subjects are engaging in different amounts of physical activity throughout the time of the study. On the other hand the control group did not receive a specific strength training program, so differences in strength gains between groups can most likely be attributed to the strength training intervention.

Randomization: Subjects were assigned to groups using randomization and concealed allocation. At baseline both groups were similar in age, sex, height and weight. There were no significant differences between groups in strength and activity outcome measures. There was a non-significant trend for the experimental group to have greater physical disability at baseline according to the GMFCS. All subjects were rated as level I, II or III according to the GMFCS. Fifty-eight percent of the subjects in the experimental group were at level III, while only 20 percent of the subjects in the control group were measured as level III. With no significant differences between groups at baseline the randomization can be considered successful.

Study: The study was a randomized control trial with 10 subjects in the control group and 11 subjects in the treatment group. Inclusion criteria comprised of being diagnosed with spastic diplegic CP, being between eight and eighteen years of age, able to walk independently with or without an assistive device, have no flexion deformity at the knee or hip greater than 25 degrees or plantarflexion greater than ten degrees, no serial casting, botulinum toxin, or orthopedic surgery within the past twelve months, and no participation in a strength training program within the past three months. Both groups were given instructions to continue with normal physical activity including sports and

physical therapy as long as it did not include strength training. The control group was given no additional intervention. The treatment group was given a six week home exercise program including heel raises, half squats and step-ups with a weighted backpack. A physical therapist adjusted the weight in the first session and at the end of the second and fourth week. The subjects completed three sets of eight to 10 repetitions of each exercise three times per week.

Outcome measures: Outcomes were measured immediately before and after the six week intervention period and 18 weeks after the start of the exercise program. The outcome measures most relevant to my clinical PICO were strength and GMFM scores. The isometric strength of ankle plantarflexors, knee extensors and hip extensors were measured using a hand-held dynamometer. Combined score of ankle plantarflexors and knee extensors as well as total extensors were also calculated. Two sections of the GMFM were scored to measure functional ability: dimension D for standing activities and dimension E for walking, running and jumping activities. The combined score of these two sections was also calculated.

The authors cited articles by Riddle et al. (1989) and Damiano et al. (1995), stating that handheld dynamometry is a reliable tool for measuring isometric strength and detecting change in strength for children with spastic diplegic CP. This type of measurement was found to have excellent test-retest reliability in people with neurological dysfunction with an ICC of 0.84 to 0.99 (Bohannan 1986). Though computerized isokinetic dynamometers are considered the gold standard for strength assessment, an evidence review by Stark et al. (2011) found hand-held dynamometry to be a valid and reliable instrument for measuring muscle strength. Stark et al. did find hand-held dynamometry to be less reliable when measuring large muscle joints, giving the knee as an example. Russell and al. (2003) report the GMFM is reliable and valid for children ages 5 months to16 years old with CP whose gross motor function is at or below that of a typically developing five year old.

Study losses: All 11 subjects in the intervention group completed the study. There was one study loss of the control group between the six-week measure and the 18-week follow-up measure. The loss was a withdrawal due to surgery and did not appear to be related to the study. There was no intention-to-treat analysis performed. All subjects were analyzed in the group to which they were randomized.

Summary of internal validity: The internal validity of this study was fair, with one major threat and two minor threats. The major threat to the study was inadequate power due to the small sample size of 21. Although the authors did a power analysis of 0.80 at an effect size of d = 1.20 for the calculated sample size of n=11, there were only 10 subjects in the control group and only 9 for the 18-week follow-up measurements. Also in the outcome reports the authors mention several instances where significant results may have been obtained with a larger sample size. A minor threat was that subjects could not be blinded to whether or not they received the treatment, and similarly, clinicians could not be blinded to whether or not they were giving the treatment. This could

possibly have interfered with performance if subjects' knowledge of their group assignment affected their performance, but this is less likely with a non-progressive neurological condition such as cerebral palsy. The final minor threat is that there was no control for the subjects' daily activity level and physiotherapy treatment excluding strength training. This makes it more difficult to determine if increases in strength were solely due to the intervention.

Evidence: The evidence most applicable to my clinical question is the results from the isometric strength testing and the GMFM prior to the intervention, after the 6 week intervention, and at the 18-week follow up. The authors reported the means and standard deviations for each group for strength and GMFM scores. The data was analyzed the data using a mixed group design.

