Beware the Transverse Plane: Variability of "Normal Gait" In Typically Developing Children

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Gait Variability

Gait matures by
4-8 years of age

Complex
Neurological
Processing

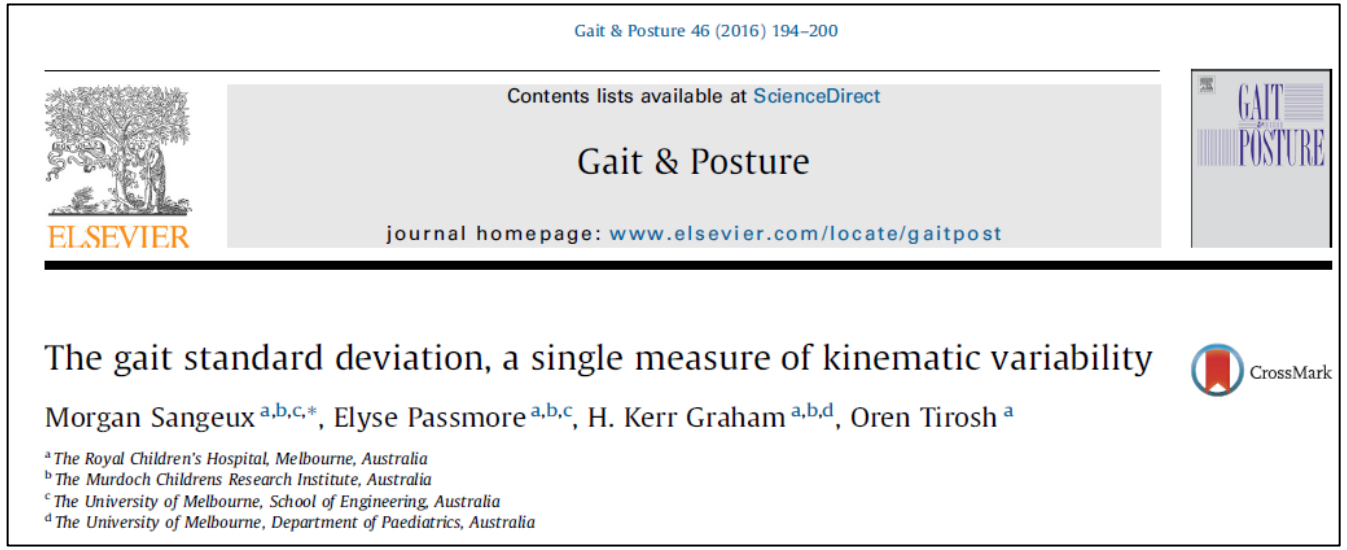
Precision Surgery

- 3D Gait Analysis is the only quantitative method to study gait
- Provides accurate and reliable data on joint and body segment motion
- An important component of “precision surgery” for a child with a fixed gait abnormality

3D Gait Analysis

Current Literature

- Stride-to-stride variability for gait variables is low, but outliers do exist
- Choosing the wrong stride for analysis can lead to improper surgical decisions
- Better quantification of gait variability is foundational for proper surgical decision-making
- Existing studies have omitted trunk or pelvis measures in variability characterization



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The gait standard deviation, a single measure of kinematic variability

