

Table 1. Quality methodology.

Author (year) ^{ref}	Åkerstedt (2009) ¹⁴	Khan (2007) ¹⁵	Patikas (2006) ¹⁶	Patikas (2006) ¹⁷	Seniorou (2007) ¹⁸	Thomason (2011) ¹⁹
Design	Prospectief Cohort	Retrospectief Cohort	RCT	RCT	RCT	RCT
<i>internal validity</i>						
Randomly divided	dna	dna	yes	yes	yes	yes
blind randomized	dna	dna	yes	yes	no	yes
defined study	yes	no	yes	yes	yes	yes
Groups of identical baseline	dna	dna	yes(SC)	yes (SC)	yes (SC)	yes (SC)
blind subjects	dna	dna	no	no	no	no
therapists blind	dna	dna	no	no	no	no
testers blind	?	no	no	no	no	no
Confounders / bias	?	yes	?	?	?	?
Use valid, reproducible measuring instruments	yes	yes	yes	yes	yes	yes
defining outcome	yes	yes	Doubtful	Doubtful	Doubtful	Doubtful
Intention to treat	dna	dna	yes	no	no	yes
<i>external validity</i>						
Inclusion/exclusion numbers (n)	yes 11	yes 85	yes 39	yes 39	yes 20	yes 19
Discription physicaltherapy intervention	no	no	no	no	no	no
Check co- intervention	no	yes	no	no	no	yes
Follow- up duration enough	yes	yes	yes	yes	yes	yes
Loss to follow- up< no0%	yes	yes	yes	yes	yes	yes
<i>results</i>						
Mean	yes	no	yes	yes	yes	yes
Standaard deviation	no	no	yes	yes	yes	yes
95 % confidence interval	no	no	yes	yes	no	yes
statistical analysis	- Descriptive statistics - Visual Analysis	no	- Within and between factor - ANCOVA - Unpaired t- tests - Chi- square nonpara. stat.	- ANCOVA - ANOVA	- within subject standard deviation - CV % - paired sample t-tests - ANCOVA	- ANCOVA - lineair regresion

ANCOVA: analysis of covariance, ANOVA: analysis of variance, CV: coefficients of variation, SC: statistical correction, dna: does not apply, ?: uncertain.

Table2. Data-extraction; study, population, surgery procedures and follow-up.

^a estimated from the description as GMFCS levels were not described.

STUDY	POPULATION					SEMLS	ASSESSMENT
Author (year) ^{ref}	N (male/ female)	N control/ intervention (male/ female)	Mean Age in years (y) (SD) [Range]	CP type	GMFCS	Surgery procedures	Follow up/ Period after surgery
Åkerstedt (2009) ¹⁴	11 (10/1)		13.8 [9-18]	bi / uni	I, II, III	CE, DFO, GE, HE RecFT	T0= before SUR T1= 1 year T2= 2 year
Khan (2007) ¹⁵	85 (53/32)		8.5 [5-12]	bi	IV, V ^a	STP= 79% BP= 21%	T0= before SUR T1= mean 3.5 year (range 2-5)
Patikas extension torq (2006) ¹⁶	39 (27/12)	CG=20 (14/6) EG=19 (13/6)	9.7 (2.8)	bi	I,II,III	CG= 144 STP 56 BP EG= 127 STP 65 BP	T0= before SUR T1= 6 months T2= 1 year
Patikas (2006) ¹⁷ walking	39 (27/12)	CG=20 (14/6) EG=19 (13/6)	9.7 (2.8)	bi	I, II, III	CG= 144 STP 56 BP EG= 127 STP 65 BP	T0= before SUR T1= 6 months T2= 1 year T3= 2 year (Only gait analysis)
Seniorou (2007) ¹⁸	20 (10/10)	AE= 9 PRT= 11	13.0 (2.0) [7-16]	bi	I, II, III	AdE, CE, CLO, DFO, DTO, GE, HE, PsE, RecFT, SPLAT TPE	T0= before SUR T1= 6 month T2= 7.5 month T3= 1 year
Thomason (2011) ¹⁹	19 (12/7):	SEMLS= 11 PRT=8	9.8 [6-12]	bi	II, II	TT, RO, SH, MtE, SF	T0= before SUR/PRT T1= 1 year T2= 2 year

AdE: adductor muscles extension; AE: active exercises; bi: bilateral; BP: bony procedure; CE: calcaneus extension; CG: control group; CLO: calcaneal lengthening osteotomy; CP: cerebral palsy; DFO: derotating femoral osteotomy; DTO: derotating tibia osteotomy; EG: exercise group; GMFCS: Gross Motor Function Classification System; GE: gastrocnemius extension; HE: hamstrings extension; MtE: muscle tendon extension; N: number; PRT: progressive resistance training; PsE: psoas extension; RecFT: rectus femoris transfer; RO: rotatie osteotomy; SD: standard deviation; SEMLS: single event multilevel surgery; SF: stabilization foot according to directive; SH: stabilization hip according to directive; SPLAT: split tibialis anterior transfer; STP: soft tissue procedure;; SUR: surgery;TPE: tibialis posterior extension; TT: tendon transfer; Uni: unilateral.