Results of the lower limb strength assessment were only significant for combined plantarflexor and knee extensor strength, in favor of the experimental group. The authors report a significant difference in combined knee extensor and plantarflexor strength increase from baseline to 6 weeks at $p = 0.046$, and from baseline to 18 weeks at $p=0.041$. There was no significant difference between improvement of the control versus intervention group in ankle plantarflexors, hip extensors, knee extensors or total extensor strength. Further analysis of the results for combined plantarflexor and knee extensor strength are shown in the Tables 1 and 2 below. The data is presented as between group comparison and within group comparison, because further analysis on the mixed group comparison design used by the authors is not possible.

Table 1. Between group of combined plantarflexor and knee extensor muscular strength differences at baseline, 6 and 18 week follow-up.

Time of Measurement	Baseline	6 week	18 week
Mean difference Experiment – Control (95% CI)	-2.6 kg (-17.53 to 22.73)	3.3 kg (-18.12 to 24.72)	10.3 kg (-9.95 to 30.55)
Effect Size (95% CI)	0.12 (-0.74 to 0.98)	0.14 (-0.71 to 1.00)	0.48 (-0.41 to 1.38)

Table 1 above shows the between group calculations I performed using the means and standard deviations reported by the authors for handheld dynamometry assessment of combined plantarflexor and knee extensor strength. The mean difference between the experimental group and control group increased from -2.6 kg at baseline to 10.3 kg at 18 weeks, indicating a trend for the experimental group to have greater strength than the control group after the intervention. This trend is also demonstrated by the increasing effect size from baseline to the 18 week assessment. The large 95% confidence interval of each of the mean differences range from negative to positive, which means that in some instances if the study were repeated the control group would have greater strength after the intervention than the intervention group. The baseline between group effect size

was small at 0.12. This is expected as the authors reported no significant baseline differences between groups. At 6 weeks the effect size remained small, with a slight increase to 0.14. The greatest between-group effect was at the 18 week follow-up. There was a medium effect size of 0.48, showing the difference in strength between groups was greatest at the 18 week assessment. There was large confidence interval for each effect size, which included a negative effect size. This shows if the study was repeated there is a chance there would be no difference between groups.

Table 2. Within group of combined plantarflexor and knee extensor muscular strength differences at 6 and 18 week follow- up.

Within group change	6 week - Baseline		18 week - Baseline	
	Experiment	Control	Experiment	Control
Mean difference (95% CI)	5.7 kg (-16.35 to 27.75)	-0.2 kg (-18.87 to 19.27)	10.7 kg (-11.26 to 32.66)	-2.2 kg (-15.15 to 19.55)
Effect Size	0.25	0.01	0.46	0.11

Table 2 above shows the within group calculations performed using the means and standard deviations reported by the authors for handheld dynamometry assessment of combined plantar and knee extensor strength. At 6 weeks the experimental group improved strength by an average of 5.7 kg, while the control group decreased strength by 0.2 kg. After 18 weeks the experimental group had improved strength by 10.7 kg, while the control group had decreased by 2.2 kg. The confidence intervals for all mean differences ranged from negative to positive numbers indicating the chance that upon repeating the experiment results could have been in favor of the control group. The control group had a small effect size of 0.01 and 0.11 for the change from baseline to 6 weeks and 18 weeks respectively. The experimental group had a medium effect size of 0.25 and 0.45 for the change from baseline to 6 weeks and 18 weeks respectively. These results indicate a trend for the intervention to result in an increase in strength, not found in the control group.

The authors reported no significant differences in change of GMFM scores between the two groups. They performed a mixed group analysis of the GMFM scores for dimension D, dimension E, and total. Although there was no statistically significant results, the authors report a trend for the experimental group to increase the GMFM dimension E score more than the control group over the first six weeks at $p=0.07$. They stated that if the sample size had at least been n=26, there would have been an 80% chance this difference would reach statistical significance.