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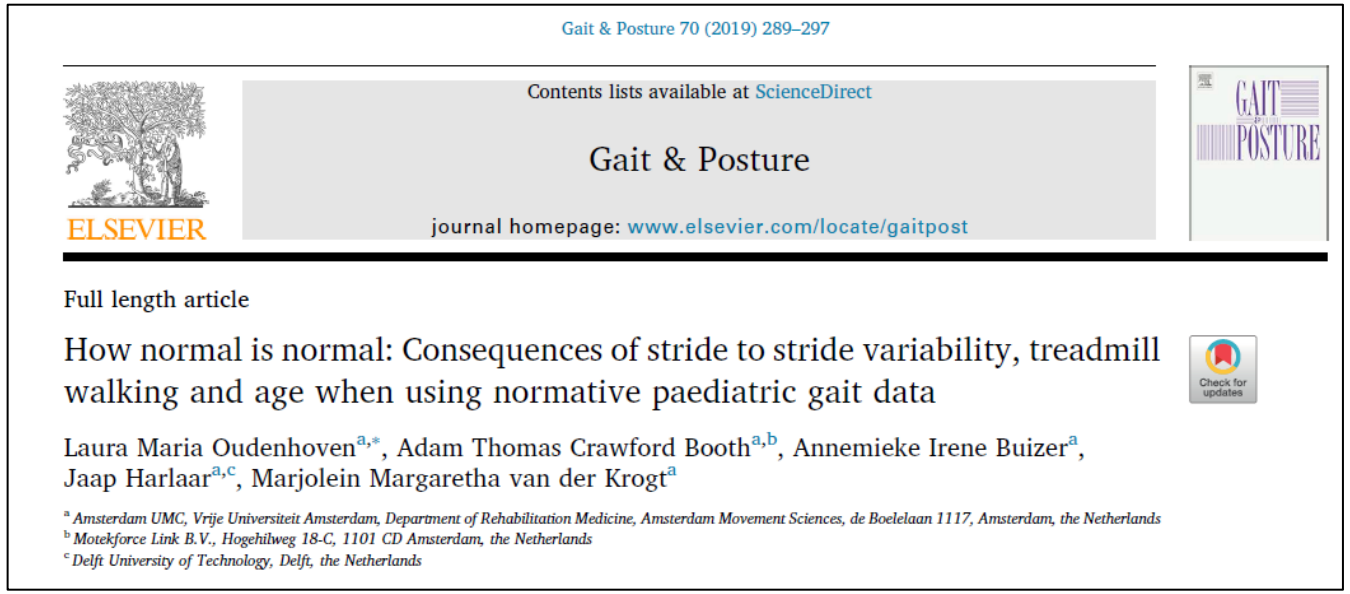

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Full length article

How normal is normal: Consequences of stride to stride variability, treadmill walking and age when using normative paediatric gait data

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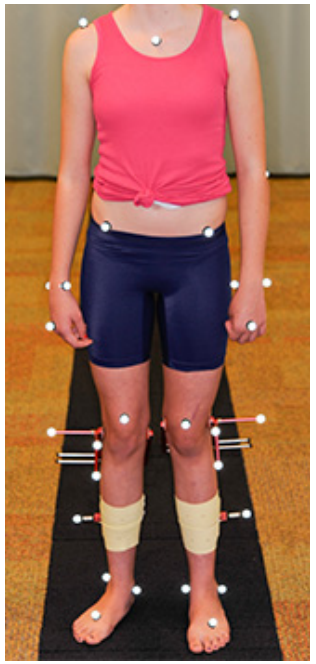
Purpose

1. Quantify stride-to-stride variability in typically developing (TD) children using three-dimensional gait analysis (3DGA) in an expanded set of 14 kinematic variables.
2. Assess the effect of laterality, age, and sex on stride-to-stride variability

Methods



	Sagittal Plane	Coronal Plane	Transverse Plane
Trunk:	Trunk Tilt	Trunk Lateral Bend	Trunk Rotation
Pelvis:	Pelvic Tilt	Pelvic Obliquity	Pelvic Rotation
Hip:	Hip Flexion	Hip Abduction	Hip Rotation
Knee:	Knee Flexion	Knee Flexion	Knee Rotation
Foot & Ankle:	Ankle Dorsiflexion		Foot Progression

