# 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

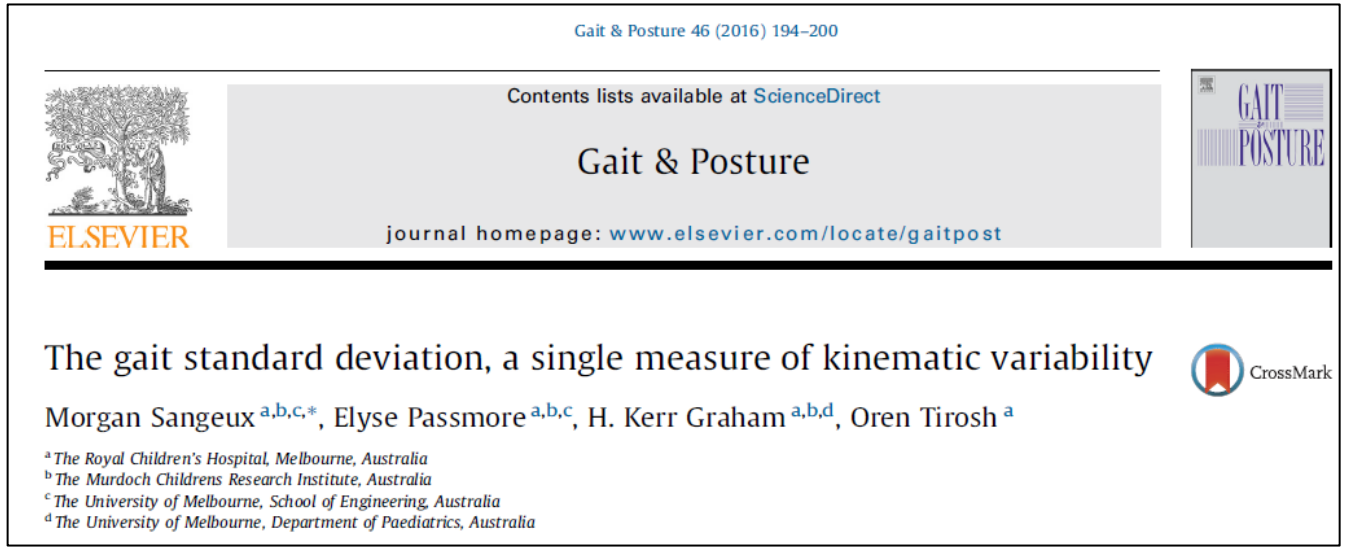
# Precision Surgery

- 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



Gait & Posture 46 (2016) 194–200

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Gait & Posture

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The gait standard deviation, a single measure of kinematic variability

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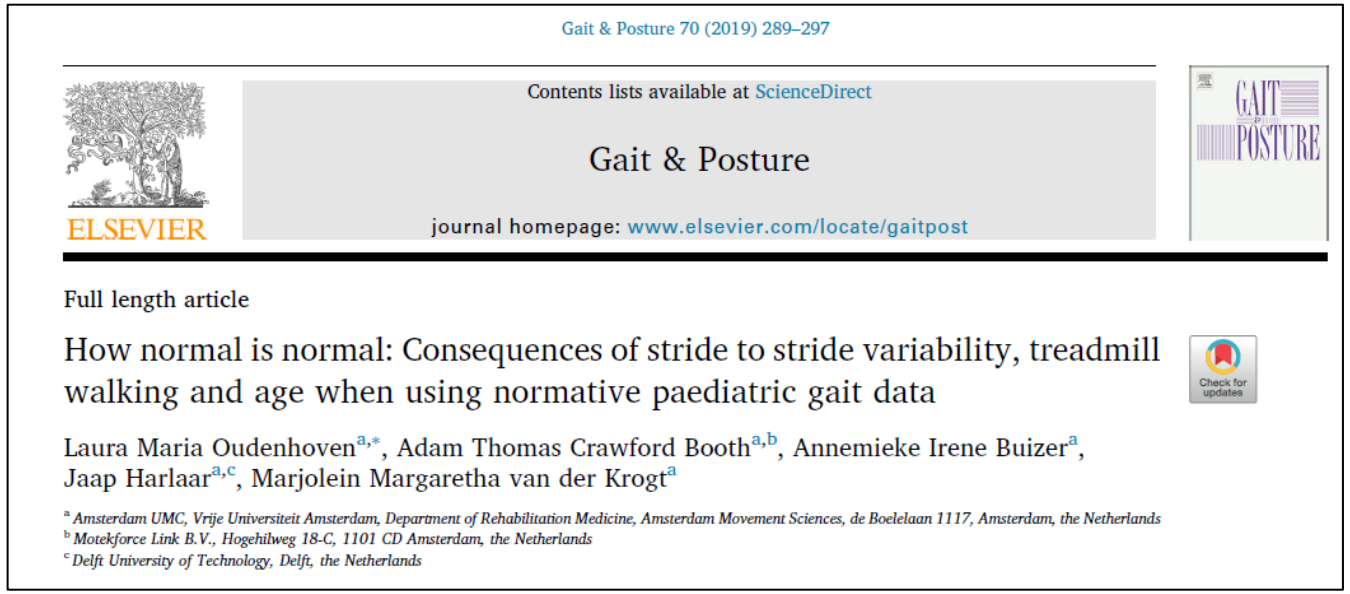

