Unlocking potential:

Motor skills beyond ambulation in children with spina bifida and the relationship to lower limb muscle strength.

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Queensland Government

Children's Health Queensland Hospital and Health Service pays respect to the Traditional Custodians of the lands on which we have the privilege to work on.

We acknowledge and pay our respects to Aboriginal and Torres Strait Islander Elders past, present and emerging.

Background

- Spina Bifida (Myelomeningocoele - MMC)
  - Congenital abnormality of the spinal cord
  - Failed neural tube closure
  - Paralysis and paresthesia below level of lesion
  - Delayed attainment of gross motor skills [1,2]

Ambulation in spina bifida

- Antigravity quadriceps [3,4]
- Pelvic stabilising muscles (hamstrings and hip abductors) [5]
- Ankle stabilising muscles (ankle dorsiflexors and plantar flexors) [6,7]

- Thoracic and high lumbar – non ambulant or with significant bracing
- Mid lumbar levels (L3-4) variable outcomes
- Sacral level – community ambulation[4,8]

What about other gross motor skills such as sitting, crawling, running and jumping??

Aims

To examine relationships between level of lesion, lower limb muscle strength and gross motor skills in children with myelomeningocoele.

Research questions:

1. What muscle strength is needed to achieve specific motor skills?
2. What motor skills can children achieve based on their level of lesion?
3. Can we predict motor skill in childhood based on MMT in infancy?

Clinical Measures

- Demographics & medical/surgical history
- Muscle Strength Assessment
  - Manual Muscle Testing (MMT) [9,10]
  - Results for stronger leg used for analysis
- Gross motor skill assessment [11]
  - GMFM items and scoring criteria
- Neurological level of lesion
  - Broughton's classification [12,13]
- Functional mobility
  - Modified Hoffer's classification [14]

Manual Muscle Testing

LOWER LIMB - MANUAL MUSCLE TEST

U.R. Number : _____
SURNAME : _____
Given Names : _____
Date of Birth : _____
Age: M ❑ F ❑

PLEASE AFFIX PATIENT LABEL

PATIENT AGE: _____
DATE OF MMT: _____
REASON FOR MMT: _____
PHYSIOTHERAPIST: _____

MUSCLES	*	LEFT	RIGHT	*	COMMENTS
QUADRATUS LUMBORUM T12-L1					
ABDOMINALS T8-T12					
ILIOPSOAS L1-2					
SARTORIUS L1-3					
HIP ADDUCTORS L2-4					
QUADRICEPS L2-4					
MEDIAL HAMSTRINGS L4-S2					
LATERAL HAMSTRINGS L4-S1					
GLUTEUS MEDIUS L4-S1					
GLUTEUS MAXIMUS L5-S1					
TIBIALIS ANTERIOR L4-L5					
TIBIALIS POSTERIOR L4-L5					
PERONEUS LONG/BREVIS L5-S1					
PERONEUS TERTIUS L5-S1					
EXT HALLUCIS LONGUS L5-S1					
TOE EXTENSORS L5-S1					
FLEX HALLUCIS LONGUS S1-S2					
TOE FLEXORS S1-S2					
GASTROC SOLEUS S1-S2					

Indicate * if possible inaccuracy of muscle grading.

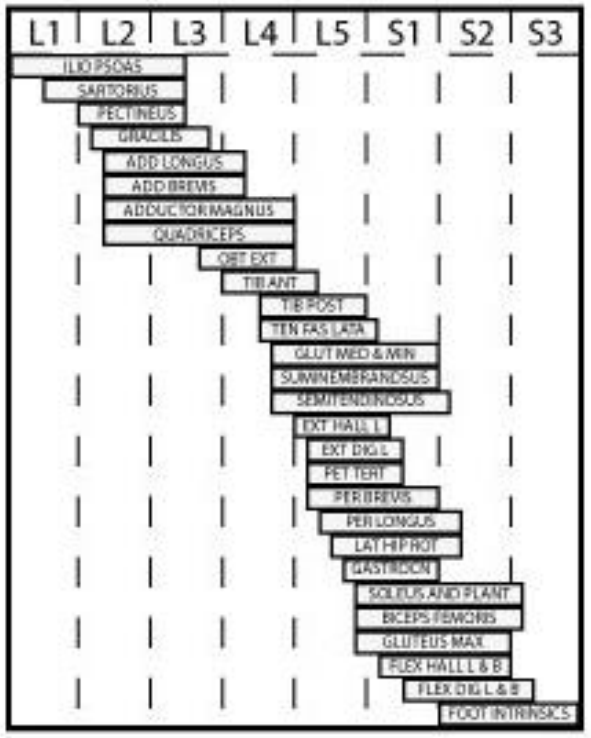
MMT CHANGES
Indicate ↑ or ↓ in comparison to previous test dated: _____