Appendix 1

Searchstring PubMed

#1 Disease
"Cerebral Palsy" [Mesh] OR "Cerebral Palsy" [tw]
#2 Population
"Child" [Mesh] OR "Child, Preschool" [Mesh] OR "Adolescent" [Mesh] OR "Pediatrics" [Mesh] OR child [tw] OR schoolchild [tw] OR "child, preschool" [tw] OR adolescent [tw] OR pediatrics [tw] OR paediatrics [tw] OR boy [tw] OR boys [tw] OR boyhood [tw] OR girl [tw] OR girls [tw] OR girlhood [tw] OR youth [tw] OR youths [tw] OR teen [tw] OR teens [tw] OR teenager [tw] OR children [tw]
3 Physical therapy
"Physical Therapy Modalities" [Mesh] OR "Physical Therapy (Specialty)" [Mesh] OR "Physical Therapy" [tw] OR physiotherapy [tw] OR Rehabilitation [MeSH] OR Rehabilitation [Subheading] OR Rehabilitation [tw] OR "Exercise" [Mesh] OR "Muscle Stretching Exercises" [Mesh] OR "Motion Therapy, Continuous Passive" [Mesh] OR "Exercise Therapy" [Mesh] OR "Resistance Training" [Mesh] OR "Exercise" [tw] OR "Muscle Stretching Exercises" [tw] OR "Motion Therapy, Continuous Passive" [tw] OR "Exercise Therapy" [tw] OR "Resistance Training" [tw] OR "motor control" [tw] OR "motor learning" [tw]
#4 Surgery
"General Surgery" [Mesh] OR "Orthopedics" [Mesh] OR "Surgery" [tiab]
#5 Combined searchstring
#1 AND #2 AND #3 AND #4

Appendix 2

1 *Protocol design of PTT program in children with CP after SEMLS.*

2
3 It is important to realize that a standard SEMLS patient does not exist. Depending on the different
4 SEMLS surgery procedures and protocols it is not possible to describe one type of fixed
5 treatment protocol or one type of patient. Therefore, it is important to consider the following
6 factors:

- 7 1. Surgery: a different progression during PTT will be seen after SEMLS depending on
8 whether one or both legs are operated and whether two or three levels of surgery (ankle, knee,
9 and hip) was needed.
- 10 2. GMFCS level: children with CP GMFCS I and II show more selectivity and are able to
11 perform the exercises more easily compared to children with GMFCS III.
- 12 3. Other factors: Cognitive level, the ability to use two hands and the support of the child's
13 system (parents, teachers etc.) have a crucial influence on the performance and progress of the
14 treatment.

15
16 During the period of immobilization, exercises and specific instructions are given according to
17 the protocols of the orthopedic surgeon. In order to make adequate use of the new alignment and
18 gait opportunities (possibilities), co-interventions such as orthosis, plaster and devices are needed
19 in the post-surgery intervention plan.¹⁻³ Adequate planning of the co-interventions is essential in
20 order to start PPT. This care preferably will be organized in a specialized multidisciplinary team
21 that will be coordinated by the rehabilitation physician. Four to six weeks after surgery, X-rays
22 will be taken and the orthopedic surgeon will decide if mobilization can be started with full body
23 weight, using temporarily ankle and knee immobilizers to guarantee the safety of the child during
24 standing. When 100% weight bearing is not allowed the child need to stand with support of a
25 stander and walk with crutches if possible combined with the non-weight-bearing exercises and
26 instructions.

27 The care for these patients needs to be individually tailored and patients and their parents should
28 be accompanied by the expert team both pre- and postoperatively.

29 We present a framework of important elements of the PTT after SEMLS at the point that the
30 child has permission from the orthopedic surgeon to bear full weight with ankle and knee
31 immobilizers, typically 4-6 weeks after surgery:

- 32 1. *Goal:*
33 From completely inactive (bedridden) to fully active on all levels (depending on the
34 rehabilitation goals) of ICF-CY in which pain and fatigue are crucial factors to be

1 considered during treatment, because the child did not bear weight on their legs for 6
 2 weeks. With guidance from a physical therapist, the child learns to regain strength within
 3 the new ROM after SEMLS and the child needs to learn a new pattern for standing and
 4 walking activities in daily live.

