The use of gait analysis in orthopaedic surgical treatment in children with cerebral palsy

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Aim of treatment

Correction of functional disorder

Requires analysis of function

Basis for decision making

Results from clinical (static) examination do not correlate with functional (dynamic) assessment

McMulkin ML et al. Correlation of static to dynamic measures of lower extremity range of motion in cerebral palsy and control populations. 2000

Aim: correction of function

Basis for decision making

Clinical examination: what is possible

Functional assessment: what happens

Basis for decision making

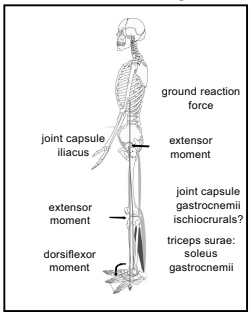
Analysis of disorder in respect of normal function:

Knowledge of normal function presupposed:

Normal function

Normal stance

Joint moments and body interactions



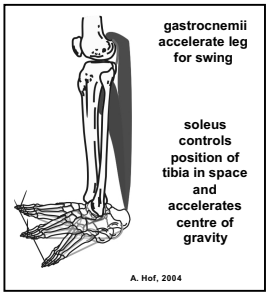
Perry 1984

Function of triceps surae and foot

Foot

= Lever arm for triceps surae muscle (plantar flexion – knee extension couple)

- Adapts at surface

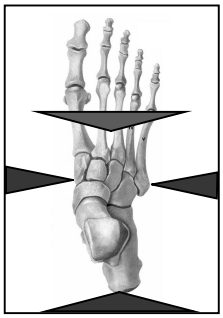


Foot control in standing

External dorsi-flexion-moment

Tibial muscles

Peroneal muscles



Triceps surae

Prerequisites for normal function

Passive: Full knee extension
Sufficient hip extension
No excessive plantar- or dorsiflexion

Active: Full active knee extension
Sufficient muscle strength

Prerequisites for normal function
Indication from clinical evaluation

Passive: Full knee extension
Sufficient hip extension
No excessive plantar- or dorsiflexion

Active: Full active knee extension
Sufficient muscle strength

Muscular problem:

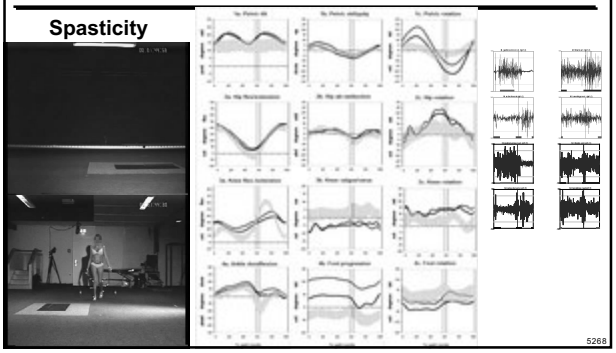
Spasticity ??

or

Weakness??
If weakness, why?

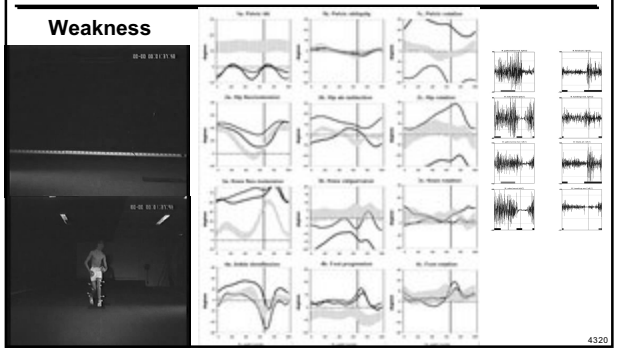
Cerebral palsy - Diplegia

Spasticity



Cerebral palsy - Diplegia

Weakness



Problem muscles:

Foot: triceps surae and other foot muscles

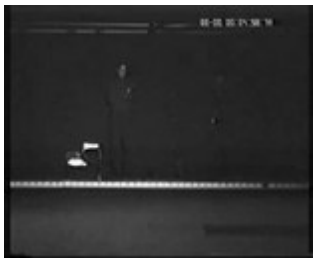
Knee: extensors

Hamstrings

Hip: extensors and rotators

Hip: Adductors

Cerebral palsy - Diplegia



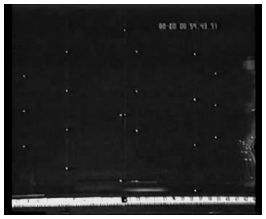
Young patients:

Plantar flexion - knee extension couple

Cerebral palsy - Diplegia

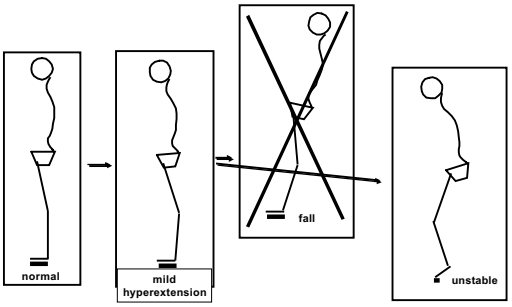
Older patients:

