Gross motor function of children with closed spinal dysraphism is explained by lower limb strength.

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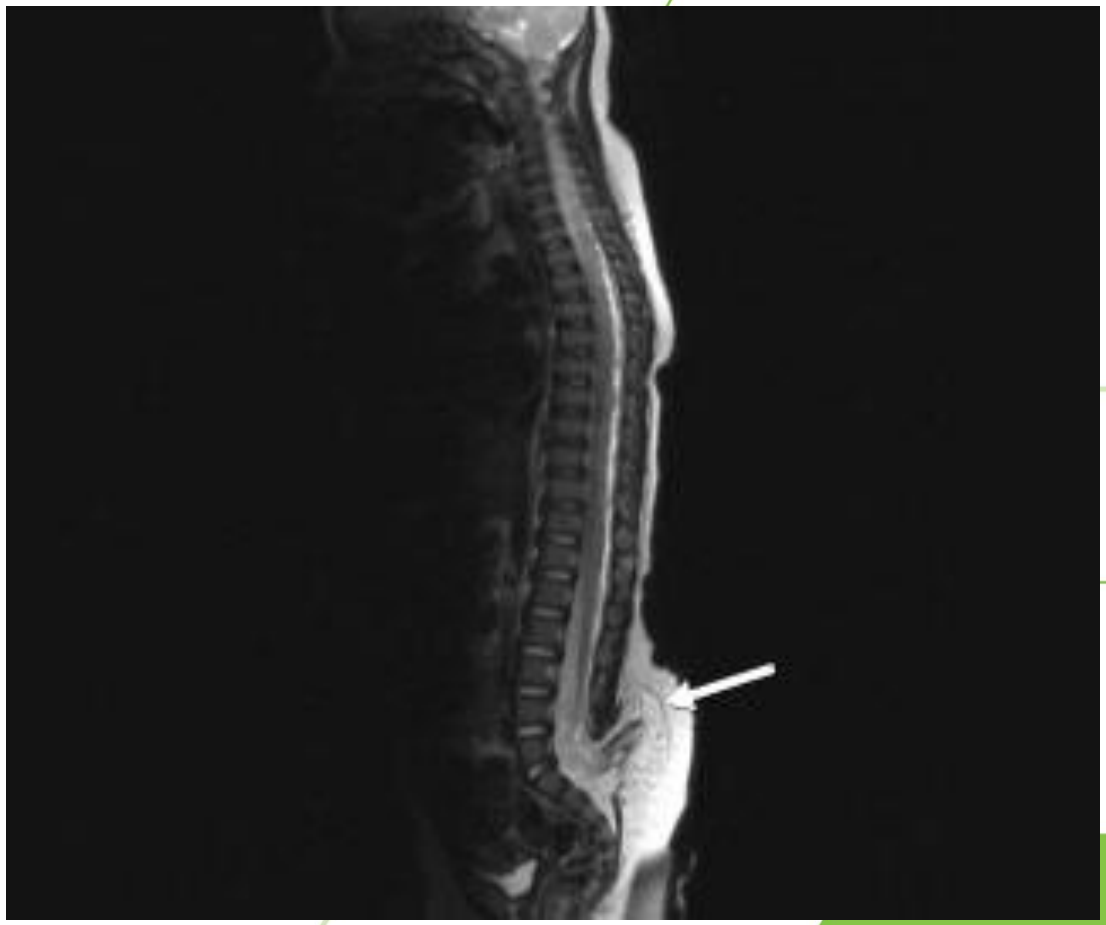
Queensland Government

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.