Methods

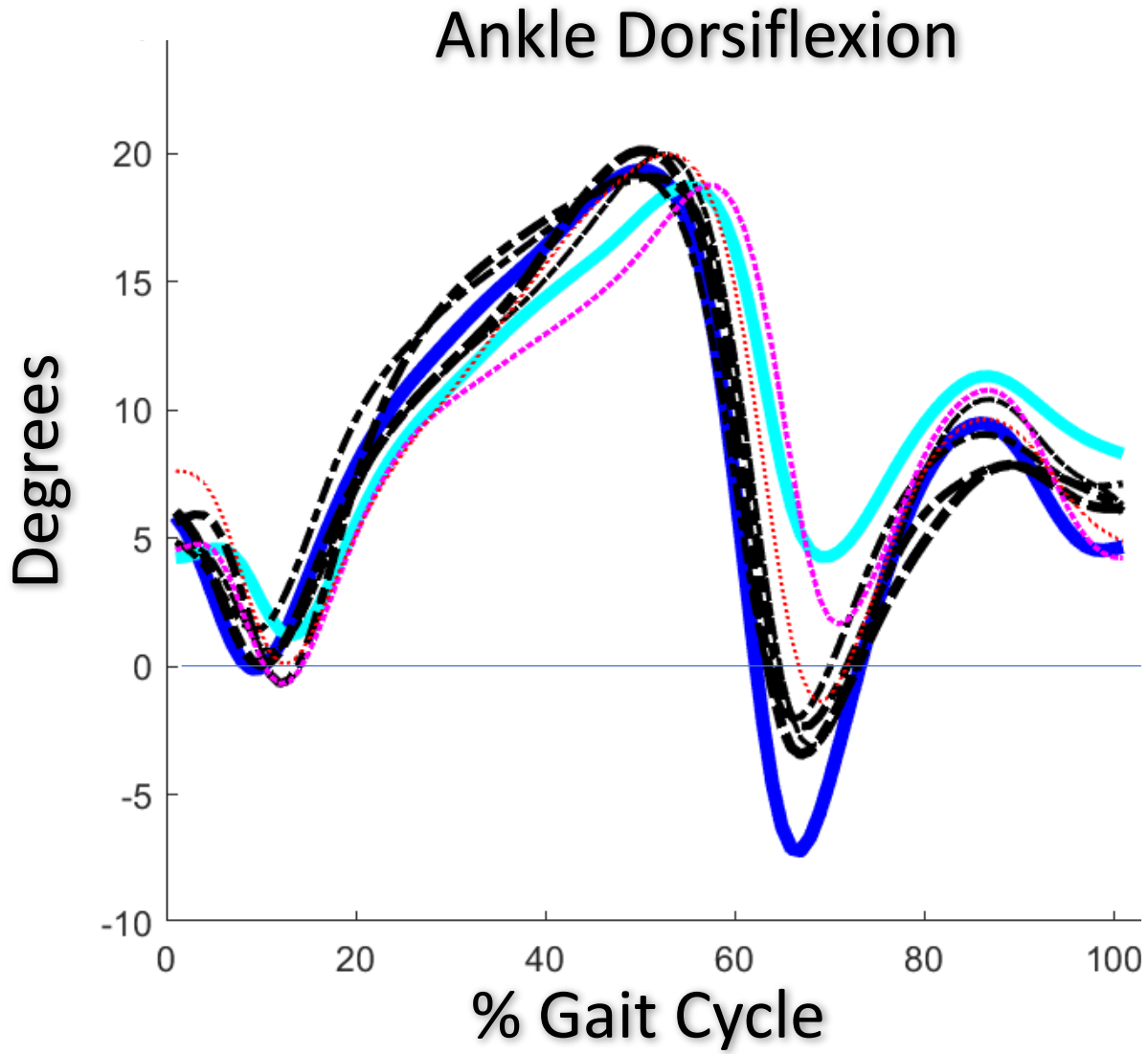
20 Female

17 Male

Ages 5 - 17

Average 7 strides

Methods: Data Collection



GVSD

Gait Variable Standard Deviation

(Best statistical measure of variability)

$$= \sqrt{\left(\sum_t SD(i,t)^2 / T \right)}$$

where:
SD = standard deviation
i = gait variable of interest
t = time point
T = total number of time points (101)