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Full length article

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

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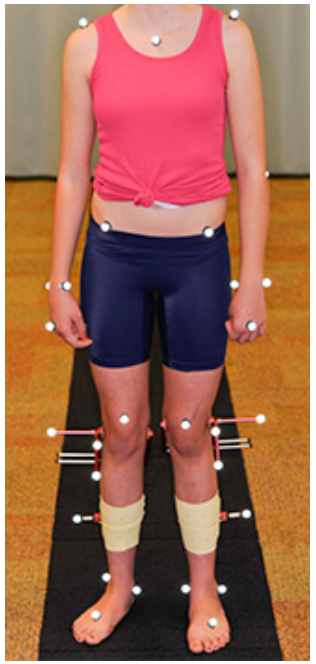
# Purpose

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

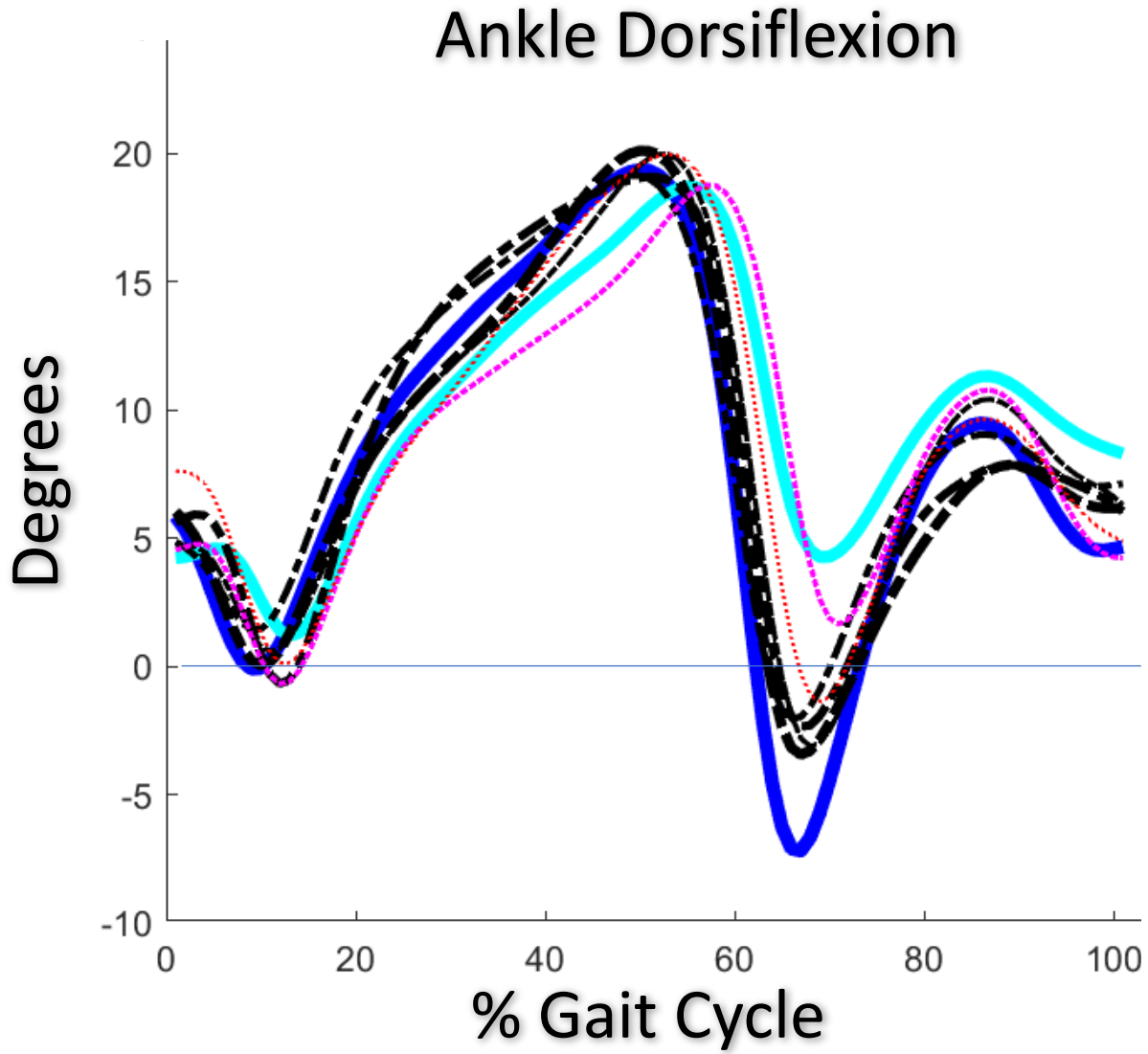