Closed Spinal Dysraphism

- Lipomyelomeningocoele, sacral agenesis/caudal regression, diastomatomyelia (split cord malformation), tethered cord
- Vertebral defect and spinal cord involvement
- Skin/epithelial covering without exposure of neural tissue
- May or may not have a subcutaneous mass
- May have cutaneous stigmata
- Prevalence 0.3-0.6/10000 births [1]



Clinical Presentation

- May be clinically asymptomatic
- May have impaired lower limb strength and sensation
- May have neurogenic bladder and bowel
- No Arnold-Chiari Malformation or hydrocephalus
- Risk of cord tethering and neurological deterioration
- Orthopaedic sequelae are common
- Asymmetrical presentations

Motor performance and LMMC

- Limited research in this population
- 58% demonstrate problems with static and dynamic balance (single leg stance, jumping and hopping) [2]
- May impact on school and community participation and ability to keep up with peers
- Assist in guiding need for therapy interventions and programs

What role does muscle weakness play in the development of motor skills in children with closed spinal dysraphism?

Aims

To examine relationships between lower limb muscle strength and gross motor skills in children with closed spinal dysraphism

Research questions:

1. Do children with CSD have difficulties with motor skills?

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

3. How do associated conditions (eg CTEV) influence gross motor skills?

Manual Muscle Testing [3,4]

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.

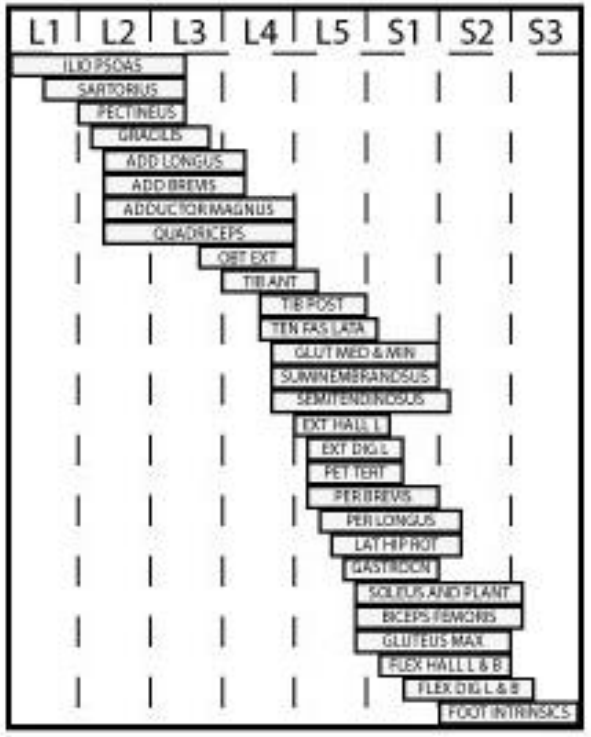
MMT CHANGES
Indicate ↑ or ↓ in comparison to previous test dated: _____

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

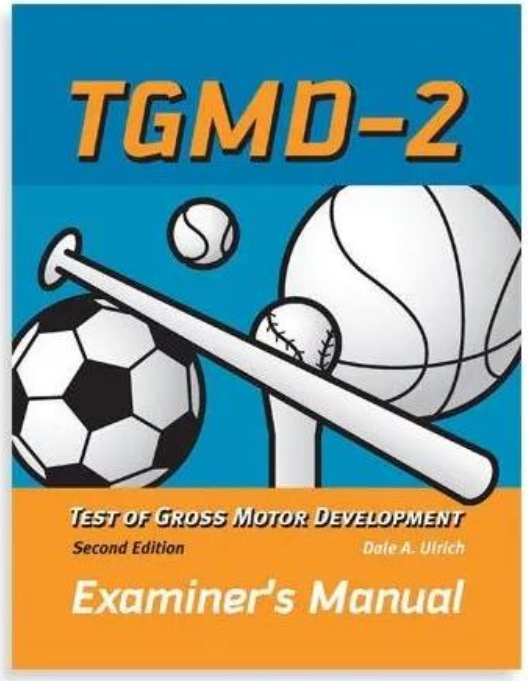
UPPER LIMB STRENGTH

GRIP STRENGTH



Test of Gross Motor Development -2nd version [5]

- Standardised norm referenced assessment for children 3-10 years with typical development
- 2 subsets
  - **Locomotor** skills *(run, gallop, hop, leap, horizontal jump and slide)*
  - **Object control** skills *(strike a stationary ball, stationary dribble, catch, kick, overhand throw and underhand roll)*
- Raw scores out of 48 points for each subset
- Percentile rank for overall, and subsets
  - Allows for comparison with age norms



Procedure and Analysis

- Both assessments completed on day of clinic attendance
- MMT data analysed separately for each lower limb due to asymmetry
- Spearman's rank-order correlation co-efficient used to observe relationships between MMT grade and gross motor skill performance
- Subgroup analysis of foot and ankle strength using Mann Whitney U independent samples test and influence of associated conditions.