GVR

Gait Variable Range

(Sensitive to outliers)

$$= \sqrt{\left(\sum_t RNG(i,t)^2 / T \right)}$$

where:
RNG = range
i = gait variable of interest
t = time point
T = total number of time points (101)

Methods: Statistical Tests

- Paired t-Test used to compare laterality
- Unpaired t-Test to compare sex differences
- ANOVA with Tukey’s Post Hoc to compare between planes of motion
- Linear regression to evaluate the effect of age

Results – Right Side

- Transverse Plane is the most variable at all body segments except for the knee
- GVSD is low, indicating that gait is consistent in TD children
- GVR is large, indicating that the range of joint motion is sensitive to outliers
- Choosing an outlier trial could affect clinical decision making

	Kinematic Measurement	GVR (deg)	GVSD (deg)
Trunk	Trunk Rotation	**9.4****	**3.4****
	Trunk Tilt	6.4	2.3
	Trunk Lateral Bend	4.5	1.6
Pelvis	Pelvic Rotation	**7.8****	**2.8****
	Pelvic Tilt	4.4	1.6
	Pelvic Obliquity	2.9	1.1
Hip	Hip Rotation	**8.3****	**3****
	Hip Flexion	6.3	2.3
	Hip Adduction/Abduction	4.1	1.5
Knee	Knee Rotation	4.7	1.8
	Knee Flexion	**8.8ǂ**	**3.2ǂ**
	Knee Varus/Valgus	1.7	0.6
Ankle	Foot Progression Angle	**10.4***	**3.8***
	Ankle Dorsiflexion	7	2.6

** Significant Difference between Transverse and Sagittal/Coronal Planes
ǂ Significant Difference between Sagittal and Transverse/Coronal Planes
* Significant Difference between Transverse and Sagittal Planes