Decompensation



Cerebral palsy

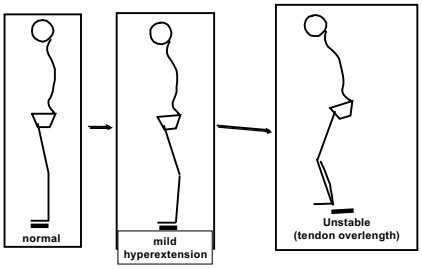
Loss of the plantar flexion - knee extension couple (1)



Cerebral palsy

Loss of the plantar flexion - knee extension couple (2)

Giving way of triceps



Heel cord lengthening (surgical)

Or

spontaneously

Cerebral palsy - Diplegia

Giving way of other foot muscles (tib. post., peron. longus etc.)

Mechanism of lever arm dysfunction

Lever arm dysfunction

valgus-abduction foot / external rotation:

- External rotation of subtalor joint forces leg into internal rotation (foot fixed against floor)
- Loss of plantar flexion – knee extension couple forces knee into flexion

Cerebral palsy
Diplegia

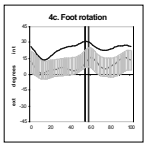
Giving way of foot muscles

Excessive dorsiflexion

Midfoot break (tib. post, peron. longus)

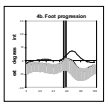
Cerebral palsy
Diplegia

Tib. post. overactivity



Foot internal rotation in 2nd half of stance phase (blue)

Not foot progression angle



Problem muscles:

Foot: triceps surae and other foot muscles

Knee: extensors

Hamstrings

Hip: extensors and rotators

Hip: Adductors

Functional analysis
Clinical examination

Knee extensor overlength / weakness

Active knee extension lag

Long quadriceps tendon

Patella fracture

Patella alta

Cerebral palsy
Diplegia

Giving way of knee extensors

Active extension lag

Knee flexion deformity

Problem muscles:

Foot: triceps surae and other foot muscles

Knee: extensors

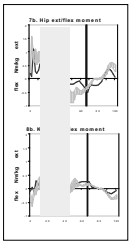
Hamstrings

Hip: extensors and rotators

Hip: Adductors

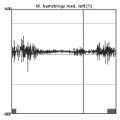
Cerebral palsy
Diplegia

Role of hamstrings?



Correlation of knee extensor moment with knee flexor moment:

Hamstrings:



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Cerebral palsy
Diplegia

Role of hamstrings?

Hip extensors

Cocontraction of knee extensors may increase efficacy of hamstrings (hypothesis)

Problem muscles:

Foot: triceps surae and other foot muscles

Knee: extensors

Hamstrings

Hip: extensors and rotators

Hip: Adductors

cerebral palsy
internal rotation gait

muscular part

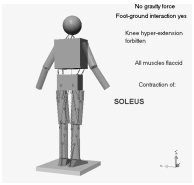
?

not adductors / hamstrings

Arnold AS, Asakawa DJ, Delp SL: Do the hamstrings and adductors contribute to excessive internal rotation of the hip in persons with cerebral palsy? Gait Posture, 2000, 3: 181-190

Functional hip malrotation

Think of triceps surae



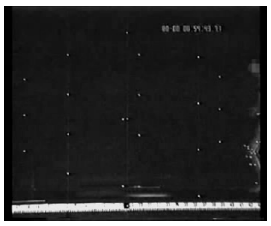
Animation: Carlo Frigo, Politechnico, Milano

In hemiplegics
not in diplegics

Cerebral palsy - Diplegia

Older patients:

Decompensation



Cerebral palsy
Diplegia

Giving way of hip extensors and external rotators

Hip flexion deformity

Increased internal rotation

Problem muscles:

Foot: triceps surae and other foot muscles

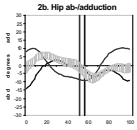
Knee: extensors

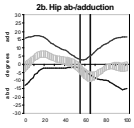
Hamstrings

Hip: extensors and rotators

Hip: Adductors

Cerebral palsy
Hip adduction



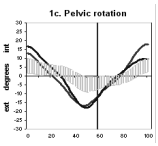


Pseudo-adduction
(caused by pelvic motion)

True adduction

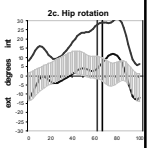
Horizontal plane kinematics

Torsions



Rotational position of pelvis

Rotation of hip (rotational position of knee)



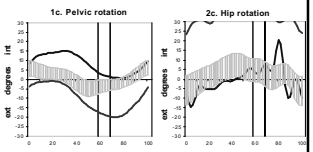
Offset = Torsion

Amplitude = funct. component

Cerebral palsy
Hip rotation (kneeing in)

Kneeing in

Bilateral derotation?