Applicability of study results:

Benefits vs. Costs: The strength assessment using hand-held dynamometry showed a significant group by time interaction in favor of the experimental group for combined plantarflexor and knee extensor strength in response to the home strength training

program. This was the primary benefit found by the authors. Even though separate measurments of plantarflexor and knee extensor strength were not large enough to be significant, when combined there was enough of a difference to be significant. Detecting this change is important because these muscles work together in functional activities such as sit to stand or ambulation to control knee extension in concert with plantarflexion and hip extension. This coordinated motor control is lacking in many children with CP. There was no significant difference between groups for the other strength measurements or the GMFM scores. It is unclear if this is due to ineffectiveness of the intervention, or other limitations of the study, particularly the small sample size. The intervention used would be a relatively low cost option for patients. The primary costs would be the patient's time, which would include 3 exercise sessions per week, the cost of the physical therapist initial session and one monitoring session every 2 weeks, as well as the financial cost of the backpack and weights. Though it did not cause any subjects to miss a session, there were three mild adverse events due to the intervention. One subject complained of pressure on the back from the weighted backpack. Replacing the backpack with a vest with pockets for the weights alleviated this problem. Two subjects complained of foot pain with heel raises. The pain was relieved by modifying the exercise so the subjects did not exceed a plantargrade position of the ankle in dorsiflexion.

Feasibility of treatment: This home exercise program could be feasible in the setting of Khayelitsha Special School. The child's progress could be monitored and modified as needed at school. The primary limitations to the feasibility of treatment would be program adherence and cost of equipment. Although the backpack and weights are relatively inexpensive, this could be a challenge for families living in low social economic status. Either outside funding would need to be obtained to cover the equipment or therapists and families would need to work together to fabricate weights out of easily accessible materials. The exercises are simple, but because the students I work with are all learning disabled, close monitoring by parents or another primary caregiver would be needed for program adherence. Within the study there was good adherence to the home exercise program with subjects completing a mean of 16.8 (SD 2.4) out of the scheduled 18 exercise sessions. Caregivers in low socioeconomic status most likely have more daily stressors and less education than the parents of the subjects in the study, who were recruited from an outpatient gait laboratory in Australia, therefore adherence to the program may be more difficult in my clinical setting.

Summary of external validity: The fair internal validity somewhat compromises the ability to generalize the results of this study, primarily the inadequate power and the inability to control for physical activity and physiotherapy outside the intervention. Subjects were similar to those who may be treated at Khayelitsha Special School in their age range and condition. The primary limiting factor to extrapolating the results of the study to the students at Khayelitsha Special School is the socioeconomic and cultural differences between the two populations.

Article 2: Lee JH, Sung IY, Yoo JY. Therapeutic effects of strengthening exercise on gait function of cerebral palsy. *Disability and Rehabilitation* 2008; 30(19): 1439-1444.

Clinical Bottom Line: Based on the results of this study, there is fair evidence to suggest that for school-age children with spastic diplegic or hemiplegic CP, an intervention of a lower extremity strength training program can increase hip extensor strength, GMFM D and E scores, and gait parameters of gait speed, stride length, and percent of double support. The exercise sessions for the intervention group consisted of an hour session including warm up stretching exercises, squat to stand, lateral step up, stair walk, lower extremity isotonic exercises, stationary bicycling, and a cool down exercise. This was done three times per week for five weeks. The exercise group demonstrated a significant improvement in comparison to the control group for hip extension strength, gait speed, stride length, and double support from baseline to 5 weeks ($p < 0.05$) and to 6 week follow-up ($p < 0.05$). Statistically significant improvement in the GMFM D and E only occurred from baseline to 5 weeks ($p < 0.05$) Threats to internal validity included small sample size and lack of subject, therapist, or assessor blinding. This would be a feasible treatment option if there was funding for equipment and time available in the school schedule for three hours of therapy per week. The primary differences between subjects in the study and our clinical patient population are cultural and socioeconomical. To be more confident applying this intervention to our patient population I would like to see further studies using a larger sample size and a patient population located in a South African township.

Article PICO:

>P: Children with spastic diplegic or hemiplegic CP, ages 4 to 12 years, level II or III on the GMFCS
>I: Five week strengthening program including one hour sessions three times per week
>C: Five weeks of conventional physical therapy including Neurodevelopmental Therapy (NDT), range of motion (ROM), not indicated by authors whether passive or active, and gait training
>O: Modified Ashworth Scale (MAS), Manual Muscle Test (MMT), GMFM, timed lateral step ups and squat to stand, three dimensional gait analysis

Blinding: There was no blinding of subjects, therapists or assessors. The blinding of therapists was not possible as they were providing the intervention program for the subjects. Lack of subject blinding is not a serious threat due to the fact that cerebral palsy is a non-progressive neurodevelopmental condition, in which impairments would not be expected to change within the time duration of this study. The lack of blinding, particularly of the assessor, presents a threat to the internal validity of the study.