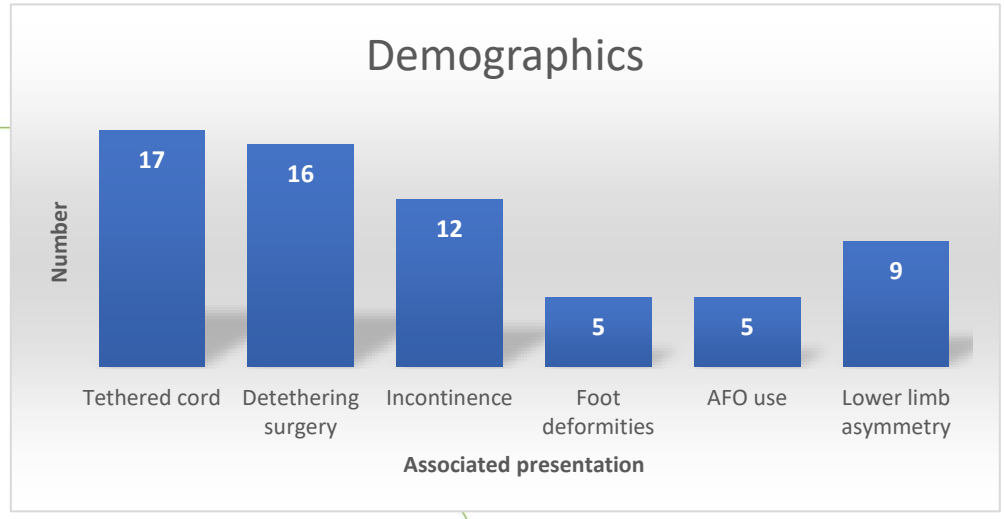
Spearman's Correlation co-efficient (r_s) between (p = <0.05)

- 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 [6]