MUCSLE STRENGTH TEST (MRC)
0=no palpable contraction
1=flicker or trace contraction
2=full ROM gravity eliminated
3=full ROM against gravity
4=full ROM against some resistance
5=full ROM against maximal resistance

MUSCLE EXAMINATION QUALITY
1. patient co-operative
2. too young to follow directions/ not co-operative in some positions
3. patient unco-operative/crying - results not necessarily accurate

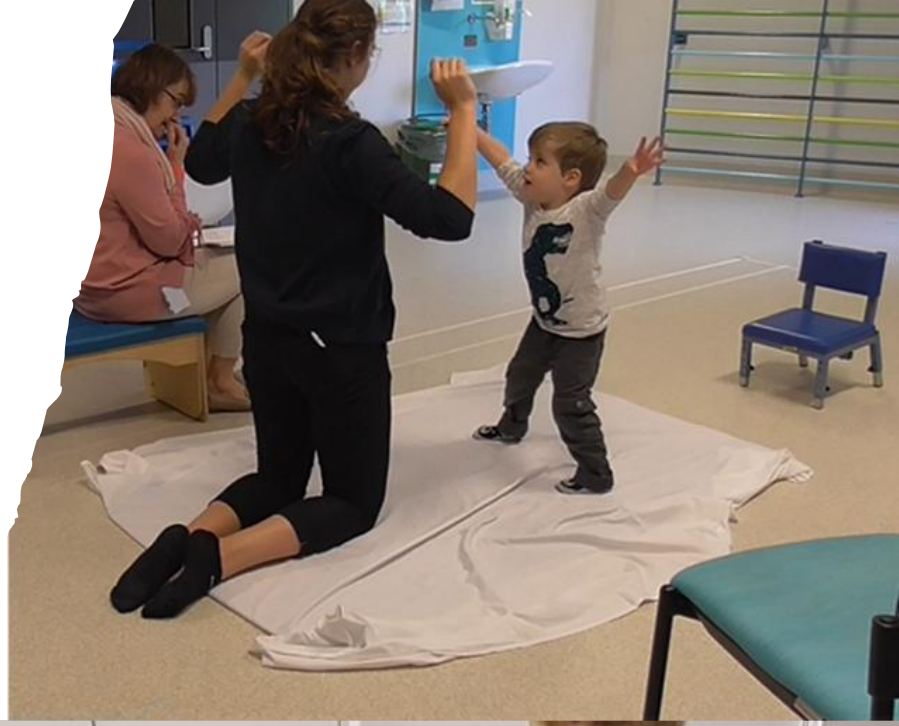
UPPER LIMB STRENGTH

GRIP STRENGTH

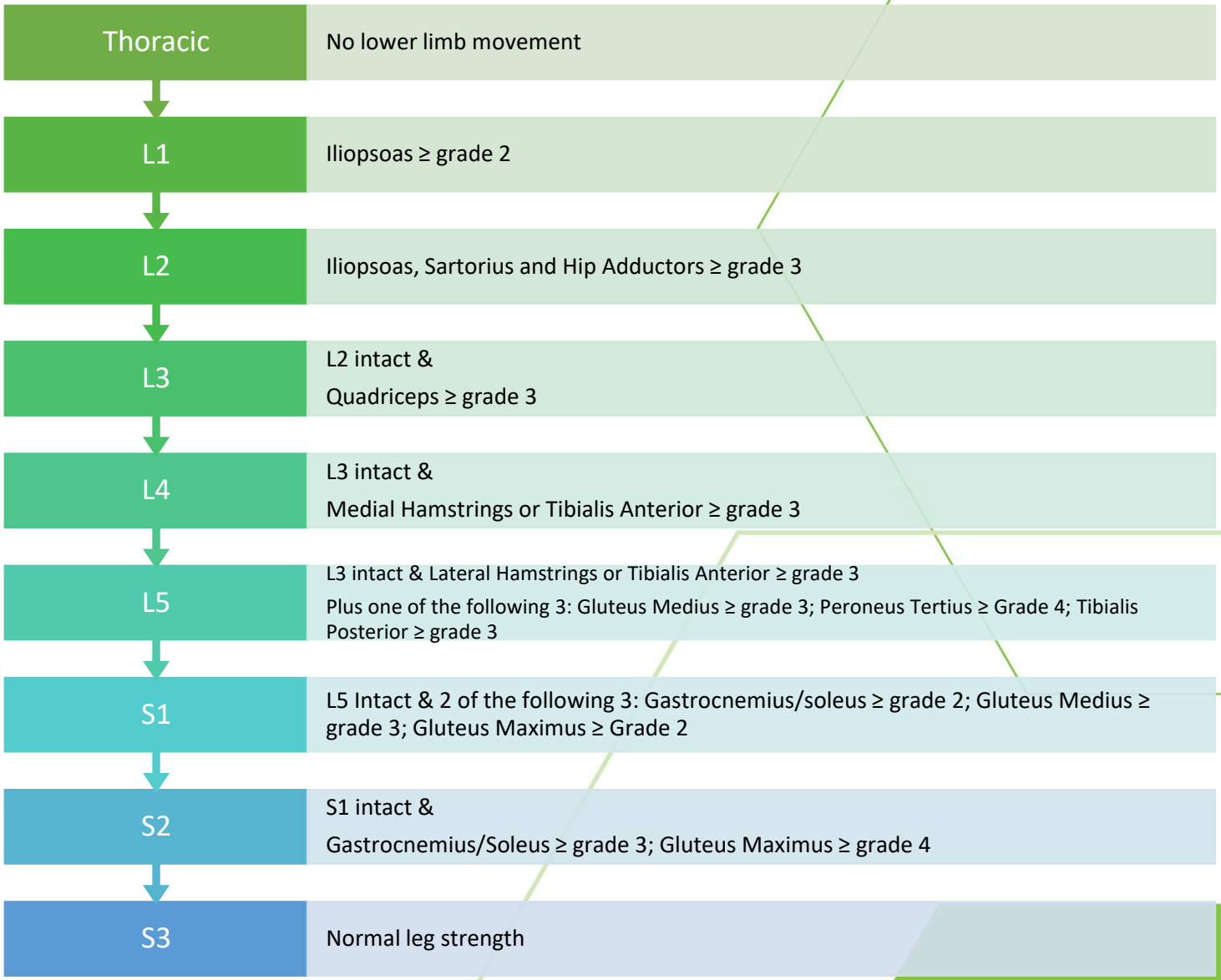


Gross motor function

- **GMFM scoring criteria**
  - **5 static positions** (sit, 4 point kneel, stand 3 or 20 sec, single leg stand)
  - **5 transition movements** (4-point reciprocal crawl, pull to stand, cruise, walk hands held and walk unassisted)
  - **5 complex motor skills** (walk with narrow base, walk along a line, run, jump, hop)
  - **Additional motor skills** (4-point non-reciprocal crawl, attain sit on small bench, attain sit on large bench)



Level of lesion



Ambulation (Modified Hoffer's Classification)

Non-Ambulant (NA)	• Uses a wheelchair for all mobility
Therapeutic Ambulant (TA)	• Walks in therapy often requiring bracing above the knee • Wheelchair for most mobility inside and outside
Household Ambulant (HA)	• Walks indoors • Wheelchair for all outdoors mobility, may use wheelchair for some indoor mobility
Community Ambulant & Wheelchair (CAW)	• Walks indoors and outdoors • Uses wheelchair for distances
Community Ambulant (CA)	• Walks for all mobility indoor and outdoors without any aids • Manages all distances

Procedure and Analysis

- Both assessments completed on day of clinic attendance
- Spearman's rank-order correlation co-efficient used to observe relationships between (p=<0.05)
  - Level of lesion and gross motor skill performance
  - Level of lesion and ambulation
  - MMT grade and gross motor skill performance
  - MMT grade and ambulation
- Non-parametric analysis required due to the ordinal nature of MMT and GMFM scores

Spearman's Correlation co-efficient (r_s) between

- 0-0.3 represents negligible correlation
- 0.3-0.5 is a low positive
- 0.5-0.7 is a moderate positive
- 0.7-0.9 is a high positive
- 0.9-1 is a very high positive [15]

