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### Title

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# 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

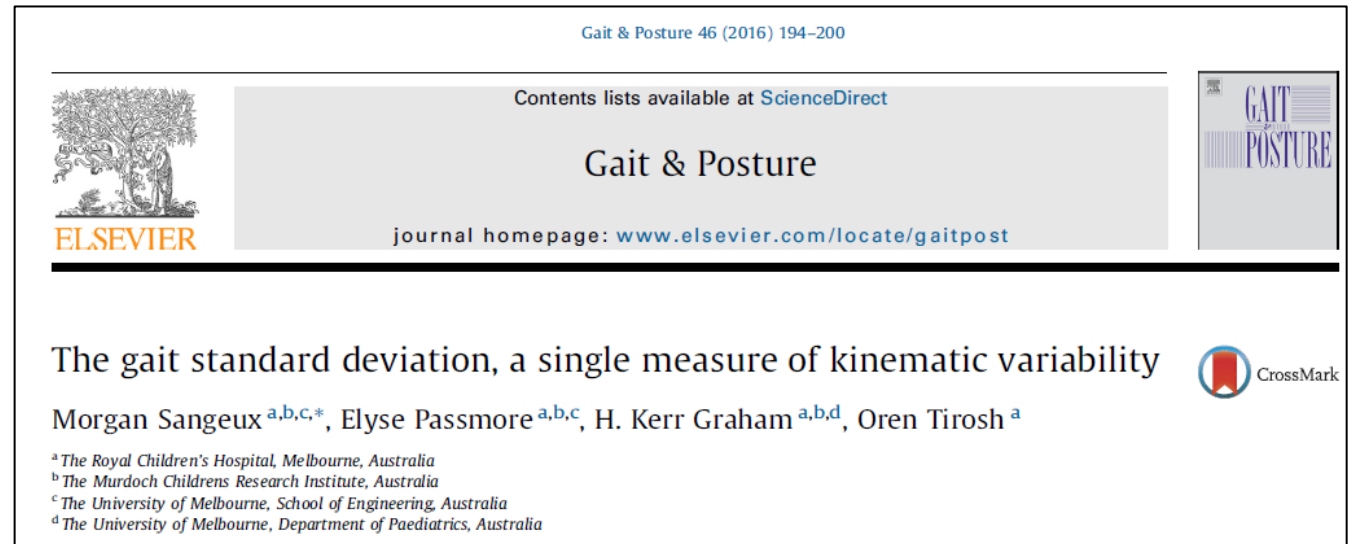


3D Gait Analysis



# 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



# 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



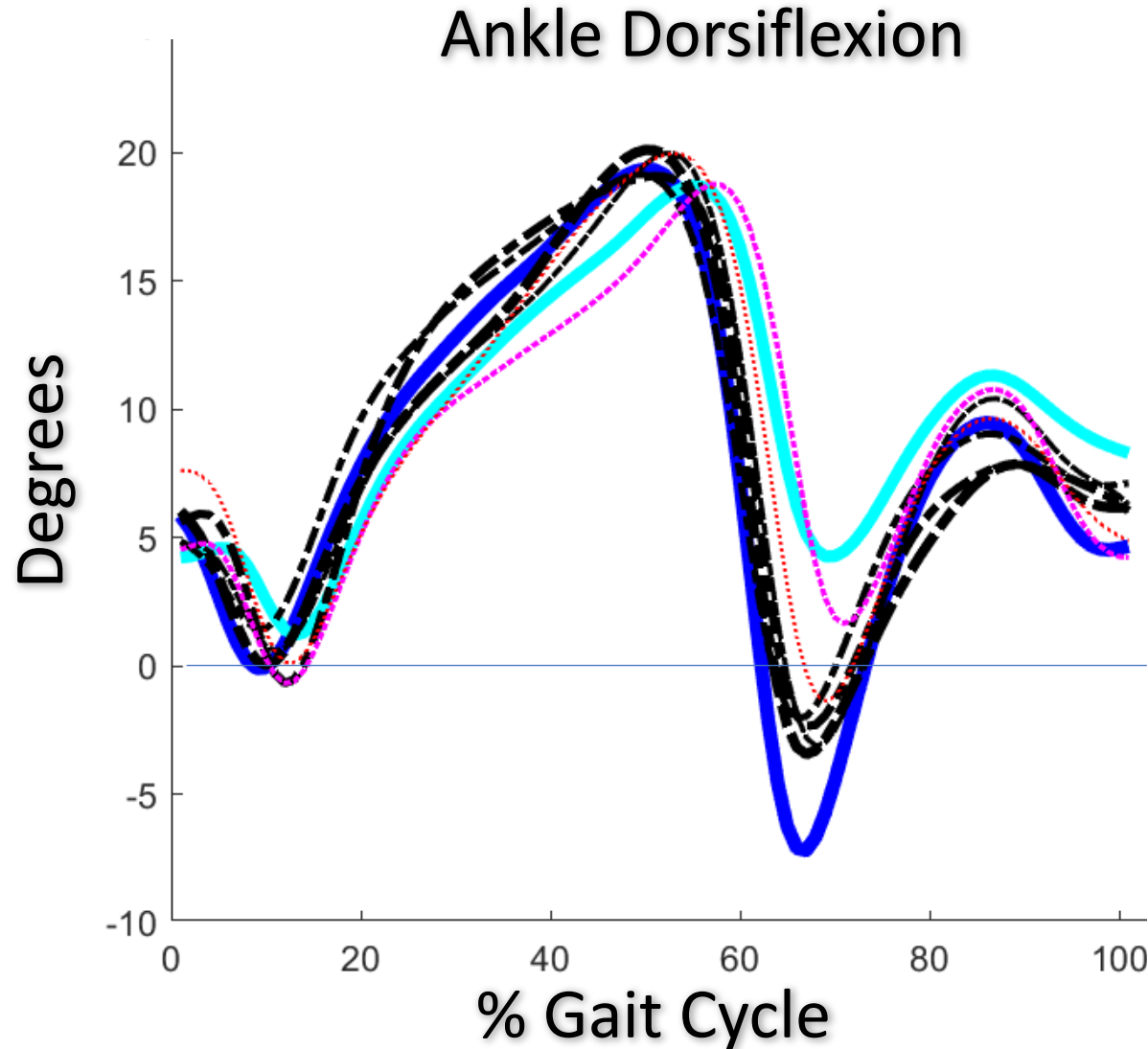
Ages 5 - 17



Average 7 strides



# Methods: Data Collection



## GVSD

*Gait Variable Standard Deviation*  
*(Best statistical measure of variability)*

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

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)*

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

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	8.8†	3.2†
	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

† 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	10.1†	3.5†
	Knee Varus/Valgus	1.7	0.6
Ankle	Foot Progression Angle	12*	4.1*
	Ankle Dorsiflexion	8.3	3