Torsions

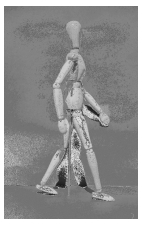
Tibial and foot torsions guesswork

Treatment

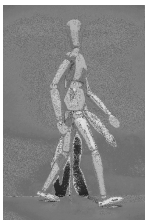
General

Toe walking
Foot strike

Equinus

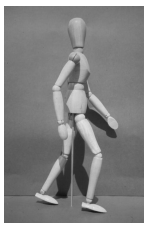


Normal position



Diplegia

Knee flexion



Diplegia
Foot deformity

Varus- or valgus? *Diplegia*

Stable stance leg

(enough time to prepare leg for swing)

Unstable stance leg

(no time to prepare leg for swing)

Diplegia
Conservative

Orthosis provides stability and stretching

To prevent foot deformities

Diplegia
Most important stabiliser

Save

Our

Soleus

Equinus foot

Beware of bilateral soleus weakening

Treatment

Spasticity

Weakness

Spasticity management
Selective dorsal rhizotomy

praeop **6 m postop**

from Gage J.: The traetment of gait problems in cerebral palsy

Gain of muscle length
Conservative

Botulinum toxin (temporary weakening):
ideal in functional shortening

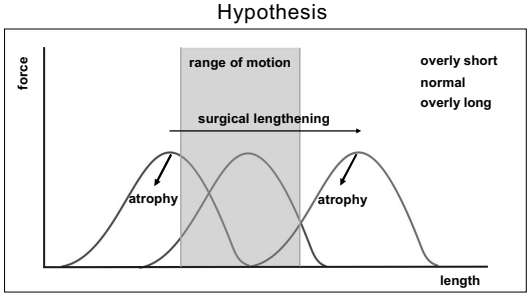
Precondition: impeding muscle / muscle group can be defined

Does not lengthen but reduces resistence

Effect comes and goes

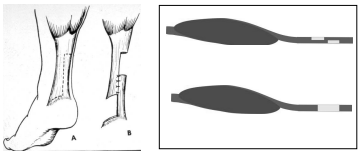
Muscle force
Effect of surgical lengtheing

Hypothesis

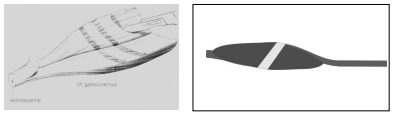


Direct surgical interventions on muscle-tendon apparatus

Tendon surgery (Z-lengthening tenotomy)



Intramuscular tenotomy (aponeurotomy)



Functional test of weakening: Botulinum toxin injection

Function only improved if weakened muscle impeded use of passive moments for posture control and gait

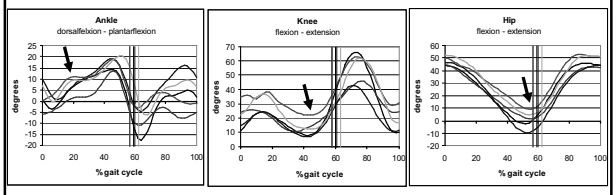
Function unchanged if weakened muscles didn't contribute to posture control and gait

Function deteriorates if weakened muscles essentially contribute to posture control and gait

surgical result not simulated (no lengthening)

Cerebral palsy Botulinum toxin test

Function only improves if target muscle impedes use of passive moments for posture control and gait before being weakened



Left hemiplegic patient:
crouch gait after Botulinum toxin

Treatment

Spasticity

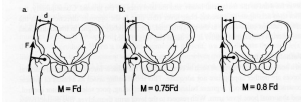
Weakness:

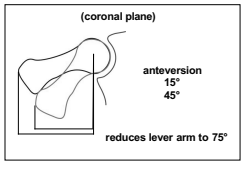
lever arms (torsions)

Lever arm femur

Effect of

- neck-shaft angle
- anteversion





from: Gage J: The Treatment of Gait Problems in Cerebral Palsy. 2004

Correction of lever arm dysfunction

Lever arm (femur):

correction of anteversion

Proximal
(plate)

Distal
(LCP plate or external fixateur)

Foot as lever arm

Lever arm in direction of gait

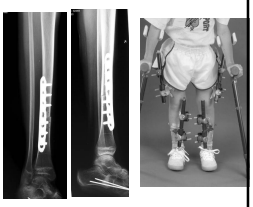
Correction of lever arm dysfunction

Lever arm (tibia):

Aim: foot aligned to direction of gait

Supramelleolar osteotomy for external / internal rotation

LCP-plate or external fixateur (immediate weight bearing)



Correction of lever arm dysfunction

Lever arm (foot):