Results

Participants

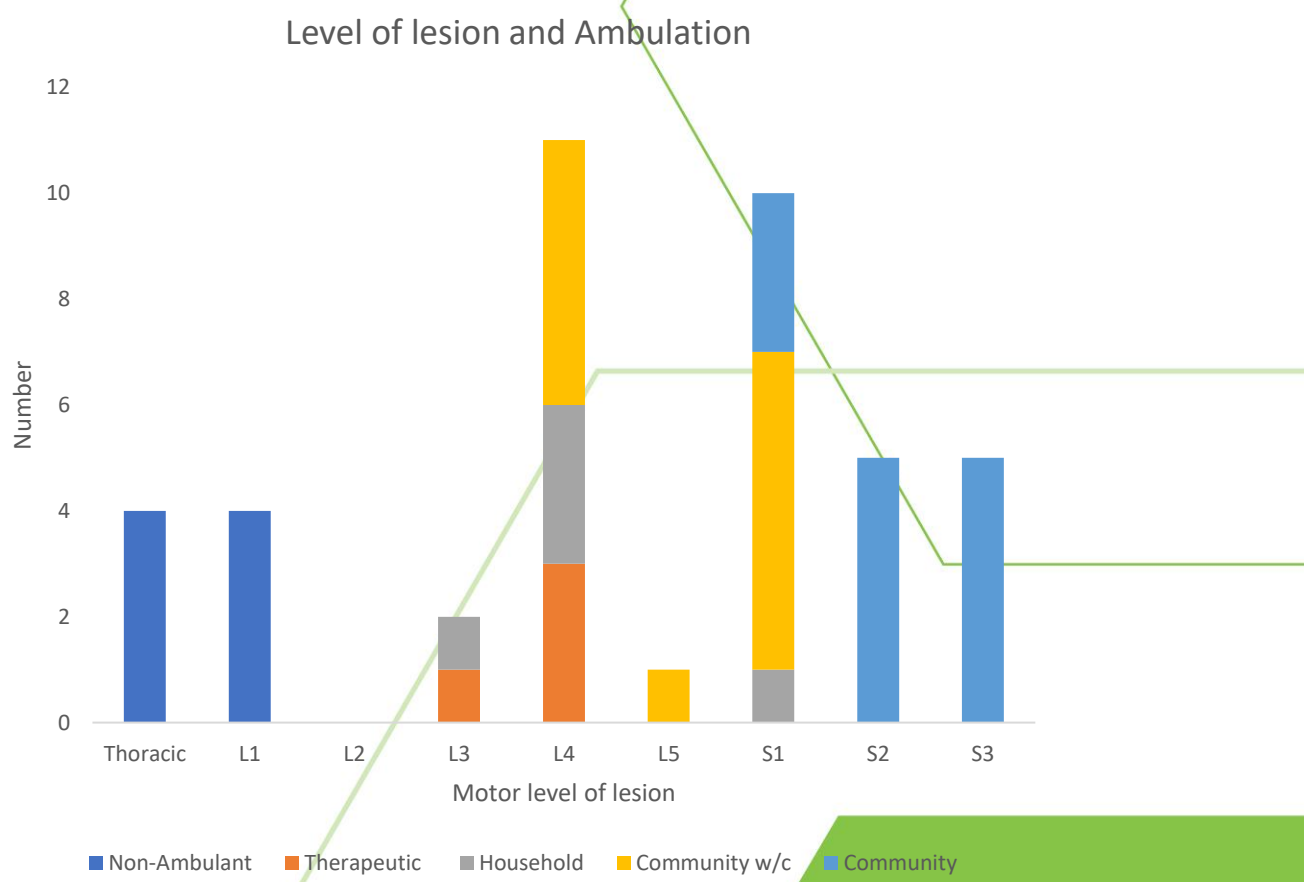
- 42 children with MMC
- 4 – 16 years (Median age 8 yrs 1 month)
- Attended QCH Spinal Disabilities Clinic 2018 – 2023
- Ethics approval and parent consent

Excluded If:

- Unable to follow instructions
- History of orthopaedic surgery if preceding 6/12
- Skin breakdown that precluded necessary assessment positions

Demographics

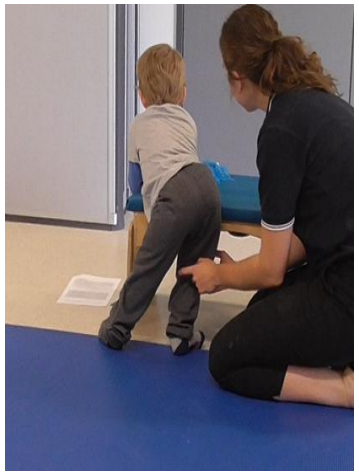
- 90% Arnold Chiari Malformation
- 76% VP shunt
- 5 % Antenatal closure
- 64% foot deformity
- 33% hip dislocation/subluxation
- 21% spinal deformity