Controls: The control group received conventional physical therapy for 5 weeks. This is described by the authors to include NDT, ROM exercises (unspecified as passive or active) and gait training. The authors do not clarify the frequency and duration of these sessions. Ideally the standard physical therapy sessions were given for the same frequency and duration as the strengthening program done by the experimental group. This is an adequate control as any additional strength gains made by the experimental group can be attributed to the strengthening program versus standard physical therapy.

Randomization: Subjects were assigned to groups using randomization and concealed allocation. At baseline both groups were similar in age, sex, and type of CP. The authors did not report any significant differences between groups in baseline outcome measures.

Study: This study was a randomized controlled trial with 9 subjects in the treatment group and 8 subjects in the control group. Inclusion criteria comprised of having a diagnosis of spastic diplegic or hemiplegic CP and scoring level II or III on the GMFCS. Exclusion criteria included being unable to follow therapists' commands, a fixed contracture at the knee or hip greater than 25 degrees, past orthopedic surgery of the lower extremity, past injection of an antispastic drug, and any disease that prevented exercise. Subjects in the treatment group participated in a five week strengthening program for the lower extremities. The sessions took place three times per week, each session lasting one hour. The program included a warm up stretching exercise, squat to stand, lateral step up, stair walk, lower extremity isotonic exercises, stationary bicycling, and a cool down exercise. The isotonic exercise consisted of two sets of ten for each muscle group using a weighted cuff for resistance. The authors did not describe the specific exercises done to target each lower extremity muscle group. The therapist selected the appropriate weight for resistance. The control group received five weeks of standard physical therapy including NDT, ROM exercises and gait training.

Outcome Measures: Outcome measures were taken at baseline immediately after the five week intervention and six weeks after the intervention. The outcome measures most relevant to my clinical question were muscle strength, GMFM scores, and linear gait parameters. The isometric strength of hip flexors, hip abductors, hip extensors, hip adductors, knee flexors, and knee extensors where measured using manual muscle testing. Two sections of the GMFM were scored to measure functional ability: dimension D for standing activities and dimension E for walking, running and jumping activities. The GMFM total was also calculated. Gait parameters included speed, stride length, cadence, percent of single limb support and percent of double limb support.
In a literature review by Cuthbert and Goodheart (2007), MMT was found to be reliable with inter-rater reliability ranging from 82 to 97 percent and test-retest reliability ranging from 96 to 98 percent. There was also good concurrent validity between handheld dynamometry and MMT. The MCID for the MMT was reported to be one full grade. Givon (2009) points out limitations to using MMT with a cerebral palsy population, including inability of the subject to isolate one muscle group, co-contraction of agonist and antagonist, and unintended stretch reflex. Givon points out computerized isokinetic machines are the gold standard for strength measurement because they provide good stabilization of the patient, accurate and repeatable measurement, and no examiner bias.

Gait parameters have face validity for demonstrating improved motor function. Sorsdahl et al. (2008) found good test-retest reliability for stride length, cadence and single limb support time in children with CP, with an ICC between 0.73 and 0.95. Russell et al. (2003) report the GMFM is reliable and valid for children ages 5 months to16 years old with CP whose gross motor function is at or below that of a typically developing five year old.

Study losses: There were no study losses, and outcomes were assessed for all subjects at each time point. There was no need for an intention to treat to analysis.

Summary of internal validity: The internal validity of this study was fair, with two major threats and one minor threat. The major threat to the study was inadequate power due to the small sample size of 17. The authors did not report a power analysis. Another major threat was no blinding of assessors. This could lead to assessor bias in outcome measures. Also the authors did not specify who did the assessments and if they were independent of the therapist and researchers. A minor threat was that subjects could not be blinded to whether or not they received the treatment, and similarly, clinicians could not be blinded to whether or not they were giving the treatment. This could possibly have interfered with performance if subjects' knowledge of their group assignment affected their performance, but this is less likely with a non-progressive neurological condition such as cerebral palsy.