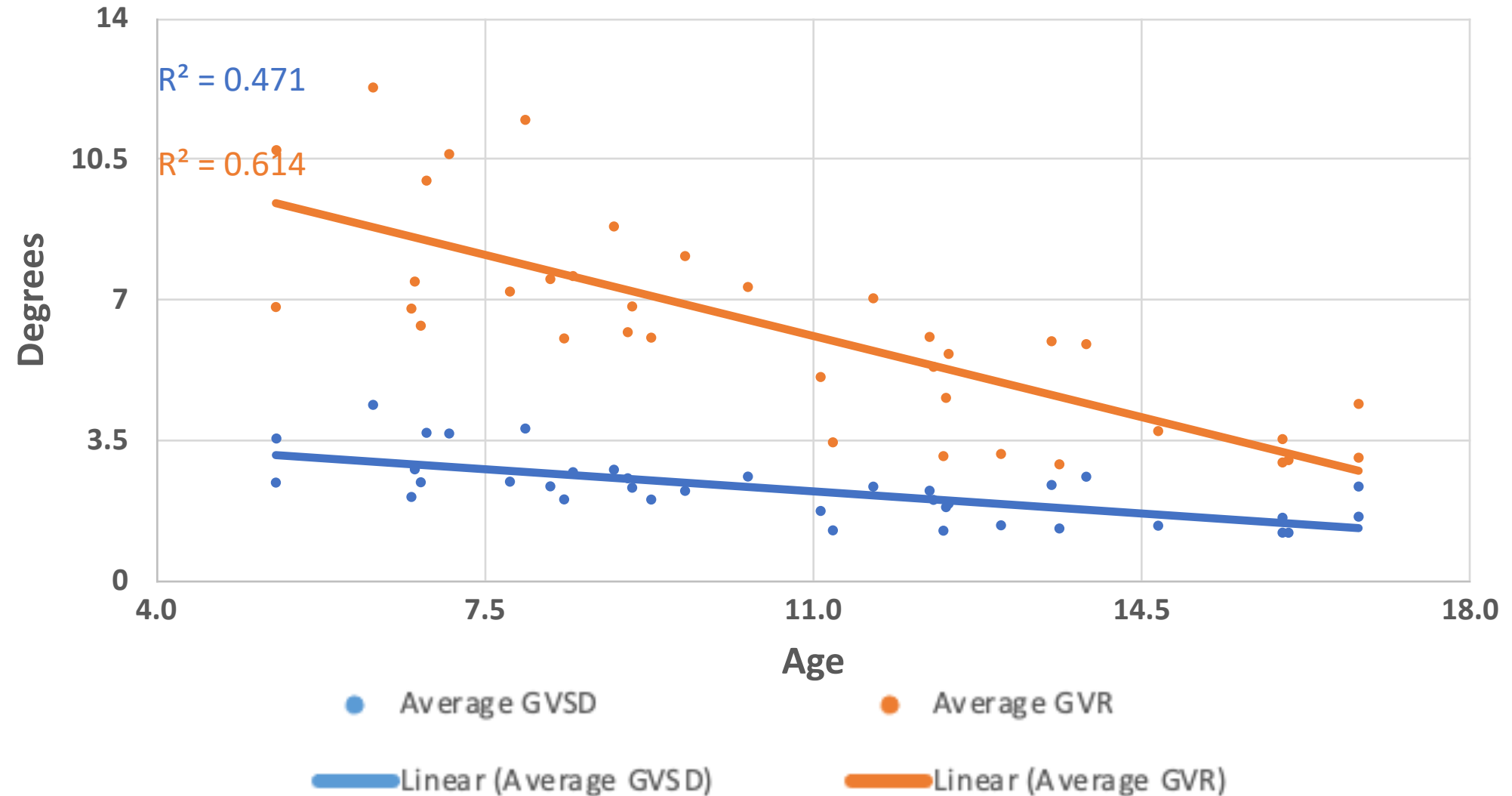
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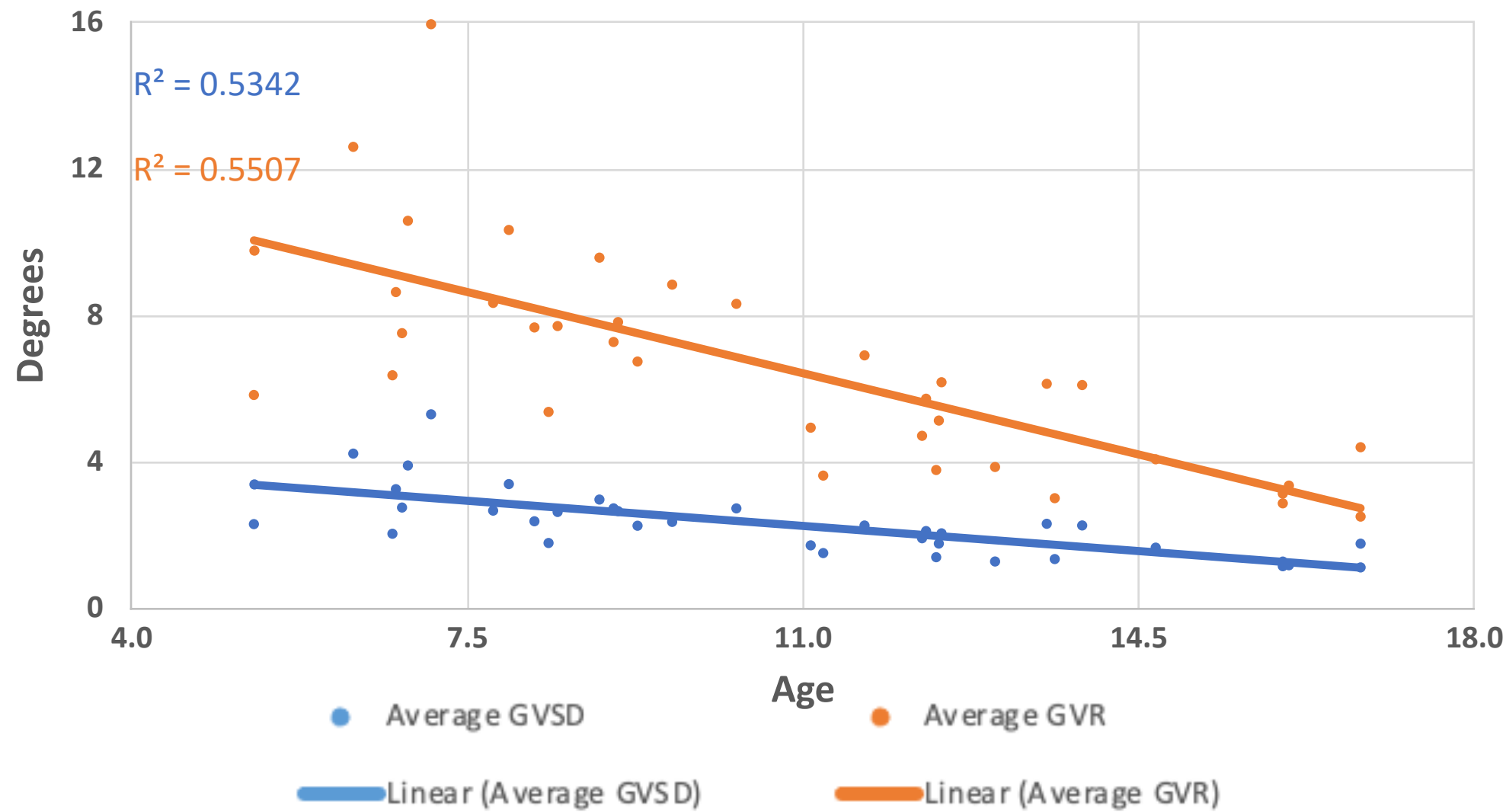
# Results – Right Side

Effect of Age on Average GVR and GVSD for Right Side



# Results – Left Side

Effect of Age on Average GVR and GVSD for 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  $12^\circ$  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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