Muscle strength, gross motor skills and ambulation

	4-point	Transitions		Independent Stand		Stepping/Walking				More complex gross motor skills					Ambulation
GMFM Item number	45	37	52	53	56	65	67	69	73	74	77	57	80	82	
	4 POINT: CRAWLS RECIPRO-CALLY FORWARD 1.8m	ON THE FLOOR: ATTAIN SIT ON LARGE BENCH	ON THE FLOOR: PULLS TO STD AT LARGE BENCH	STD: ARMS FREE 3 SEC	STD: ARMS FREE 20 SEC	STD 2 HANDS ON LARGE BENCH: CRUISE 5 STEPS	STD 2 HANDS HELD: WALKS FORWARD 10 STEPS	STD: WALKS FORWARD 10 STEPS	STD: WALKS FORWARD 10 STEPS BETWEEN PARALLEL LINES 20cm APART	STD: WALKS FORWARD 10 STEPS ON A STRAIGHT LINE	STD: RUNS 4.5m (15') STOPS & RETURN	STD: LIFTS FOOT ARMS FREE 10 SEC	STD: JUMPS 30cm (12') HIGH BOTH FEET	STD ON R FOOT: HOPS ON R FOOT 10 TIMES	MODIFIED HOFFER'S CLASSI-FICATION (NA, TA, HA, CAW, CA)
Iliopsoas L1-2	.795**	.784**	.735**	.786**	.803**	.823**	.767**	.737**	.752**	.699**	.755**	.727**	.682**	.618**	.723**
Quadriceps L2-4	.878**	.857**	.809**	.733**	.677**	.846**	.739**	.620**	.640**	.616**	.673**	.624**	.582**	.505**	.683**
Medial Hamstrings L4-S2	.735**	.713**	.649**	.828**	.878**	.754**	.840**	.833**	.864**	.805**	.847**	.788**	.811**	.718**	.828**
Lateral Hamstrings L4-S1	.700**	.678**	.612**	.832**	.903**	.695**	.811**	.825**	.905**	.841**	.860**	.824**	.863**	.828**	.851**
Gluteus Medius L4-S1	.623**	.578**	.534**	.816**	.869**	.601**	.752**	.813**	.918**	.867**	.865**	.848**	.916**	.827**	.858**
Gluteus Maximus L5-S1	.581**	.539**	.498**	.846**	.883**	.537**	.777**	.839**	.914**	.872**	.883**	.873**	.903**	.824**	.869**
Tibialis Anterior L4-L5	.545**	.506**	.467**	.746**	.861**	.583**	.686**	.767**	.893**	.883**	.834**	.848**	.932**	.872**	.858**
Tibialis Posterior L4-L5	.448**	.415**	.384*	.710**	.858**	.479**	.599**	.676**	.869**	.854**	.759**	.829**	.905**	.826**	.788**
Peroneus Longus/Brevis L5-S1	.426**	.395*	.365*	.683**	.816**	.456**	.571**	.646**	.791**	.821**	.723**	.797**	.851**	.820**	.804**
Peroneus Tertius L5-S1	.466**	.432**	.399*	.712**	.862**	.499**	.625**	.707**	.872**	.832**	.798**	.823**	.881**	.858**	.831**
Toe Extensors L5-S1	.447**	.415**	.383*	.668**	.842**	.478**	.598**	.675**	.866**	.819**	.795**	.812**	.877**	.911**	.802**
Toe Flexors S1-S2	.395**	.366*	.338*	.617**	.770**	.422**	.528**	.596**	.759**	.781**	.732**	.774**	.818**	.872**	.745**
Gastrocnemius S1-S2	.358*	.332*	.307*	.596**	.734**	.383*	.479**	.541**	.718**	.726**	.664**	.774**	.793**	.818**	.773**

Question 1.
What muscle strength is needed to achieve specific motor skills?