Evidence: The evidence most applicable to my clinical question is the results from the MMT, GMFM, and linear gait parameters prior to the intervention, after the 5 week intervention, and at the 6-week follow up. The authors reported the means and standard deviations for the control and intervention group for each of these outcome measures. The data was analyzed using a mixed group design.

Results of the lower limb strength assessment were only significant for hip extension, in favor of the experimental group. The authors reported a significant difference in hip extension strength increase from baseline to 5 weeks at $p < 0.05$, and from baseline to 6 week follow-up at $p < 0.05$. There was no significant difference between improvement of the control versus intervention group in hip flexion, hip abduction, hip adduction, knee flexion, and knee extension strength. Further analysis of the results for hip extension strength is shown in the Tables 2 and 3. The data is presented as between group comparison and within group comparison, because further analysis on the mixed group comparison design used by the authors is not possible.

Table 2. Between group of hip extension muscular strength differences at baseline, 5 weeks and 6 week follow-up.

Time of Measurement	Baseline	5 week	6 week follow-up
Mean difference Experiment – Control (95% CI)	0.1 (-0.78 to 0.98)	0.4 (-0.48 to 1.28)	0.5 (-0.38 to 1.38)
Effect Size (95% CI)	0.12 (-0.84 to 1.07)	0.47 (-0.50 – 1.43)	0.59 (-0.39 to 1.56)

Table 2 above shows the between group calculations I performed using the means and standard deviations reported by the authors for MMT of hip extensor strength. The mean difference between the experimental group and control group increased from 0.1 at baseline to 0.5 at the 6 week follow-up, indicating a trend for the experimental group to have greater strength than the control group after the intervention. This trend is also demonstrated by the increasing effect size from baseline to the 6 week follow-up assessment. The baseline between group effect size was small at 0.12. This is expected as the authors reported no significant baseline differences between groups. At 5 weeks there was a medium effect size of 0.47. The greatest between-group effect was at the 6 week follow-up. There was a large effect size of 0.59, showing the difference in strength between groups was greatest at the follow-up assessment. There was a large confidence interval for each effect size and mean difference, including a negative number. This shows if the study was repeated there is a chance there would be no difference between groups.

Table 3. Within group of hip extensor muscular strength differences at 5 and 6 week follow- up.

Within group change	5 week - Baseline		6 week follow-up - Baseline	
	Experiment	Control	Experiment	Control
Mean difference (95% CI)	0.3 (-0.42 to 1.02)	0.0 (-1.01 to 1.01)	0.4 (-0.32 to 1.12)	0.0 (-1.06 to 1.06)
Effect Size (95% CI)	0.43	0	0.57	0

Table 3 above shows the within group calculations performed using the means and standard deviations reported by the authors for manual muscle testing at 5 weeks immediately post intervention and 6 weeks post intervention. At 5 weeks the experimental group manual muscle test scores increased an average of 0.3, while the control group had no change in the mean score. After 6 weeks the experimental group had improved mean manual muscle test score by 0.4, while the control group still had no change in the mean score. The confidence intervals for all mean differences ranged from negative to positive numbers indicating the chance that upon repeating the experiment results could have been in favor of the control group. The control group had an effect

size of 0 for the change from baseline to 5 weeks and the 6 week follow-up. The experiment group had a medium effect size of 0.43 from baseline to 5 weeks and a large effect size of 0.57 for the change for baseline to the 6 week follow-up. These results indicate a trend for the intervention to result in an increase in strength, not found in the control group.

Results of the GMFM scores were only significant for GMFM section D and E immediately after the intervention, in favor of the experimental group. The authors report a significant difference in the GMFM D and E scores increase from baseline to 5 weeks at $p < 0.05$, and from baseline to 6 week follow-up at $p < 0.05$. There was no significant difference between improvement of the control versus intervention group for the GMFM total score, or the GMFM D and E at the 6 week follow-up. Further analysis of the results for GMFM D and E are shown in Table 4. The data is presented as a within group comparison, because further analysis on the mixed group comparison design used by the authors is not possible.