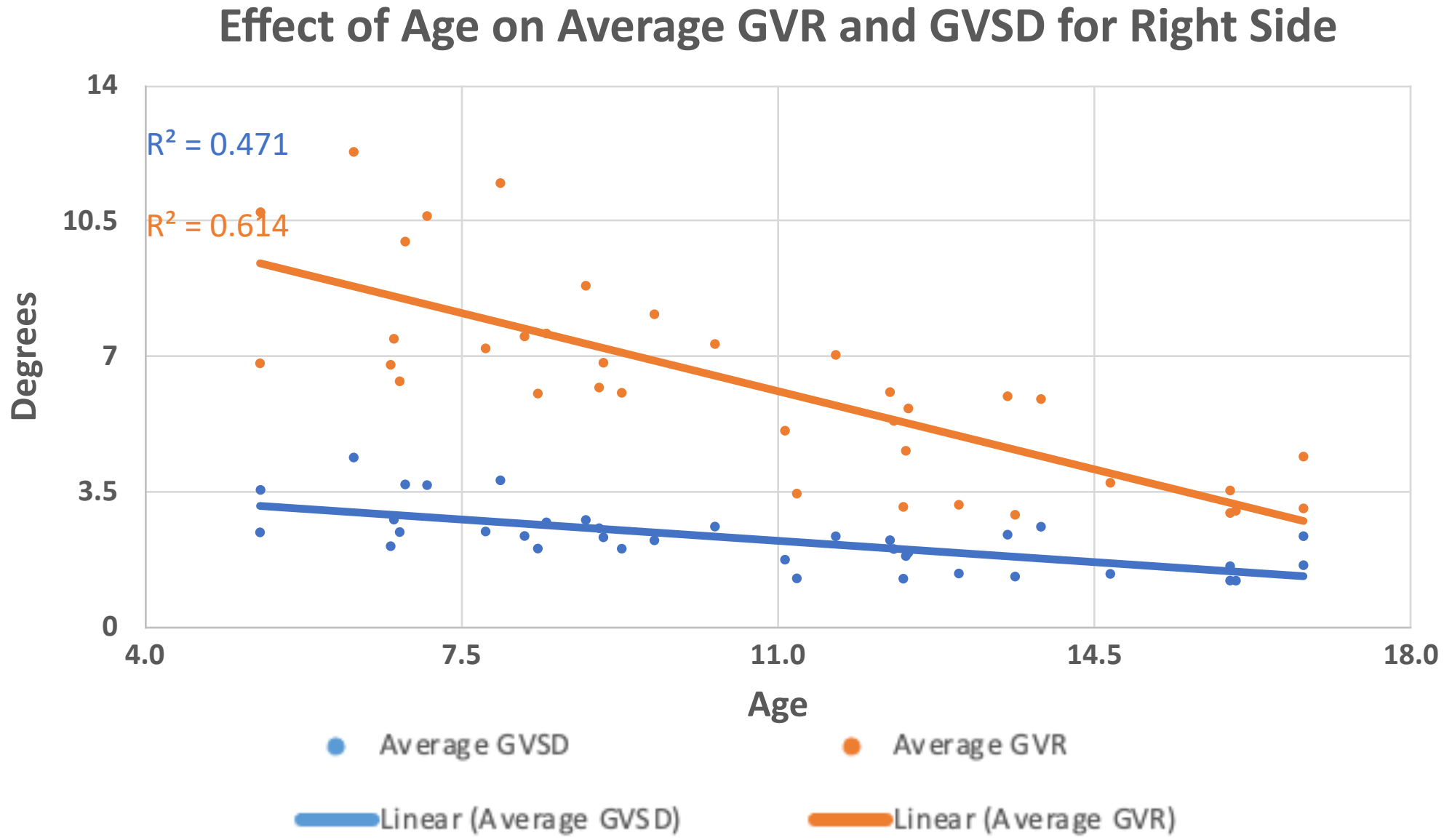
Results – Left Side

- Transverse Plane is the most variable at trunk, pelvis, and ankle. Knee has most variability at the sagittal plane.
- GVSD is low, indicating that gait is consistent in TD children
- GVR is large, indicating that the range of joint motion is sensitive to outliers
- Choosing an outlier trial could affect clinical decision making