Pull to stand at large bench
hip flexors
adductors and
quadriceps

Reciprocal 4 pnt crawl –
hip flexors, quads
and hamstrings

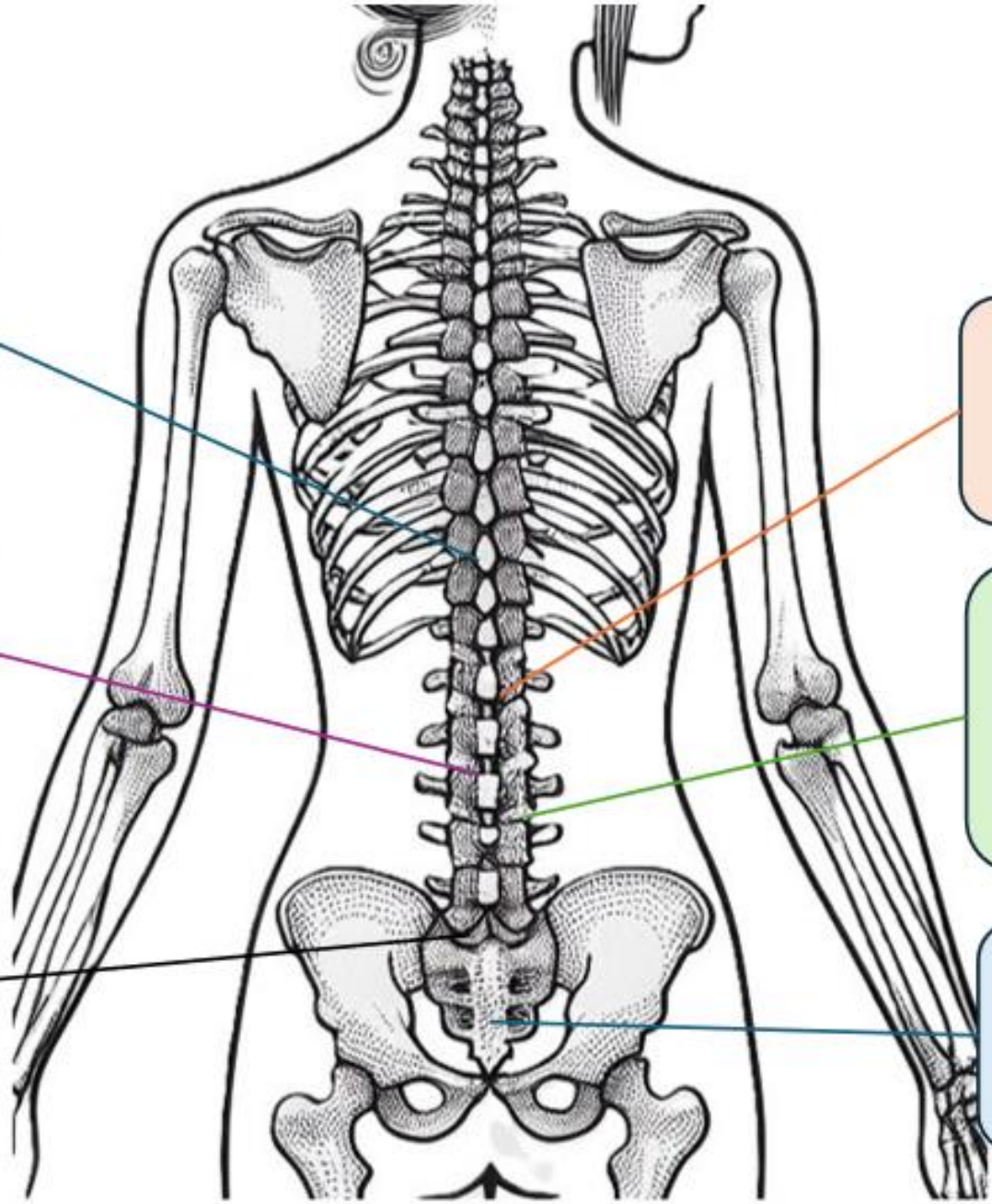
Independent walking
hip and knee flexors,
gluteals and ankle
dorsiflexors

More advanced gross motor skills
pelvic stability muscles
and foot and ankle
muscles

Key gross motor skills and related muscle strength

Question 2. What motor skills can children achieve based on their level of lesion?

Expected motor skills based on level of lesion



Thoracic
Likely to achieve at least momentary sitting balance. May rely on upper limbs for support. May achieve transition from floor to small bench
Wheelchair for mobility

Mid lumbar (L3)
Likely to be able to reciprocal crawl, pull to stand and transition from floor to large bench. Needs support for standing and stepping
Ambulant with aids in therapy or home
Wheelchair for community mobility