5
 6 *2. Frequency and duration 4-6 weeks post-operatively till 24 months*

- 7 • 4 to 6 weeks post-surgery, depending on the consolidation of the bones, the intense 4
 8 weeks of daily PTT starts till 8 to 10 weeks for 1.5-2 hours, combined with 1.5 to 2.5
 9 hours independent performance of instructed exercises by child and parents.
- 10 • From week 8 to 10 weeks till 6 months weeks; 3-5 times a week 1 hour a day PTT and
 11 1-2 hours a home program
- 12 • 6-12 months; 2-4 times a week 1 hour a day PTT and 0.5-1 hours a home program
- 13 • 12-24 months; 1-2 times a week ½ -1 hour a day PTT

14 See table 1.

15
 16
 17 Table 1. SEMLS treatment schedule

Surgery	Post-surgery recovery time	Time line		Frequency Per week	Duration PTT	Duration independent exercises Institute	Duration independent Program at home
		Start	End				
SEMLS	4-6 weeks	4-6 Weeks	8-10 weeks	Daily	1.5-2 h	1.5-2.5 h	
		8-10 weeks	6 months	3-5	1 h		1-2 h
		6 Weeks	12 months	2-4	1 h		0.5-1 h
		12 months	24 month	1-2	0.5-1		

18 Note: More or less PTT is possible depending on the policy of the orthopedic surgeon
 19

20 *3. Intensity and method of treatment*

- 21 • *4 to 6 weeks post-surgery:* It is essential for the start of the PTT to manufacture
 22 optimal ankle and knee immobilizers. From day one the child will be placed in a standing
 23 position with the immobilizers to support standing and to guarantee the safety of the child.
 24 Within the treatment during the transition from standing to walking, it is important to align the
 25 orthoses with shoes.

26 From day one the child starts with strength training 3-4 times a week from unloaded to functional
 27 loaded exercises according to the method of progressive resistance exercise training using the
 28 repetition maximum method.⁴ This means 1-3 sets of each exercise and within each set, muscle

1 fatigue is reached between 6-12 repetitions. Criteria for quality of moving are leading during
2 muscle strength exercises to increase the load. The following muscle groups are trained
3 specifically: hip extensors, hip abductors, knee extensors, abdominal muscles and when possible
4 plantar flexors depending on the use of ankle foot orthoses (AFO's).

5 First, the aspect of the quality of movement while standing and walking is essential. The
6 focus on the gait pattern is heel strike, extension of the knee and hip during midstance with a
7 minimal pelvic drop and keep extend the knee and hip throughout the standing phase in order to
8 facilitate knee flexion during swing phase. The child needs to adapt to the weight on their heels
9 during standing and walking, which is a new condition, as before SEMLS, the child did not bear
10 weight on their heels. Use of manual and verbal feedback ⁵, walking aids and technologies, such
11 as body weight support treadmill training and body weight support over ground training (Zero-
12 G), are beneficial in learning a new gait pattern.^{6:7}

13 The child starts always in the walkway and weight supported treadmill training will be
14 used along with crutches, tripods or a backward rollator. If possible, Zero-G training will be used.
15 The bodyweight supported treadmill training will start daily when knee flexion reaches 80
16 degrees. The speed starts from 0.1 to 0.5 km/h, with 30-50% bodyweight support and 2-3 x 2
17 minutes walking. After 4 weeks the speeds vary from 0.5 to 1.5km/h, with 10-30% bodyweight
18 support and 3 x 3-6 minutes walking. The amount of time the patient will use a walking device
19 will depend on individually recover time.

20 When the SEMLS is performed on one leg and the child has an optimal hand function,
21 crutches are used. When the SEMLS is performed on two legs and the child has an optimal hand
22 function, tripods are used. When indicators are described of a restricted cognitive level are
23 present, a limited use of two hands and the support of the child's system is confined, a backward
24 rollator will be considered. The child leaves the rehabilitation center with the aid of a walking
25 device. The decision of which walking aid to use will depends on the progress of the child.

26 It is important to keep the active and passive ROM obtained by SEMLS. During the
27 immobilization period, knee immobilizers are worn and the knee flexion is limited. ROM
28 exercises and variation of posture will be provided including; the hip flexors, hip adductors, knee
29 flexors, knee-extensors and the m. gastrocnemius. Variation of posture will be offered during the
30 day by having the child lying in prone, sitting with straight legs, standing in a stander, biking on a
31 Motomed or a special hometrainer to optimize the active and passive ROM and will be used
32 daily 1-2 times for 10-30 minutes.