Conservative


Plantar support


OSSA


Nancy-Hylton


AFO

Surgical


Calcaneal lengthening (Evans)



Calcaneo-cuboidal fusion


Subtalar fusion

Treatment

Spasticity

Weakness:

tendon shortenings

Achilles tendon shortening

Prerequisite: plantarflexion of ~20°

Suture under good tension

Protection for 3-6 months (cast, stiff AFO all day)

Problems:

- Suture gives way
- Stretchability of muscle
- Protection

Achilles tendon shortening

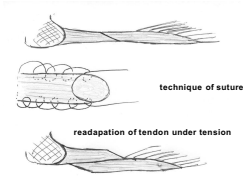
Foot preparation

Difficult procedure

Immediate stretching possible

About 6 weeks of frame

Achilles tendon shortening



Full tension in 20°
of plantar flexion

Achilles tendon shortening

Aftercare

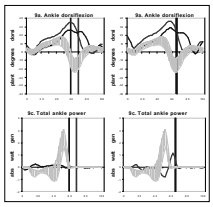
6 weeks lower leg cast

4 weeks without weight bearing

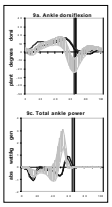
Rigid AFO for 3 months, optionally longer in case of danger of relapse

Achilles tendon shortening

Conclusion out of kinematics and kinetics



Adequate triceps power only in maximal dorsiflexion (tendon overlength)



Adequate triceps power at correct dorsiflexion angle after heel cord shortening

4594a/c Spina bifida

Muscle shortenings in CP

Preliminary results: 2000-2006

Achilles tendon shortening (n=24)

	mean	min	max
Age at op	18.6	8	50
follow-up	3.2	0.8	7.8

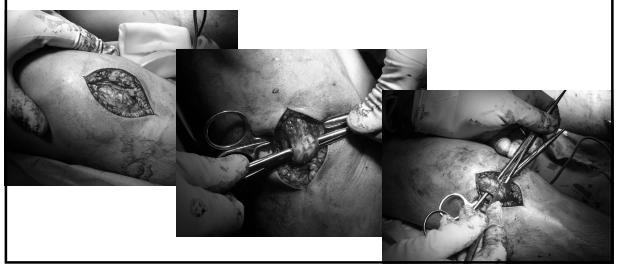
	CP	not CP
n=	13	13

goal reached	yes	no	2nd time
n=	17	7	1

Re-balancing of hamstrings and knee extensors

2. Knee extensor shortening

(+ Supracondylar extension osteotomy)



Re-balancing of hamstrings and knee extensors

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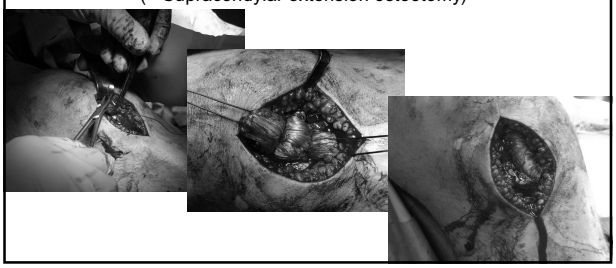


Re-balancing of hamstrings and knee extensors

Aftercare

No flexion >40° for 6 weeks

Knee extension splint for 6 weeks

Full weigth bearing after4 weeks (in splint)

After 6 weeks muscle exercise program (3-6 weeks)

Muscle shortenings in CP

2000-2006

Preliminary results:

Knee extensor shortening (n=38)

	mean	min	max
Age at op	17.1	10	36
follow-up	1.7	0.5	5.7

	CP	not CP
n=	36	2

goal reached	yes	no	2nd time
n=	33	5	2

Muscle shortenings in CP

Hip extensors & external rotators

?

Results

Cerebral palsy – Diplegia Results

Spasticity

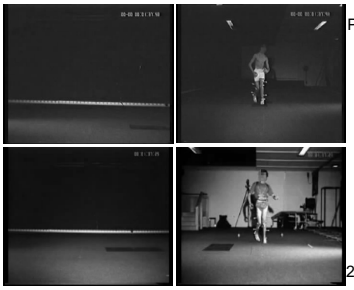
Preop.

Improvement by correction of biomechanics – spasticyty remains

2y postop.

Cerebral palsy – Diplegia Results

Weakness



Preop.

Improvement by correction of biomechanics

2y postop.

Cerebral palsy – Diplegia
Results

Good & consistent long term results

Gage, Ounpuu, Abel, ...

preop 1y postop 10y postop

The use of gait analysis in orthopaedic surgical treatment in children with cerebral palsy

Summary

The more factors corrected the better the functional outcome

Only few parameters adequately picked up by clinical exam

Gait analysis

- provides possibility to correlate movement with activity during function
- corrects for distorsions due to rotational malposition