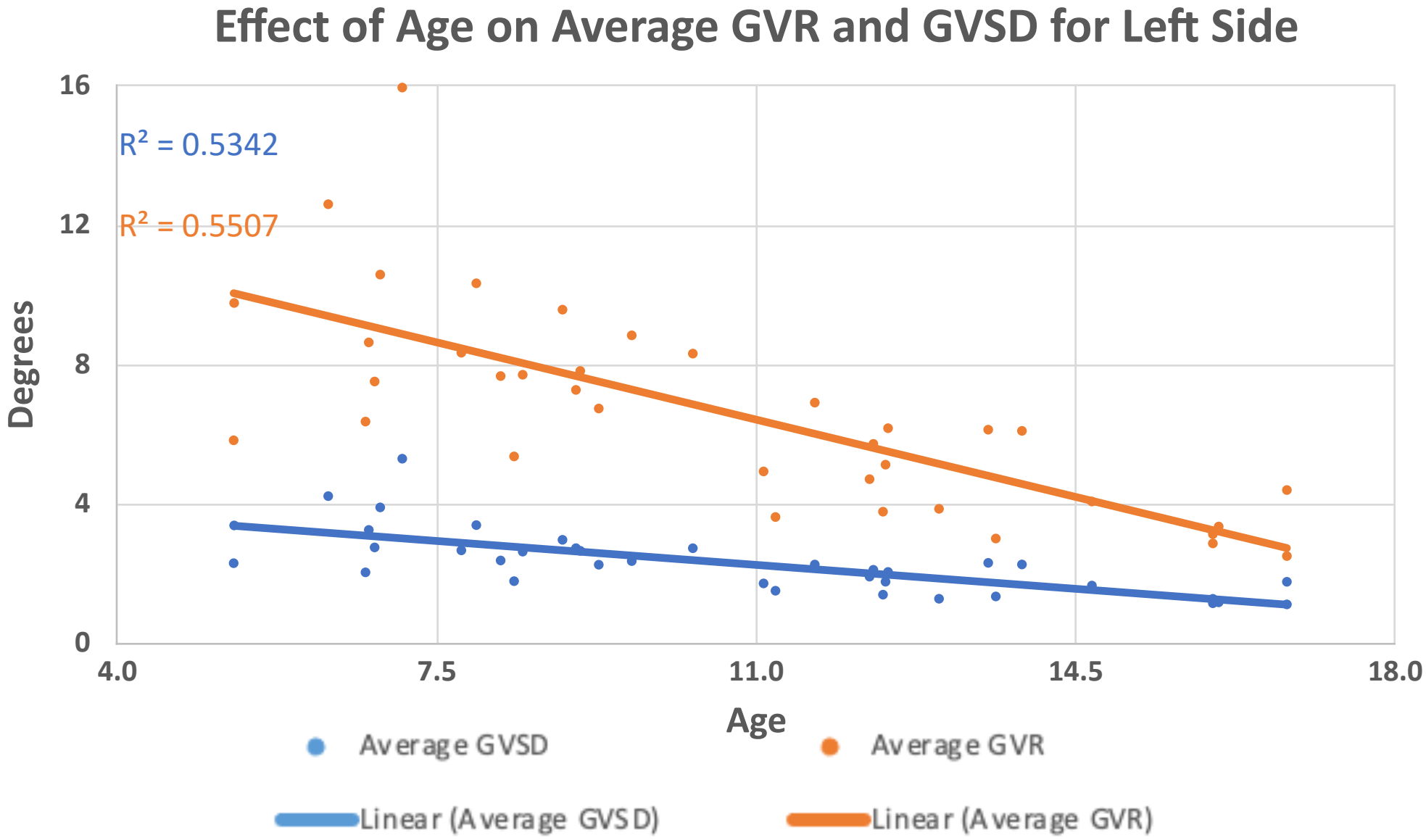
	Kinematic Measurement	GVR (deg)	GVSD (deg)
Trunk	Trunk Rotation	**9.5****	**3.3****
	Trunk Tilt	6.7	2.4
	Trunk Lateral Bend	4.6	1.6
Pelvis	Pelvic Rotation	**7.8****	**2.8****
	Pelvic Tilt	4.4	1.6
	Pelvic Obliquity	3	1.1
Hip	Hip Rotation	8	2.8
	Hip Flexion	6.6	2.3
	Hip Adduction/Abduction	4.2	1.5
Knee	Knee Rotation	4.8	1.7
	Knee Flexion	**10.1ǂ**	**3.5ǂ**
	Knee Varus/Valgus	1.7	0.6
Ankle	Foot Progression Angle	**12***	**4.1***
	Ankle Dorsiflexion	8.3	3

** Significant Difference between Transverse and Sagittal/Coronal Planes
ǂ Significant Difference between Sagittal and Transverse/Coronal Planes
* Significant Difference between Transverse and Sagittal Planes

Results – Right Side



Results – Left Side



Conclusions:

- Statistically and clinically significant kinematic variability was the greatest in the transverse plane in all body segments except for the knee, where variability was greatest in the sagittal plane.
- Foot progression can have up to a 12° GVR, indicating that surgeons should not place emphasis on a single trial in isolation for surgical treatment.
- Variability of gait decreases in older children, so determination of fixed gait deviations will be more accurate closer to skeletal maturity.
- Sex and laterality had no statistically significant effect on variability.

Limitations & Further Research

- Limitations:
  - Equal weight given to all 101 time points of the gait cycle
  - Analysis limited to typically developing children
- Future Directions:
  - Expand analysis to children with neuro-developmental disorders
  - Assess variability at clinically significant points in the gait cycle.
    - For example: Ankle position at initial foot contact.

Thank You!

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