Results

Participants

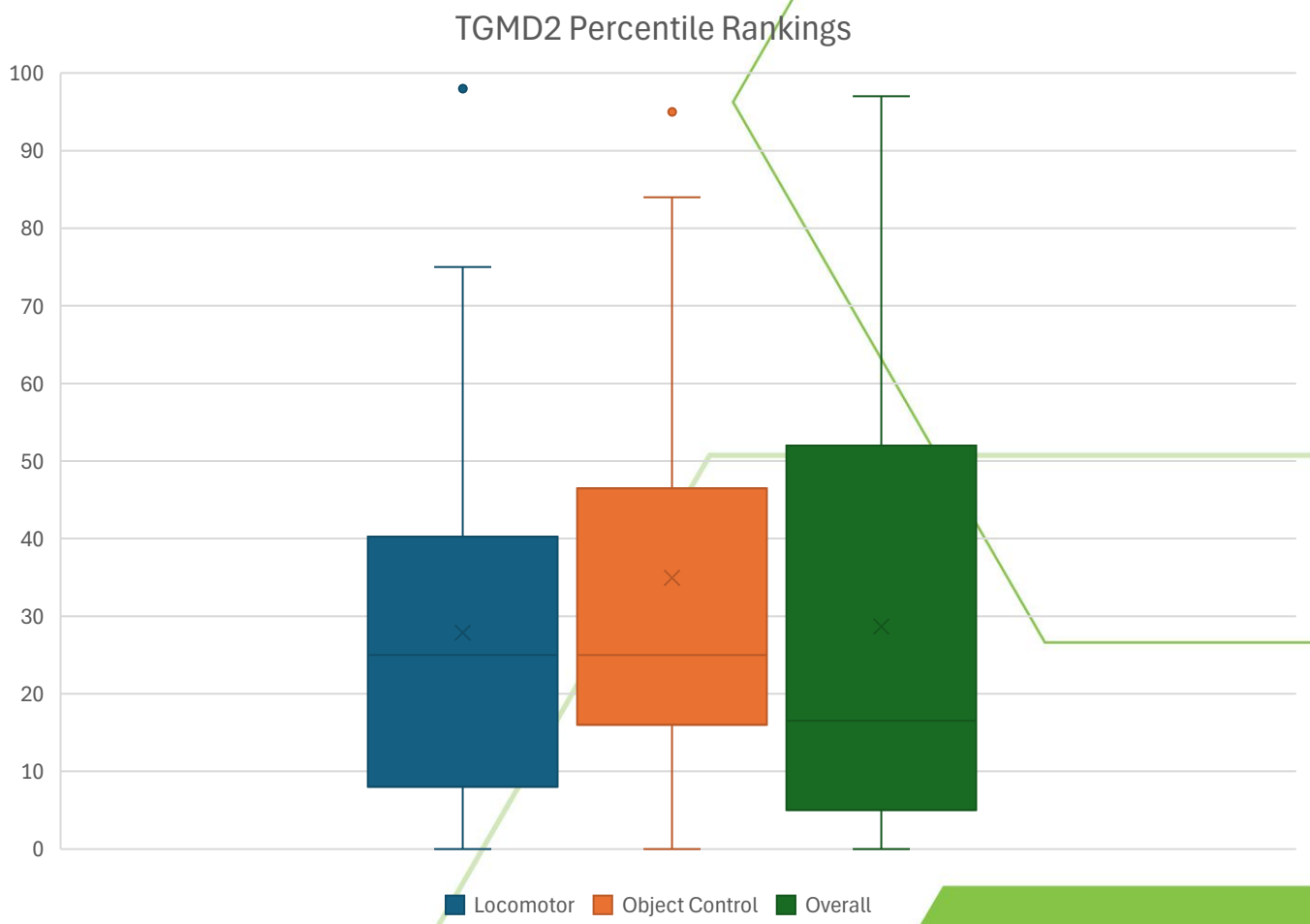
- 22 children with CSD aged 5-13 years (mean 9 years 2 months)
  - 17 LMMC
  - 3 sacral agenesis
  - 1 meningocoele
  - 1 diastomatomyelia



- Excluded:
  - Unable to understand or follow test directions
  - Orthopaedic injury or surgery to lower limb or spine in preceding 6 months
  - Pressure injury precluding application of test positions or manual resistance
  - Diagnosis of spina bifida occulta

Gross motor skills and CSD

- Children with CSD have difficulties with gross motor skills across both locomotor and object control domains
  - Median TGMD-2 Overall score on the 16th percentile
  - 75% of children scored equal to or below 52nd percentile.
  - Median Locomotor and Object Control scores on the 25th percentile
  - 75% of children scoring equal to or below the 46th percentile for each subtest



Relationship between strength and TGMD2 Percentile rank

3a. Dominant Side	*Locomotor* Percentile	*Object Control* Percentile	*Overall* Percentile
Trunk			
Quadratus lumborum	-0.216	0.219	0.045
Abdominals	0.081	0.329	0.251
Hip			
Iliopsoas	-0.126	0.152	0.063
Sartorius	0.082	0.239	0.237
Hip adductors	-0.166	-0.084	-0.089
Gluteus medius	-0.025	0.297	0.226
Gluteus maximus	-0.027	0.115	0.106
Knee			
Quadriceps	-0.314	-0.122	-0.242
Medial hamstrings	-0.156	-0.13	-0.12
Lateral hamstrings	0.209	-0.054	0.207
Ankle			
Tibialis anterior	0.402	0.224	0.399
Tibialis posterior	*0.461	0.294	*0.463
Peroneus L/B	*0.530	0.128	0.4
Peroneus tertius	0.228	0.005	0.177
Gastrocnemius/soleus	0.276	0.308	0.331
Foot			
Extensor hallucis longus	*0.454	0.098	0.366
Toe extensors	*0.438	0.099	0.346
Flexor hallucis longus	**0.579	0.361	**0.580
Toe flexors	0.406	0.189	0.393