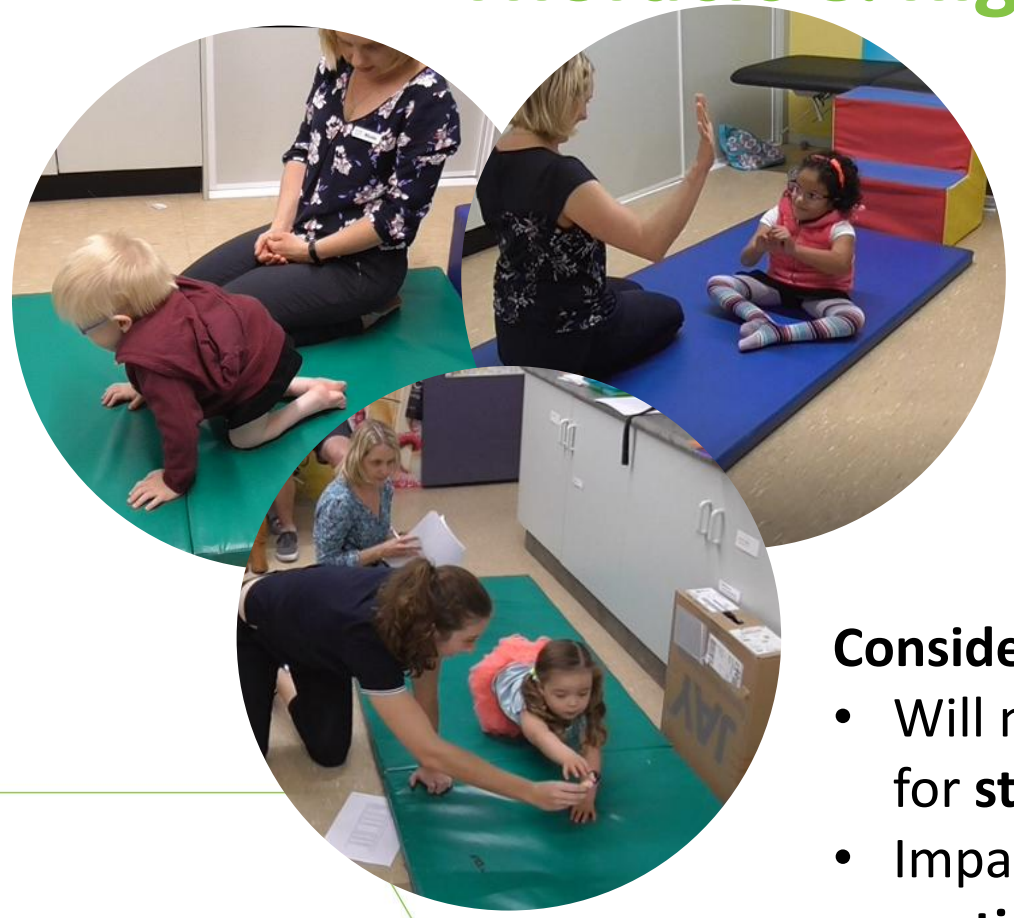
High sacral (S1)
Independent steps, can narrow base of support, runs. May have difficulty with static standing. Unlikely to be able to walk along a line, stand on one leg, jump or hop.
Ambulant in community. May use wheelchair for distances

High lumbar (L1-2)
Likely to attain sitting on a small bench and partially attain sitting on a large bench. Most can attain 4-point position and modified crawl for floor mobility
Wheelchair for mobility

Low lumbar (L4-5)
Can pull to stand and cruise, can manage a few steps with support. Difficulty standing still for >3 seconds. May take independent steps.
Ambulant with or without aids in therapy or home or community. Likely to use wheelchair for community mobility

Low sacral (S2-3)
Can walk, stand still, run. May be able to walk along a straight line, stand on one leg, jump and hop.
Ambulant in community. Does not need wheelchair for distances

Thoracic & high lumbar level lesions



Thoracic (weak abdominals and absent lower limb strength)

- May need upper limbs to prop in sitting
- Difficulty with independent floor mobility

High lumbar (abdominals, hip flexors +/- adductors)

- Achieve 4 pnt kneel and modified crawl

Considerations for therapy:

- Will not achieve weight bearing with upper limb support – need for **standing frames**
- Impact on fine motor and bimanual play – need for **supported seating**
- Delayed floor mobility and impact on cognition, language and social development as well as spatial and topographical memory - Early introduction of **wheeled mobility**

Midlumbar levels (L3)

(Hip flexors, adductors, strong quads)

- Reciprocal crawl, pull to stand and transfer onto high bench
- Need support for standing and stepping
- Ambulate at home, require aids, orthotics and w/c mobility

Considerations for therapy:

Use weight bearing to achieve independence in pressure relieving activities and transfers

Upright activities may be for function, therapy or experiential

Low Lumbar (L4-5)