20 Female

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

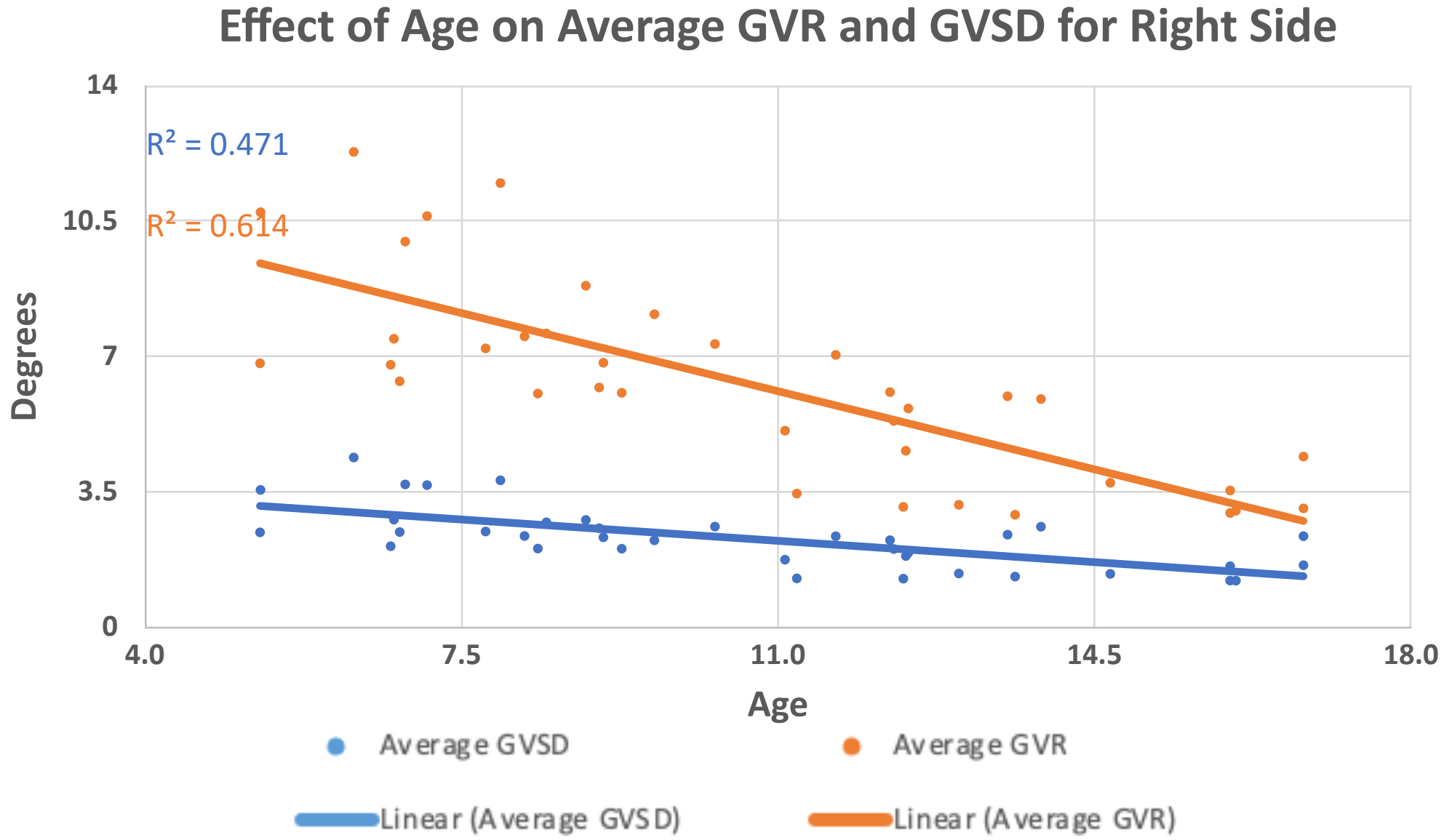
# Results – Left Side

- 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

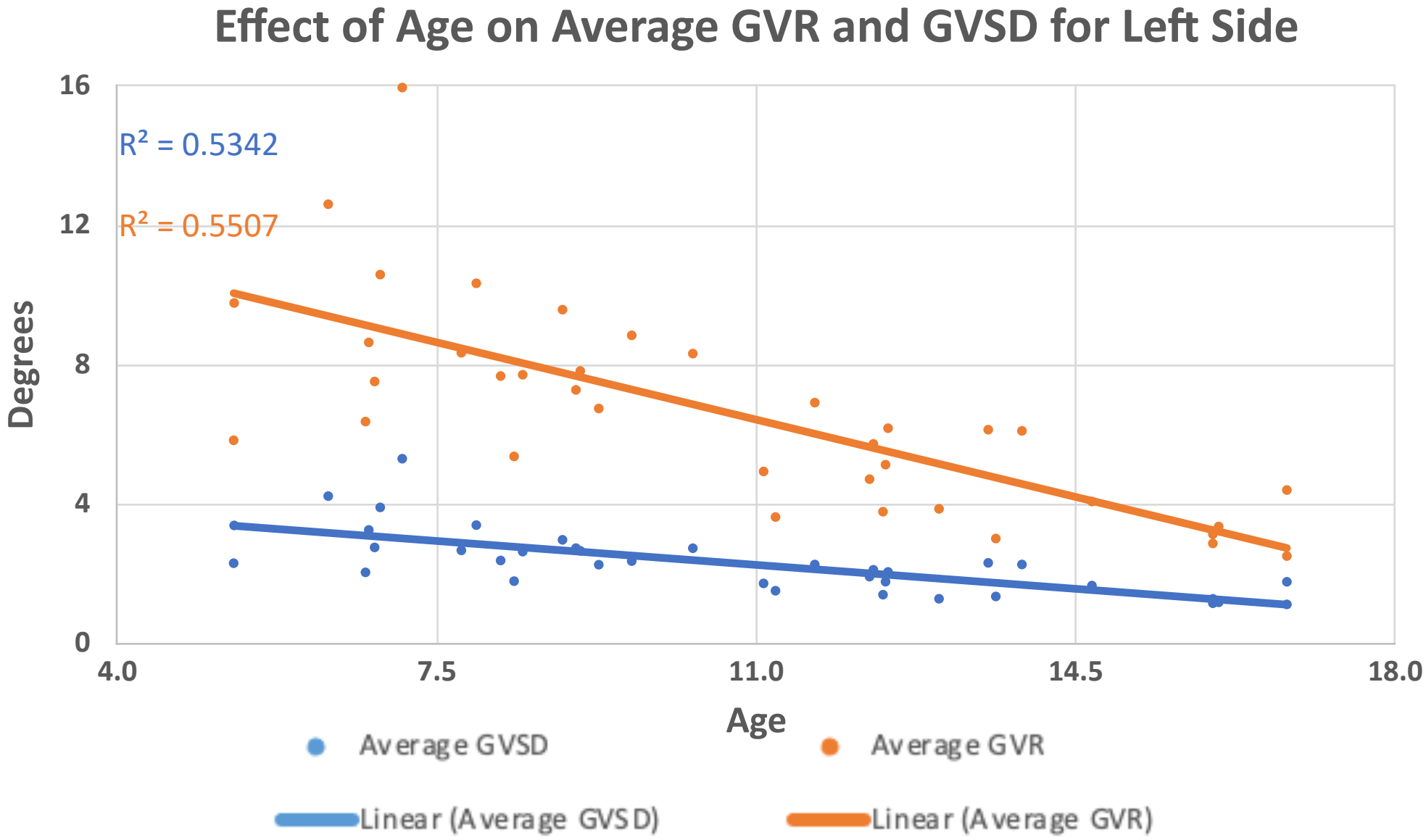
| | Kinematic Measurement | GVR (deg) | GVSD (deg) |
|---|---|---|---|
| Trunk | Trunk Rotation | **9.5**** | **3.3**** |
| | Trunk Tilt | 6.7 | 2.4 |
| | Trunk Lateral Bend | 4.6 | 1.6 |
| Pelvis | Pelvic Rotation | **7.8**** | **2.8**** |
| | Pelvic Tilt | 4.4 | 1.6 |
| | Pelvic Obliquity | 3 | 1.1 |
| 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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