33 Balance training will be started in standing position with knee and ankle immobilizers.
34 Exercises start with weight shifting from one leg to the other, balance while walking with

1 (minimal) walking aids and to training for falls. For children that have SEMLS performed on one
2 leg, it is possible to stand without the knee immobilizers at the end of the first week or beginning
3 of the second week of the PTT. For children that have SEMLS performed on two legs, it is
4 possible to stand without the knee immobilizers in the end of the second week or beginning of the
5 third week of the PTT. Practice based observation indicates that this has been the case for the vast
6 majority of children.

7 From the beginning of the rehabilitation, a daily, individually structured home program
8 will be made of the four elements described above, including variation of posture and exercises
9 for: strength, gait, the active and passive ROM and balance. However, recovery time for the child
10 is also an essential part. Activity of daily living (transfers in- and out of bed, dressing, toilet
11 etcetera) are part of daily training, preferably during daily care using devices when necessary
12 guided by an occupational therapist. A multidisciplinary approach is necessary to maintain the
13 methods and the quality of exercise training to ensure the quality of the treatment.

14 After 4 weeks of training in a rehabilitation center, the treatment is transferred to a private
15 practice where the patient was previously being treated, coached by the physical therapist of the
16 rehab center. Focal points of treatment will be gait training, strength training, balance training,
17 maintaining the active and passive ROM related to meaningful and functional activities.
18 Outlining of the orthosis remains a point of attention.

19 • *2-6 months:* In this phase it is likely possible to work on the specific activities that
20 are part of the child's request, because the cardiovascular and strength condition on body and
21 functioning level is still insufficient. Functional (supported) gait training to learn a new walking
22 pattern and preservation of the new active ROM is continued. Functional muscle strength training
23 is intensified in load. Orthoses are used and the use of a walking aid is reduced depending on the
24 abilities of the child. Based on our clinical experience we advise to use an assistive device until
25 the patient is strong enough to overcome trunk sway (leaning to one side when lifting the
26 opposite leg) or a minimal pelvic drop. Balance and gait training on the GRAIL (Gait Real-time
27 Analysis Interactive Lab) is optional.

28 • *6 to 12 months:* The patient's needs are now prioritized, taking into account the
29 post-surgery recovery. In the first half year, the focus was therefore more on function and activity
30 level (ICF-CY) and from this period on the emphasis is more on participation level. The walking
31 is optimized and functional muscle strength training is intensified in load with more complex
32 exercises and combined with aerobic/anaerobic endurance training. The support during gait

1 training is further minimalized during daily activity, depending on the child's progress with the
2 training. In this phase the initial request and goals of the child are more within reach and a high
3 frequency and intensity of the PTT is required due to the need to improve muscle strength, as the
4 condition of the body is still recovering from SEMLS. Balance and gait training on the GRAIL is
5 optional.

6 • *12-24 months:* The emphasis is on fine-tuning of daily life activities and sports
7 activities, which includes functional strength training combined with the emphasis on
8 aerobic/anaerobic endurance training. The frequency of physical therapy is dependent on the goal
9 of the patient in this phase. Children with GMFCS I and II walk without walking devices. Most
10 children will go through the pubertal growth spurt with marked changes in height, weight and
11 sometimes in body mass index ² and therefore monitoring is important.

12 Evaluations by the rehabilitation center take place 25 weeks, 1 year, 2 and 5 years post-
13 operatively as seen in the literature. ^{8;9} Twelve weeks post-operatively, the child is seen by the
14 orthopedic surgeon for monitoring the progression of the consolidation of the child's bones.

15 *Suggestions for measuring instruments for evaluation*

16 Pre- and post-measurements are depending on the goals of the child and the parents, for the
17 SEMLS and the PTT. We advise the following measurements on the different ICF-CY levels:¹⁰⁻²¹

- 18 • Function level:
 - 19 ○ physical examination of lower extremity (mobility, selectivity, strength, spasticity)
 - 20 ○ 3 D Gait analysis (step-length, walking speed, kinematics lower limbs)
 - 21 ○ 10 meter timed walking test
 - 22 ○ 1 minute walking test
- 23 • Activity and participation level:
 - 24 ○ Canadian Occupational Performance Measure
 - 25 ○ The Goal Attainment Scaling
 - 26 ○ Gross Motor Function Measure (Domain D and E)
 - 27 ○ Functional Mobility Scale
 - 28 ○ Mobility questionnaire
 - 29 ○ Quality of life Questionnaire to be determined

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