3b. Non-dominant side	*Locomotor* Percentile	*Object Control* Percentile	*Overall* Percentile
Trunk			
Quadratus lumborum	-0.216	0.219	0.045
Abdominals	0.081	0.329	0.251
Hip			
Iliopsoas	-0.021	0.222	0.147
Sartorius	0.17	0.303	0.313
Hip adductors	-0.106	0.091	0.025
Gluteus medius	0.093	0.351	0.279
Gluteus maximus	0.129	0.312	0.273
Knee			
Quadriceps	-0.314	-0.122	-0.242
Medial hamstrings	-0.082	0.039	-0.006
Lateral hamstrings	0.257	0.189	0.294
Ankle			
Tibialis anterior	*0.446	0.391	*0.488
Tibialis posterior	0.269	0.384	0.399
Peroneus L/B	0.417	0.27	0.407
Peroneus tertius	0.251	0.224	0.33
Gastrocnemius/soleus	*0.463	0.33	*0.448
Foot			
Extensor hallucis longus	**0.548	0.292	*0.497
Toe extensors	*0.479	0.23	0.417
Flexor hallucis longus	*0.461	0.345	*0.493
Toe flexors	*0.450	0.312	*0.468

Strength and gross motor function – dominant side

4a. Dominant Side						
	Run	Gallop	Hop	Leap	Jump	Slide
Trunk						
Quadratus lumborum	0.122	0.033	0.137	0.018	0.07	-0.216
Abdominals	0.222	0.159	0.228	0.062	-0.02	0.078
Hip						
Iliopsoas	0.268	0.027	0.102	-0.013	0.192	-0.09
Sartorius	0.261	0.193	0.158	0.177	0.071	0.01
Hip adductors	0.006	-0.037	-0.128	0.204	-0.024	-0.118
Gluteus medius	0.402	-0.116	0.161	0.202	-0.161	0.255
Gluteus maximus	*0.428	-0.085	0.117	0.052	-0.335	0.145
Knee						
Quadriceps	0.185	0.018	-0.176	-0.301	0.018	-0.249
Medial hamstrings	0.009	-0.183	-0.009	0.009	0.035	-0.035
Lateral hamstrings	360	-0.229	0.334	-0.042	0.196	0.173
Ankle						
Tibialis anterior	*0.479	-0.052	*0.508	-0.037	0.308	0.202
Tibialis posterior	**0.614	-0.041	*0.531	0.101	0.304	0.371
Peroneus L&B	**0.619	-0.124	*0.479	0.24	0.243	0.404
Peroneus tertius	0.31	-0.178	0.297	0.006	0.237	0.092
Gastro/soleus	*0.516	-0.037	0.331	0.257	*0.459	**0.592
Foot						
Extensor Hallucis Longus	*0.475	-0.135	*0.449	0.061	0.197	0.29
Toe Extensors	**0.538	-0.206	0.417	0.197	0.19	*0.436
Flexor Hallucis Longus	**0.803	0.001	**0.589	0.276	0.118	*0.464
Toe Flexors	**0.627	-0.125	0.354	0.298	0.152	*0.424