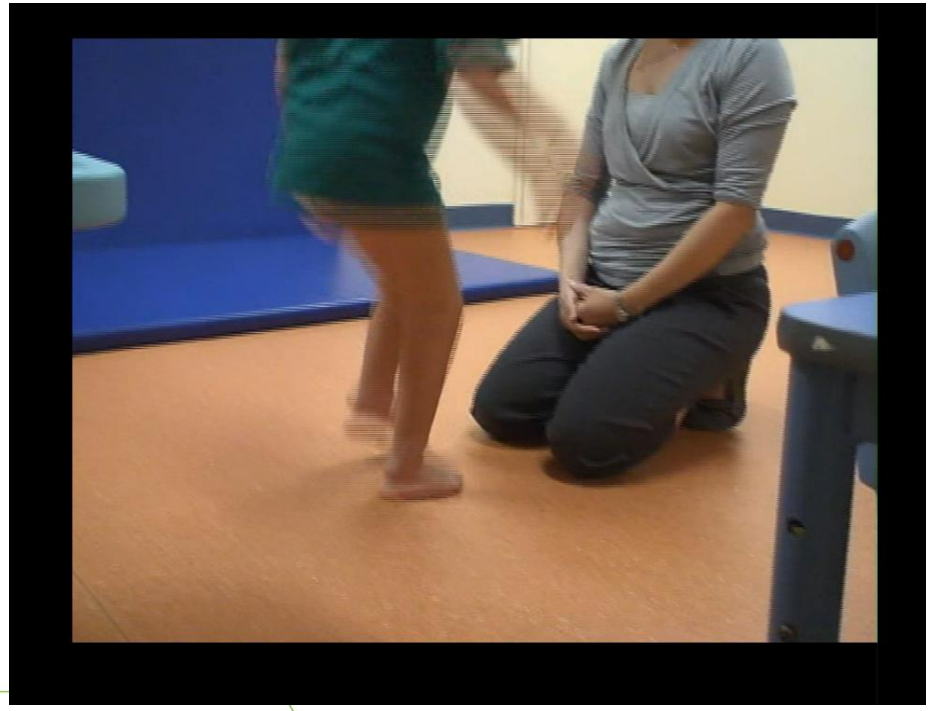
(Hamstrings +/- gluteus medius)

- Pull to stand, cruise, take steps
- Difficulty with static stand
- Walk with or without aids (w/c for community)

Considerations for therapy:

- AFOs improve gait pattern,
- Walking aids may reduce trunk sway
- Wheelchairs assist in functional mobility and fatigue management

Sacral Levels



High sacral (Glut max >grade 2, weak gastroc and foot muscles)

- Walk independently
- Difficulty walking along a line, single leg stand, jump and hop

Low sacral (Strong gastroc, may or may not have strong foot intrinsics)

- Can walk, stand still, run
- May walk along a line, jump, hop and single leg stand
- Only 1 child with S3 level lesion was able to achieve all motor skills

Considerations for therapy:

- The role of CNS and sensory impairments (tactile, visual, prioprioceptive and vestibular) have on motor control and gross motor skills

Question 3. Can we predict motor skill in childhood based on MMT in infancy?

Muscle strength in infancy and gross motor skills

- Subgroup n=19 (median age 6 yrs)
- MMT first 6 months of life
- Graded 0-3

	Ambulation			Key Gross Motor Items			
	Ambulant (therapeutic, household or community) Vs Non-ambulant	Ambulant (household or community) vs Non or therapeutic ambulant	Modified Hoffer's Classification	ON THE PULLS TO STD AT LARGE BENCH	STD: MAINTAINS ARMS FREE 20 SEC	STD, 2 HANDS HELD: WALKS FORWARD 10 STEPS	STD: WALKS FORWARD 10 STEPS
Quadriceps L2-4	.998**	.573*	.563*	.726**	.401	.609**	.504*
Medial Hamstrings L4-S2	.583*	.588*	.474*	.504*	.524*	.794**	.758**
Lateral Hamstrings L4-S1	.530*	.754**	.586*	.475*	.637**	.898**	.900**
Gluteus Medius L4-S1	.449	.783**	.821**	.309	.826**	.874**	.890**
Gluteus Maximus L5-S1	.434	.757**	.620**	.299	.536*	.745**	.739**
Tibialis Anterior L4-L5	.391	.862**	.742**		.767**	.987**	1.00**

Need to look beyond strength of quadriceps when determining potential for ambulation in infants with MMC

Take home points

- Several positive relationships have been identified between strength of lower limb muscles and gross motor skills in children with spina bifida

- While quadriceps strength is important for achieving supported weight bearing, pelvic and ankle stability muscles appear to be necessary for achieving independent walking and more complex gross motor skills

- Understanding the relationship between muscle strength or level of lesion and gross motor skills may improve goal setting and planning for adaptive equipment in children with spina bifida

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