Table 4. Within group of GMFM D and E score differences at 5 weeks

Within group change (5 week – baseline)	GMFM D		GMFM E	
	Experiment	Control	Experiment	Control
Mean difference (95% CI)	0.2 (-25.95 to 26.35)	0.1 (-35.96 to 35.96)	1.1 (-35.07 to 37.27)	0.4 (-35.61 to 36.41)
Effect Size	0.01	0.00	0.03	0.01

Table 4 above shows the within group calculations performed using the means and standard deviations reported by the authors for the GMFM D and E at 5 weeks immediately post intervention. At 5 weeks the experimental group's GMFM D mean score increased 0.2, and the control group's mean score increased by 0.1. At 5 weeks the experimental group's GMFM E mean score increased 1.1, and the control group's mean score increase by 0.4 The large confidence intervals for all mean differences ranged from negative to positive numbers indicating the chance that upon repeating the experiment results could have been in favor of the control group. The control group had an effect size of 0 for the GMFM D and a small effect size of 0.01 for the GMFM E. The experiment group had a small effect size of 0.01 for the GMFMD and 0.03 for the GMFM E. These results indicate a weak trend for the intervention to result in a slightly greater increase in GMFM D and E scores strength than the control group.

Results of the linear gait parameter measurements were significant for speed, stride length and double support, in favor of the experimental group. The authors reported a significant difference in the change of these parameters from baseline to 5 weeks at $p < 0.05$, and from baseline to 6 week follow-up at $p < 0.05$. There was no significant difference between improvement of the control versus intervention group for cadence or single support. Further analysis of the results for speed, stride length, and double support is shown in the Table 5. The data is presented as a within group comparison, because

further analysis on the mixed group comparison design used by the authors is not possible.

Table 5. Within group of gait speed, stride length, and double support score differences at 5 weeks and 6 week follow-up.

Within group change	Speed (cm/s)		Stride Length (cm)		Double Support (%)	
	Experiment	Control	Experiment	Control	Experiment	Control
5 week - baseline Mean difference (95% CI)	19.9 (-15.77 to 55.57)	-1.6 (-43.96 to 47.16)	17.5 (-7.25 to 42.25)	-1.7 (-27.47 to 30.87)	-6.2 (-6.54 to 18.94)	3.3 (-17.43 to 24.03)
5 week - baseline Effect Size	0.65	0.04	0.80	0.05	0.52	0.19
6 week follow-up - baseline Mean difference (95% CI)	23.5 (-11.76 to 58.76)	-2.0 (-40.64 to 44.64)	21.4 (-4.03 to 46.83)	1.3 (-28.27 to 30.87)	-3.9 (-8.51 to 16.31)	3.9 (-13.01 to 20.81)
6 week follow-up - baseline Effect Size	0.77	0.05	0.98	0.04	0.33	0.22

Table 5 above shows the within group calculations performed using the means and standard deviations reported by the authors for gait speed, stride length and double support percent at 5 weeks immediately post intervention and 6 weeks post intervention. At 5 weeks the mean experimental group gait speed increased 19.9 cm/s with a large effect size of 0.65. The mean control group gait speed decreased 1.6 cm/s with a small effect size of 0.04. After 6 weeks the experimental group improved mean gait speed by 23.5 cm/s with a large effect size of 0.77. The mean control group gait speed decreased 2.0 cm/s with a small effect size of 0.05. These results indicate the intervention resulted in an increase in gait speed, versus a decreased gait speed for the control group. At 5 weeks the mean experimental group stride length increased 17.5 cm with a large effect size of 0.80. The mean control group stride length decreased 1.7 cm with a small effect size of 0.05. After 6 weeks the experimental group improved mean stride length by 21.4 cm with a large effect size of 0.98. The mean control group stride length increased 1.3 cm with a small effect size of 0.04. These results indicate the intervention resulted in an increase in stride length, not found in the control group. At 5 weeks the mean experimental group double support decreased 6.2 percent with a medium effect size of 0.52. The mean control group double support increased 3.3 percent with a small effect size of 0.19. After 6 weeks the experimental group decreased double support by 3.9 percent with a medium effect size of 0.33. The mean control group double support

increased 3.9 percent with a small effect size of 0.22. These results indicate a trend for the intervention to result in a decrease percent of double support, compared to an increase in double support percent for the control group. The confidence intervals for all mean difference of the linear gait parameters ranged from negative to positive numbers indicating the chance that upon repeating the experiment results could have been in favor of the control group.