Strength and gross motor function – non-dominant side

4b. Non-dominant Side						
Lower Limb Muscle	Run	Gallop	Hop	Leap	Jump	Slide
Trunk						
Quadratus lumborum	0.122	0.033	0.137	0.018	0.07	-0.216
Abdominals	0.222	0.159	0.228	0.062	-0.02	0.078
Hip						
Iliopsoas	0.415	0.034	0.139	0.161	0.171	0.141
Sartorius	0.385	0.202	0.194	0.323	0.059	0.198
Hip adductors	-0.047	-0.061	-0.141	0.384	0.12	-0.036
Gluteus medius	*0.467	-0.074	0.202	0.311	-0.787	0.302
Gluteus maximus	*0.431	0.041	0.188	0.292	-0.222	0.185
Knee						
Quadriceps	0.185	0.018	-0.176	-0.301	0.018	-0.249
Medial hamstrings	-0.022	-0.188	-0.058	0.34	0.153	0.085
Lateral hamstrings	0.308	-0.23	0.267	0.269	0.273	0.273
Ankle						
Tibialis anterior	0.373	0.023	0.395	0.343	0.234	0.341
Tibialis posterior	0.34	-0.174	0.385	0.314	0.224	0.287
Peroneus L&B	0.42	-0.268	0.358	*0.496	0.264	0.417
Peroneus tertius	0.264	-0.221	0.292	0.337	0.309	0.231
Gastro/soleus	**0.579	-0.076	0.385	*0.466	0.327	**0.688
Foot						
Extensor Hallucis Longus	**0.577	-0.091	0.416	0.408	0.347	**0.677
Toe Extensors	*0.515	-0.188	0.357	*0.437	0.335	**0.656
Flexor Hallucis Longus	**0.587	-0.184	0.386	*0.467	0.134	*0.498
Toe Flexors	*0.527	-0.179	0.311	*0.488	0.21	*0.492

Subgroup analysis

- Strong ankle and foot muscles (Gd 4-5)
- Weak ankle and foot muscles (Gd 3 or less)

			Exact sig. (2-sided test)		
A. Strength group	Strong Group (n)	Weak Group (n)	Overall Percentile rank	Locomotor Percentile rank	Object Control Percentile rank
Ankle strength	18	4	***0.008**	***0.005**	0.085
Foot Strength	19	3	***0.011**	***0.006**	0.133
B. Associated Conditions	Without (n)	With (n)			
AFO	17	5	***0.009**	***0.002**	0.190
CTEV	20	2	***0.033**	***0.021**	0.821
Foot deformity	17	5	0.344	0.068	0.360
Bladder or bowel incontinence	10	12	0.528	0.483	0.689

Summary

- Children with CSD have difficulties with gross motor skills compared to age matched peers
- Positive relationships between overall gross motor and locomotor skill performance and greater strength in ankle and foot muscles
- Greater antigravity foot and ankle strength discriminates performance in locomotor and overall skills
- Children with CSD who have CTEV and those that wear AFOs demonstrating lower gross motor and locomotor performance than those without
- Poor performance of object control skills – despite no strong correlation with individual muscle strength

Conclusion

- Consider other factors that may impact on motor skill performance in CSD
  - Potential sensory impairments (sensation/proprioception)
  - Experience and participation
- Clinicians should focus on assessing and monitoring strength of foot and ankle muscles in children with CSD as these muscles have a greater influence on gross motor performance

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References

1. Nalbandyan M, Howley MM, Cunniff CM, Romitti PA, Browne ML. Descriptive and risk factor analysis of nonsyndromic sacral agenesis: National Birth Defects Prevention Study, 1997–2011. Am J Med Genet A. 2019;179(9):1799-814.

2. Schoenmakers MAGC, Gulmans VAM, Gooskens RHJM, Helders PJM. Spina bifida at the sacral level: more than minor gait disturbances. Clinical Rehabilitation. 2004;18(2):178-85.

3. Tan JL, Thomas NM, Johnston LM. Reproducibility of Muscle Strength Testing for Children with Spina Bifida. Physical & Occupational Therapy in Pediatrics. 2017;37(4):362-73.

4. Hislop HJ, Avers D, Brown M, Daniels L. Daniels and Worthingham's muscle testing : techniques of manual examination and performance testing. 9th ed. St. Louis, Mo.: Elsevier; 2014.

5. Ulrich DA, Sanford CB. TGMD-2:Evidence of Reliability and Validity. Journal of sport & exercise psychology. 2000;22.

6. Hinkle DE, Wiersma W, Jurs SG. Applied statistics for the behavioral sciences : hbk. 5th ed: Houghton Mifflin; 2003.