Applicability of study results:

Benefits vs. Costs: The strength assessment using manual muscle testing showed a significant group by time interaction in favor of the experimental group for hip extension, but the improvement was less than the MCID of 1. There was a small increase in the GMFM D and E scores for the intervention group immediately post intervention, but not at the 6 week follow up. There was also a small decrease in percent time spent in double support during gait for the intervention group compared to the control group who had a small increase in double support time. The largest effect sizes in favor of the intervention group were found to be in the improvement of gait speed and stride length immediately after the intervention and at the 6 week follow. There was no significant difference between groups for the total GMFM score, cadence or single support time. It is unclear if this is due to ineffectiveness of the intervention, or other limitations of the study, particularly the small sample size. The cost of the intervention for the patient is variable, being a lower cost option if it was offered in the school and a higher cost if it required going to an outpatient clinic. The primary costs would be the patient's time, which would include three one-hour sessions per week, the financial cost of 15 hour-long physical therapy sessions, as well as equipment costs including a stationary bicycle and weight cuffs. There were no study losses or serious adverse events caused by the intervention. There was some complaints of muscle soreness after the sessions, but not severe enough to prevent continuing with the exercise program.

Feasibility of treatment: This exercise program would not be feasible in the setting of Khayelitsha Special School. The primary limitations to the feasibility of treatment would be time restraints of working in the school setting, lack of equipment, and lack of detailed explanation of the intervention. The authors do not specify isotonic exercises included in the program. It would be difficult to remove a child from class 3 hours every week for physical therapy. It might be possible to do this as an afterschool program, but there would most likely not be transport available for the students. Outside funding would need to be obtained to cover the cost of equipment. The exercises are simple, but because the student population I work with all have learning disabilities, there may be more challenges in adhering to the intervention protocol. Subjects in this study were excluded if they could not follow commands of the physical therapist.

Summary of external validity: The fair internal validity somewhat compromises the ability to generalize the results of this study, primarily the inadequate power and lack of assessor blinding. Subjects were similar to those who may be treated at Khayelitsha Special School in their age range and condition. The main difference between my clinical population and the population used in the study was study subjects were all from Korea

and attending an outpatient clinic. The primary limiting factor to extrapolating the results of the study to the students at Khayelitsha Special School is the situational and cultural differences between the two populations.

Synthesis and Discussion: The purpose of this paper was to determine if lower extremity strengthening exercises can increase strength and improve motor function, particularly gait, in ambulatory children with CP. The two chosen studies were randomized control trials with PEDRO scores of 7 and 8. Both studies included school-age subjects who were ambulatory and diagnosed with CP. Both studies used an exercise intervention involving lower extremity strengthening. The Dodd et al. study used an intervention of a 6 week home exercise program, while the Lee et al. study used a 5 week program of individual exercise sessions with a physical therapist.

The results of these studies are mixed, but they demonstrate the potential of lower extremity strength training to improve strength and motor function in ambulatory children with CP. Each study found significant strength gains in different muscles. In Dodd et al. study strength improvements only occurred in combined plantarflexor and knee extensor strength, while the strength improvements from the Lee et al. study only occurred in hip flexors. These differences may be due to difference exercise protocols used in each study. Dodd et al. found no significant change in GMFM scores, while Lee et al. found significant improvements in GMFM D and E immediately after the intervention, though the improvements were very small. The largest effect sizes in either study were for improvements in gait parameters of speed and stride length, showing these may be the primary benefits of lower limb strengthening exercises in children with CP. Other potential improvements in functional activity related to the strength gains reported in these two studies included transfers, stair climbing, kicking, and jumping.

In the studies I compared, the generalizability to my patient population is compromised by fair internal validity, not having enough subjects for adequate power, no subjects from South Africa, and no subjects having an intellectual disability. More research is needed to determine the optimal lower limb strengthening interventions to improve strength and motor function in ambulatory children with CP. In conclusion I can cautiously apply lower extremity strengthening interventions to improve strength and motor function in students with CP at Khayelitsha Special School and to similar populations in the United States. Though it would not be feasible to replicate either of these exercise protocols with students in South Africa due to funding, time restraints, and low parent participation, I can incorporate lower limb strengthening activities such as step-ups, lateral step-ups, half squats, squat to stand, heel raises, and stair climbing into treatment sessions with this patient population. It will also be important to provide education to other healthcare providers, teachers, and parents about the potential benefit of lower limb strengthening for these students.

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